Maroun Semaan Faculty of Engineering and Architecture (MSFEA)

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Historical Background

The first programs leading to a master's degree in MSFEA were introduced in 1962. Since then other programs have been added to help meet the growing demand for advanced engineering education. Between October 1990 and October 1994, six new master's degree programs were introduced: the Master of Engineering Management (1990), four programs leading to the degree of Master of Engineering with majors in computer and communications engineering, electric power engineering, electronics, devices and systems, and environmental and water resources engineering (1991-1993), and the Master of Mechanical Engineering (1994) with majors in applied energy, materials and manufacturing, or thermal and fluid sciences. In 1998, two programs were added: the Master of Urban Design and the Master of Urban Planning and Policy. In 2014, two master's degree programs were introduced in chemical engineering: the Master of Science degree program and the Master of Engineering degree program. In 2016, a Master of Science degree program in biomedical engineering was introduced.

In 2007, PhD programs started accepting students in three departments of MSFEA: the Civil and Environmental Engineering department (PhD in civil engineering and PhD in environmental and water resources engineering), the Electrical and Computer Engineering department (PhD in electrical and computer engineering), and the Mechanical Engineering department (PhD in mechanical engineering). In 2016, a new PhD program in biomedical engineering was established.

Mission

We offer world-class educational programs that prepare students for the engineering, architecture and design professions. Rooted in the liberal education model, our programs also prepare students to be engaged citizens and leaders, entrepreneurs and researchers who deploy their skills with ingenuity, integrity and a sense of responsibility towards future generations. Our faculty produces transformative knowledge and technology through internationally-recognized research and design, and seeks to leverage the special contexts of Lebanon and the region to define highly novel and relevant research programs. We impact policy and practice through our alumni and by directly engaging industry, government and the public at large.

Master's Degree Programs

The Maroun Semaan Faculty of Engineering and Architecture offers graduate programs leading to the degree of Master of Engineering (ME) with majors in civil engineering, environmental and water resources engineering, electrical and computer engineering, mechanical engineering and chemical engineering. The faculty also offers the degrees of Master of Engineering Management (MEM), Master of Urban Design (MUD), Master of Urban Planning and Policy (MUPP), Master of Mechanical Engineering with a major in applied energy, and Master of Science (MS) with majors in chemical engineering, biomedical engineering and energy studies. MSFEA also offers a Master of Science program in environmental technology as part of the Interfaculty Graduate Environmental Sciences Program.

In addition, a professional diploma in green technologies with majors in energy, buildings and water is offered in the faculty for professionals who wish to enhance their knowledge in the field.

The requirements for admission to the master's programs are those specified for the master's degree in the Admissions section of this catalogue with the following interpretations and additions.

Waiving of Credits

The department or program of the intended major may recommend waiving up to 9 credits of coursework for students who have completed a Bachelor of Engineering (BE) degree and are applying for admissions to a Master of Engineering (ME) program, which is subject to approval by the advisor, chairperson and the MSFEA Graduate Studies Committee. To apply, the student must have completed advanced engineering courses (normally at the 600-level and above) that meet the program requirements with a grade of at least B+ or 80. In addition, the total number of transferable credits from BE to ME should not exceed 12. This means that if a student has taken a credit overload during his/her undergraduate BE studies, s/he can waive a maximum of 12 credits.

For the Master of Urban Planning and Policy (MUPP) and the Master of Urban Design (MUD) programs, the Architecture and Design (ArD) Department may recommend waiving up to nine credits of coursework for students who have completed a Bachelor of Architecture degree, and up to six credits of coursework for students who have completed a Bachelor of Landscape Architecture degree.

The ArD Department may also recommend waiving up to six credits of coursework for students who have completed a Bachelor of Engineering degree and are applying for admission to the MUPP program.

Waiving of credits is subject to approval by the program coordinator, the chairperson, and the MSFEA Graduate Studies Committee. To apply, the student must have completed the advanced course(s) with a grade of at least B+ or 80 or equivalent. An advanced course is a course taken during the senior (third) or later year(s) of undergraduate study and deemed equivalent, by program coordinator, chairperson, and MSFEA Graduate Studies Committee, to a course listed under Mandatory Courses or Elective Courses in the MUD/MUPP section of the Graduate Catalogue.

Regulations for Master's Students Taking Undergraduate Courses

Master's level students who are required to take undergraduate courses must obtain a grade of at least C+ or 70 in each undergraduate course taken. If a student fails to obtain a grade of C+ or 70 in any of these undergraduate courses, the student is allowed to repeat that course only once. Failure to meet the requirements will result in the student being dropped from the graduate program.

Curricula and Courses

The curricula and courses offered in each department are presented in the appropriate sections of this catalogue.

Courses Open to Students from other Faculties

Students from other faculties are allowed to take any course for credit offered by the MSFEA, provided space is available, the prerequisites are satisfied and the student has prior approval of both his/her faculty and the department offering the course.

Doctor of Philosophy (PhD) Programs

The Maroun Semaan Faculty of Engineering and Architecture offers graduate programs leading to the degree of Doctor of Philosophy (PhD) with specializations in biomedical engineering, civil engineering, electrical and computer engineering, environmental and water resources engineering, and mechanical engineering.

Criteria for Regular Admission to PhD Programs

Candidates for a doctoral degree program must hold a master's degree or its equivalent and must demonstrate outstanding academic ability (minimum average of 85 (3.7) or its equivalent) at the master's level as well as the potential to conduct scholarly research. Additional specific requirements for each program can be found in the departmental sections of this catalogue. Application to the doctoral program will follow the deadlines set by the Admissions Office. All applicants are required to take the General Exam part of the Graduate Record Examination (GRE) and submit their scores. Students other than AUB graduates and graduates of recognized colleges or universities in North America, Great Britain, Australia and New Zealand must meet the English Readiness for University Study in English (RUSE) set for master's students.

Admission to a PhD program requires the recommendation of the department offering the program and the approval of the MSFEA Graduate Studies Committee.

Criteria for Admission to the Accelerated PhD Programs

To apply to the accelerated program, students must have an average of 85 (3.7) or above in their undergraduate work. This applies to the average in the major as well as the cumulative average.

In addition to meeting the requirements described in the General University Academic Information section of the catalogue, there may be specific requirements described in the departmental sections.

Financial Support Available to Graduate Students

The MSFEA offers several types of graduate assistantships to the most qualified applicants to its graduate programs, which include fellowships, graduate research assistantships (GRA), graduate teaching assistantships (GTA), and graduatete administrative assistantships (GAA).

Students who receive financial support are expected to maintain a high level of academic performance, satisfactory progress toward a degree and satisfactory performance of the work assignments associated with the aid.

These fellowships, GRAs , GTAs, and GAAs covering tuition are available for students at the graduate level in return for assisting faculty members and departments in teaching and/or research for a specified number of hours per week. Applicants are selected on the basis of their academic record and the needs of the relevant department. For more information, refer to Full-Time Status for University Graduate Assistants and Graduate Research Assistants (page 54).

Applicants opting for the non-thesis track are normally not offered graduate assistantships.

Biomedical Engineering Graduate Program

Coordinator:	Mhanna, Rami (Biomedical Engineering, MSFEA)
Co-coordinator:	Jaffa, Ayad (Biochemistry & Molecular Genetics, FM)
Coordinating Committee Members:	Amatoury, Jason (Biomedical Engineering, MSFEA) Daou, Arij (Biomedical Engineering, MSFEA) Darwiche, Nadine (Biochemistry & Molecular Genetics, FM) Khoueiry, Pierre (Biochemistry & Molecular Genetics, FM) Khraiche, Massoud (Biomedical Engineering, MSFEA) Kobeissy, Firas (Biochemistry & Molecular Genetics, FM) Saad, Walid (Chemical Engineering, MSFEA)

Background

The Biomedical Engineering Graduate Program (BMEP) is a joint MSFEA and FM interdisciplinary program that offers two degrees: Master of Science (MS) in Biomedical Engineering and Doctor of Philosophy (PhD) in Biomedical Engineering. The BMEP is housed in the MSFEA and administered by both MSFEA and FM via a joint program coordinating committee (JPCC).

The mission of the BMEP is to provide excellent education and promote innovative research enabling students to apply knowledge and approaches from the biomedical and clinical sciences in conjunction with design and quantitative principles, methods and tools from the engineering disciplines to address human health related challenges of high relevance to Lebanon, the Middle East and beyond. The program prepares its students to be leaders in their chosen areas of specialization committed to lifelong learning, critical thinking and intellectual integrity.

The curricula of the MS and PhD degrees are composed of core and elective courses balanced between biomedical sciences and engineering and between fundamental and applied knowledge.

The curricula include the following three research focus areas:

- **Biomedical Systems:** This focus area includes research directions such as devices, instrumentation, biomechanics, biomaterials, drug delivery systems and tissue engineering.
- **Biomedical Cybernetics:** This focus area includes research directions such as biomedical and health informatics, computational biology, biomedical signal/image processing and biomedical systems engineering.
- **Cardiovascular and Pulmonary Engineering:** This focus area includes research directions such as fluid mechanics, modeling, simulation, imaging, devices, and implants related to both human cardiovascular and pulmonary systems.

A student may select his/her courses to satisfy the requirements of one of the three focus areas.

The MS and PhD degrees are open to students holding degrees from relevant fields of study including basic sciences, biomedical sciences, computer science, engineering, health sciences, and mathematics. Due to the interdisciplinary nature of the program, eight remedial undergraduate courses in sciences, math and engineering have been identified to cover the needed prerequisite knowledge; the remedial courses required by each admitted students are customized on a case-by-case basis depending on the student's undergraduate degree. Remedial undergraduate courses do not count as credit towards the MS or PhD degree completion. Grades on these remedial courses will appear on the transcript as Pass/Fail with a passing grade of C+ or 70/100.

Master of Science in Biomedical Engineering

The BMEP offers a Master of Science (MS) degree in Biomedical Engineering with two options: thesis option and non-thesis option.

Admission Requirements

The application procedures and admission requirements to the MS program follow AUB's General University Academic Information as documented in the Graduate Catalogue. To be considered for admission, applicants must hold a bachelor's degree in a relevant field of study from AUB or its equivalent, or from a recognized institution of higher learning.

Accepted students in the thesis option are eligible to apply to the Graduate Fellowship and Assistantship Program (GFAP).GFAP support cannot be used to cover the tuition for remedial undergraduate courses.

Course Requirements

The MS program consists of 30 credits. The curriculum design is divided into core courses and elective courses in addition to a master's thesis for the thesis option. This program does not provide credit towards New York State licensure.

Core graduate courses: 18 credits of core courses from biomedical sciences and engineering.[1]

Required core courses (18 cr.)		Credits
BIOC 321	Nucleic Acids and Basic Genetics	1
BIOC 322	Protein Biochemistry	1
BMEN 600	Biomedical Engineering Applications	3
BMEN 601	Computational Modeling of Physiological Systems	3
BMEN 672	Hospital Lab Rotation	0
BMEN 673L	Biomedical Engineering Lab	1
EPHD 310	Basic Biostatistics[1]	3
HUMR 310 (A, B, or C)	Biomedical Research Techniques	1
HUMR 314	Research Seminar	1
PHYL 346	Human Physiology	4

Restricted elective graduate courses: 6 credits restricted elective courses customized per focus area and required by both thesis and non-thesis options.

1) EPHD 310 can be replaced by another advanced level statistics course based on JPCC's approval.

Restricted elective courses (6 cr.)		Credits	Systems	Cyber-netics	Cardio-vascular
BIOC 325	Receptors and Signal Transduction	2		X	
BIOC 326A	Bioinformatics Tools and Applications in Genomics	1		X	
BMEN 603	Tissue Engineering	3	X		X
BMEN 604	Engineering of Drug Delivery Systems	3	X		X
BMEN 605	Biomedical Imaging	3		X	X
BMEN 606	Nanobiosensors	3	X	X	
BMEN 607	Biomechanics	3	X		
BMEN 608	Biomaterials and Medical Devices	3	X		X
BMEN 609	Computational Neuroscience	3	X	X	
BMEN 610	Micro and Nano Neural Interfaces	3	X		
BMEN 611	Computational Modeling in Biomechanics	3	X	X	X
EECE 601 or EECE 602	Biomedical Engineering I or Biomedical Engineering II	3	X	X	X
EECE 603	Biomedical Signal and Image Processing	3		X	X
EECE 605	Neuromuscular Engineering	3	X	X	
EECE 633 or EECE 663 or EECE 667 or EECE690 or EECE 693	Data Mining or System Identification or Pattern Recognition or Introduction to Machine Learning Neural Networks	3		X	
HUMR 305	Cell and Tissue Biology	3	X		
PHYL 302	Cardiovascular Physiology	2			R
PHYL 300A	Pulmonary Physiology	1			R

Free elective graduate courses for the non-thesis option: 6 credits additional elective courses. These courses should be taken from engineering and should be approved by the student's advisor and the coordinator of the joint program coordinating committee.

Master thesis for the thesis option: 6 credits master's thesis in biomedical engineering. The thesis requirements follow AUB's General University Academic Information as documented in the Graduate Catalogue.

PhD in Biomedical Engineering

Admission Requirements

The application procedures and admission requirements to the PhD program follow AUB's General University Academic Information as documented in the Graduate Catalogue. To be considered for admission, applicants must hold a bachelor's or master's degree in a relevant field of study from AUB or its equivalent, or from a recognized institution of higher learning.

Acceptance into the PhD program is determined by academic performance as well as an assessment of readiness, potential and ability to develop into independent researchers as judged by interviews by faculty members, a written statement, letters of recommendation, GRE scores, and other means of assessment such as publications and industrial experience.

Accepted students are eligible to receive scholarships that fully cover their tuition fees and provide a monthly stipend.

Degree Requirements

General requirements for master's degree holders: Based on AUB's guidelines, a minimum of 48 credit hours beyond those required for the master's degree, of which a minimum of 18 credit hours must be in graduate level course work and a minimum of 24 credit hours of thesis work, must be taken. Requirements also allow a maximum of 3 credit hours out of the 18 credits of coursework as tutorial course and include a 0-credit comprehensive examination preparation course and a 0-credit thesis proposal preparation course.

General requirements for bachelor's degree holders: Based on AUB's guidelines, a minimum of 78 credit hours beyond those required for the bachelor's degree, of which a minimum of 36 credit hours must be in graduate level coursework and a minimum of 30 credit hours of thesis work, must be taken. Requirements also allow a maximum of 6 credit hours out of the 36 credits of coursework as tutorial courses and include a 0-credit comprehensive examination preparation course and a 0-credit thesis proposal preparation course.

To earn a PhD degree in Biomedical Engineering, the student must complete the following requirements:

- Satisfy the course and research credit requirements
- Satisfy the residence requirement and all other pertinent AUB regulations
- Have at least one international refereed journal article based on the PhD thesis
- Have at least one refereed conference paper based on the PhD thesis
- Have a cumulative average of 85 (3.7) or above
- Pass the comprehensive and oral qualifying examinations
- Successfully defend the PhD thesis

The following are the graduate level course requirements for students admitted with a bachelor's degree. The total number of credits is at least 36 credits divided among core, restricted elective and free elective courses. Students admitted with a master's degree can waive as many courses as possible without going below the minimum required 18 credits of coursework.

Core graduate courses: 21 credits of core courses from biomedical sciences and engineering.[12]

Required core courses (21 cr.)		Credits
BIOC 321	Nucleic Acids and Basic Genetics	1
BIOC 322	Protein Biochemistry	1
BIOM 385	Research Ethics	1
BMEN 600	Biomedical Engineering Applications	3
BMEN 601	Computational Modeling of Physiological Systems	3
BMEN 671	PhD Lab Rotation1	1+1
BMEN 672	Hospital Lab Rotation	0
BMEN 673L	Biomedical Engineering Lab	1
BMEN 675	Approved Experience	0
EPHD 310	Basic Biostatistics2	3
HUMR 310 (A, B, or C)	Biomedical Research Techniques	1
HUMR 314	Research Seminar	1
PHYL 346	Human Physiology	4

Restricted elective graduate courses: 9 credits restricted elective courses customized per focus area.[3]

Restricted elective courses (9 cr.)[3]		Credits	Systems	Cyber-netics	Cardio-vascular
BIOC 325	Receptors and Signal Transduction	2		R	
BIOC 326A	Bioinformatics Tools and Applications in Genomics	1		R	
BMEN 603	Tissue Engineering	3	X		X
BMEN 604	Engineering of Drug Delivery Systems	3	X		X
BMEN 605	Biomedical Imaging	3		X	X
BMEN 606	Nanobiosensors	3	X	X	
BMEN 607	Biomechanics	3	X		
BMEN 608	Biomaterials and Medical Devices	3	X		X
BMEN 609	Computational Neuroscience	3	X	X	
BMEN 610	Micro and Nano Neural Interfaces	3	X		
BMEN 611	Computational Modeling in Biomechanics	3	X	X	X
EECE 601 or EECE 602	Biomedical Engineering I or Biomedical Engineering II	3	X	X	X
EECE 603	Biomedical Signal and Image Processing	3		X	X
EECE 605	Neuromuscular Engineering	3	X	X	

1) Students are required to take two PhD lab rotation courses where each lab rotation is 1 credit (one lab rotation in MSFEA and one lab rotation in FM).
2) EPHD 310 can be replaced by another advanced level statistics course based on JPCC's approval.
3) Courses marked as "R" are required, and courses marked as "X" are possible elective options.

EECE 633 or EECE 663 or EECE 667 or EECE690 or EECE 693	Data Mining or System Identification or Pattern Recognition or Introduction to Machine Learning Neural Networks	3		X	
HUMR 305	Cell and Tissue Biology	3	R		
PHYL 300A	Pulmonary Physiology	1			R
PHYL 302	Cardiovascular Physiology	2			R

Free elective graduate courses: 6 credits additional elective courses. These courses should be taken based on the student's specific area of research as approved by the student's advisor.

Course Descriptions

BMEN 600 Biomedical Engineering Applications 3 cr.

Biomedical engineering is an interdisciplinary domain which applies principles of engineering to find solutions for biological and health problems. Biomedical engineering aims to improve our fundamental understanding of biological processes and develop approaches for optimized therapeutic/diagnostic healthcare procedures. The field of biomedical engineering involves the development of materials to replace or enhance the operation of damaged or malfunctioning biological entities, development of diagnostic and therapeutic tools, modeling of biological systems, signal processing and bioinformatics. This course will introduce students to biomedical engineering and provide insight into the various applications in the biomedical engineering field. The course will be divided into modules, and each will be given by a specialist in a certain biomedical engineering area.

BMEN 601/ MECH 635 Computational Modeling of Physiological Systems 3 cr.

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

BMEN 602 Computational Modeling of Cardiovascular and Pulmonary Systems 3 cr.

The need for better understanding the mechanics and tools for computational modeling of cardiovascular and respiratory systems in healthy and diseased conditions is constantly increasing. This is a result of the enormous advances made in the science and engineering of both surgical and therapeutic medicine. This course covers the modeling and simulation of cardiovascular and respiratory systems. It will provide the students with a thorough understanding of the anatomy, physiology and mechanics of cardiovascular and respiratory systems as well as the computational tools for modeling and simulation of cardiac, circulatory and respiratory systems in healthy and diseased conditions.

BMEN 603/ CHEN 675 Tissue Engineering 3 cr.

