Department of Mechanical Engineering

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

General Information

The department of Mechanical Engineering offers three graduate master's programs which include the degree of Master of Engineering with a major in Mechanical Engineering (Thesis/Non-Thesis), the degree of Master of Mechanical Engineering with a major in Applied Energy (Thesis/Non-Thesis), the degree of Master of Science in Energy Studies (Thesis/Non-Thesis), in addition to the degree of Doctor of Philosophy (PhD) in Mechanical Engineering.

Master of Engineering (ME)

The Department offers the following programs, all leading to the Master of Engineering in Mechanical Engineering degree:

- Master of Engineering, major Mechanical Engineering (Thesis)
- Master of Engineering, major Mechanical Engineering (Non-Thesis)
- Master of Mechanical Engineering in Applied Energy (Thesis)
- Master of Mechanical Engineering in Applied Energy (Non-Thesis)

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 Maroun Semaan Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of the university catalogue.

Master of Engineering (ME), Major: Mechanical Engineering

ME Thesis Program Requirements:

In this program, students may choose a concentration in any of the following areas:

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

The student is encouraged to select a concentration area of personal interest. The master's degree requires a minimum of 21 credit hours of coursework and a thesis equivalent to 9 credits. Twenty to twenty-four months of research are usually required to complete the master's degree. The student and the graduate advisor, 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 term of graduate work.

The required 21 course credit hours and the 9 credits for thesis are distributed as follows:

- A mandatory 3-credit course in applied mathematics

Acceptable courses include, but are not limited to, the following:

ENMG	604	Deterministic Optimization Models
MATH	307	Topics in Analysis
MECH	630	Finite Element Methods in Mechanical Engineering
MECH	663	Computational Fluid Dynamics
MECH	691	Convex Optimization
MECH	764	Advanced Topics in Computational Fluid Dynamics

The math or math-oriented course offered by other departments must be approved by the graduate student's advisor.

- Three engineering technical courses (9 credit hours) in the concentration area and at least one from the list of fundamental courses in the area.
- Three engineering elective courses (9 credit hours) with a maximum of two courses in other departments within the MSFEA, also subject to the approval of the graduate student's advisor.
- Seminar Course: MECH 797 (0 credit hours). Students must register for the course each time it is offered.
- Thesis: MECH 799 (equivalent to 9 credit hours) should be completed based on independent research.

ME Non-Thesis Program Requirements:

The course-based master's program requires a minimum of 33 credit hours of graduate level courses:

- A minimum of one 3-credit course in applied mathematics. Acceptable courses are listed on the previous page.
- Three engineering technical courses (9 credit hours) in the concentration area and at least one from the list of fundamental courses in the area.
- Seven engineering electives courses (21 credit hours) within ME with the option of having a maximum of two courses in other departments within the MSFEA, also subject to the approval of the graduate student's advisor.
- Seminar Course: MECH 797 (0 credit hours). Students must register for the course every time it is offered.
- Qualification examination: comprehensive exam (MECH 799T) should be done upon the completion of the coursework in all major and minor areas.

List of Mechanical Engineering courses for the thesis and non-thesis option is shown below:

Thermal and Fluid Sciences:

Fundamental Courses: MECH 701 (Principles of Combustion), MECH 760 (Advanced Fluid Mechanics), MECH 761 (Convection Heat Transfer), MECH 762 (Advanced Thermodynamics), MECH 707 (Statistical Mechanics and Thermodynamics), MECH 764 (Advanced Topics in Computational Fluid Dynamics), MECH 763 (Radiative Heat Transfer), MECH 766 (Turbulent Flow and Transport), MECH 767 (Heat Conduction)

Technical Electives: MECH 602 (Energy Conservation and Utilization), MECH 603 (Solar Energy), MECH 604 (Refrigeration), MECH 606 (Aerosol Dynamics), MECH 607 (Micro Flows Fundamentals and Applications), MECH 609 (Experimental Methods in Fluid Dynamics), MECH 663 (Computational Fluid Dynamics), MECH 665 (Unsteady Gas Flow), MECH 702 (Pollutant Formation and Control in Combustion), MECH 703 (Combustion Modeling), MECH 600 (Applied Reservoir Engineering I), MECH 608 (Applied Reservoir Engineering II), MECH 653 (System Analysis and Design), MECH 670 (Laboratory for Renewable Energy in Buildings), MECH 671 (Renewable Energy Potential, Technology and Utilization in Buildings), MECH 672 (Modeling Energy Systems), MECH 673 (Energy Efficient Buildings with Good Indoor Air Quality), MECH 674 (Energy Economics and Policy), MECH 675 (Building Energy Management Systems), MECH 676 (Passive Building Design), MECH 678 (Solar Electricity), MECH 679 (Energy Audit Lab), MECH 705 (Bioheat Modeling and Human Thermal Environments), MECH 751 (Simulation of Multiphase Flows), MECH 765 (Advanced Finite Volume Techniques), MECH 768 (Transport Through Porous Media), MECH 769 (Advanced Scientific Computing), MECH 770 (HVAC and Refrigeration Systems Lab), MECH 771 (HVAC System Control Strategies and Energy Efficiency), MECH 772 (Moisture and Control of Humidity Inside Buildings), MECH 773 (Numerical Methods in Energy Technology), MECH 778 (Special Projects on Renewable Energy Systems Design)