In a world of aging population, an ever-increasing demand for improvement of healthcare services and need for replacement organs and tissues are arising. The limited pool of donors together with the problem of donor organ rejection is a strong driver for engineering tissues and other body parts. Tissue engineering is an interdisciplinary field that uses cells, biomaterials, biochemical (e.g. growth factors) and physical (e.g. mechanical stimulation) signals, as well as their combination to generate tissue-like structures. The goal of tissue engineering is to provide biological substitutes that can maintain, restore or improve the function of damaged organs in the body. This course will introduce interested students to the new field of tissue engineering and provide insight on cutting edge applications in this area.

BMEN 604/ CHEN 673 Engineering of Drug Delivery Systems 3 cr.

This course focuses on recent advances in the development of novel drug delivery systems. The fundamentals of drug delivery are discussed. Various strategies to tune and control the release of active agents for optimized therapeutic outcomes are explored. The course covers polymers and techniques used to produce drug nanoparticles, with specific examples of nanoparticle-based drug delivery systems. *Prerequisites: CHEN 314 and CHEN 411, or consent of instructor.*

BMEN 605 Biomedical Imaging 3 cr.

Biomedical imaging offers an unprecedented view into the structure and function of a living body, and as such plays an essential role in medical practice and research. This course will provide students with an overview of the key concepts underlying the primary diagnostic biomedical imaging modalities, including: ultrasound, x-ray, computed tomography, magnetic resonance and nuclear imaging. In particular, students will gain an understanding of the physical principles and theoretical bases governing the operation of each imaging modality, the technology that translates theory into practice, and the basic methods involved in image formation. Students will also learn the limitations of each imaging procedure, while being exposed to their vast applications in the clinic and research. *Prerequisite: consent of instructor.*

BMEN 606 Nanobiosensors 3 cr.

This course will provide a comprehensive analysis of the field of nanoengineering with a focus on biosensors including common modalities, basic theoretical considerations for sensor operation, physics of detection and applications in research and medical diagnostics. The course will cover the major types of electronic nanobiosensors for biological signal detection (potentiometric, amperometric, and mass based sensors) and their applications in the fields of neural engineering, DNA sequencing and cardiovascular early disease detection. The course will enable students to have a strong grasp of fundamentals of biosensor design, select sensors for various applications and evaluate new and emerging technologies. *Prerequisites: EECE 210 (or equivalent) and BIOL 210 (or equivalent); or consent of instructor.*

BMEN 607/ 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. *Prerequisites: CIVE 210, MECH 320 or CIVE 310; or consent of instructor.*

BMEN 608/ MECH 634 **Biomaterial and Medical Devices** **3 cr.**

A course that examines the structure-property relationships for biomaterials and the medical applications of biomaterials and devices. The first part of the course focuses on the main classes of biomaterials, metal, ceramic, polymeric and composite implant materials, as well as on 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.*

BMEN 609 **Computational Neuroscience** **3 cr.**

The human brain, perhaps the most complex, sophisticated, and complicated learning system, controls virtually every aspect of our behavior. The central assumption of computational neuroscience is that the brain computes. What does that mean? Generally speaking, a computer is a dynamical system whose state variables encode information about the external world. In short, computation equals coding plus dynamics. Some neuroscientists study the way that information is encoded in neural activity and other dynamical variables of the brain. Others try to characterize how these dynamical variables evolve with time. The study of neural dynamics can be subdivided into two separate strands. One tradition, exemplified by the work of Hodgkin and Huxley, focuses on the biophysics of single neurons. The other focuses on the dynamics of networks, concerning itself with phenomena that emerge from the interactions between neurons. Therefore computational neuroscience can be divided into three subspecialties: neural coding, biophysics of neurons, and neural networks. This course will introduce engineers, physicists, computational scientists, mathematicians and other audiences to the neurosciences from the cellular level and the network level as seen from computational lenses. *Prerequisites: BIOL 201 (or equivalent) and Math 202, or consent of instructor.*

BMEN 610 **Micro and Nano Neural Interfaces** **3 cr.**

Neural interfaces are micro and nano devices that form the connection between the biological neural tissue and the external electronic devices. These devices are designed for mapping, assisting, augmenting, or repairing neural pathways. The course will focus on physical, chemical and neurophysiological principles of neural interfaces, theoretical and functional basis for their design, micro and nano fabrication techniques and applications in neural prosthesis for Brain Machine Interface. Topics covered in class will include; Neural Engineering, Brain Machine Interface, Microfabrication, Nanofabrication, Soft-lithography, Electrokinetics, Electrochemistry, Neural probes, Biocompatibility, Microelectrodes, NeuroMEMS (neuro microelectromechanical systems, BioMEMS (biomedical microelectromechanical systems). *Prerequisite: consent of instructor.*

BMEN 611/ MECH611 **Computational Modeling in Biomechanics** **3 cr.**

This course is open to engineering, science and medical students wanting a glimpse into the world of computational finite element modeling and simulation to investigate and solve biomedical problems. Students will take a journey through the processes involved in producing a computational finite element model in the biomedical field; starting at construction of model geometry from medical imaging data (CT/MRI), through to model creation, simulation and visualization using finite element analysis software (ANSYS Workbench). Students will also be exposed to a selection of experimental lab techniques in biomechanics and physiology to acquire data required for model development and

validation. In pursuit of developing an appreciation for the areas covered, the course will incorporate a mix of theory, demonstrations, practice, real-world modeling applications and research seminars. *Pre-requisites MATH 201 and consent of instructor.*

BMEN 671 PhD Lab Rotation 1 cr.
PhD students in Biomedical Engineering are required take two laboratory rotations (1 credit each) in different faculty research laboratories within the MSFEA and/or FM. Students may also enroll in a third elective laboratory rotation. This aims to familiarize students with potential thesis mentors and expose them to different research environments.

BMEN 672 Hospital Lab Rotation 0 cr.
MS and PhD students in Biomedical Engineering are required to do a lab rotation in the Medical Engineering Department at AUB Medical Center (AUBMC). This aims to familiarize students with the typical activities and responsibilities of a biomedical engineer in a working environment and expose them to different equipment and tools.

BMEN 673L Biomedical Engineering Lab 1 cr.
This laboratory course aims to introduce students to the practical issues in the areas of biomedical instrumentation design and biological signal processing. A particular emphasis will be placed on signal transduction, electronic circuit design for recording and conditioning physiological signals. The lab will introduce hand-on laboratory experiments on biomedical sensors, analog signal amplifiers and filters, digital acquisition and transmission, and basic digital filtering. In addition, some experiments cover topics that demonstrate the various levels of complexity that characterize biological signals. Signal processing tools include spectral and cepstral analysis, de-noising and artifact removal, filter banks and wavelet decompositions, Hilbert transforms, and information-theoretic measures. *Pre-requisite: Consent of instructor*

BMEN 675 Approved Experience 0 cr.

BMEN 796 Special Project in Biomedical Engineering 3 cr.

BMEN 797 Special Topics in Biomedical Engineering 1 cr.

BMEN 798 Special Topics in Biomedical Engineering 3 cr.

BMEN 799T MS Comprehensive Exam 0 cr.
Every term.

BMEN 799 MS Thesis 6 cr.
Every term. Prerequisite: BMEN 799T.

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

BMEN 981 Qualifying Exam Part II: Defense of Thesis Proposal 0 cr.
Every term. Prerequisite: BMEN 980.

BMEN 982 PhD Thesis 3 cr.
Every term. Taken while total required credit hours have been completed.

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

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

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

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

BMEN 987 PhD Thesis Defense 0 cr.
Every term. Prerequisite: BMEN 981.

BIOC 321 Nucleic Acids and Basic Genetics 15.0; 1 cr.
This course discusses the principles of nucleic acid structure and function in eukaryotes. It includes the information for basic genetics in terms of genome structure as well as the diversity of gene regulation. Required from MS and PhD students in biomedical Sciences. requires consent of coordinator for other graduate disciplines. *First term.*

BIOC 322 Protein Biochemistry 10.10; 1 cr.
This course deals with the biochemistry of proteins including their basic units, different structures, folding process and protein-protein interactions. It focuses on how changes at the structural level modify function. The course also covers the principles of protein purification and sequencing, and introduces students to protein database, molecular modeling and systems biology. Required from MS and PhD students in biomedical sciences. Requires coordinator approval for other graduate disciplines. *First term.*

BIOC 325 Receptors and Signal Transduction 25.10; 2 cr.
This course covers classical pathways involved in receptor signaling and activation of downstream targets and the molecular mechanisms involved. It deals with the inter- and intracellular communication, from the generation of signaling molecules through the cellular responses. Required from MS and PhD students in biomedical sciences. Requires consent of coordinator for other graduate disciplines. *First term.*

BIOC 326A Bioinformatics Tools and Applications in Genomics 1 cr.
This course will discuss the relationships among sequence, structure and function in biological networks, as well as advances in modeling of quantitative, functional and comprehensive genomics analyses. It will assess computational issues arising from high-throughput techniques recently introduced in biomedical sciences, and cover very recent developments in computational genomics, including genome structural variant discovery, epigenome analysis, cancer genomics and transcriptome analysis.

BIOM 385 Research Ethics 15.0; 1 cr.
This course introduces the fundamentals of responsible conduct of research, emphasizing the ethical practice of human research. The course recaps history of ethical principles, the development of research codes of conduct and ethical practices, familiarizes students with the different kinds of ethical issues that they might come across throughout their careers and allows scholars to reflect critically on what it means to be an ethical and responsible researcher. *Summer term.*

EECE 601 Biomedical Engineering I 3 cr.
This course includes an introduction to: general instrumentation configuration and performance of instrumentation systems; types and characteristics of transducers; sources and characteristics of bioelectric signals; types and characteristics of electrodes; temperature regulation and measurement; cardiovascular system, measurements and diagnostic equipment; blood instruments; patient care and monitoring; and electrical safety of medical equipment. *Prerequisites: BIOL 210 or BIOL 202 or PHYL 246, and EECE 210; or PHYS 228 and PHYS 228L; or consent of instructor.*

EECE 603 Biomedical Signal and Image Processing 3 cr.
Fundamentals of digital signal processing as implemented in biomedical applications. It provides a concise treatment of the tools utilized to describe deterministic and random signals as the basis of analyzing biological signals: data acquisition; imaging; denoising and filtering; feature extraction; modeling. The course is tightly coupled with a practical component through laboratory projects. Examples include the auditory system, speech generation, electrocardiogram, neuronal circuits and medical imaging. Students should have reasonable software skills in Matlab. *Prerequisites: STAT 230 and EECE 340, or equivalent; or consent of instructor.*

EECE 633 Data Mining 3 cr.
This course is an introduction to data mining. Data mining refers to knowledge discovery from huge amounts of data to find non-trivial conclusions. Topics will range from statistics to machine learning to database, with a focus on analysis of large data sets. The course will target at least one new data mining problem involving real data for which the students will have to find a solution. *Prerequisite: EECE 330 or consent of instructor.*

EECE 663 System Identification 3 cr.
This course introduces the basic mathematical tools to fit models into empirical input-output data. General time-series modeling and forecasting, such as stock prices, biological data and others. Topics include nonparametric identification methods: time and frequency response analysis; parametric identification: prediction error, 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.

EECE 667 Pattern Recognition 3 cr.
The course provides an overview of the algorithms used in machine learning. The course discusses modern concepts for model selection and parameter estimation, decision-making and statistical learning. Special emphasis will be given to regression and classification for a supervised mode of learning. Students will be assigned typical machine learning problems to investigate as projects.

EECE 690 Introduction to Machine Learning 3 cr.
The course provides an overview of machine learning theory and algorithms that learn from experience to predict or control yet to be seen instances. The course discusses the intuition and the theory of some selected modern machine learning concepts as well as practical know-how to successfully apply them to new problems. It covers topics in supervised learning such as parametric/ non-parametric, generative/ discriminative algorithms for classification and regression and in unsupervised learning for clustering, dimensionality reduction and reinforcement learning. The course also includes case studies and applications so that students can gain practice on regularization, model selection, parameter estimation, Bayesian networks, hidden Markov models, support

vector machines, reinforcement learning, neural networks and deep learning. Students cannot receive credit for both EECE 664M and EECE 633 and 667. *Prerequisites: EECE 330, and MATH 218 or MATH 219, and STAT 230 or STAT 233 or consent of instructor.*

EECE 693 Neural Networks 3 cr.
The course provides a comprehensive foundation to artificial neural networks and machine leaning with applications to pattern recognition and data mining; learning processes: supervised and unsupervised, deterministic and statistical; clustering; single layer and multilayer perceptrons; least-mean-square, back propagation and Al-Alaoui algorithms; radial-basis function networks; committee machines; principal component analysis; self-organizing maps; and current topics of interest.

EPHD 310 Basic Biostatistics 2.2; 3 cr.
An introductory biostatistics course that covers basic concepts in statistical methods. The course demonstrates methods of exploring, organizing and presenting data. The course presents the foundation of statistical inference from estimation, to confidence interval and testing of hypothesis. Applications include comparing population means or proportions via data obtained from paired or independent samples, one-way ANOVA. Also, it introduces simple linear regression, correlations, logistic regression and nonparametric methods for data analysis.

HUMR 305 Cell and Tissue Biology 30.33; 3 cr.
Consists of the first half of Basic Histology, HUMR 209, covering cells and tissues. Open to graduate students outside the department.

HUMR 310 (A, B, or C) Biomedical Research Techniques 1 cr.
A guided laboratory course in research methods used in cell biology and physiology. HUMR 310A covers Cell Biology Techniques; HUMR 310B covers Genomics and Proteomics; HUMR 310C covers Mouse Models and In Vivo Studies. Used in cell biology and physiology.

HUMR 314 Research Seminar 0.32; 1 cr.
Presentation and discussion of timely research topics designated by members of the department.

PHYL 302 Cardiovascular Physiology 31.6; 2 cr.
Presents the cardiovascular system with clear reference to pathophysiological and clinical events. Didactic lectures and seminar sessions define physiological concepts and emphasize structure-function relationships. Laboratory sessions familiarize the student with instrumentation and techniques in the cardiovascular field. *Open to all graduate students in the department.*

PHYL 346 Human Physiology for Paramedical and Undergraduate Students 48; 4 cr.
Outlines fundamental principles of human physiology and the mechanisms governing the function of different body organs. *Prerequisites: BIOC 246 and BIOL 201 (or BIOL 210).*

Professional Post Graduate Diploma Program in Green Technologies (Pro-Green)

Coordinator:	Ghaddar, Nesreen (Mechanical Engineering, MSFEA)
Program Teaching Faculty:	Ahmad, Mohamad (Chemical and Petroleum Engineering, MSFEA)
	Bdeir, Fadl (Industrial Engineering, MSFEA)
	Chehab, Ghassan (Civil and Environmental Engineering, MSFEA)
	Fares, Dima (Lecturer, Green Technologies Program, MSFEA)
	Ghaddar, Tarek (Chemistry, FAS)
	Ghali, Kamel (Mechanical Engineering, MSFEA)
	Jaafar, Hadi (Irrigation Engineering and Water Management, FAFS)
	Karaki, Sami (Electrical and Computer Engineering, MSFEA)
	Moukalled, Fadl (Mechanical Engineering, MSFEA)
	Salam, Darine (Civil and Environmental Engineering, MSFEA)
	Srour, Issam (Civil and Environmental Engineering, MSFEA)
	Zaidouny, Lamiss (Chemical and Petroleum Engineering, MSFEA)

General Description

The Pro-Green Diploma Program is a unique and focused diploma program that caters to professionals aspiring to enhance or complement their technical and decision-making skills in green technologies or progress in green businesses in the areas of energy utilization, building design, construction and management systems, sustainable and safe water production, water management and waste water treatment.

The American University of Beirut, the Lebanese American University and the American University in Cairo are jointly offering the Professional Post Graduate Diploma in Green Technologies in three specializations:

- Professional Post Graduate Diploma Program in Green Technologies; Major: Energy
- Professional Post Graduate Diploma Program in Green Technologies; Major: Buildings
- Professional Post Graduate Diploma Program in Green Technologies; Major: Water

Objectives

The Green Technologies Diploma Program is designed to address the trend towards healthier and more socially responsible communities by training professionals on effective ways to develop and advance sustainable energy and water efficiency in production, utilization, storage and re-use.

The program objectives are:

- To foster problem-solving competencies among professionals pursuing careers in green industries,
- To develop lifelong learning skills among professionals from different disciplines,
- To assist professionals in acquiring the diverse and critical skills needed to advance in their green technology careers,
- To develop expertise in green technologies related to applications in energy, buildings and water.

Upon successful completion of the Green Technology Diploma Program in any area of specialization, students/trainees will be able to:

- Acquire in-depth understanding of green technologies relevant to jobs in planning, design and implementation methods for sustainable energy, buildings, and water technologies and industries,
- Build analysis and hands-on skills needed for development and implementation of green products and processes in the area of specialization (energy, buildings or water),
- Develop lifelong learning skills in the green technologies field. The pro-green diploma program emphasizes lifelong learning through the establishment of a community of practice and through problem/project-based learning, including case studies related to real life applications from the participants' own fields of practice.
- Identify how economic analysis, policy and regulatory frameworks can help in expanding the green technologies market.

Eligibility

The program is intended for professionals and individuals interested in and/or involved in the development and implementation of green technologies in their practice, including architects, engineers, facility managers and contractors. The courses are offered at the postgraduate level. Applicants should have a recognized and related bachelor's degree in natural science, mathematics, engineering or architecture. Applicants who join the program may have to complete pre-requisites for courses offered in the diploma program or obtain the consent of the course instructor and program coordinator. The core courses are designed to include remedial preparation in areas related to social sciences.

Admissions Requirements

Applicants to the graduate program, other than AUB graduates and graduates of colleges or universities recognized and located in North America, Great Britain, Australia and New Zealand, must meet the Readiness for University Studies in English (RUSE) as explained in the next heading.

Applicants should have a bachelor's degree in architecture, engineering or science from recognized universities to be enrolled in the diploma program. Professional experience might be considered on a case by case basis where students may register for courses not working towards receiving the diploma and their performance is assessed towards their registered courses.

The only three documents required for enrollment in the Green Technologies Diploma Program are the following:

- A copy of the applicant's bachelor's degree (diploma): Bachelor of Architecture (BA), Bachelor of Engineering (BE), Bachelor of Science (BS).
- A photocopy of the front page of the applicant's passport or national ID.
- Readiness for University Studies in English (RUSE) according to the distribution listed on http://www.aub.edu.lb/admissions/english.

Structure and Program Requirements

The Green Technologies Diploma Program shares a set of core courses that can be registered and followed at any of the joint universities. Each major specialization will also include a number of required specialization courses and one or two elective courses depending on the major. The admission procedures, teaching and examination regulations and academic calendars at universities are carefully coordinated. The program will include a major e-learning format through blended and online course offerings.

The required core courses of the program provide a solid foundation in both technical and economic aspects of green technologies in energy, buildings and water, allowing the student to simultaneously understand advances in selected green technologies and their interrelations with market economy, policy and energy laws. The specialization courses consist of more in-depth development of expertise in the selected major through a number of specialization courses selected in the major, elective courses and a graduation project.

The diploma program permits part-time enrollment. To obtain the professional diploma degree in green technologies in any of the offered specializations, the student must complete a minimum of 18 credits of coursework depending on the specialization, including a project in an area related to the selected specialization. The diploma program credit requirement is distributed as follows:

18 credits (or more) are required to complete the diploma:

- 6 credits of core courses
- 6 to 8 credits of courses in the area of specialization excluding the project in the area of specialization
- 2 to 4 credits for elective course as approved by project advisor/s from the list of elective courses as well as courses from other specializations outside the student's declared specialization.
- 2-credit Project (equivalent to 2 credit hours)
- 0 credit Seminar/Webinar (to be registered twice)

26 credits are required to complete the diploma with a double specialization: A student must complete a minimum of 8 credit hours of graduate course work over and above the requirements for the first specialization.

- 6 credits in the second specialization
- 2 credits project in the second specialization

34 credits are required to complete the diploma with a triple specialization: A student must complete a minimum of 8 credit hours of graduate course work over and above the requirements for the two other specializations.

- 6 credits in the third specialization
- 2 credits project in the third specialization

The diploma program permits part-time and full-time enrollment.

The diploma can be completed in 12-18 months, but the student has up to 3 years to complete the diploma.

The core, specialization and elective courses are summarized in the following sections.

Course Requirements

Core Courses

Students are required to complete the following 6 credits of core courses that are common to the three specializations in Energy, Buildings and Water:

PRGR 601	**Green Economy, Policies and Law**	**3 cr.**
PRGR 602	**Green Technologies System Approach to Sustainability and Management**	**3 cr.**
PRGR 698B	**Seminar/Webinar**	**0 cr.**

Specialization Courses

Students are required to complete a minimum of 6 credits from their selected specialization. The courses in the various specializations are listed below.[1]

Energy Specialization		**Credits**
PRGR 603	Solar Radiation and Energy Conversion	2
PRGR 604	Solar PV Electricity	2
PRGR 605	Wind Energy	2
PRGR 606	Energy Storage	2
PRGR 609	Renewable Energy Lab	2
PRGR 615	Biofuels	2
PRGR 616	Waves, Tidal and Hydro Energy	2
PRGR 617	Energy Efficiency in Buildings Evaluation and Design	2
PRGR 620	Energy Systems and Sustainable Environments	2
PRGR 621	Waste to Energy Processes and Technologies	2
PRGR 699E	Project	2

Buildings Specialization		**Credits**
PRGR 630	Sustainable Preservation and Restoration of Existing Buildings	2
PRGR 631	Low Energy Architecture and Passive Building Designs	2
PRGR 632	Sustainable Building Materials	2
PRGR 633[1]	Renewable Energy Systems and Energy Efficiency in Buildings	2
PRGR 634	Moisture and Control of Humidity in Buildings	2
PRGR 637	Green Building Basics and Building Rating Practices	2
PRGR 639	Construction and Demolition Waste Management	2
PRGR 641	HVAC Systems for Energy Efficient Acclimatization	2
PRGR 643	Heat Pumps and Innovative Methods to Improve Performance with Direct Applications	2
PRGR 645	Building Energy System Modeling	2

1) Can be counted as an Energy specialization course.

Buildings Specialization		Credits
PRGR 646[1]	Energy Management Systems of Buildings	2
PRGR 699B	Project	2

Water Specialization		Credits
PRGR 664	Water Instrumentation	2
PRGR 665[1]	Water Basics	2
PRGR 666	Water Infrastructure Systems	2
PRGR 667	Water Treatment and Water Desalination	2
PRGR 668	Wastewater and Sludge Treatment	2
PRGR 669	Green Agriculture and Irrigation Systems	2
PRGR 6811	Sustainable Water Resources Management	2
PRGR 699 W	Project	2

Elective Courses

The elective courses can be selected from specialization courses outside the chosen area of specialization. In addition, a number of elective course modules can be selected from the following: [1]

Elective Courses		Credits
PRGR 670	Life Cycle Assessment	2
PRGR 673	Research Skills Development - General	2
PRGR 677	Cost-Benefit Analysis	2
PRGR 679	Project Management, Risk Management and Planning	2
PRGR 680	Innovation and Knowledge Transfer	2

Course Loads, Credit Transfer and Sample Program

Course Loads

Typically the maximum number of credits for the diploma that may be taken in a regular term is up to 5 or 6 credits, yet the student can follow her/his own pace.

Requirements for Double Specialization

Students may enroll and earn a diploma in two specializations. To fulfill the basic requirement for the double specialization, a student must complete a minimum of 8 credit hours of graduate coursework over and above the requirements for the first specialization. This will include 6 credits in the second specialization as well as 2 credit hours for a project. The minimum total credit hours for a double specialization in the Green Technologies Diploma Program would be 26.

1) Water Core Course

Requirements for Three Specializations

For a diploma in three specializations, a student must complete a minimum of 8 credit hours of graduate coursework over and above the requirements for the two other specializations. This will include 6 credits in the third specialization as well as 2 credit hours for a project. The minimum total credit hours for a triple specialization in the Green Technologies Diploma Program would be 34.

Course Descriptions

Core Courses

PRGR 601 Green Economy, Policies and Law 3 cr.
The course offers mainly an introduction to green economics with an overview of policies and law related to green economy. The course explains the axioms of green economics including financial analysis of green alternatives related to the built environment, such as economics and cost concepts, the time value of money, worth of green investments and economic evaluation of green alternative choices. Analysis of green public sector projects as well as risk and uncertainty in economic evaluation, generating quantitative analysis and developing economic models that assess the impact of green investments, and their impact are also discussed.

PRGR 602 Green Technologies System Approach to Sustainability and Management 3 cr.
This course addresses the system approach to emerging sustainable technologies and its applications in the building industry in sixteen modules. A number of modules are focused on the knowledge base for the current technologies, the challenges, risks and suitability while few modules are focused on the application side of the technology using analysis tools.

Energy Specialization Courses

PRGR 603 Solar Radiation and Energy Conversion 2 cr.
The course covers characteristics of solar radiation and relative motion of Earth and Sun; beam incidence angles; sun-path diagrams and collector shading; clear sky models; isotropic and anisotropic diffuse radiation models; and utilizability. This module also covers solar thermal energy conversion with emphasis on the design, performance and selection of solar thermal technologies, such as tracking and stationary solar concentrators, solar water heaters and systems, solar thermal power plants, solar ponds, and solar updraft towers.

PRGR 604 Solar PV Electricity 2 cr.
The course covers the principles of solar radiation and solar electricity using Photo-Voltaic (PV) technology. Solar Radiation: components, geometry of earth and sun, geometry of collector and sun beam, efect of earth's atmosphere, and measurements of solar radiation. This module also covers semi-conductor basics, photo-voltaic (PV) module characteristics, efficiency analysis; PV module types: mono-crystalline, polycrystalline, amorphous, multilayer cells, current research; PV module manufacture; grid connection and grid-codes, remote (off-grid) connections; economics and sustainability aspects.

PRGR 605 Wind Energy 2 cr.
The course is an introduction to wind energy and fundamentals of converting wind energy to electrical energy. The module covers wind turbine types and components, turbine systems, power generation and control systems, connection to the electric grid, maintenance, wind site assessment, and wind farms mechanism on land and offshore

PRGR 606 Energy Storage 2 cr.
The course covers the fundamental principles of energy storage technologies, the main economics aspects of each technology, and a case study analysis of a particular project. The technologies that will be discussed encompass: solar power (solar chimneys, geothermal and Photovoltaic), chemical storage (biofuels, hydrogen), electrochemical (batteries), thermal (thermocline, molten salt, and ice storage), mechanical (compressed air storage, flywheel, and pumped hydroelectric energy), electrical (super capacitors, and superconducting magnetic energy storage) hydropower (tidal and waves), and wind power.

PRGR 609 Renewable Energy Lab 2 cr.
A laboratory course that covers: PV modules, such as characteristics, effect of alignment, temperature, irradiance and shading, maximum power tracking, implementation of grid tie, grid tie with battery backup, stand alone, and direct PV systems. Other topics include: wind turbine, implementation of a stand-alone and grid tie systems, Doubly-fed induction generator, synchronization, effect of wind speed on voltage and frequency, optimal operating point, fault ride through testing, balanced and unbalanced faults. *Labs are non-mandatory electives and are generally offered face to face. Students have the option to take the lab virtually.

PRGR 615 Biofuels 2 cr.
Course material includes: studies of types, sources and processing of biodiesel, biomass, bio-methane and bioethanol. Assessing advantages, problems and principles in biofuel production, biogas and digester design and solid biomass processing will also be discussed.

PRGR 616 Waves, Tidal and Hydro Renewable Energy 2 cr.
This course gives an overview of the use of ocean thermal, wave, tidal and hydro energy. It provides a comprehensive analysis of hydro renewable energy collection and utilization for electric power production and other applications with an emphasis on design, sizing, performance analysis and selection of hydro renewable energy technologies. Mini-hydro systems are also covered. It also discusses a variety of designs for devices for extracting energy from waves, and the technologies and methods for generating electricity from different ocean temperatures between the warm surface water of the ocean and the cold deep water.

PRGR 617 Energy Efficiency in Buildings Evaluation and Design 2 cr.
The module discusses various schemes of conserving energy in buildings and energy types including: space heating and cooling, water heating, and energy for lighting and powering electrical and electronics equipment. It also covers passive and active energy conservation techniques including energy efficient HVAC equipment. The course addresses integration of solar energy into boilers and condensing units of building systems, and introduces optimized control strategies. The students will also 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 measures are then applied to deduce possible savings and their economic value.

PRGR 620 Energy Systems & Sustainable Environments 2 cr.
This course introduces students to the concept of sustainability in the context of energy use. It stresses on the different aspects involved in our daily-life use of energy: environmental, societal, political, financial, etc. It covers technologies and means used in improving the sustainability of current fossil-fuel (coal, oil and gas) based energy systems, electric and nuclear systems by reducing their environmental and societal impacts. Finally, it introduces different renewable ('clean') energy technologies that can be used as alternatives to traditional ('dirty') energy systems.

PRGR 621 Waste to Energy Processes and Technologies 2 cr.
The course is divided into the following parts. Part 1 – Fundamental principles of waste management with particular emphasis on organic wastes, waste generation and characterization, and techniques for waste collection, storage, transport, and utilization (including recycling and recovery). The focus is on the application of engineering science to develop integrated waste management systems. Part 2 – Waste-to-energy technology including: mass burning and modular combustion, refuse derived fuel systems, anaerobic digestion, composting, comparison and bench-marking of the technologies with respect to energy efficiency. Also covered are the environmental impacts, costs, etc. , hazardous waste generation, producer responsibility, and legislation. Part 3 – Waste-to-energy projects implementation concepts including risk assessment (waste, energy and materials market, environmental protection, and legal issues) and the implementation process in regards to feasibility, siting, procurement/ ownership, financing, plant construction, and operations.

Buildings Specialization Courses

PRGR 630 Sustainable Preservation and Restoration of Existing Buildings 2 cr.
The course examines the benefits of greening existing buildings and covers sustainable restoration processes involving: energy audits, construction materials, structural elements, electromechanical systems, site improvement, water conservation, and indoor environmental quality; in addition to associated operations, management, and costs.

PRGR 631 Low Energy Architecture and Passive Building Design 2 cr.
This course 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. Bioclimatic design and concepts. Case studies will be used extensively as a vehicle to discuss the success/ failure of ideas and their physical applications.

PRGR 632 Sustainable Building Materials 2 cr.
The course covers the description of sustainable building materials and products, such as categories and types, factors and criteria for evaluation and selection, specifications and standards, life cycle assessment concepts and tools and integration into projects.

PRGR 633 Renewable Energy Systems and Energy Efficiency in Buildings[1] 2 cr.

The course focus is on HVAC design optimization and energy conservation measures in built in environment to enhance the building's energy efficiency while maintaining space thermal comfort and indoor air quality requirement. In addition it includes concepts of district cooling/heating systems, dehumidification and personalized ventilation systems. It also covers renewable energy integration in building systems including photo-voltaic, solar-thermal and geothermal. 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.

PRGR 634 Moisture and Control of Humidity in Buildings 2 cr.

The course covers sources of moisture and factors affecting its entry and buildup inside the buildings, such as construction practices and choice of building materials, and furniture. Other topics including: impact of moisture on thermal comfort and energy performance of the air conditioning system, solid/liquid desiccant dehumidification, and hybrid air conditioning systems, are discussed. This module also covers modeling of moisture transport the industrial need to control indoor humidity, and moisture-caused health issues, including, mold formation and growth.

PRGR 637 Green Building Basics and Building Rating Practices 2 cr.

This course covers the assessment of building design and construction operations, such as project rating systems (LEED, BREEAM, QSAS, etc.). Other topics include: embodied energy, carbon content and emission of CO2, SO2 and NOx of building materials, elements, and construction process. Water conservation, water management systems, water efficient landscaping, green roofing, rainwater harvesting, sanitary fixtures and plumbing systems, wastewater treatment and reuse, and process water strategies are also discussed.

PRGR 639 Construction and Demolition Waste Management 2 cr.

The course covers building disposal techniques including deconstruction, as well as, selective and partially selective demolition, design and construction for deconstruction, and reuse. Other topics include: waste minimization through prefabrication, preassembly and modular construction. Sustainable waste management including: recycling and reusing waste materials, and components, are also discussed.

PRGR 641 HVAC Systems for Energy Efficient Acclimatization 2 cr.

The course covers energy conservation measures in the built-in environment to enhance the building's energy efficiency while maintaining space thermal comfort and indoor air quality requirement. Other topics include: overall and segmental thermal comfort models with localized air quality. 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. Students will also study the ASHRAE requirements for ventilation, personalized ventilation, and personalized cooling devices.

1) Can be counted as Energy concentration course.

PRGR 643 Refrigeration and Heat Pumps 2 cr.
This course is designed to introduce students to refrigeration and heat pump theory. Topics introduced include: basic mechanical vapor-compression cycle, refrigerant properties, multistage vapor compression cycles, compressors types, condensers and evaporators, expansion devices, refrigeration piping material, selection and proper sizing, and simulation of heat pumps and cost-effective design options.

PRGR 645 Building Energy System Modeling 2 cr.
The course covers indoor space thermal modelsand 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 are also discussed.

PRGR 646 Energy Management Systems of Buildings[1] 2 cr.
The Building Management Systems course provides the necessary tools to control, monitor and optimize the building's facilities, mechanical and electrical equipment for comfort, safety and efficiency. It covers the principles of the building automation systems (BAS) applied to commercial HVAC equipment, lighting systems, fire and security systems; with keen emphasize on the control routine for energy efficiency.

Water Specialization Courses

PRGR 664 Water Instrumentation 2 cr.
This course offers an introduction to the instrumentation trade as it applies to the day-to-day operation of water/wastewater treatment plants. Topics discussed include types of instruments and control equipment, process measurement and control principles, terminology, design and control system documentations, operator training and troubleshooting techniques. It is important to note that this course is not aimed to create tradespersons, but is designed from the viewpoint of plant operators so they can develop more awareness of the plant staff and allow them to effectively monitor and control the plant and major equipment, the treatment process, water production and plant wastes.

PRGR 665[2] Water Basics 2 cr.
This course covers basic information about major issues related to water scarcity and quality, and introduces the fundamentals of water chemistry and microbiology, as well as water treatment.

PRGR 666 Water Infrastructure Systems 2 cr.
The course covers analysis and design using commercially available software such as water distribution systems including: pipes, reservoir, pumps and losses. It also covers results visualizations and assessment including: pressure, velocity, head losses, analysis, and design using commercially available software. This software include wastewater collection systems including: pipes, manholes, drop manholes, wet wells, and other appurtenances. Maintenance and safety are also discussed including: sampling, sampling methods and parameters, analysis and data handling, management, and supervision.

1) Can be counted as Energy concentration course
2) Water core course

PRGR 667 Water Treatment and Water Desalination 2 cr.
The course covers physical, chemical and biological water quality parameters determinations and standards; water treatment units: screens; sedimentation, coagulation/flocculation processes, filtration and disinfection. This course will also survey the commonly used thermal and membrane based desalination technologies. Environmental, sustainability and economic factors, which may influence the performance, affordability and more widespread use of desalination systems for fresh water production and reuse, will be highlighted.

PRGR 668 Wastewater and Sludge Treatment 2 cr.
The overarching goals of this course are: a) Design a civil engineering component/ system by applying standards appropriate for design including: codes, regulations, and incorporating multiple constraints into the design in the civil engineering areas of environmental engineering, b) Identify problem setting and related assumptions, limitations, and solution requirements in the environmental engineering field, c) Formulate methods and strategies considering all relevant perspectives, solution models, and alternative solution paths, d) Use selected models, methods, and data to produce the appropriate solution, e) Use industry standard software to analyze and design engineering components.

PRGR 669 Green Agriculture and Irrigation Systems 2 cr.
This course covers the water requirements of plants, irrigation scheduling, soil moisture and ET sensors, modern irrigation systems: micro-sprinkler systems, drip systems, irrigation efficiency, and energy demands of irrigation systems, smart irrigation, and controllers, and use of renewable energy for irrigation. Topics covered include: the role of soil water content in irrigation, evapotranspiration in relation to green agriculture, smart irrigation, and agricultural and landscape water requirements. In addition, students will be introduced to different irrigation systems and to the implementation of controllers in smart irrigation.

PRGR 681[1] Sustainable Water Resources Management 2 cr.
This course is concerned with quantitative methods for analyzing water resource problems. Topics covered include the design and management of facilities for river basin development, flood control, water supply, hydropower, and other activities related to water resources. Stochastic and deterministic methods for approaching and analyzing water resources problems will be discussed.

Elective Courses

PRGR 670 Life Cycle Assessment 2 cr.
This module introduces the principles and methods of life cycle thinking and life cycle assessment (LCA) with specific reference to agricultural and energy systems using attributional LCA. The module will be based around the ISO 14040 methodology and will involve developing a LCA model common software package such as MS-Excel. It will focus on the four common stages of LCA: (i) Definition of the goal and scope; (ii) Life cycle inventory analysis; (iii) Life cycle impact assessment; and (iv) Interpretation with a specific focus on carbon footprint, water footprint and energy audit. Case studies will consider LCA studies of agricultural systems, energy systems.

1) Water Core Course

PRGR 673 Research Skills Development – General 2 cr.
This course introduces students to research methods, tools and techniques useful for tackling projects related to environmental science and engineering. Topics covered include need identification and problem definition, concept generation and evaluation, information search and literature review, managing the solution development process, team behavior and group dynamics, qualitative data collection with interviews, quantitative data collection with surveys, considering economic and other impacts, professional standards and codes, and communicating a technical solution.

PRGR 677 Cost-Benefit Analysis 2 cr.
This course provides a practical outlook on cost-benefit analysis for engineering projects. Topics covered include conceptual foundations and economic background, valuation techniques, decision criteria, uncertainty and risk analysis, and environmental and social aspects of costs and benefits.

PRGR 679 Project Management, Risk Management and Planning 2 cr.
This course covers the water requirements of plants, irrigation scheduling, soil moisture and ET sensors, modern irrigation systems: micro-sprinkler systems, drip systems, irrigation efficiency, and energy demands of irrigation systems, smart irrigation, and controllers, and use of renewable energy for irrigation. Topics covered include: the role of soil water content in irrigation, evapotranspiration in relation to green agriculture, smart irrigation, and agricultural and landscape water requirements. In addition, students will be introduced to different irrigation systems and to the implementation of controllers in smart irrigation.

PRGR 680 Innovation and Knowledge Transfer 2 cr.
The aim of this course is to help students understand theory and practice for managing innovation and managing green ventures while exercising corporate social responsibility and sustainability within the organization, and in the external environment.

Students will learn how to initiate, manage and implement a sustainable innovative project by collaboratively working on a venture which will be written up and presented at the end of the term.