Design, Materials and Manufacturing:

Fundamental Courses: MECH 624 (Mechanics of Composite Materials), MECH 720 (Advanced Machine Design), MECH 721 (Elasticity and Plasticity), MECH 630 (Finite Element Methods in Mechanical Engineering)

Technical Electives: MECH 615 (Continuum Mechanics), MECH 619 (Quality Control in Manufacturing Systems), MECH 622 (Advanced Manufacturing Processes), MECH 631 (Micro Electro Mechanical Systems), MECH 632 (Structural Health Monitoring), MECH 633 (Biomechanics), MECH 634 (Biomaterials and Medical Devices), MECH 637 (Micromechanics and Crystal Plasticity), MECH 736 (Modeling Solidification Processes)

Mechatronics:

Fundamental Courses: MECH 643 (Mechatronics and Intelligent Machines Engineering), MECH 645 (Noise and Vibration Control), MECH 740 (Advanced Dynamics), MECH 641 (Robotics), MECH 642 (Computer Vision), MECH 650 (Autonomous Mobile Robotics), , MECH 653 (Systems Analysis and Control)

Technical Electives: MECH 628 (Design of Mechanisms), MECH 644 (Modal Analysis), MECH 648 (Non-Linear Systems: Analysis, Stability and Control), MECH 647 (Hydraulic Servo Systems), MECH 654 (Adaptive Control), MECH 677 (Heat Pumps)

Master of Mechanical Engineering (ME), Major: Applied Energy (APPE)

The objectives of the master's program leading to the Master of Mechanical 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,
- and assess and evaluate the impact of new technical developments in energy systems on society, the environment and the economy.

APPE Thesis Program Requirements:

Program Structure

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

The program consists of 30 credits distributed as follows:

- 9 credits of mandatory courses
- 3 credits of lab
- 6 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.
- A 3-credit general graduate technical elective from science, math or engineering as approved by thesis advisor.
- Seminar Course: MECH 797 (0 credit hours). 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 788 (equivalent to 9 credit hours). The thesis must be based on independent research.

APPE Non-Thesis Program Requirements:

The course-based master's program requires a minimum of 33 credit hours of graduate level courses distributed as follows:

- 9 credits of mandatory courses
- 3 credits of lab
- 15 credits of elective courses selected with the approval of the graduate student's advisor in any of the areas described above
- 6 credits of general graduate technical electives from science, math or engineering as approved by thesis advisor

- Seminar Course: MECH 797 (0 credit hours). 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.
- Qualification examination: Comprehensive Exam (MECH 799T) should be done upon the completion of the coursework in all major and minor areas

List of APPE courses for the thesis and non-thesis option is shown below:

Mandatory Courses, 3 credits each:

MECH 671	Renewable Energy Potential, Technology and Utilization in Buildings, or
EECE 675	Renewable Energy Systems or
ENST 300	Energy Science and Technology
MECH 672	Energy Systems Modeling
MECH 673	Energy Efficient Buildings with Good Indoor Environment
MECH 674	Energy Economics and Policy **or**
EECE 672	Energy Planning and Policy

Lab Courses, 3 credits each:

MECH 670	Renewable Energy Lab
MECH 679	Energy Audit Lab
MECH 680	HVAC and Refrigeration Systems Lab

Technical Electives, 3 credits each:

MECH 603	Solar Energy
MECH 670	Renewable Energy Lab
MECH 676	Passive Building Design
MECH 677	Heat Pumps
MECH 678	Solar Electricity
MECH 679	Energy Audit Lab
MECH 680	HVAC and Refrigeration Systems Lab
MECH 681	Green Building Basics and LEED Practices
MECH 771	HVAC Systems Control Strategies and Energy Efficiency
MECH 772	Moisture and Control of Humidity Inside Buildings
MECH 778	Special Project in Renewable Energy and Energy Efficiency

Any course from the thermal and fluid sciences concentration in the Master of Mechanical Engineering program can be selected.