In addition, the course will cover the management process required to transform an innovative idea into a commercial opportunity or business proposition.

Department of Architecture and Design

Chairperson:	Al-Harithy, Howayda
Graduate Programs Coordinator:	Harb, Mona
Architecture Program Coordinator:	Aramouny, Carla
Graphic Design Program Coordinator:	Gharbieh, Ahmad
Binladen Chair for Architecture in the Islamic World:	Damluji, Salma-Samar
Professors:	Al-Harithy, Howayda; Damluji, Salma-Samar; Fawaz, Mona; Harb, Mona; Musfy, Leila
Associate Professors:	Abedini, Reza; Ghaibeh, Lina; Najjar, Karim
Assistant Professors:	Abbasy, Ghazal; Acikgoz, Umit; Aramouny, Carla; Gharbieh, Ahmad; Haddad, Rana; Khoury, Yara; Mismar, Omar; Yeretzian, Aram
Adjunct Professors:	Farhat, Ramzi; Makhzoumi, Jala; Saliba, Robert; Yazigi, Serge
Senior Lecturers:	Al-Kadi, Makram; Azar, Mia; Boyadjian, Rafi; El-Imam, Hatem; Fayad, Nicolas; Freiji, Mayda; Frem, Sandra; Genz, Bettina; Hassan, Sinan; Hayek, Joanne; Jamal, Sany; Kadi, Salim; Kosermelli, Simone; Mallat, Bernard; Nader, Karim; Nader, Marc; Samara Fouad; Richani, Sandra
Lecturers:	Abi Hanna, Ghita; Basbous, Monica; Baz, Joan; Apelian, Khajag; Bastormagi, Etienne; Bou Nasr, Roland; El Rouss, Anastasia; Hachem, Pascal; Kanaan, Joy; Majzoub, Raafat; Moussawer, Karim; Muhsen, Dana; Sukkarieh, Rasha; Youssef, Shawki; Zahzah, Abdul-Rahman
Instructors:	Berro, Maher; Mezher, Fouad; Kanaan, Mohamad
Lab Instructor:	Azzi, Ghinwa

Graduate Programs

Master of Urban Design (MUD)

Master of Urban Planning and Policy (MUPP)

General Information

The MUPP and MUD programs offer a first graduate degree to students interested in acquiring the necessary skills to tackle the challenges of contemporary urbanization while upholding the principles of livability, sustainability and equity. The programs prepare students to be highly qualified, well-rounded professionals who are able to address the multi-faceted issues of today's built environments, focusing on Lebanon and the region. The two-year curriculum combines theoretical and methodological seminar courses designed to secure a command of the tools of intellectual inquiry with hands-on studio courses articulated around real-life exercises. The training is multi-disciplinary and research-based. Through these courses, students learn to analyze urban contexts and formulate interventions in the form of projects and/or policies.

Our graduates work in a wide range of positions within the private, non-profit and, less frequently, public sector. Most occupy leading positions in the region where they have contributed to forwarding innovative and visionary ideas about the practices of planning and design.

Mission Statements
Master of Urban Design

The Master of Urban Design program aims at preparing highly qualified, well-rounded professionals who are able to deal with the multifaceted design challenges in today's urban environments in Lebanon and the region. The program emphasizes mastery of the design tools necessary for the effective practice of urban design. Students are exposed to a multidisciplinary understanding of contemporary urban challenges that trains them to position the design profession amidst other city professions. They learn to integrate design tools with policy strategies and institutional analysis. The Master of Urban Design has adopted the studio-based approach to professional education as the main context of learning. The program accepts university graduates and practitioners from design fields and prepares them to occupy leading professional roles in design and planning firms and in public and non-profit agencies.

Master of Urban Planning and Policy

The Master of Urban Planning and Policy program aims to prepare highly qualified, well-rounded professionals who are able to address the multifaceted issues of urban planning and policymaking in today's urban environments in Lebanon and the region. The program is designed to provide a broad professional education in urban planning. Emphasis is placed on the development of multidisciplinary analytical skills necessary to address contemporary urbanization as well as mastery of the tools and approaches adopted in the contemporary practice of urban planning and policymaking. The program guides students in defining a specific area of expertise within the wider practice of urban planning and in locating their expertise in relation to other city professions. The program welcomes university graduates with professional degrees and/or degrees in the social sciences and prepares them to occupy leading professional roles in the public, private and non-profit sectors.

Program Structure and Agenda

Each of the two graduate programs spans two years of full-time enrollment. The MUPP track requires students to take a total of 30 credits of which 9 are to be taken in a sub-discipline of specialization where planning and policymaking skills are applied and 6 in applied studio format. The MUD track requires students to take a total of 33 credits of which 12 are to be taken in applied design studios. The two tracks share a common core of 21 credits consisting of three core courses (Research Methods, Planning Theory and Policy, and Urbanism), one planning/design workshop and a 6-credit final thesis. The thesis is research-based and aims at generating innovative ways of thinking and understanding the context of urban and regional planning and design practice. In addition, all students enrolled in the MUPP/MUD programs are required to register for the 0-credit "City Debates" seminar at least twice during their university enrollment.

Common Core MUPP/MUD

MUPP Courses

URPL 630	Research Methods	3
URPL 631	Introduction to Planning Theory and Policy	3
URPL 632	Urbanism	3
URPL 661/ URDS 601	Planning and Design Workshop	6
URPL 660	City Debates Seminar	0
URPL 662/ URDS 603	Comprehensive Exam in Field	0
URPL 663/ URDS 604	Thesis in Field	6
		Total 21

MUPP students are required to take three courses (9 credits) in a field of applied social science or engineering (such as sociology, economics, public administration, civil or environmental engineering) leading toward a concentration area such as urban policy, community development, transportation, labor, housing or environmental sustainability. Other options may be agreed upon with the MUPP/MUD academic advisor.

Three courses in area of concentration	9
	Total 9

MUD Courses

MUD students are required to take one design studio and two approved electives (12 credits).

URDS 602	Urban and Landscape Design Studio	6
Two approved electives		6
		Total 12

Program Agenda

The typical course load for the Urban Planning and Policy and Urban Design tracks is normally distributed over two years as shown below. Course distribution is subject to approval of the academic advisor.

Urban Planning and Policy

First Year

Fall term		Credits
URPL 631	Introduction to Planning Theory and Policy	3
	One Concentration Area Elective	3
		Total 6

Spring term		Credits
URPL 632	Urbanism	3
URPL 630	Research Methods	3
	One Concentration Area Elective	3
URPL 660	City Debates Seminar	0
		Total 9

Second Year

Fall term		Credits
URPL 661	Planning and Design Workshop	6
	One Concentration Area Elective	3
URPL 662	Comprehensive Exam in the Field	0
		Total 9

Spring term		Credits
URPL 663	Urban Planning Thesis	6
URPL 660	City Debates Seminar	0
		Total 6

Urban Design

First Year

Fall term		Credits
URPL 631	Introduction to Planning Theory and Policy	3
	One Area Elective	3
		Total 6

Spring term		Credits
URDS 601	Urban and Landscape Design Studio	6
URPL 632	Urbanism	3
URPL 660	City Debates Seminar	0
		Total 9

Second Year

Fall term		Credits
URDS 602	Planning and Design Workshop	6
	One Approved Elective	3
		Total 9

Spring term		Credits
URPL 660	City Debates Seminar	0
URPL 630	Research Methods	3
URDS 603	Comprehensive Exam in the Field	0
URDS 604	Urban Design Thesis	6
		Total 9

Admission Qualifications

Applicants who meet all the AUB and MSFEA regulations governing admission to graduate study, including acceptable AUB Readiness for University Studies in English (refer to the Readiness for University Studies in English (RUSE) page 41), and who hold the equivalent of an undergraduate degree in architecture, landscape architecture, environmental design, urban or regional planning, engineering, public health, economics, public administration, sociology or other social science degree, may be admitted to the Master of Urban Planning and Policy Program as regular graduate students.

Applicants who meet all the AUB and MSFEA requirements governing admission to graduate study, including acceptable AUB Readiness for University Studies in English (RUSE) (refer to the Readiness for University Studies in English (RUSE) page 41), and who hold the equivalent of a professional Bachelor of Architecture or a Bachelor of Landscape Architecture degree, may be admitted to the Master of Urban Design Program as graduate students.

The Department of Architecture and Design may recommend waiving up to nine credits of course work for students who have completed a Bachelor of Architecture degree and are applying for admission to the Master of Urban Planning and Policy or the Master of Urban Design programs.

The Department of Architecture and Design may further recommend waiving up to six credits of coursework for students who have completed a Bachelor of Landscape Architecture degree and are applying for admission to the Master of Urban Planning and Policy or the Master of Urban Design programs. The Department of Architecture and Design may also recommend waiving up to six credits of coursework for students who have completed a Bachelor of Engineering degree and are applying for admission to the Master of Urban Planning and Policy program. Waiving of credits is subject to approval by the program coordinator, chairperson, and the MSFEA Graduate Studies Committee. To apply, the student must have completed the advanced courses with a grade of at least B+ or 80 or equivalent.

Course Descriptions

Mandatory Core Courses

Each of the following courses is required for MUPP/MUD students. Non-majors must secure approval of the program advisor and the instructor concerned to enroll in any of the courses listed below.

URDS 601 Planning and Design Workshop 6 cr.

This course seeks to introduce students to the actual practice of urban planning and design. It engages them in a cyclical process of documenting and analyzing a real-life setting; "framing" issues to be addressed (problems and assets) in a multidisciplinary way; and conceptualizing, formulating and developing interventions that work across small and large scales. Students become familiar with local planning tools and learn how to borrow and adapt experiences and approaches developed elsewhere. They also learn how to work in multidisciplinary teams, talk across the various disciplines of design and planning (e.g. landscaping, traffic, land use), and translate and communicate their ideas to stakeholders. The course is open only to students enrolled in the MUPP/MUD programs.

URDS 602 Urban and Landscape Design Studio 6 cr.
The aim of this course is to build on students' knowledge and skills for improving the quality of the physical urban environment, and reinforcing the identity of place through design intervention. Students investigate a selected study area in terms of its morphological evolution and unique physical features, alongside a clear reading of the social, institutional and economic dynamics impacting urban form. Through a critical assessment of development and planning processes, students articulate a set of design guidelines on sector, subsector and block levels. The outcome consists of scale drawings and 3D representations with an explicative written report emphasizing design problematic, methodology, recommendations and implementation framework.

URDS 603 Comprehensive Exam 0 cr.
This is a 0-credit course. Grading mode: Pass/Fail; Type: Urban Design Comprehensive Exam.

URDS 604 Urban Design Thesis 6 cr.
Supervised research and design is conducted individually by the student leading first to a thesis proposal approved by the Graduate Studies Committee and culminating in a final thesis in urban design. A thesis is expected to test either an approach/tool in the local context or inform a conception/theorization of a particular planning and/or design issue on the basis of a grounded investigation. All theses need to lead to practical recommendations and/or a well-formulated proposal for an intervention that can be qualified as contributions to the field of urban design.

URPL 630 Research Methods 3 cr.
This course trains students to develop the research skills needed for the practice of urban planning and design. It takes them through the process of formulating and elaborating the research required for grounding and guiding the planning of their design thesis proposals. Students learn to identify an issue characterizing a particular urban condition and to problematize this issue vis-à-vis relevant conceptual frameworks. They are introduced to research design and qualitative and quantitative methods of inquiry. Students also learn to analyze the data and articulate substantiated findings on the basis of which urban planning, policy and/or design goals, guidelines and strategies can be formulated.

URPL 631 Introduction to Planning Theory and Policy 3 cr.
This course is designed to introduce students enrolled in the Urban Design or Urban Planning and Policy programs to current debates and practices in the field of urban planning and design in lower income countries. It looks at how, where and by whom interventions in the city are being generated and how the goals of such interventions have evolved over the past decades. The course is conducted in seminar format where students learn to discuss and interpret approaches and test their applicability to the local and regional context of the Middle East. Special value is placed on allowing students to articulate their own positions as future professional urban planners and/or urban designers.

URPL 632 Urbanism 3 cr.
This is an introductory course to contemporary debates in the field of urban studies within the social sciences and their implications for the practices of architecture, urban design and urban planning. Special emphasis is placed on understanding processes of place making (that is looking at the forces behind the production of space) and the influence of place on its dwellers (that is seeing how places/spaces influence/dictate

how people act). Course readings and class discussions will pay particular attention to the relevance of these theoretical debates to the regional geographic context, including numerous case studies about the Middle East. The course is open to graduate students in the MUPP/MUD program as well as to senior undergraduates and graduates interested in urban studies throughout the University. *Prerequisite: ARCH 224 or consent of instructor.*

ARCH 032/ URDS 634 **Contested Urban Heritage/ Reconstructed Cityscapes.** **3 cr.**
The seminar focuses on urban heritage and the politics of its identification, conservation, and representation in relation to processes of nation building and postwar reconstruction in the Arab World. The principal theoretical position recognizes heritage as an intrinsically contested notion. The seminar is interdisciplinary in its approach and aims at an understanding of urban heritage, not only as a historical product, but as a negotiated entity that is reproduced everyday through the dynamics of city life; social, economic and political. Issues such as collective memory, invented traditions, constructed identities, heritage tourism, cultural consumption and sacred scapes are debated and examined through case studies that include Jerusalem, Beirut, Cairo, Riyadh, and Dubai.

URPL 660 **City Debates Seminar** **0 cr.**
The yearly seminar titled City Debates addresses various urban issues. In particular, it tackles ongoing planning and design concerns from a multidisciplinary perspective related to Lebanon's post-war development in its regional context. *Spring term. Annually.*

URPL 661 **Planning and Design Workshop** **6 cr.**
See description of URDS 601.

URPL 662 **Comprehensive Exam** **0 cr.**
This is a 0-credit course. Grading mode: Pass/Fail; Type: Planning Comprehensive Exam.

URPL 663 **Planning Thesis** **6 cr.**
Supervised research conducted individually by the student leading to a thesis proposal approved by the Graduate Studies Committee and culminating in a final thesis in urban planning and policy. A thesis is expected to build on a real case study context, and either test an approach/tool in the local context or inform a conception/theorization of a particular planning and/or design issue on the basis of grounded investigation. All theses need to lead to practical recommendations and/or a well-formulated proposal for an intervention that can be qualified as contributions to the fields of urban planning and policy.

Elective Courses

MUPP/MUD elective courses are open to graduates and senior undergraduates from all AUB departments.

URPL 621 **Urban Form and Transformation** **3 cr.**
The course examines the formation and transformation of cities through the analysis of their urban fabrics in terms of buildings, lots, blocks and streets, and their dynamic relationship through space and time. Students are exposed to the theories and methods of typo- morphological analysis as a bridge between architecture and urban design. The goal is to build their ability to understand urban physical layouts and structures

and to explain their underlying shaping processes. The course concludes by considering ways in which this operational knowledge of urban form contributes to the practice of physical planners and designers through the investigation of case studies.

URPL 623 Urban Economics 3 cr.
The course introduces students to the analytical tools necessary for study of the development and growth of urban areas as well as the analysis of specific urban issues such as pollution, housing, land use and public transportation. The course places special emphasis on the national and regional contexts.

URPL 637/ ARCH 036 Illegal Cities 3 cr.
This seminar is designed as an introduction for students enrolled in Architecture, Urban Planning and Policy, and Urban Design to the ongoing debates about the relationship between law and the building process, specifically looking at its actual materialization in illegal/informal settlements. The course is based on a combination of lecture/seminar sessions in which various theorizations of the city/law nexus are explored and on field studies/class discussions in which the applications of these theories are investigated using a local case study.

URPL 641 Introduction to GIS and Spatial Analysis for Planning and Architecture 3 cr.
This course offers an introduction to geographic information systems (GIS) as applied to urban and regional planning, community development and local government. Emphasis is placed on learning GIS technology and spatial analysis techniques through extensive hands-on exercises using real-world data sets, such as the census of population and housing. The course includes a small project on an urban planning problem involving the selection of appropriate methods, the use of primary and secondary data, computer-based modeling and spatial analysis.

URPL 664 Urban Land Use Planning 3 cr.
This course examines the theory and practice of land use planning as it has developed within the wider practice and theorization of planning. The course explores ways in which land use controls have been developed and managed in different institutional and regional contexts, unraveling the different conceptualizations of planning that support each of them. Special emphasis is placed on the case of Lebanon where the practice of land use planning is explored through a detailed introduction to planning institutions, agencies and regulations.

URPL 665/ ARCH 062 Development and Planning Policies 3 cr.
The course examines local and regional development and spatial planning projects and policies. It investigates policy governance and institutional setup of projects, the role of professional expertise, as well as spatial impacts, socio-economic and political impacts on cities and regions. Using case-study analysis, students learn how the built environment's growth and development is being managed across different contexts by a constellation of stakeholders negotiating conflicting interests, often yielding unequally distributed benefits and costs.

URPL 666 Transportation Planning and Policy 3 cr.
The course focuses on transportation policy and planning for transportation facilities and services as well as the interaction between transportation and built, natural and social environments. The course's intent is to provide students with the necessary knowledge for analyzing transportation problems in the field, as well as the policy framework for examining the broader social, economic and environmental implications of alternative transportation planning decisions. The course discusses policy-making and policy instruments, considers alternative institutional arrangements for policy development and implementation, and evaluates the efficacy of different policy interventions. The interaction between technical analysis and policy-making is also addressed.

URPL 668 Heritage Management Policies 3 cr.
The course explores how different threads of professional practice can be engaged in heritage protection, valuation and administration. It examines the different stakeholders and their roles in heritage preservation, ranging from local authorities, antiquities departments, the courts, local businesses, NGOs, regional and international organizations, UNESCO, etc. The course focuses on regulatory framework and tools of urban heritage preservation; economic and social valuation of urban heritage; site management and integrated approaches; as well as the role and agency of different stakeholders and negotiation frameworks.

URDS624 / ARCH024 Hybrid Beirut: Morphogenesis of the Contemporary City 3 cr.
Looking East and West, Beirut has developed its own response to early modernization through the assimilation of Western urban models and architectural trends. The resulting cultural hybridity and townscape diversity can only be understood by exploring the transitional years of the city formation and transformation from a medieval Arab-Islamic town in the 1840s to a showcase of the French Mandate in the Levant in the 1920s and 30s. This course is an attempt to read contemporary Beirut through its recent colonial past, and to trace the continuity and change in its social, economic and cultural conditions as mirrored in the urban structure and building typologies.

URDS 632 From Urban Design to Landscape Urbanism 3 cr.
This course explores the changing conception of city space examining the shifts in environmental design theory and practice from the 1970s until now. The class covers the foundation of urban design as a traditional discipline while opening up to emerging design ideologies and tactics in response to contemporary urban mutations. The course will appeal to students in architecture, landscape architecture and physical planning who are interested in crossing the boundaries between disciplines and exploring new potentialities in design thinking.

URDS 664 Ecological Landscape Design and Planning 3 cr.
The course, which is an introduction to the theory and methodology of ecological landscape design and planning, aims to introduce the holistic approach of landscape ecology and its application to the sustainable management of natural and cultural landscapes/ecosystems. The course syllabus is planned to prioritize Mediterranean ecosystems and landscapes and equally to promote interdisciplinary collaboration in research and project management.

Department of Civil and Environmental Engineering

Chairperson:	Abdul Malak, Mohamed-Asem
Professors:	Abdul Malak, Mohamed-Asem; Ayoub, George; Basha, Habib; El Fadel, Mutasem; Hamad, Bilal; Harajli, Muhamad; Mabsout, Mounir; Sadek, Salah
Associate Professors:	Abou Zeid, Maya; Chehab, Ghassan; Hantouche, Elie; Khoury, Hiam; Najjar, Shadi; Saad, George; Srour, Issam
Assistant Professors:	Abdulsattar, Harith; Alameddine, Ibrahim; Bilbeisi, Rana; Dabaghi, Mayssa; Salam, Darine; Yeretzian, Aram
Adjunct Professor:	Kaysi Isam; Yehya, Alissar
Part-Time Senior Lecturer:	Fawwaz, Youssef
Part-Time Lecturers:	Al-Naghi, Hani; Basha, Hisham; El Meski, Fatima; Elsouri, Amer; Hatem Mousallem, Manal; Malaeb, Lilian; Nader, Halim
Part-Time Instructor:	Demachkieh, Farah; Hage Ali, Nadine
Laboratories:	Al Hassanieh, Dima; El-Khatib, Helmi; Ezzeddine, Farah; Zayyat, Ramez

Graduate Programs

Master of Engineering and Master of Science Programs

The Department of Civil and Environmental Engineering (CEE) offers the degree of Master of Engineering (ME) with the following majors and concentrations:

- Major: Civil Engineering (CE) Concentration: Construction Engineering and Management, Geotechnical, Materials, Structural and Transportation
- Major: Environmental and Water Resources Engineering (EWRE) Concentration: Environmental Engineering and Water Resources Engineering

Also offered is a program leading to the degree of Master of Science (MS) in Environmental Science with the following major:

- Major: Environmental Technology (ET)
- The master's degree programs equip students with the necessary tools for professional practice and/or the pursuit of higher education.

Doctor of Philosophy Programs

The Department of Civil and Environmental Engineering (CEE) offers the degree of Doctor of Philosophy (PhD) with the following majors and concentrations:

- Major: Civil Engineering (CE) Concentration: Construction Engineering and Management, Geotechnical, Materials and Transportation
- Major: Environmental and Water Resources Engineering (EWRE) Concentration: Environmental and Water Resources

Master of Engineering (ME)

General Information

The Department of Civil and Environmental Engineering offers two graduate programs leading to the ME degree:

- Thesis Program
- Non-Thesis Program

The Thesis Program prepares students through course work and provides them with significant research experience in their selected area of concentration. All graduate students must satisfy either the thesis or the non-thesis program requirements. The program will be indicated on the student's transcript.

Admission Requirements

To be eligible for admission to the graduate program, a student must hold a bachelor's degree in Civil Engineering or a related field. Students with a bachelor's degree in majors other than Civil Engineering must fulfill the prerequisite course requirements as set by the department. Students 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 this catalogue.

Bachelor of Engineering holders from a 5-year equivalent engineering program may obtain a waiver for 9 credits of relevant graduate level courses from their BE degree as long as they maintain a minimum grade of B+ or 80 or its equivalent in each of these courses.

Bachelor of Science holders must complete an additional 18 credits of engineering courses prior to enrollment in the master's program and must achieve a GPA of at least 3.2 or an average of at least 80 percent in these courses. No credit toward the graduate degree is given for these courses.

A minimum of one calendar year of residence is required for graduation. The student must also satisfy all relevant Maroun Semaan Faculty of Engineering and Architecture (MSFEA) and AUB requirements.

Major: Civil Engineering (CE)

Thesis Program Requirements

In order to fulfill the graduation requirements in the CE Thesis Program, a student must complete a minimum of 24 credit hours of graduate courses and a thesis based on independent research, equivalent to at least 6 credit hours. The required course work is distributed as follows:

- A minimum of four graduate courses (12 credit hours) in the field of concentration
- A maximum of two graduate courses (6 credit hours) in a relevant CEE field
- A maximum of two graduate courses (6 credit hours) of relevant electives in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Omit
- Seminar course (CIVE 600)

The courses that fall in the elective category must be pre-approved by the department. Up to two senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

Non-Thesis Program Requirements

In order to fulfill the graduation requirements in the Non-Thesis Program, a student must complete a minimum of 33 credit hours of graduate courses. The required course work is distributed as follows:

- A minimum of five graduate courses (15 credit hours) in the field of concentration
- A maximum of three graduate courses (9 credit hours) in a relevant CEE field
- A maximum of three graduate courses (9 credit hours) of relevant electives in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Comprehensive Exam (CIVE 799T)
- Seminar course (CIVE 600)

The courses that fall in the elective category must be pre-approved by the department. Up to three senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

Major: Environmental and Water Resources Engineering (EWRE)

Thesis Program Requirements

In order to fulfill the graduation requirements in the CE Thesis Program, a student must complete a minimum of 24 credit hours of graduate courses and a thesis based on independent research, equivalent to at least 6 credit hours. The required course work is distributed as follows:

- A minimum of two core graduate courses (6 credit hours) in the area of specialty
- A minimum of two graduate elective courses (6 credit hours) in the area of specialty
- A minimum of two graduate courses (6 credit hours) in the minor area
- A maximum of two graduate elective courses (6 credit hours) in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Comprehensive Exam (CIVE 799T)
- Seminar course (CIVE 600)

The courses that fall in the elective category must be pre-approved by the department. Up to two senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

Non-Thesis Program Requirements

In order to fulfill the graduation requirements in the Non-Thesis Program, a student must complete a minimum of 33 credit hours of graduate courses. The required course work is distributed as follows:

- A minimum of three core graduate courses (9 credit hours) in the area of specialty
- A minimum of three graduate elective courses (9 credit hours) in the area of specialty
- A minimum of three graduate courses (9 credit hours) in the minor area
- A maximum of two graduate elective courses (6 credit hours) in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Seminar course (CIVE 600)

The courses that fall in the elective category must be pre-approved by the department. Up to three senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

Specialization: Environmental Engineering

Minor: Water Resources Engineering

- Core Courses: CIVE 550, CIVE 551, CIVE 552, CIVE 553, CIVE 555
- Elective Courses: CIVE 645, CIVE 650, CIVE 651, CIVE 652, CIVE 653, CIVE 654, CIVE 655, CIVE 656, CIVE 657, CIVE 751, CIVE 755

Specialization: Water Resources Engineering

Minor: Environmental Engineering

- Core Courses: CIVE 541, CIVE 542, CIVE 640, CIVE 641, CIVE 642
- Elective Courses: CIVE 644, CIVE 645, CIVE 647, CIVE 648, CIVE 656, CIVE 740

Master of Science (MS)

Major: Environmental Technology (ET)

The Department of Civil and Environmental Engineering offers a graduate program leading to the degree of Master of Science in Environmental Technology (ET). The program is part of the Interfaculty Graduate Environmental Sciences Program (IGESP) and is open to non-engineering students who hold a degree in basic sciences. For more details, on the IGESP program, refer to the Interdisciplinary Research Centers and Programs section of this catalogue.

In order to fulfill the graduation requirements in the MS Program, a student must complete a minimum of 24 credit hours of graduate courses and a thesis equivalent to 6 credit hours, or 27 credit hours of graduate courses and a project course equivalent to 3 credit hours.

The required course work is distributed as outlined below:

- Two courses selected from the following sequences:
  - No more than one course from the ENVH program (3 cr.) ENSC 640/ENHL 310, ENSC 641/ENHL 312, ENSC 642/ENHL 314
  - No more than one course from the ECOM program (3 cr.) ENSC 630/EDEM630, LDEM 301, LDEM 302
  - No more than one course from the EPP program (3 cr.) ENSC 650/PSPA 316
- A minimum of three graduate core courses (9 cr.) in Environmental Engineering
- A minimum of two graduate elective courses (6 cr.) in Environmental Engineering
- Experimental Design and Statistical Methods course (3 cr.) (CIVE 602)
- Comprehensive Exam (ENSC 695)
- Seminar course (CIVE 600) when offered

Doctor of Philosophy (PhD)

General Information

The PhD programs offered by the CEE department train graduate students to address and solve current problems in civil and environmental engineering. PhD students are trained to be future educators and proficient researchers geared to assume leadership roles in their profession.

The objectives of the PhD program are to:

- cultivate expertise in concentration areas of Civil and Environmental Engineering,
- develop research skills necessary for the formulation and solution of challenging problems,
- and acquire teaching expertise through assistance in class lectures and laboratory sessions.

Admission Requirements

To be eligible for admission to the PhD program, a candidate must:

- hold a master's degree in Civil and Environmental Engineering or a related discipline from AUB or another recognized institution of higher learning (for admission in the regular track), or a bachelor's degree in Civil Engineering or a related discipline (for admission in the accelerated track). A minimum cumulative course average of 85 over 100, or its equivalent, is required for admission.
- submit a complete application including a statement of interest, transcripts of academic records from all institutions attended after high school, a curriculum vitae and three letters of recommendation,
- provide scores for the General Exam part of the Graduate Record Examination (GRE),
- demonstrate proficiency in the English language if English is not the native language (refer to the catalogue section on Readiness for University Study in English (RUSE)),
- and complete an interview either in person or by phone (for non-AUB students).

The application to the doctoral program will follow the deadlines set by the Office of Admissions at AUB. Admission decisions for the PhD program are made upon the recommendations of the CEE department and the MSFEA Graduate Studies Committee, with the approval of the AUB Board of Graduate Studies.

Regular PhD Program Requirements

The regular PhD program requires a minimum of 24 credit hours of course work beyond the master's degree and 24 credit hours of thesis work. The course work consists of

- a minimum of 12 credits in the area of concentration,
- 6 credits in a related area,
- and 6 credits in an area other than the candidate's field of research, which can be taken inside or outside the department.

Accelerated PhD Program Requirements

The accelerated PhD program requires a minimum of 36 credit hours of course work beyond the bachelor's degree and 42 credit hours of thesis work. The course work consists of

- a minimum of 21 credits in the area of concentration,
- 9 credits in a related area,
- and 6 credits in an area other than the candidate's field of research, which can be taken inside or outside the department.

Candidacy Requirements

Qualifying Exam Part I: Comprehensive Exam

All students admitted to the PhD program must successfully complete a written comprehensive examination administered by the department. The purpose of the comprehensive exam is to ascertain the student's knowledge in his/her field of specialization and related areas. The written exam will cover major topics from within the concentration area and related fields. Normally, a student on the regular track will take the comprehensive exam no later than 18 months after enrollment in the PhD program and after completing a minimum of 18 credits of courses. A student on the accelerated track will usually take the comprehensive exam no later than 24 months after enrollment in the PhD program and after completing a minimum of 30 credits of courses. Students who do not pass the comprehensive exam may, upon the recommendation of the department, take it for a second time the following term. Failing the exam a second time will result in the student's discontinuation from the graduate program. See Qualifying Exam Part I: Comprehensive Exam under General University Academic Information section.

Qualifying Exam Part II: Defense of Thesis Proposal

See Qualifying Exam Part II: PhD Thesis Defense under General University Academic Information section.

Admission to Candidacy

See Admission to Candidacy under General University Academic Information section.

Thesis Requirements

Refer to General University Academic Information section.

Thesis Committee

See PhD Thesis Committee under General University Academic Information section.

Thesis Defense

See PhD Thesis Defense under General University Academic Information section.

PhD Publication Requirements

See PhD Publications Requirements under General University Academy Information section.

Residence Requirements

See Residence Requirements under General University Academy Information section.

Graduation Requirements

To earn a PhD degree in the Department of Civil and Environmental Engineering, a student must fulfill the following graduation requirements:

- Attain a minimum cumulative average of 85 (3.7) in 24 credits (regular program) or 36 credits (accelerated program) of course work taken at the PhD level
- Attain a minimum grade of B or 75 for courses taken at the PhD level
- Pass the PhD thesis defense
- Satisfy the minimum residency requirements
- Have at least two publications according to one of the following options: (1) in two internationally refereed journals, (2) in two international conferences, or (3) in one internationally refereed journal and one international conference.
- Satisfy all pertinent AUB regulations

Sample Study Program

A typical program of study for a PhD student is shown below.

Year	Semester	Course	Credits	Total	Timeline
1	**Fall**	**Major course**	**3**		
		Major course	**3**		
		Minor course	**3**	**9**	
	Spring	**Major course**	**3**		
		Major course	**3**		
		Minor course	**3**	**18**	
	Summer	**Thesis**	**9**	**27**	
2	**Fall**	**Minor Course**	**3**		
		Minor Course	**3**	**33**	**Comprehensive Exam**
	Spring	**Thesis**	**9**	**42**	
	Summer	**Thesis**	**6**	**48**	
3	**Fall**	**Thesis**	**0**	**48**	
	Spring	**Thesis**	**0**	**48**	**Proposal Defense**
4	**Fall**	**Thesis**	**0**	**48**	
	Spring	**Thesis**	**0**	**48**	**Thesis Defense**

PhD in Civil Engineering (CE)

The concentration areas and specialized tracks of the PhD programs in CE are consistent with the fields of expertise and research interests of the faculty members and the existing research and laboratory facilities. The specialty areas are as follows:

Structural and Materials Engineering

- Advanced design and behavior of concrete, steel structures and fiber-reinforced composites
- Strengthening and rehabilitation of structural systems, and structural health monitoring
- Advanced concrete technology including plain, hot-weathered and high-strength concrete
- Petrographic, chemical, and mechanical properties of sands and aggregates
- Seismic evaluation and assessment, and earthquake engineering design
- Numerical modeling and computer-aided structural engineering

Construction Engineering and Management

- Pre-project planning and design management for construction projects
- Construction estimating, planning and scheduling
- Construction technologies, methods, equipment and safety
- Construction project delivery, management and contracts
- Construction contract administration and dispute resolution
- IT and BIM applications in construction
- Construction systems analysis and lean applications
- Sustainability issues related to building design and construction
- Construction business environment and risks

Geotechnical Engineering

- Land reclamation and site improvement
- Geographic Information Systems (GIS) used in decision-making and expert tool applications
- Geo-environmental engineering with reference to waste disposal and site contamination
- Geotechnical earthquake engineering, geo-hazards and risk assessment
- Behavior of soils

Transportation Systems

- Urban transportation planning and modeling (transport and mobility considerations in urban universities, characterization of uncontrolled traffic conditions and walkability in urban areas, travel demand modeling)
- Public transport (operational planning and market arrangement implications in mass transit systems)
- Transportation and the environment (modeling and estimation of traffic induced emissions)
- Road safety (modeling and simulation of aggressive driver behavior)
- Maritime transport (maritime shipping, optimization of container terminal operations)
- Project evaluation (feasibility assessment and project delivery of transport infrastructure projects)

PhD in Environmental and Water Resources Engineering (EWRE)

The PhD program in EWRE focuses on the following courses and research topics:

- Water and wastewater treatment systems
- Solid and industrial waste treatment/management
- Air quality management and air pollution control
- Environmental and water resources management and planning
- Water Quality Modeling
- GIS and IT applications for environmental and water resources management
- Watershed modeling and management
- Hydrologic systems analysis
- Hydraulic systems analysis
- Environmental biotechnology and bioremediation
- Fate and impact of emerging environmental contaminants
- Biofuels and bioenergy

Course Descriptions

Common Courses

CIVE 501 Computer Methods in Civil Engineering 3 cr.
A course on the use of computers for analysis, design and decision-making in civil engineering, including programming, numerical, and CAD methods and applications. *Prerequisite: EECE 231.*

CIVE 600A Seminar in Civil Engineering 0 cr.
A seminar that consists of current research or applied civil engineering projects presented by faculty members, students or invited speakers.

CIVE 600B Seminar in Environmental Engineering and Sciences 0 cr.
A seminar that consists of current research or applied environmental projects presented by faculty members, students or invited speakers.

CIVE 601 GIS and Geospatial Data Modeling 3 cr.
A course that examines the concepts and principles of Geographic Information Systems (GIS). It provides coverage of state-of-the-art GIS methods and tools: spatial and terrain analysis, geostatistical analysis, time series analysis and development of GIS integrated models.

CIVE 602 Experimental Design and Statistical Methods 3 cr.
A course that covers the main steps required to efficiently plan, conduct, analyze and interpret results from experimental and observational studies. The course focuses on statistical inference and modeling. Topics covered include ANOVA, t-tests, regression models and non-parametric tests. The course involves working within a statistical modeling environment.

CIVE 603 Numerical Modeling 3 cr.
A course that deals with ordinary differential equations: initial-, boundary- and characteristic-value problems; partial differential equations: steady state, time dependent and oscillatory problems; techniques: Runge-Kutta, shooting, iterative and finite difference methods. *Prerequisite: MATH 251.*

Structural Courses

CIVE 610 Numerical Methods in Structural Analysis 3 cr.
A course that introduces the matrix approach for the modeling and analysis of structural systems; computer modeling/analysis using specialized software (SAP2000); computer implementation and code development; nonlinear analysis of frames. *Prerequisites: CIVE 411 and EECE 231.*

CIVE 611 Bridges 3 cr.
A course that discusses types of bridges; influence lines; loads and their distribution on bridges; serviceability of bridges; methods of design of bridge deck, superstructure and substructure. *Prerequisite: CIVE 311.*

CIVE 612 Advanced Steel Design 3 cr.
A course that investigates stability, column strength, beam-columns, composite steel-concrete construction, plate buckling, plate girders, torsion, combined torsion and bending, eccentrically loaded connections, influence of connection stiffness on moment demand and general moment connection. *Prerequisite: CIVE 412.*

CIVE 613 Prestressed Concrete 3 cr.
A course on material characteristics, prestress losses, working strength design procedures, composite construction, ultimate flexural strength and behavior, shear design and continuous prestressed concrete members. *Prerequisite: CIVE 413.*

CIVE 614 Special Topics in Concrete 3 cr.
A course that reviews reinforced concrete (R/C) design; torsion in R/C members; wind load on structures; earthquake load and seismic design of structures; design of shear walls; design of corbels, brackets and deep girders; circular and rectangular water tanks; and spherical, conoidal, and ellipsoidal domes. *Prerequisite: CIVE 414.*

CIVE 615 Strengthening and Rehabilitation of Concrete Structural Systems 3 cr.
A course on assessment of materials and structural deficiency using field test or analytical methods; repair and strengthening materials; strengthening and repair techniques; strengthening of structural members in flexure, shear and axial load; and upgrading of gravity load-designed buildings for earthquake load resistance. *Prerequisites: CIVE 311 and CIVE 413.*

CIVE 616 Earthquake Engineering 3 cr.
A course that examines the nature of earthquake ground motion, seismic hazard evaluation in engineering practice, response analysis of structures and effect of soil conditions on structural response and behavior under earthquake ground motion and design of structures under earthquake loading. *Prerequisite: CIVE 411.*

CIVE 710 The Finite Element Method 3 cr.
A course that introduces basic elements, interpolation and shape functions, variational formulation methods, Galerkin and weighted residual methods, isoparametric elements, numerical integration, error estimation and modeling issues, and finite elements in structural dynamics. *Prerequisite: CIVE 610.*

CIVE 711 Advanced Mechanics of Solids 3 cr.
A course that covers theories of stress and strain; generalized Hook's law; modes of failure and failure criteria; energy principles and applications; torsion; beams on elastic foundations; introduction to the theory of plates; thin-wall and thick-wall cylinder. *Prerequisite: CIVE 411.*

CIVE 712 Structural Dynamics 3 cr.
A course on analysis of vibration of single degree, multi-degree and infinite degree of freedom systems; free and forced vibration response; analysis of dynamic response by approximate methods; introduction to earthquake engineering. *Prerequisite: CIVE 411.*

CIVE 713 Behavior of Reinforced Concrete Members 3 cr.
A course on building codes; limit state design; mechanical characteristics of concrete and steel reinforcement; creep and shrinkage; flexure: moment-curvature and force-deformation relationships; columns: axial force-moment-curvature relationships; shear: mechanisms of shear resistance and truss analogy; bond and anchorage of reinforcement. *Prerequisite: CIVE 414*.