Master of Science Degree Program in Energy Studies

Professors:	Ghaddar, Nesreen (MECH); Karaki, Sami (EECE)
Associate Professors:	Kazan, Michel (PHYS); Khodr, Hiba (PSPA)
Lecturers:	Alawieh, Leen; El-Meouchi, Chadia; Harajli, Hassan; Rached, Mounir

Educational Goals and Program Learning Outcomes

The Master of Science in Energy Studies program is planned to consolidate and build on AUB's excellent research and professional profile addressing current and future energy research needs of the region in areas such as energy science and technology, economics, public policy and energy management. The program's educational goals are:

- to promote an interdisciplinary approach to understanding and evaluating various modes of energy supply and end-use efficiency of energy systems within the context of sustainability and development in the region
- to develop effective collaboration skills among students from different disciplines including energy science and technology, economics and public policy
- Upon successful completion of this interdisciplinary course of study, students will:
  - evaluate different sources of energy related to energy extraction, conversion, and utilization for both traditional systems and sustainable/renewable energy alternatives,
  - apply methods of economic analysis, risk and decision analysis, environmental impact assessment and policy techniques for performing energy planning and reaching, and decision-making while addressing sustainability in supply and demand,
  - and understand advances in selected energy technologies, products and energy end-use efficiency and their impact on market economy and development activities.

Admission Requirements

Admission requirements to the program will follow AUB Graduate Studies Policies. Bachelor degree holders from relevant fields of study are eligible to apply for admission into the Energy Studies master's program. Remedial courses may be needed for students as would be recommended by the program.

Applicants to any graduate program other than AUB graduates and graduates of recognized colleges or universities in North America, Great Britain, Australia and New Zealand must demonstrate proficiency in the English language. See Readiness for University Studies in English (RUSE) under Admissions section (page 42).

Credit Waiver Policy

The Energy Studies program may recommend a waiving of up to 6 credits of graduate coursework for students who have completed a Bachelor of Engineering Degree (BE) and are applying for admissions to a Master of Energy Studies Program (MS-ENST). This is subject to approval by the advisor, the chairperson and the MSFEA Graduate Studies Committee. In addition, the total number of transferable credits from BE to MS-ENST should not exceed 9 credits when a student has taken credit overload during his/her undergraduate BE studies. To apply, the student must have completed graduate electives that meet the program requirements with a score of at least 80 or equivalent.

Degree Requirements

MS-ENST Thesis Program Requirements

The program permits full-time or part-time enrollments. To obtain a master's degree in energy studies (thesis program), the student must complete a minimum of 24 credits of graduate coursework, 6 credits of interdisciplinary thesis work on energy-related fields and a 0-credit seminar. The course work is distributed as follows:

- 9 credits of required core courses
- 3 or 6 credits of elective courses from List A on energy resources, economics and policy
- 6 or 9 credits of elective courses from List B on energy science and technology
- 3 credits of elective course as approved by the thesis advisor/s if the elective is not from List A or B
- 0 credit seminar

Credit Summary

Course	Credits
Required core courses	9 cr.
Elective courses from List A	3 or 6 cr.
Elective courses from List B	6 or 9 cr.
Elective graduate course	3 cr.
Thesis	6 cr.
Seminar	0 cr.
Total number of credits required for graduation	**30 cr.**

MS-ENST Non-Thesis Program Requirements

To obtain a master's degree in energy studies (non-thesis program), the student must complete a minimum of 30 credits of graduate coursework and a 0-credit seminar. The coursework is distributed as follows:

- 9 credits of required core courses
- 6 or 9 credits of elective courses from List A on energy resources, economics and policy
- 9 or 12 credits of elective courses from List B on energy science and technology
- 3 credits of elective course as approved by thesis advisor/s if the elective is not from List A or B
- 0-credit seminar

Credit Summary

Course	Credits
Required Core Courses	9
Elective courses from List A	6 or 9
Elective courses from List B	9 or 12
Elective graduate course	3
Seminar	0
Total number of credits required for graduation	**30**

Required Core Courses		**Credits**
ECON 333	Energy Economics and Policy	3
PSPA 352	Foundation of Public Policy	3
ENST 300	The Science and Technology of Energy (FAS/MSFEA)	3
List A	**Energy Resources, Economics and Policy Courses**	**Credits**
ENST 310	Advanced Energy Economics	3
ENST 320	Energy Law and Case Studies	3
ECON 337	Economic Development (with focus on energy and development)	3
ECON 338	Economics of Natural Resources and the Environment)	3
ECON 305	Econometrics I	3
ECON 347	Economics Forecasting	3
MFIN 360	Energy Finance	3
ENMG 601	Management Theory	3
ENMG 603	Probability and Decision Analysis	3
ENMG 604	Deterministic Optimization Models	3
ENMG 632	Project Planning Scheduling and Control	3
ENMG 656	Management of Technological Innovations	3
PSPA 316	International Environmental Policy	3
PSPA 362	Policy Research and Analysis	3
PSPA 381	Special Topics in Energy and Public Policy	3
ENST 396	Topics In Energy Issues: The Case Of Lebanon	3
ENST 396C	Special Topics in Energy Issues: Energy Strategies for Developing Countries	3
ENST 398	Special Projects in Energy Studies in Cooperation With Industry and/or NGO and Legislative Bodies	3
List B	**Energy Science and Technology Courses**	**Credits**
CHEM 324E	Electrochemistry	3
CHEM 331	Chemical Instrumentation for Environmental Analysis	3
CHEM 352C	Renewable Energy	3
CHEN 690	Reservoir Engineering	3
CHEN 798A	Waste Minimi.in the Proc.Indus	3
CIVE 628	Sustainable Building Design and Construction	3
CIVE 656	Air Pollution Control I	3
CIVE 659	Environmental Impact Assessment	3
CIVE 601	GIS and Geospatial Data Modeling	3