CIVE 714 Seismic Design of Reinforced Concrete Structures 3 cr.
A course on the seismic behavior and design of reinforced concrete structures; introduction to concepts of seismic design and performance-based earthquake engineering; mechanical behavior of steel reinforcement, concrete and confined concrete under monotonic and cyclic loading; seismic behavior, analysis and design of reinforced concrete elements and systems; design of special structural/shear wall systems; design of special moment resisting frames. *Prerequisites: CIVE 411 and CIVE 414*.

Construction Engineering and Management Courses

CIVE 520 Construction Contract Administration 3 cr.
The course deals with contract documents, with focus on specifications structure, procedural requirements, specifying methods and the basis for unit rate estimation. It covers the engineer's roles along with contract administration issues. *Prerequisite: CIVE 421*.

CIVE 522 Building Construction and Estimating 3 cr.
A course that exposes students to different building systems (concrete, masonry, steel, waterproofing, mechanical and electrical, etc.) and how to price them by choosing the best materials and methods. The use of drawings and specifications will also be covered. *Prerequisites: CIVE 400 (site work) and CIVE 421*.

CIVE 524 Logistics, Technologies and Productivity Concepts 3 cr.
The course covers construction site layout, team organization, information flow and complexities. Focus is on productivity improvement approaches, data gathering for analysis of construction operations, issues related to process innovation and automation.

CIVE 525 Design of Temporary Support Structures 3 cr.
A course that covers design and construction of temporary support structures used in the construction industry, including concrete formwork, scaffolding, caissons, cofferdams and dewatering systems.

CIVE 620 Pre-Project Planning and Feasibility Analysis 3 cr.
A course that covers the studies needed to make a go-ahead decision, including assimilation of client needs, surveys of project area and infrastructure conditions, scope validation, team development, project planning and cost estimation, and financial feasibility. *Prerequisite: CIVE 421 or equivalent.*

CIVE 621 Design Management for Large Projects 3 cr.
The course covers the characteristics of the design phase, design team selection, and design services agreement formation and negotiation. It focuses on value engineering and management, constructability considerations and project cost management during design.

CIVE 622 Advanced Topics in Construction Management (Blended) 3 cr.
A course that focuses on the construction phase of a project's life cycle. Topics include: site organization structure, construction safety, labor management, materials procurement systems, site information management, scheduling, project controls and sustainability. *Prerequisite: CIVE 421 or equivalent.*

CIVE 623 Construction Project Management 3 cr.
The course offers an extended overview of project management. It covers integrated planning-estimating-scheduling concept; project time, budget and quality baselines; materials management and subcontracting issues; and integrated project cost-time control. *Prerequisite: CIVE 421 or equivalent.*

CIVE 624 Building Information Modeling 3 cr.
A course that covers Building Information Model (BIM) use and benefits in design and construction. It addresses collaborative design, clash detection, level of development (LOD), BIM contracts, automated code checking, simulation, BIM and lean applications, and integrated project delivery.

CIVE 625 IT Applications in Construction 3 cr.
A course that covers computing tools impacting the construction industry such as mobile sensing, instrumentation and information systems to support field engineering tasks and computerized systems applications to perform specific functions, such as estimating, scheduling and cost control.

CIVE 626 Lean Construction Methods and Applications (Blended) 3 cr.
A course on lean theory, production control, value stream mapping, process improvement, project definition, lean design, integrated project delivery, advanced lean scheduling, risk assessment, budget under uncertainty and project monitoring. *Prerequisite: CIVE 421.*

CIVE 627 Construction Systems Analysis and Simulation 3 cr.
A course that covers planning and simulation modeling of construction operations, design of efficient processes, construction productivity and resource use considerations, production system design, construction supply chain management and analysis of construction systems.

CIVE 628 Sustainable Building Design and Construction 3 cr.
A course that covers principles of sustainable design and construction, including life-cycle assessment, economic and environmental impacts, carbon footprint, and green building rating systems such as LEED and BREEAM.

CIVE 629 Construction Business Management 3 cr.
A course that covers the principles of business management of construction companies and projects including financial management, accounting, costs and profits management, cash flows management, evaluation of sources of construction funding and financial decisions analysis. *Prerequisite: CIVE 370.*

CIVE 720 Construction Technology for Tall Buildings 3 cr.
A course on the latest construction practices and processes for tall buildings from foundation to roof. It covers advanced methods, materials, equipment and systems used for the construction of tall buildings, as well as principles of sustainable construction. *Prerequisite: CIVE 422.*

CIVE 721 Advanced Scheduling Analysis 3 cr.
A course that provides advanced techniques in construction scheduling. It examines monitoring, updating and controlling the project schedule. It introduces the methods used in performing forensic scheduling analysis. *Prerequisite: CIVE 423.*

CIVE 722 Project Deliverance and Contracts 3 cr.
The course offers an overview of project delivery organizations, risk considerations and contracts. It covers the elements of construction contracts, with emphasis on contract formation, substantial completion and close-out processes. *Prerequisite: CIVE 421 or equivalent.*

CIVE 723 Dispute Resolution on Projects 3 cr.
The course covers construction contract conditions governing claims and disputes. Focus is on claim evolvement and administration (including issues dealing with time barring, notification and substantiation) and ADR methods and amicable settlement. *Prerequisite: CIVE 421.*

CIVE 724 Mediation of Engineering Disputes 3 cr.
This course focuses on the use of mediation for resolving construction related disputes. Topics include: dispute avoidance in construction, alternative dispute resolution techniques, and the mechanics of mediation and negotiation. *Prerequisite: CIVE 520.*

CIVE 725 Construction Decisions Under Uncertainty 3 cr.
A course that covers construction project and organization decisions for the uncertain future. The course addresses decision theory, competitive bid analysis, probabilistic modeling and simulation, and multiple regression analysis in managing construction. *Prerequisite: STAT 230.*

Geotechnical Courses

CIVE 631 Applied Foundation Engineering 3 cr.
A course on braced excavations, retaining structures, deep foundations, slope stability and computer applications. *Prerequisite: CIVE 431.*

CIVE 632 Soil Behavior 3 cr.
A course on soil mineralogy, soil formation and composition; influence of geological factors on properties; colloidal phenomena in soils; soil structure; analysis of conduction phenomena (hydraulic, diffusive, thermal and electrical); compressibility, strength and deformation properties. *Prerequisite: CIVE 430.*

CIVE 633 Soil and Site Improvement 3 cr.
A course that covers compaction, admixture stabilization, foundation soil treatment, reinforced soil and composite materials, and material sites reclamation.

CIVE 634 Shear Strength of Soils 3 cr.
A course that covers stresses within a soil mass, tests to measure stress strain properties, stress-strain relationships, shear strength, drained and undrained conditions, constitutive models, and failure criteria applications. *Prerequisite: CIVE 430.*

CIVE 635 Earth Dams 3 cr.
A course that examines hydraulic dams, rolled earth dams, homogenous dams, thin core dams, filters, causes of dam failures, see page control and seismic stability of dams.

CIVE 636 Geotechnical Earthquake Engineering 3 cr.
A course on causative mechanisms and characteristics of earthquakes; evaluation dynamic soil properties local site response; seismic soil-structure interaction; evaluation and mitigation of soil liquefaction; seismic code provisions and additional current topics. *Prerequisite: CIVE 430.*

Water Resources Courses

CIVE 541 Engineering Hydrology 3 cr.
A course that outlines hydrologic principles, rainfall-runoff analysis, flood routing, frequency analysis and ground water hydrology. *Prerequisites: CIVE 340 and MATH 202.*

CIVE 542 Urban Hydrology 3 cr.
A course that covers design rainfall, infiltration, overland flow, channel flow, storm sewer hydraulics, stormwater detention and simulation models. *Prerequisite: CIVE 440.*

CIVE 640 Advanced Hydraulics 3 cr.
A course that covers closed conduit flow, water distribution systems, transient analysis, open channel flow, flood control, culvert hydraulics and design of various hydraulic structures. *Prerequisite: CIVE 440.*

CIVE 641 Surface Water Hydrology 3 cr.
A course on design storm, rainfall-runoff modeling, flood routing, reservoir routing, simulation models and stochastic hydrology. *Prerequisite: CIVE 541 or equivalent.*

CIVE 642 Groundwater Hydrology 3 cr.
A course that deals with properties of groundwater, Darcy's law, steady groundwater flow, unsteady groundwater flow, well hydraulics, unsaturated flow, sea-water intrusion and numerical modeling. *Prerequisite: CIVE 541.*

CIVE 644 Coastal Engineering 3 cr.
A course on small-amplitude wave theory (linear theory); finite-amplitude wave theory (nonlinear theory); conoidal wave theory; solitary wave theory; wave refraction, diffraction and reflection; wave forces and interaction with man-made structures; and design of maritime structures, e.g., breakwaters. *Prerequisite: CIVE 440.*

CIVE 645 Surface Water Quality Modeling and Management 3 cr.
An introductory course on surface water quality pollution problems in streams, rivers, lakes, reservoirs and estuaries with a focus on both the quantitative modeling aspects of surface water quality and the management and policy aspects of it. Both mechanistic and empirical models for assessing the status of surface water bodies are introduced.

CIVE 647 Water Resource Systems: Planning and Management 3 cr.
A course that introduces principles demonstrating steps in engineering policy planning as it applies to water resources management. Emphasis will be placed on systems and socio-economic analysis, conflict management and concepts in strategic assessment.

CIVE 648 Climate Change and Water Resources 3 cr.
An introductory course on global climate change and its potential impacts on water resources and related sectors. It explores drivers of climate change, greenhouse gases emissions and mitigation efforts, and adaptation options with emphasis on Integrated Water Resources Management.

CIVE 740 Transport Phenomena in Surface and Subsurface Waters 3 cr.
A course on advection, diffusion and dispersion of pollutants; transport in rivers and estuaries; transport in groundwater; numerical modeling; design of wastewater discharge system.

Environmental Courses

CIVE 550 Water Treatment and Laboratory 3 cr.
A course that examines the quality and principles of municipal and industrial water treatment processes and methods of testing for physical, chemical and biological parameters. *Prerequisite: CIVE 251 or equivalent, or consent of instructor.*

CIVE 551 Wastewater Treatment and Laboratory 3 cr.
A course that examines the quality and principles of municipal wastewater treatment processes and methods of testing for physical, chemical and biological parameters. *Prerequisite: CIVE 252 or equivalent, or consent of instructor.*

CIVE 552 Waste Management and Treatment 3 cr.
A course on engineering principles, practices and techniques for the management of solid wastes: sources, composition, properties, impacts, generation, storage, collection and transport, processing, resource recovery and disposal.

CIVE 553 Environmental Biotechnology 3 cr.
A course that examines current and emerging environmental biotechnologies used for environmental quality evaluation, monitoring and remediation of contaminated environments, and provides students with working knowledge of the science that underpins them. *Prerequisite: CIVE 252 or equivalent, or consent of instructor.*

CIVE 555 Air Quality Management 3 cr.
A course on the principles, practices and techniques for the management of air pollution: Types, sources, properties, impacts, standards, control technologies, atmospheric dispersion, emissions and indoor air quality.

CIVE 650 Water and Sewage Works Design 3 cr.
A course that examines the design of water and wastewater schemes, including design reports and a literature search on the development of conventional treatment processes. *Prerequisite: CIVE 550 or CIVE 551, or consent of instructor.*

CIVE 651 Processes in Water and Wastewater Treatment 3 cr.
A course on sedimentation, filterability, permeability and fluidization, ion exchange, aeration, flotation, membrane filtration and aerobic digestion. Experimental applications of processes. *Prerequisites: CIVE 251 and CIVE 252, or equivalents; or consent of instructor.*

CIVE 652 Landfill Engineering Design 3 cr.
A course on solid waste disposal with emphasis on design development of landfill elements, site selection and characterization, gas extraction and management, leachate collection and management, liners, covers, closure and post-closure monitoring. *Prerequisite: CIVE 552.*

CIVE 653 Environmental Chemistry and Microbiology 3 cr.
A course that deals with organic, inorganic and physical chemistry; chemical equilibrium; reaction kinetics; acidity, alkalinity; composition, morphology and classification of micro-organisms; energy, metabolism and synthesis; growth, decay and kinetics; and biological water quality indicators. *Prerequisites: CIVE 251 and CIVE 252, or equivalents; or consent of instructor.*

CIVE 654 Environmental Bioremediation 3 cr.
A course that discusses the application of biological treatment for the remediation of contaminated environments and highlights current engineering methods/design used to enhance biodegradation.

CIVE 655 Air Pollution and Control 3 cr.
A course that examines processes and design equipment for the control of particulates and gaseous emissions. *Prerequisite: Consent of instructor.*

CIVE 656 Environmental Impact Assessment 3 cr.
A course on procedures of assessing/preparing/reviewing/presenting environmental impacts of developmental projects/facilities: industrial facilities, waste management/disposal, wastewater treatment, transportation, dams and reservoirs, irrigation/drainage schemes, coastal zone developments, natural resource management, etc. *Prerequisite: E4 status or consent of instructor.*

CIVE 657 Methods of Environmental Sampling and Analysis 3 cr.
A course on sampling techniques and instrumental methods in environmental sciences; determination of pollutants in water, air and soil; analytical techniques; adaptation of procedures to specific matrices; case studies. *Prerequisites: CIVE 251 and CIVE 252, or equivalents; or consent of instructor.*

CIVE 658 Industrial Waste Management 3 cr.
A course on engineering principles, practices and techniques for the management of industrial hazardous wastes: sources, generation and properties. Impacts and auditing of industrial facilities. Basic treatment processes and disposal methods. Site remediation. *Prerequisite: E4 status or consent of instructor.*

CIVE 659 Environmental and Water Conflict Management 3 cr.
A course on the development of case studies in environmental and water conflict management taught under a framework of role-play of opponents' perspective and decision-making thereof.

CIVE 751 Wastewater Reclamation and Reuse 3 cr.
A course that examines environmental issues in water reuse, risk assessment, water reclamation technologies, storage of reclaimed water, usage of reclaimed water, and planning of wastewater reclamation and reuse. *Prerequisite: CIVE 551.*

CIVE 755 Air Pollution Modeling 3 cr.
A course that deals with mathematical models, air pollution meteorology, plume rise, dispersion and atmospheric chemistry, meteorological models, as well as Gaussian, statistical and other special application models. *Prerequisite: CIVE 555 or consent of instructor.*

Transportation Courses

CIVE 661 Urban Transportation Planning I 3 cr.
An introductory course on methods and models used in transportation planning with emphasis on the urban context. Topics include travel patterns in urban areas, data requirements for planning and data collection techniques, transportation/land-use interaction, travel demand and network models, transport supply options and evaluation techniques. *Prerequisite: CIVE 460 or CIVE 461.*

CIVE 662 Traffic Engineering 3 cr.
A course that outlines traffic engineering studies, traffic control of signalized and unsignalized intersections, signal control hardware and maintenance, arterial performance and operations, and network optimization. *Prerequisite: CIVE 460.*

CIVE 663 Transportation Systems Analysis 3 cr.
A course that introduces methods, models and applications of transportation systems analysis focusing on both supply/performance and demand/economics. *Prerequisite: CIVE 460 or CIVE 461.*

CIVE 664 Design and Management of Transport Operations 3 cr.
A course on probabilistic and optimization methods for designing efficient operations in freight carrier, airline, transit and traffic modes. Topics include crew and vehicle scheduling in freight, airline, transit modes; vehicle routing and facility location problems in carrier systems; runway and air traffic operations; and reliability in transit services. *Prerequisites: CIVE 460 and STAT 230, or equivalents.*

CIVE 665 Transportation Economics 3 cr.
A course that investigates the application of economic principles to the evaluation of projects and policies in the transport sector such as transport project benefits, costs and financing, and pricing in the transport sector. *Prerequisite: CIVE 461.*

CIVE 666 Public Transportation 3 cr.
A course on public transportation modes and services; single route, network and strategic planning; tasks involved in system operations; management of public transportation organizations; privatization issues. *Prerequisite: CIVE 460 or CIVE 461.*

CIVE 761 Urban Transportation Planning II 3 cr.
A course that examines advanced topics in urban transportation planning, transportation systems management techniques, travel demand analysis and discrete choice modeling of travel demand. *Prerequisite: CIVE 661.*

CIVE 762 Traffic Flow Theory 3 cr.
A course on characteristics of traffic flow, density and speed; models describing traffic flows; hydrodynamic analogue; and computer simulation models. *Prerequisite: CIVE 460.*

Materials Courses

CIVE 670 Concrete Technology 3 cr.
A course that examines Portland cements; aggregates; pozzolans; proportioning normal concrete mixtures; pumping concrete; consolidating, finishing and curing concrete; durability; testing hardened concrete; high-strength concrete; light and heavy weight concretes; and hot and cold weather concreting.

CIVE 671 Pavement Engineering 3 cr.
A course that examines highway and airport pavement design, flexible and rigid pavement types and wheel loads, stresses in flexible and rigid pavements, pavement behavior under moving loads and soil stabilization. The course covers empirical, mechanistic-empirical and mechanistic design methodologies. *Prerequisite: CIVE 461.*

CIVE 672 Highway Materials and Construction 3 cr.
A course that covers various materials constituents in highway pavement structures with emphasis on asphalt concrete, aggregate-soil mixtures, geotextiles and bituminous liquids. Materials properties, design, quality control and methods of construction will be described. *Prerequisite: STAT 230.*

CIVE 673 Pavement Management Systems 3 cr.
A course that covers the principles of pavement management including types of pavement systems, common distresses and their assessment, pavement evaluation and rating systems, in addition to performance prediction and life cycle analysis. Various field assessment methods in addition to non-destructive and accelerated tests will be discussed and demonstrated. Maintenance and rehabilitation techniques will be compared with emphasis on selection of the most efficient, environment-friendly and cost-effective approaches. Students will utilize computer applications using GIS, regional and international inventory data and relevant software packages. *Pre or corequisite: CIVE 671 or CIVE 672.*

CIVE 770 Viscoelastic Behavior of Construction Materials 3 cr.
A course that covers viscoelastic behavior of construction materials, particularly asphalt concrete and polymer composites. The course deals with basic concepts in material characterization, rheology, time-temperature superposition principles, and linear and nonlinear viscoelastic models.

Multidisciplinary Courses

CIVE681 Evaluation of Cost Alternatives 3 cr.
A course that covers the basic principles of economic evaluations using fundamental concepts of time value of money to compare cost alternatives related to construction, design and real property development.

CIVE 682 Infrastructure Systems Management 3 cr.
A course on modeling and optimization methods and their application to inspection, performance prediction and maintenance decision-making for the management of infrastructure systems.

CIVE 683 Reliability Based Design of Civil Systems 3 cr.
A course that covers applications of reliability theory in assessing the safety and reliability of civil systems in the presence of uncertainty; decision-making and risk analysis; definition of the probability of failure; modeling uncertainty in resistance and load; load and resistance factor design (LRFD) in structural and geotechnical engineering; basics of design code calibration.

CIVE 684 Environmental Geotechnics 3 cr.
A course on geotechnical practice in environmental protection and restoration; influence of physical and chemical processes in soils on the evaluation of contaminant distribution; design of waste containment systems, slurry walls and soil stabilization; the applicability and use of geosynthetics; and technologies for site restoration and cleanup. *Prerequisite: CIVE 430.*

CIVE 685 Environmentally Sustainable Renewable Energy Sources 3 cr.
A course that covers basic principles, potentials and limitations of various renewable energy sources and technologies, including solar energy, hydroelectricity, wind energy, bio-energy, fuel cells, batteries and supercapacitors. Sustainability and impact of renewable energy sources on the environment will be discussed. *Prerequisite: CIVE 251 or CHEM 202.*

CIVE 686 Environmentally Responsive Buildings 3 cr.
A course that enhances knowledge pertaining to design aspects and application possibilities of climate responsive and environmentally friendly buildings. The impact of using construction building materials throughout the lifecycle of projects will also be discussed. At the end of the course, students will be equipped with the necessary knowledge to make informed decisions regarding green projects in their careers.

Special Courses

CIVE 690	**Special Projects**	**3 cr.**
CIVE 691	**Special Topics in Civil and Environmental Engineering**	**3 cr.**
CIVE 692	**Advanced Topics in Civil and Environmental Engineering**	**3 cr.**
CIVE 799	**ME/MS Thesis**	**6 cr.**
CIVE 980	**Qualifying Exam I: Comprehensive Exam**	**0 cr.**
CIVE 981	**Qualifying Exam II: Thesis Proposal Defense**	**0 cr.**
CIVE 982	**PhD Thesis**	**3 cr.**
CIVE 983	**PhD Thesis**	**6 cr.**
CIVE 984	**PhD Thesis**	**9 cr.**
CIVE 985	**PhD Thesis**	**12 cr.**
CIVE 986	**PhD Thesis**	**0 cr.**
CIVE 987	**PhD Thesis Defense**	**0 cr.**

Baha and Walid Bassatne Department of Chemical Engineering and Advanced Energy

Chairperson:	Ahmad, Mohammad
Professor:	Ahmad, Mohammad
Associate Professors:	Al-Hindi, Mahmoud; Azizi, Fouad; Saad, Walid; Zeaiter, Joseph
Assistant Professors:	Boyadjian, Cassia; Ghorayeb, Kassem; Maalouf, Elsa
Instructor:	Itani, Adnan
Assistant Lab Instructor:	El Berjawi, Mohammad

General Information

The Baha and Walid Bassatne Department of Chemical Engineering and Advanced Energy offers the degrees of Master of Engineering in Chemical Engineering and Master of Science in Chemical Engineering.

Master of Engineering (ME), Major: Chemical Engineering

The Baha and Walid Bassatne Department of Chemical Engineering and Advanced Energy fosters a community of scholars among its faculty members and graduate students, who have an interest in advancing knowledge and contributing to the profession.

The ME program will be open to students with a Bachelor of Engineering (BE) in Chemical Engineering or other related disciplines.

The student must complete a minimum of 21 credit hours of courses and a 9 credit-hour thesis (30 credit hours in total) on a full- or part-time basis. A minimum of one calendar year of residence is required for graduation from this program.

Students who have a Bachelor of Engineering in a degree other than chemical engineering will be accepted as ME in chemical engineering and should take CHEN 417 and CHEN 470.

The required 30 credit hours of courses and thesis are distributed as follows:

- 3 credits of applied mathematics
- 6 credits of chemical engineering core required courses
- 6 credits of chemical engineering electives
- 6 credits of non-chemical engineering electives
- 9 credits of thesis work

The courses that fall into each category are detailed below:

Applied Mathematics Course

The math course or math-oriented course offered by other departments must be approved by the graduate advisor. Additional math courses may be counted as non-chemical engineering electives. Acceptable courses include but are not limited to:

CIVE 710	**The Finite Element Method**	**3 cr.**
MATH 350/ CMPS 350	**Discrete Models for Differential Equations**	**3 cr.**
MATH 351/ CMPS 351	**Optimization and Nonlinear Problems**	**3 cr.**
CMPS 354	**The Finite Element Method**	**3 cr.**
ENMG 604	**Deterministic Optimization Models**	**3 cr.**
MECH 630	**Finite Element Methods in Mechanical Engineering**	**3 cr.**
MECH 663	**Computational Fluid Dynamics**	**3 cr.**

Core Required Courses

CHEN 611	**Transport Phenomena**	**3 cr.**
CHEN 617	**Chemical Reactor Analysis and Design**	**3 cr.**

Special Courses and Thesis

A student should register for the Thesis Proposal (CHEN 799T) and pass it before being allowed to register for his/her thesis. If a student fails CHEN 799T, s/he must register for CHEN 799TR and take the exam during the next term (excluding summer). Once completed, the student can register for CHEN 799, then CHEN 799 (A-E) in subsequent terms until the completion of his/her independent research with the exception of CHEN 797, students are not allowed to take any of the listed special courses and Thesis more than once . The Seminar course is compulsory and students should register it every term (excluding summer).

Students must register for the following to complete their thesis requirements:

CHEN 799T/ 799TR	**Thesis Proposal**	**0 cr.**
CHEN 799	**Thesis**	**9 cr.**
CHEN 799A/ B/C	**Thesis**	**(9cr, 0 billing) 9 cr.**
CHEN 799D/E	**Thesis**	**(9 cr., 1 billing)**
CHEN 797	**Seminar**	**0 cr.**

Chemical Engineering Elective Courses:

Students can choose courses from the following list:

Please note that students can only credit 600-level (or above) courses in the department.

CHEN 610	**Materials Design and Characterization**	**3 cr.**
CHEN 612	**Desalination**	**3 cr.**
CHEN 613	**Membrane Separation Processes**	**3 cr.**
CHEN 615	**Advanced Mass Transfer Processes**	**3 cr.**
CHEN 618	**Colloid and Interface Science**	**3 cr.**
CHEN 619	**Sustainability Science: Human and Environment Interaction**	**3 cr.**
CHEN 620	**Reaction Engineering and Reactor Design II**	**3 cr.**
CHEN 630	**Sustainable Biorefinery Processes**	**3 cr.**
CHEN 651	**Advanced Process Control**	**3 cr.**
CHEN 670	**Advanced Process Flowsheeting**	**3 cr.**
CHEN 672	**Polymer Science**	**3 cr.**
CHEN 673	**Engineering of Drug Delivery Systems**	**3 cr.**
CHEN 674	**Process Operations and Diagnosis**	**3 cr.**
CHEN 675	**Tissue Engineering**	**3 cr.**
CHEN 690	**Reservoir Engineering**	**3 cr.**
CHEN 696	**Reservoir Modeling**	**3 cr.**
CHEN 796	**Engineering Literature Critique**	**1 cr.**
CHEN 798	**Special Topics in Chemical Engineering I**	**3 cr.**

Non-Chemical Engineering Elective Courses:

Students can choose courses from the following list:

Please note that students can only credit 600-level (or above) courses in the Maroun Semaan Faculty of Engineering and Architecture (or at an equivalent level in other faculties).

BMEN 600	**Biomedical Engineering Applications**	**3 cr.**
BMEN 601	**Computational Modeling of Physiological Systems**	**3 cr.**
BMEN 605	**Biomedical Imaging**	**3 cr.**
BMEN 606	**Nano Biosensors**	**3 cr.**

CIVE 602	**Experimental Design and Statistical Methods**	**3 cr.**
CIVE 651	**Processes in Water and Wastewater Treatment**	**3 cr.**
CIVE 652	**Landfill Engineering Design**	**3 cr.**
CIVE 654	**Environmental Bioremediation**	**3 cr.**
CIVE 655	**Air Pollution and Control**	**3 cr.**
CIVE 656	**Environmental Impact Assessment**	**3 cr.**
CIVE 658	**Industrial Waste Management**	**3 cr.**
CIVE 710	**The Finite Element Method**	**3 cr.**
CIVE 740	**Transport Phenomena in Surface and Subsurface Waters**	**3 cr.**
CIVE 755	**Air Pollution Modeling**	**3 cr.**
CMPS 350	**Discrete Models for Differential Equations**	**3 cr.**
CMPS 351	**Optimization and Non-Linear Problems**	**3 cr.**
CMPS 354	**The Finite Element Method**	**3 cr.**
EECE 601	**Biomedical Engineering I**	**3 cr.**
EECE 602	**Biomedical Engineering II**	**3 cr.**
EECE 663/ MECH 656	**System Identification**	**3 cr.**
EECE 671	**Environmental Aspects of Energy Systems**	**3 cr.**
EECE 672	**Energy Planning and Policy**	**3 cr.**
EECE 675	**PV and Wind Electric Energy Systems**	**3 cr.**
ENMG 601	**Management Theory**	**3 cr.**
ENMG 602	**Introduction to Financial Engineering**	**3 cr.**
ENMG 603	**Probability and Decision Analysis**	**3 cr.**
ENMG 604	**Deterministic Optimization Models**	**3 cr.**
ENMG 611	**Supply Chain Design and Management**	**3 cr.**
ENMG 612	**Advanced Supply Chain Design and Management**	**3 cr.**
ENMG 616	**Advanced Optimization Techniques**	**3 cr.**
ENMG 622	**Simulation Modeling and Analysis**	**3 cr.**
ENMG 623	**Stochastic Models and Applications**	**3 cr.**
ENMG 633	**Advanced Topics in Project Management**	**3 cr.**

ENMG 654	**Technology-Based Entrepreneurship**	**3 cr.**
ENGM 659	**Introduction to System Dynamics**	**3 cr.**
ENMG 663	**Product Design and Development**	**3 cr.**
MATH 350	**Discrete Models for Differential Equations**	**3 cr.**
MATH 351	**Optimization and Non-Linear Problems**	**3 cr.**
MECH 603	**Solar Energy**	**3 cr.**
MECH 606	**Aerosol Dynamics**	**3 cr.**
MECH 607	**Micro-Flows Fundamentals and Applications**	**3 cr.**
MECH 609	**Experimental Methods in Fluid Dynamics**	**3 cr.**
MECH 627	**Polymers and Their Properties**	**3 cr.**
MECH 630	**Finite Element Methods in Mechanical Engineering**	**3 cr.**
MECH 634	**Biomaterial and Medical Devices**	**3 cr.**
MECH 663	**Computational Fluid Dynamics**	**3 cr.**
MECH 672	**Modeling Energy Systems**	**3 cr.**
MECH 674	**Energy Economics and Policy**	**3 cr.**
MECH 678	**Solar Electricity**	**3 cr.**
MECH 701	**Principles of Combustion**	**3 cr.**
MECH 747	**Nonlinear Finite Element Analysis**	**3 cr.**
MECH 751	**Simulation of Multiphase Flows**	**3 cr.**
MECH 760	**Advanced Fluid Mechanics**	**3 cr.**
MECH 761	**Convection Heat Transfer**	**3 cr.**
MECH 764	**Advanced Topics in Computational Fluid Dynamics**	**3 cr.**
MECH 765	**Advanced Finite Volume Techniques**	**3 cr.**
MECH 766	**Turbulent Flow and Transport**	**3 cr.**
MECH 767	**Heat Conduction**	**3 cr.**
MECH 768	**Transport Through Porous Media**	**3 cr.**
MECH 773	**Numerical Methods in Energy Technology**	**3 cr.**
MECH 798A	**Fundamentals of Energy and Resource Recovery**	**3 cr.**

Master of Science (MS), Major: Chemical Engineering

The Baha and Walid Bassatne Department of Chemical Engineering and Advanced Energy fosters a community of scholars among its faculty members and graduate students, who have an interest in advancing knowledge and contributing to the profession.

The MS program is open to students with a Bachelor of Science (BS) in Chemical Engineering or other related disciplines. Additionally, it is also open to students with a Bachelor of Science degree in chemistry, biology, mathematics or physics.

The student must complete a minimum of 31 credit hours of courses and 9 credit hours of thesis work (40 credits in total) on a full- or part-time basis. A minimum of one calendar year of residence is required for graduation from this program.

The required 40 credit hours of courses and thesis are distributed as follows:

- 3 credits of applied mathematics
- 12 credits of core required courses
- 10 credits of chemical engineering electives
- 6 credits of non-chemical engineering electives
- 9 credits of thesis work

The courses that fall in each category are detailed below:

Applied Mathematics Course:

The math course or math-oriented course offered by other departments must be approved by the graduate student advisor. Additional math courses may be counted as non-chemical engineering electives. Acceptable courses include but are not limited to:

CIVE 710	**The Finite Element Method**	**3 cr.**
MATH 350/ CMPS 350	**Discrete Models for Differential Equations**	**3 cr.**
MATH 351/ CMPS 351	**Optimization and Nonlinear Problems**	**3 cr.**
CMPS 354	**The Finite Element Method**	**3 cr.**
ENMG 604	**Deterministic Optimization Models**	**3 cr.**
MECH 630	**Finite Element Methods in Mechanical Engineering**	**3 cr.**
MECH 663	**Computational Fluid Dynamics**	**3 cr.**

Core Required Courses:

CHEN 570	**Process Synthesis and Optimization**	**3 cr.**
CHEN 571	**Chemical Product Design**	**3 cr.**
CHEN 611	**Transport Phenomena**	**3 cr.**
CHEN 617	**Chemical Reactor Analysis and Design**	**3 cr.**

Special Courses and Thesis:

A student should register for the Thesis Proposal (CHEN 799T) and pass it before being allowed to register for his/her thesis. If a student fails CHEN 799T, s/he must register for CHEN 799TR and take the exam during the next term (excluding summer). Once completed, the student can register for CHEN 799, then CHEN 799 (A-E) in subsequent terms until completion of his/her independent research.

Students must register for the following to complete their thesis requirements.

CHEN 799T/ CHEN 799TR	**Thesis Proposal**	**0 cr.**
CHEN 799	**Thesis**	**9 cr.**
CHEN 799A/ B/C	**Thesis**	**(9cr, 0 billing)**
CHEN 799D/E	**Thesis**	**(9 cr., 1 billing)**
CHEN 797	**Seminar**	**0 cr.**

Chemical Engineering Elective Courses:

Students can choose courses from the following list:

Please note that students can only credit 600-level (or above) courses in the department.

CHEN 610	**Materials Design and Characterization**	**3 cr.**
CHEN 612	**Desalination**	**3 cr.**
CHEN 613	**Membrane Separation Processes**	**3 cr.**
CHEN 615	**Advanced Mass Transfer Processes**	**3 cr.**
CHEN 618	**Colloid and Interface Science**	**3 cr.**
CHEN 619	**Sustainablity Science: Human and Environment Interaction**	**3 cr.**
CHEN 620	**Reaction Engineering and Reactor Design II**	**3 cr.**
CHEN 630	**Sustainable Biorefinery Processes**	**0 cr.**
CHEN 651	**Advanced Process Control**	**3 cr.**
CHEN 670	**Advanced Process Flowsheeting**	**3 cr.**
CHEN 672	**Polymer Science**	**3 cr.**
CHEN 673	**Engineering of Drug Delivery Systems**	**3 cr.**
CHEN 674	**Process Operations and Diagnosis**	**3 cr.**
CHEN 675	**Tissue Engineering**	**3 cr.**
CHEN 690	**Reservoir Engineering**	**3 cr.**
CHEN 696	**Reservoir Modeling**	**3 cr.**
CHEN 796	**Engineering Literature Critique**	**1 cr.**
CHEN 798	**Special Topics in Chemical Engineering I**	**3 cr.**

Non-Chemical Engineering Elective Courses:

Students can choose courses from the following list:

Please note that students can only credit 600-level (or above) courses in the Maroun Semaan Faculty of Engineering and Architecture (or at an equivalent level in other faculties).

BMEN 600	**Materials Design and Characterization**	**3 cr.**
BMEN 601	**Computational Modeling of Physiological Systems**	**3 cr.**
BMEN 605	**Biomedical Imaging**	**3 cr.**
BMEN 606	**Nano Biosensors**	**3 cr.**
CIVE 602	**Experimental Design and Statistical Methods**	**3 cr.**
CIVE 651	**Processes in Water and Wastewater Treatment**	**3 cr.**
CIVE 652	**Landfill Engineering Design**	**3 cr.**
CIVE 654	**Environmental Bioremediation**	**3 cr.**
CIVE 655	**Air Pollution and Control**	**3 cr.**
CIVE 656	**Environmental Impact Assessment**	**3 cr.**
CIVE 658	**Industrial Waste Management**	**3 cr.**
CIVE 710	**The Finite Element Method**	**3 cr.**
CIVE 740	**Transport Phenomena in Surface and Subsurface Waters**	**3 cr.**
CIVE 755	**Air Pollution Modeling**	**3 cr.**
CMPS 350	**Discrete Models for Differential Equations**	**3 cr.**
CMPS 351	**Optimization and Non-Linear Problems**	**3 cr.**
CMPS 354	**The Finite Element Method**	**3 cr.**
EECE 601	**Biomedical Engineering I**	**3 cr.**
EECE 602	**Biomedical Engineering II**	**3 cr.**
EECE 663 / MECH 656	**System Identification**	**3 cr.**
EECE 671	**Environmental Aspects of Energy Systems**	**3 cr.**
EECE 672	**Energy Planning and Policy**	**3 cr.**
EECE 675	**PV and Wind Electric Energy Systems**	**3 cr.**
ENMG 601	**Management Theory**	**3 cr.**
ENMG 602	**Introduction to Financial Engineering**	**3 cr.**

ENMG 603	**Probability and Decision Analysis**	**3 cr.**
ENMG 604	**Deterministic Optimization Models**	**3 cr.**
ENMG 611	**Supply Chain Design and Management**	**3 cr.**
ENMG 612	**Advanced Supply Chain Design and Management**	**3 cr.**
ENMG 616	**Advanced Optimization Techniques**	**3 cr.**
ENMG 622	**Simulation Modeling and Analysis**	**3 cr.**
ENMG 623	**Stochastic Models and Applications**	**3 cr.**
ENMG 633	**Advanced Topics in Project Management**	**3 cr.**
ENMG 654	**Technology-Based Entrepreneurship**	**3 cr.**
ENGM 659	**Introduction to System Dynamics**	**3 cr.**
ENMG 663	**Product Design and Development**	**3 cr.**
MATH 350	**Discrete Models for Differential Equations**	**3 cr.**
MATH 351	**Optimization and Non-Linear Problems**	**3 cr.**
MECH 603	**Solar Energy**	**3 cr.**
MECH 606	**Aerosol Dynamics**	**3 cr.**
MECH 607	**Micro-Flows Fundamentals and Applications**	**3 cr.**
MECH 609	**Experimental Methods in Fluid Dynamics**	**3 cr.**
MECH 627	**Polymers and Their Properties**	**3 cr.**
MECH 630	**Finite Element Methods in Mechanical Engineering**	**3 cr.**
MECH 634	**Biomaterial and Medical Devices**	**3 cr.**
MECH 663	**Computational Fluid Dynamics**	**3 cr.**
MECH 672	**Modeling Energy Systems**	**3 cr.**
MECH 674	**Energy Economics and Policy**	**3 cr.**
MECH 678	**Solar Electricity**	**3 cr.**
MECH 701	**Principles of Combustion**	**3 cr.**
MECH 747	**Nonlinear Finite Element Analysis**	**3 cr.**
MECH 751	**Simulation of Multiphase Flows**	**3 cr.**
MECH 760	**Advanced Fluid Mechanics**	**3 cr.**
MECH 761	**Convection Heat Transfer**	**3 cr.**
MECH 764	**Advanced Topics in Computational Fluid Dynamics**	**3 cr.**

MECH 765	**Advanced Finite Volume Techniques**	**3 cr.**
MECH 766	**Turbulent Flow and Transport**	**3 cr.**
MECH 767	**Heat Conduction**	**3 cr.**
MECH 768	**Transport Through Porous Media**	**3 cr.**
MECH 773	**Numerical Methods in Energy Technology**	**3 cr.**
MECH 798A	**Fundamentals of Energy and Resource Recovery**	**3 cr.**

Science Majors

Students who have a Bachelor of Science degree in chemistry, biology, mathematics or physics will be accepted as prospective graduate students in the MS program.