CIVE 686	Enviro Responsive Bldgs	3
CIVE 691A	Scales of Sustainability	3
ENMG 602	Introduction to Financial Engineering	3
ENMG 622	Simulation Modeling and Analysis	3
ENMG 633	Advanced Topics in Project Management	3
ENMG 655	Management of Technology	3
ENMG 698	Special Topics in Engineering Management	3
ENST 330	Energy Science and Technology Lab	3
ENST 396B	Biofuels Between Food and Energy Security	3
ENST396D	Energy Resources & Renewable Technologies: Regional Analysis	3
EECE 670	Power System Planning	3
EECE 671	Environmental Aspects of Energy Systems	3
EECE 672	Energy Planning and Policy	3
EECE 675	Renewable Energy Systems	3
ENST 398	Special Projects in Energy Studies in Cooperation with Industry and/or NGO and Legislative Bodies	3
GEOL 300	Elements of Petroleum Geology	3
MECH 600	Applied Reservoir Engineering I	3
MECH 671	Renewable Energy Potential, Technology and Utilization in Buildings	3
MECH 673	Energy Efficient Buildings With Good Air Quality	3
PHYS 340	Atmospheric Physics and Energy	3

Comprehensive Exam

See General University Academic Information section in this catalogue (page 52).

Prerequisite Courses

Students who join the program may have to complete prerequisites for courses offered in the program or obtain the consent of the course instructor and program chair. The core courses are designed to include remedial preparation in social science. This will enable the waiver of social science prerequisites for students who join from sciences, math, business or engineering majors. BA holders from the economics major may not need remedial courses beyond the core energy science course. Students from other social science majors or arts may be required to take one or more remedial courses over and above program requirements as would be recommended by the chair of the program upon admissions. Suggested remedial courses for BA holders are PHYS 210, MATH 201 or Math 204, and STAT 201 or their equivalents. These remedial courses are part of the general education requirements of most universities. The prerequisites by topic include:

- Preliminary concepts of fluid dynamics, heat, and first and second law of thermodynamics
- Methods of differentiation and integration
- Partial derivatives and multivariable functions
- Vector functions
- Probability and elementary statistics

The minimum passing grade for a prerequisite course taken after admission to the graduate program is 70. If a student fails to obtain a grade of 70 in any of the undergraduate prerequisites, s/he is allowed to repeat the course only once.

Sample Program

The sample program schedule is given in the following table:

Fall (Term I)		**Spring (Term II)**	
Course Title	Cr.	Course Title	Cr.
Core Course I	3	Core Course II	3
List A Elective	3	List B Elective	3
List B Elective	3	Graduate Elective	3
Seminar	0		
Total Credits	9	Total Credits	9
Fall (Term III)		**Spring (Term IV)**	
Course Title	Cr.	Course Title	Cr.
Core Course III	3	Thesis	6
List A or B Elective	3	Seminar	0
Seminar	0		
Total Credits	**6**	**Total Credits**	**6**

Graduation Requirements

See General University Academic Information section in this catalogue (page 52).

Dual Master's Degree – Master of Engineering in Engineering Management and Energy Studies (thesis option only)

The dual master's degree – Master of Engineering in Engineering Management and Energy Studies – program is primarily intended for individuals with a bachelor's degree in engineering who seek to deepen their knowledge in advanced energy studies and engineering management subjects.

Applicants must be accepted in both programs in accordance with the policies of each program and with AUB policies regarding dual graduate degrees.

A student wishing to apply for the dual degree may submit a single dual-degree application that will be sent to each program simultaneously when first applying for graduate admissions. If the student is already registered in one degree, s/he may apply for the second degree no later than the end of a student's second term at AUB.

The program permits full-time or part-time enrollments. To fulfill the basic requirements for the dual degree, a student must complete a minimum of 18 credit hours of graduate coursework in each degree program. The remaining credits include additional course work and a thesis both of which are credited to the dual degree. The program requires a minimum of 42 credit hours of graduate coursework and 6 credits of thesis work. The coursework is distributed as follows:

- 9 credits of core Energy Studies (ENST) courses
- 6 credits of core Engineering Management (ENMG) courses
- 6 credits of common courses: Required core ENMG (ENST List A Electives)
- 12 credits of ENMG elective courses
- 6 credits of elective courses from ENST List B on energy science and technology
- 3 credits of elective course as approved by thesis advisor/s (ENST)

The courses that are counted toward both degrees are:

ENMG 603	**Probability and Decision Analysis**	**3 cr.**
ENMG 604	**Deterministic Optimization Model**	**3 cr.**
Comprehensive Exam		**0 cr.**
Thesis		**6 cr.**

Sample Schedule

Term: Fall I		
Course Number & Title	**Credits**	**Prerequisite(s)**
ECON 333 Energy Economics and Policy	3	
PSPA 352 Foundations of Public Policy	3	
ENST 300 The Science and Technology of Energy	3	PHYS 210 or equivalent
Term credit total	**9**	
Term: Spring I		
Course Number & Title	**Credits**	**Prerequisite(s)**
ENMG 601 Management Theory	3	
ENMG 602 Introduction to Financial Engineering	3	
ENMG Elective 1	3	
Term credit total	**9**	
Term: Fall II		
Course Number & Title	**Credits**	**Prerequisite(s)**
ENMG 603 Probability and Decision Analysis	3	
ENMG 604 Deterministic Optimization Models	3	
ENST List B Elective 1	3	
Term credit total	**9**	
Term: Spring II		
Course Number & Title	**Credits**	**Prerequisite(s)**
ENMG Elective 2	3	
ENMG Elective 3	3	
ENST List B Elective 2	3	
Term credit total	**9**	
Term: Fall III	**Credits**	**Prerequisite(s)**
Course Number & Title		
ENMG Elective 4	3	
ENST Elective Graduate Course	3	
Comprehensive Exam	0	
Term credit total	**6**	
Term: Spring III	**Credits**	**Prerequisite(s)**
Course Number & Title		
Thesis	6	
Term credit total	6	
Program Total	**48**	

Doctor of Philosophy (PhD)

Specialization: Mechanical Engineering

The Maroun Semaan Faculty of Engineering and Architecture offers a graduate program of study leading to the PhD degree with specialization 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 capacity 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 who are not AUB graduates or graduates of recognized colleges or universities in North America, Great Britain, Australia and New Zealand are required to meet the Readiness for University Studies in English (RUSE) (See page 42).

PhD Program Description

The PhD program in mechanical engineering requires a minimum of 18 credit hours of coursework beyond the master's degree. The student must pass a two-part PhD Qualification Examination. In addition, the student must submit an original thesis based on independent research that makes a significant contribution to her/his area of research. The thesis 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 thesis work is required.

Advisors

After admission into the department, a general advisor 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 thesis advisor by the end of the first term after admission into the program. The student must seek the faculty members that are in the student's area of interest and discuss possible research topics for the PhD thesis with them. Once an advisor 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 coursework beyond the master's degree. The program is composed of 3 credit hours of advanced study in mathematics, 9 credit hours of technical graduate level courses of advanced study in the student's area of research (major course area requirements), and 6 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, which is composed of 6 credit hours of courses, must be taken from outside 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 coursework needed beyond the master's degree.

Mathematics Course Requirements

A 3-credit advanced course in mathematics is required from all doctoral candidates. The course must be approved by the candidate's advisor. The mathematics course requirement is satisfied if the student has completed at least 6 credits of advanced courses in math beyond the bachelor's degree.

Major Course Area Requirements

At least 9 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 thesis advisor. This will enable the doctoral candidate to pursue coursework in direct support of her/his research. The coursework must address all recommendations made during the qualification period by the student's advisor and thesis committee.

The following major course areas are offered:

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

Minor Subject Requirements

The minor is a program of advanced study that will help the student develop knowledge and some competence in an area related to her/his research other than the candidate's major field of study. Two graduate courses (not less than 6 credits) must be taken in a coherent field that is different from the major field of study. These 6 course credit hours must be taken from outside the Mechanical Engineering Department (i.e., in other engineering or basic science departments). Part 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 coursework 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 AUB. The minor subject must be approved in advance by the student's thesis committee and the MSFEA Graduate Studies Committee. The approval of the department offering the minor should also be sought.

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

PhD Qualification Examination

See PhD Qualifying Exam under General University Academic Information section (page 70).

Qualifying Exam Part I: Comprehensive Exam

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

For more Information, see Qualifying Exam Part I: Comprehensive Exam under General University Academic Information (page 70).

Qualifying Exam Part II: Defense of Thesis Proposal

See Qualifying Exam Part II: Defense of Thesis Proposal under General University Academic Information (page 71).

PhD Thesis Requirements

Following successful completion of the first part of the qualifying examination, all PhD candidates must submit a thesis proposal summarizing their thesis problem and 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 thesis 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 Thesis Committee

See PhD Thesis Committee under General University Academic Information (page 72).

External Examiner

An external examiner of high standing from abroad will be nominated by the chair of the department in consultation with the thesis advisor to review the thesis 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 thesis and incorporate revisions in the work in a timely manner. The external examiner may choose to attend the thesis defense and participate in the deliberations.

All PhD candidates must defend their thesis in an oral examination, which is open to the community, during which the candidate is examined by her/his 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 advisor is required. Acceptable courses include the following:

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 701, MECH 760, MECH 761, MECH 762, MECH 707, MECH 764, MECH 763, MECH 766, MECH 767, MECH 602, MECH 603, MECH 604, MECH 606, MECH 607, MECH 609, MECH 663, MECH 665, MECH 702, MECH 703, MECH 600, MECH 608, MECH 653, MECH 670, MECH 671, MECH 672, MECH 673, MECH 674, MECH 675, MECH 676, MECH 678, MECH 679, MECH 705, MECH 751, MECH 765, MECH 768, MECH 769, MECH 770, MECH 771, MECH 772, MECH 773, MECH 778

Design, Materials and Manufacturing:

MECH 624, MECH 720, MECH 721, MECH 630, MECH 615, MECH 619, MECH 622, MECH 631, MECH 632, MECH 633, MECH 634, MECH 637, MECH 736

Mechatronics:

MECH 643, MECH 645, MECH 740, MECH 641, MECH 642, MECH 650, MECH 628, MECH 644, MECH 648, MECH 647, MECH 653, MECH 654, MECH 677

Seminar Course

Seminar Course: MECH 797 (0-credit). The student must register for the course once a year. This is a pass/fail course.

PhD Thesis

MECH 899 PhD Thesis: The thesis is based on original, independent research. A student is required to register for a minimum of 30 credits of thesis work. A student may register for a maximum of 12 credits in any given term. The student must submit a thesis based on results of original, independent research. The PhD thesis is expected to make a significant contribution to the field of mechanical engineering. Upon completion of the thesis and after its approval by the student's thesis advisor, a final oral examination will constitute the thesis defense.

Residence Requirements

The student must register for at least four terms 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 Graduate Council.

Accelerated Doctor of Philosophy, Major: Mechanical Engineering

Admission Requirements

- A bachelor's degree with a minimum major and cumulative average of 85 over 100 or its equivalent
- Graduate Record Examination (GRE) general test scores
- Three recommendation letters (one from the final year project supervisor)
- A written statement of purpose that shows the research potential in the proposed area of study
- All applicants must also satisfy the university requirements for admission to PhD accelerated track.

Course Requirements

The completion of at least 78 credits of graduate study consisting of combined coursework and research beyond the bachelor's degree is required for the PhD accelerated track in Mechanical Engineering.

- A minimum of 36 credit hours must be in approved graduate level coursework and a minimum of 30 credit hours of thesis work. In addition, normally a maximum of 6 credit hours of the 36 credits of coursework may be tutorial courses.

- The basic program of study for the PhD accelerated track is built around one major area and a minimum of one minor area. Students take courses to satisfy the major and minor area requirements and to acquire the knowledge needed for the Qualifying Exam Part I and Qualifying Exam Part II.
- The major area can be in one or a combination of two of the ME areas.
- Students must take:
  - At least 2 courses (6 credit hours) in advanced mathematics. The courses must be approved by the candidate's supervisor. The mathematics course requirement is satisfied if the student has completed at least 6 credits of advanced courses in math beyond the bachelor's degree.
  - Students must take at least 6 graduate courses (18 credit hours) in their major area.
  - They must also take 2 graduate courses (6 credit hours) in their PhD minor area. The minor courses must be taken from outside the Mechanical Engineering department (i.e., in other engineering or basic science departments). If the student chooses mathematics as a minor, then the courses taken to fulfill the mathematics course requirements will count towards the minor subject requirements.
  - Finally, students must take 2 graduate electives courses within the Mechanical Engineering department.

Residence Requirements

- The student must register for at least eight terms beyond the completion of the bachelor's degree.
- Requirements for the PhD degree in the accelerated track must be completed within a period of twelve regular terms after starting graduate work beyond the bachelor's degree. Extension beyond the twelve regular terms limit requires the approval of the ME graduate committee, MSFEA GSC and GC.
- Students deemed by the department, within one to two years after admission into the accelerated track, as not qualified to complete a PhD degree, may be granted a master's degree in the area after completing the equivalence of a non-thesis master's.

For other requirements and rules, please refer to the PhD in Mechanical Engineering section (page 62).

PhD Qualifying Exam

Refer to Qualifying Exam Part I and II section.

Graduation Requirements

A student can graduate at the end of any academic term upon satisfying the following requirements:

- Met the residence requirements and all pertinent AUB regulations
- Had at least two papers, based on her/his PhD thesis, 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 is not on probation
- Passed the Doctoral Qualifying Examination
- Successfully defended a thesis of original scholarly work
- Deemed worthy by the faculty

Course Descriptions

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 aspect, 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; 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 aerosol collections of solid or liquid particles suspended in gases, such as clouds, smoke, 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 consent 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** **3 cr.**

This course introduces the advanced concepts and principles needed to analyze hydrocarbon reservoir fluid systems, and defines the size and content 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 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, emphasis is 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 in 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 media. Topics include fundamentals of tensor calculus, stress, deformation and strain, general principles, and constitutive equations for solids and fluids. Applications. *Prerequisites: MECH 320, MATH 218 (or equivalent), MATH 212 (or equivalent), or graduate level standing.*

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 state of the art 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 property 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 how 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 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 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 given to the application of quality management techniques to solve industrial case problems. The course emphasizes the philosophy and fundamentals of quality control, the statistical 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 and 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, 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 and 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 and 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 locations; data acquisition systems and instruments; and 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; additionally, students will be introduced to the damage detection and condition assessment process. *Prerequisite: MECH 320, 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, 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 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, dermatologic 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 and PHYL 346, or consent of instructor.*

MECH 637 Micromechanics and Crystal Plasticity 3 cr.
This course covers the 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, EECE 460 or consent of instructor.*

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.*

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 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.

MECH 647/ EECE 699 **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 436, or MECH 314 and EECE 460.*

MECH 648/ EECE 669 **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 436 or EECE 460.*

MECH 650/ EECE 698 **Autonomous Mobile Robotics** **3 cr.**

This course is designed to provide engineering graduate and 4th 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 436; or EECE 230 and EECE 460.*

MECH 653/ EECE 660 **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, EECE 460 or equivalent.*

MECH 654/ EECE 665 **Adaptive Control** **3 cr.**

A course that includes the control of partially known systems; analysis and design of adaptive control systems; self-tuning regulator; model reference adaptive control of uncertain dynamic systems; typical applications. *Prerequisite: MECH 436, EECE 460 or equivalent.*

MECH 655/ EECE 662 **Optimal Control** **3 cr.**

A course on optimization theory and performance measures, calculus of variations, the maximum principle, dynamic programming, numerical techniques and LQR control systems.

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

This course introduces the 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.

MECH 663 Computational Fluid Dynamics 3 cr.
A course that deals with the 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 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.*

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 environments 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 is 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 corequisite: 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: 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 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 designed to give 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 will then be applied to deduce possible savings and their economic value. *Pre- or co-requisite: MECH 672.*

MECH 680 HVAC and Refrigeration Systems Lab 3 cr.
A course designed to give 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. Students will learn how to use and develop test equipment and plan for assessing system's performance according to ISO or ASHRAE standards. 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 term. *Pre- or corequisite: MECH 673.*

MECH 681 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).

MECH 691 Convex Optimization 3 cr.
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.*

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. *Prerequisite: CHEM 202, MECH 412, MECH 414 or equivalent.*

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, and CHEM 202; or consent 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 and MECH 412; or equivalent.*

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, as well as the clothing and 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 and 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 and phase diagram computation; microstructure evolution and 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 consent 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 equation 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 and so on); 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 in addition to basic relations for continuous fluids; vorticity dynamics, Kelvin Helmholtz theorems; Navier-Stokes equations; turbulence and oscillating flows: *Prerequisite: MECH 314.*

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 3 cr.
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.*

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 in which 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 and 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 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 test 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.
Prerequisite: MECH 799T or MECH 799TR.

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 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 mold growth, decay of construction materials paintings, and so on. *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 of the indoor climate, consumption of energy, and 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 798H 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.
Prerequisite: MECH 799T or MECH 799TR.

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 980 **Qualifying Exam Part I: Comprehensive Exam** **0 cr.**
Every term.

MECH 981 **Qualifying Exam Part II: Defense of Thesis Proposal** **0 cr.**
Every term.

MECH 982 **PhD Thesis** **3 cr.**
Every term. Taken while total required credit hours have not been completed.

MECH 983 **PhD Thesis** **6 cr.**
Every term. Taken while total required credit hours have not been completed.

MECH 984 **PhD Thesis** **9 cr.**
Every term. Taken while total required credit hours have not been completed.

MECH 985 **PhD Thesis** **12 cr.**
Every term. Taken while total required credit hours have not been completed.

MECH 986 **PhD Thesis** **0 cr.**
Every term. Taken while total required credit hours have not been completed.

MECH 987 **PhD Thesis Defense** **0 cr.**
Every term.

Energy Studies Interdisciplinary Courses

ENST 300 The Science and Technology of Energy (FAS/MSFEA) 3.0; 3 cr.
This course examines the fundamental principles of energy conversion processes as well as their impact on the environment and provides a clear physical explanation of these principles. It also offers a survey of current energy conversion technologies. Topics are selected based on their future promise energy sources. The course starts with introductory topics providing a minimum base on thermodynamics, kinetic theory of gases, heat transfer and fluid flow and the concept of energy efficiency. Topics include: applications in heat engines, solar thermal, photovoltaic energy conversion, wind, biomass and fuel cells. *Prerequisite: PHYS 210 or equivalent.*

ENST 310 Advanced Energy Economics 3.0; 3 cr.
This course covers advanced topics in both oil and natural gas economics with a clear distinction between these two energy sources. It is to cover in depth analyses of topics such as supply and demand, formation and forecast of prices, investment in oil and gas fields and infrastructure, the economics of transporting oil and natural gas (as piped or liquefied gas), as well as that related to the end-use of crude oil, petroleum products and natural gas in all its assortment. *Prerequisite: ECON 333.*

ENST 320 Energy Law and Case Studies 3.0; 3 cr.
This course is concerned with regulation of energy, energy resources and energy facilities. Among the topics examined are the regulation of rates and services, the state public utility commissions and the interaction with environmental law. Attention is given to energy resources (such as oil, natural gas and coal reserves, and hydropower resources) and to the generation, transmission and distribution facilities. Special emphasis is placed on the current and future roles of renewable energy, energy efficiency and nuclear energy, as well as on the regulation and deregulation of electricity. *Prerequisite: PSPA 352.*

ENST 330 Energy Science and Technology Lab 3.0; 3 cr.
This course is designed to give students “hands-on” experience on selected energy science and technology topics in solar energy; electrochemical energy storage; thermoelectric technologies; fuel cells; thermo-hydraulics of power systems; energy efficiency in a wide range of systems; hybrid engines; thermal management of electronics; and energy efficient buildings. The selected topics vary from term to term.

ENST 396 Topics in Energy Issues: The Case of Lebanon 3.0; 3 cr.
This course addresses contemporary issues in energy economics facing Lebanon. It evaluates energy sector economic policies in production and pricing, taxation and conservation, and provides alternatives policies and solutions.

ENST 396A Special Topics in Energy Issues: The Future of Nuclear Power 3.0; 3 cr.
This course will provide students with a deeper understanding of nuclear energy and the underlying economic, security, and technological challenges associated with it. Covered topics include the basic physics of nuclear energy, overview of nuclear technologies, economics of nuclear power and examination of safety and security risks. The course aims to provide a policy-oriented platform to assess the prospects of a global nuclear “renaissance” as well as the realities of nuclear power deployment in the Middle East. Prerequisite: *MECH 310, PHYS 210 or PHYS 211.*

ENST 396B **Special Topics in Energy Issues: Biofuels Between Food and Energy Security** **3.0; 3 cr.**

This course provides students with a deeper understanding of biofuels. The course examines the different biofuel options and their ecological as well as socio-economic impacts. Covered topics include the consequences of biofuel production for food and energy security as well as for the environment. Particular emphasis is placed on biofuel production in developing countries. The course aims to identify criteria for sustainable biofuel production that contributes to energy independence, economic growth and environmental protection.

ENST 396C **Special Topics in Energy Issues: Energy Strategies for Developing Countries** **3.0; 3 cr.**

This course provides students with a deeper understanding of the different energy resources (fossil energy such as oil, coal and natural gas; nuclear energy; and the different options of renewable energies like hydropower, solar energy, on- and offshore-wind energy, biofuels, energy derived from animal waste) and their use in developing countries. The course examines the energy strategies in developing countries in relation to issues such as combatting climate change, stimulating economic growth and contributing to energy independence. Amongst other cases, special emphasis of the course will be on Lebanon's challenges in the energy sector. The course also looks at the role of developed countries and international organizations to help developing countries in meeting their energy needs in a sustainable way.

ENST 396D **Energy Resources & Renewable Technologies: Regional Analysis** **3 cr.**

This course will provide students with a deeper understanding of the different energy technologies in Arab countries. Which local economic, political, and geographic conditions influence the energy situation (import and export dependency, choice of energy sources, etc.) of countries in the region? How are the Arab countries interconnected with each other on energy issues? Apart from the regional dynamics, which global forces (such as climate agreements and oil market prices) influence the energy situation in Arab world countries? The course will examine the use of energy resources like conventional energy (fossil oil, coal and natural gas), nuclear energy, renewables (hydropower, solar energy, onshore and offshore wind energy, use of biomass) to provide a better understanding of the energy situation and challenges in Arab world countries such as the finiteness of fossil resources and ecological problems. The students will learn to develop regional strategies for a sustainable energy transition (under environment, social, economic and technical criteria) that take impacts from global markets and local developments into consideration.

ENST 397 **Seminar**

Must be registered once per year.

ENST 395A/B **Comprehensive Exam**

ENST 699 **Thesis** **6 cr.**

ENST 398 **Special Projects in Energy Studies in Cooperation** **3.0; 3 cr.**

With Industry and/or NGO and Legislative Bodies .