It is the responsibility of these students to have completed the equivalent of both MATH 218 and MATH 251 prior to joining the program.

If MATH 251 is not taken, the student has to take EECE 231/CMPS 200 first, then in the next term, the student has to register MATH 251 to pass graduate courses.

Students will also have to pass the following courses with a minimum cumulative average of 3.2 or 80 before joining the MS program:

Required core chemical engineering courses: CHEN 311, CHEN 312, CHEN 314, CHEN 411 and CHEN 417 .

Additionally, one of the following three courses is required: CHEN 351, CHEN 451, CHEN 470.

Engineering Majors

Students who have a Bachelor of Engineering other than chemical engineering will have to take the following: CHEN 417 and CHEN 470.

Course Descriptions

CHEN 570 Process Synthesis and Optimization 3 cr.
An introduction to the design and synthesis of the large scale production and processing of materials such as water, chemicals, petroleum products, food, drugs and waste. The course introduces principles of optimization: continuous, linear and nonlinear, and mixed-integer linear and nonlinear problems. Applications will address heat exchanger network synthesis, energy system designs, distillation and separation system selection, and optimization and design under uncertainty. *Prerequisites: CHEN 411, CHEN 451 and CHEN 470.*

CHEN 571 Chemical Product Design 3 cr.
This course covers the application of the design process of products based on chemical technology. It covers the entire design process from initial identification of product needs to the generation and selection of product ideas and culminates in the manufacture of a new product. *Prerequisite: CHEN 470.*

CHEN 610 Materials Design and Charaterization 3 cr.
This course is designed for chemical engineering students who want to gain knowledge and technical exposure with modern analytical instrumentation used in research and industry. The course will cover the theoretical and scientific aspects involved in analytical applications including: spectroscopy, chromatography, X-ray diffraction etc. It also encompasses laboratory sessions for sample preparation and instrumental operation, analytical method optimization and data interpretation. At the end of the course, students will become familiar with various analytical instruments and methods, and they will be able to decide on the appropriate instrument to carry out specific laboratory analysis. *Prerequisites: CHEN 410 and CHEM 219*

CHEN 611 Transport Phenomena 3 cr.
This course covers the application of the principles of momentum, heat and mass transfer to steady state and transient problems; molecular concepts; transport in turbulent flow; boundary layer theory; and numerical applications. *Prerequisite: CHEN 411 or MECH 412.*

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

CHEN 613 Membrane Separation Processes 3 cr.
The course will provide a general introduction to membrane science and technology: transport mechanisms, membrane preparation and boundary layer effects. The course will also cover the various types of membranes used in industry: microfiltration, ultrafiltration, reverse osmosis, electro-dialysis and pervaporation. *Prerequisites: CHEN 312 and CHEN 411.*

CHEN 615 Advanced Mass Transfer Processes 3 cr.
This course will cover a review of molecular and turbulent diffusion and mass transfer coefficients, mass transfer equipment design including absorption and cooling towers, adsorption and ion exchange. *Prerequisite: CHEN 411 or MECH 412.*

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

CHEN 618 Colloid and Interface Science 3 cr.
This is a first course in colloid and interface science. The repulsive and attractive forces at interfaces are described along with the dynamics of the interfaces. Topics include stability of macroemulsions, formulation and properties of microemulsions and surface metal-support interactions of catalysts. *Prerequisite: CHEN 314 or MECH 414.*

CHEN 619 Sustainability Science: Human and Environment Interaction 3 cr.
Sustainability is the grand challenge of our time especially with the UN SDG (Sustainable Development Goals) 2030 Agenda. This course addresses the basics of sustainability science and its challenges to promote economic growth and address social needs, while tackling climate change and environmental protection. The goal of the course is to introduce students to the four pillars of sustainability (human, economic, social, environmental) and help them incorporate its principles and models into engineering design practices. Students will be also introduced to current challenges, active debates and unresolved research questions in sustainability.

CHEN 620 Reaction Engineering and Reactor Design II 3 cr.
This course covers reaction kinetics, heterogeneous catalytic reactions, transport processes with fluid-solid heterogeneous reactions, noncatalytic gas-solid reactions, catalyst deactivation and gas-liquid reactions. *Prerequisite: CHEN 417.*

CHEN 630 Sustainable Biorefinery Proces 3 cr.
This course provides students with an understanding of the principles, technologies and design of sustainable bioprocesses and biorefineries. In this course we will focus on techniques and processes needed to efficiently disentangle, separate and convert different biomass based feedstock into biofuels and high value chemicals. We will also explore the design of a biorefinery taking into account feedstock and the desired product. The design will be evaluated with respect to sustainability and economic criteria. The students will have the opportunity to work in a team on a feasibility/ simulation/ experimental project. *Prerequisite: CHEN 417.*

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

CHEN 670 Advanced Process Flow-Sheeting 3 cr.
This course highlights the engineering tools used during the lifecycle of chemical plants from the Front-End and Engineering Design (FEED) stage to operation. Flow-sheeting tools will be used for analysis, dynamic modeling for startup-shutdown and control dynamics, and plant-wide optimization for plant performance improvement. *Prerequisite: CHEN 570.*

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

CHEN 673 / BMEN 604 Engineering of Drug Delivery Systems 3 cr.
This course focuses on recent advances in the development of novel drug delivery systems. The fundamentals of drug delivery are discussed. Various strategies to tune and control the release of active agents for optimized therapeutic outcomes are explored. The course covers polymers and techniques used to produce drug nanoparticles, with specific examples of nanoparticle-based drug delivery systems. *Prerequisites: CHEN 314 or MECH 414, and CHEN 411 or MECH 412.*

CHEN 674 Process Operations and Diagnosis 3 cr.
This course covers troubleshooting, fault detection and diagnostics in key chemical processes. Statistical tools such as Principle Component Analysis, Fisher Discriminant Analysis, Partial Least Squares and Canonical Variate Analysis methods are studied. Analytical and knowledge-based approaches are also covered. Processes and case studies include: gas-oil separation (GOSP), natural gas processing (AGR, NGL, SRU, fractionation, amine scrubbing), crude oil refining (CDU, VDU, delayed cocking, fluid catalytic cracking) and power plants. *Prerequisites: CHEN 451 and CHEN 570.*

CHEN 675/ BMEN 603 Tissue Engineering 3 cr.
Tissue engineering is an interdisciplinary field that uses cells, biomaterials, biochemical (e.g. growth factors) and physical (e.g. mechanical stimulation) signals, as well as their combination to generate tissue-like structures. The goal of tissue engineering is to provide biological substitutes that can maintain, restore or improve the function of damaged tissues in the body.

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. Students cannot receive credit for both CHEN 690 and PETR 421. *Prerequisites: CHEN 314 or MECH 414, and CHEN 490.*

CHEN 696 Reservoir Modeling 3 cr.
This course introduces students to the theory and practice of hydrocarbon reservoir simulation. It details the mathematics of the governing equations and numerical techniques that form reservoir simulation models. The course will cover data preparation, simulation grid preparation, reservoir model calibration, forecasting of future performance, and interpretation of simulation results. Students will learn, through practical cases and projects using PetrelTM / ECLIPSETM, about the elements of a reservoir simulation model, the types of reservoir simulators and the role of simulation in field development planning, reservoir management and production optimization.

CHEN 796 Engineering Literature Critique 1 cr.
This is a project-based course in which students will be asked to conduct an extensive literature review of an assigned engineering topic and present, in both written and oral formats, a critical review of this literature. *Prerequisite: Consent of advisor.*

CHEN 797 Seminar 0 cr.
This is a seminar that consists of presentations on current research or applied projects in chemical engineering or related fields. Seminars are presented by students, faculty members or invited scholars. This is a pass/fail course based on attendance.

CHEN 798 Special Topics in Chemical Engineering I 3 cr.
This class is available to graduate students wishing to gain knowledge in a specific area in which no graduate level classes are offered. The proposed class would involve a directed study for which the student(s) would be given credit. Students wishing to take the class would be assigned a suitable class advisor most familiar with the specific area of interest. Students will be required to present the term work in an organized publication format. *Prerequisite: Consent of advisor.*

CHEN 799 (A-E) Thesis 9 cr.
Every term. *Prerequisite: CHEN 799T or CHEN 799TR.*

CHEN 799 (9 cr., 7.14 billing)

CHEN 799A/B/C (9 cr., 0 billing)

CHEN 799D/E (9 cr., 1 billing)

CHEN 799T/ 799TR Thesis Proposal 0 cr.
Every term. The Masters Thesis Proposal grading mode is P/F. If a student fails CHEN 799T.

Department of Electrical and Computer Engineering

Chairperson:	Mansour, Mohammad
Professors:	Abou Faycal, Ibrahim; Artail, Hassan; Bazzi, Louay; Chaaban, Farid; Chedid, Riad; Chehab, Ali; Dawy, Zaher; Elhajj, Imad; El-Hajj, Ali; Jabr, Rabih; Kabalan, Karim; Karaki, Sami; Kayssi, Ayman; Mansour, Mohammad; Masri, Wassim; Saade, Jean; Sabah, Nassir
Associate Professors:	Awad, Mariette; Bazzi, Ali; Costantine, Joseph; Saghir, Mazen; Tawk, Youssef; Karameh, Fadi; Kanj, Rouwaida; Zaraket, Fadi
Assistant Professors:	Daher, Naseem; Issa, Ibrahim; Nassif, Roula
Adjunct Professor:	Khoury, Shahwan
Lecturers:	Asadallah, Fatima Al-Zahra; Droubi, Ghassan; Hijazi, Basma; Marmar, Ali; Moukallid, Ali
Instructors:	Dinnawi, Rafica; Kanafani, Zaher; Kanso, Ali; Makarem, Nabil

Graduate Programs

The Department of Electrical and Computer Engineering offers the degree of Master of Engineering (ME) in Electrical and Computer Engineering and the degree of Doctor of Philosophy (PhD) in Electrical and Computer Engineering.

Master of Engineering in Electrical and Computer Engineering

The ME program (ME) degree with two options: A non-thesis and a thesis option. The ME degree develops future engineering professionals who drive innovations, conduct research, and advance technology for a successful career in industry and academia.

- ECE Thesis Program
- ECE Non-Thesis Program

All programs must satisfy either the thesis program requirements or the non-thesis program requirements. The program is indicated on the student's transcript. Accepted students normally are eligible for Graduate Fellowship and Assistantship Program (GFAP) and Graduate Research Assistant (GRA). Refer to the General University Academic Information section.

Requirements

All relevant requirements and regulations of the university and the Maroun Semaan Faculty of Engineering and Architecture for the master's degree apply to the ME in ECE programs.

In order to be eligible for admission, a student must have a bachelor's degree from an accredited university.

Students whose undergraduate degree is in an area other than engineering and students whose undergraduate degree is a three-year degree are considered prospective graduate students. The supplementary courses must be completed within four consecutive regular terms.

Master's Thesis Program Requirements (30 cr.)

- 24 course credit hours of which
  - a minimum of 21 credits of graduate level courses
  - a minimum of 18 credits of ECE courses
  - a minimum of 9 credits of graduate level in the major area
- 6 credits for master's thesis
- the seminar course (should be registered for a minimun of 2 terms)
- Students have to declare their major area by the end of the registration period of their last term.

Note: A student may declare a minor area after registering for at least two courses in the area.

Master's Non-Thesis Program Requirements (33 cr.)

- 33 credit hours in graduate courses
  - a minimum of 24 credits of ECE courses
  - a minimum of 12 graduate credits in the major area
- the seminar course (should be registered a minimum of 2 terms)
- Students have to declare their major area by the end of the registration period of their last term.

Note: A student may declare a minor area after registering for at least two courses in the area.

Major and Minor Areas

The major and minor areas for the ME and PhD in ECE programs are shown below with their corresponding courses.

- **Applied Electromagnetics and RF Systems:** EECE 680, EECE 681, EECE 682, EECE 683, EECE 684, EECE 685, EECE 686, EECE 687, EECE 688
- **Artificial Intelligence and Machine Learning:** EECE 633, EECE 634, EECE 639, EECE 664, EECE 667, EECE 668, EECE 690, EECE 693, EECE 699
- **Biomedical Engineering:** EECE 601, EECE 603, EECE 605
- **Communications and Signal Processing:** EECE 640, EECE 641, EECE 644, EECE 645, EECE 646, EECE 691, EECE 692, EECE 694, EECE 695
- **Computer Hardware Systems:** EECE 612, EECE 616, EECE 617, EECE 621, EECE 622, EECE 623, EECE 624, EECE 625, EECE 626
- **Computer Software Systems:** EECE 631, EECE 636, EECE 637, EECE 638, EECE 642, EECE 652, EECE 696, EECE 731, EEE 732
- **Control Systems:** EECE 660, EECE 661, EECE 662, EECE 663, EECE 665, EEE 669, EECE 697, EECE 698

- **Energy and Power Systems:** EECE 670, EECE 671, EECE 672, EECE 673, EECE 674, EECE 675, EECE 676, EECE 677, EECE 678, EECE 679
- **Networks and Security:** EECE 632, EECE 635, EECE 647, EECE 651, EECE 653, EECE 655, EECE 656, EECE 657

PhD in Electrical and Computer Engineering

Mission

The PhD program in ECE creates knowledge through advanced coursework and original research with expert faculty to shape the next generation of leaders for careers in academia and industry. It provides students with research-intensive studies in the different areas of ECE to develop competencies and proficiency in emerging technologies, and the latest advancements in science and engineering

Objectives

The objectives of the program are to:

- provide students with research opportunities to acquire an in-depth of knowledge in one specialization area of electrical and computer engineering and familiarity with allied areas,
- provide opportunities for doctoral students to develop competence in performing independent research, communicating effectively and learning independently,
- advance the state of electrical and computer engineering research at AUB, in Lebanon and in the region,
- and advance state of the art in electrical and computer engineering.

Program Outcomes

Graduates of the program are expected to have:

- breadth of knowledge in electrical and computer engineering and depth of knowledge in their specific area of research,
- an ability to identify and define research problems,
- experience in performing research and communicating the results effectively,
- experience in doing independent academic work,
- and a published contribution to the existing literature in electrical and computer engineering.

Applicants who have an excellent record of academic achievement and potential for creative and independent work may be admitted into one of the following categories:

- Students Holding a Master's Degree
- Students Holding a Bachelor's Degree
- The minimum admission requirements for the two categories are described below.

Admission Requirements for Students Holding a Master's Degree

Applicants to the PhD program must hold a master's degree in Electrical and Computer Engineering or a related discipline from AUB or another recognized institution of higher education, with a minimum cumulative average of 85 (3.7) over 100 or its equivalent. Admission is determined by evaluating the following:

- Academic transcripts from the institution(s) of higher education attended by the applicant
- Graduate Record Examination (GRE) general test scores
- A written statement of purpose
- Three letters of recommendation
- A portfolio that includes a resume and samples of work
- An interview conducted with the ECE Graduate Committee (EGC) in person, by phone or over the Internet
- Satisfaction of the university requirements for admission to PhD programs

Program Requirements for Students Holding a Master's Degree

Completion of at least 48 credits of graduate study consisting of combined course work and research beyond the master's degree is required for the PhD degree in Electrical and Computer Engineering. A minimum of 18 credits of course work and a minimum of 24 credits of research and thesis work are required.

The basic program of study for the PhD degree is built around one major area and at least one minor area. Students take courses to satisfy the major and minor area requirements and acquire the knowledge needed for the written and oral examinations.

- The major area has to be in one of the ECE areas.
- Students must take at least 4 graduate courses, including courses prior to admission to the PhD program, in their PhD major area.
- Students must also take at least 2 graduate courses in their PhD minor area, including courses taken prior to admission to the PhD program.
- The minor courses have to be from one of the ECE areas.

Students must maintain a cumulative average of 85 (3.7) over 100 in order to remain in good standing. The cumulative average is calculated for courses taken beyond the master's degree. Students will be placed on probation if they fail a course (below C+ or 70) or have a cumulative average that falls below 85 (3.7). In such cases, students have one term to raise their cumulative average to a minimum grade of 85 (A-) and have to repeat failed courses as soon as the concerned courses are offered. Failure to do so will result in academic dismissal. Students cannot earn a PhD with a cumulative average below 85 (3.7).

PhD Qualifying Exam for Students Holding a Master's Degree

Refer to the General University Academic Information section.

Qualifying Exam Part I: Comprehensive Exam for Students Holding a Master's Degree

After taking at least 15 credits of coursework and mastering the knowledge delineated in the PhD major area, students take the Qualifying Exam Part I: Comprehensive Exam. The exam is given twice a year at the end of the fall and spring terms. Students are informed beforehand of the subjects that will be covered in the examination. Students who do not pass may repeat the exam only once during the following term. If students do not pass the exam after their second attempt, they will be asked to discontinue their PhD studies.

Students sit for two exams that together constitute the comprehensive examination with one in the major area and one in the minor area. These two exams are taken separately at different times during the same examination period. The major area exam consists of eight questions, out of which five questions should be answered in four hours. The minor area exam consists of six questions, out of which three questions should be answered in two and a half hours. The area exams are prepared by the corresponding area faculty committee and are designed to evaluate the student's understanding of the fundamentals in the area. Passing the comprehensive exam requires an average of no less than 3.2 or 80 over 100, with no less than 3.2 or 80 over 100 in the major area and no less than 2.2 or 70 over 100 in the minor area. Refer to the General University Academic Information section.

Admission to Candidacy for Students Holding a Master's Degree

Students must be admitted to candidacy at least two terms before obtaining the PhD degree.

For admission to candidacy, students are expected to have:

- submitted a program approved by the thesis committee, ECE Graduate Committee (EGC), MSFEA Graduate Studies Committee (GSC) and Graduate Council (GC),
- passed the Qualifying Exam Part I and II,
- completed at least 12 credits of graduate courses beyond the master's degree,
- attained a cumulative average of at least 85 (3.7) in all courses taken beyond the master's degree,
- and maintained good academic standing.

Residence Requirements for Students Holding a Master's Degree

A student must register for at least four terms beyond the completion of the master's degree. Requirements for the PhD degree must be completed within a period of ten regular terms years after starting graduate work beyond the master's degree. Extension beyond the five-year limit requires the approval of the EGC, MSFEA GSC and GC.

Admission Requirements for Students Holding a Bachelor's Degree (Accelerated PhD Track)

- A bachelor's degree with a minimum major and cumulative average of 85 (3.7) over 100 or its equivalent in Electrical and Computer Engineering
- Graduate Record Examination (GRE) general test scores
- Three letters of recommendation (one from the FYP supervisor)
- An applicant's written statement of purpose that shows the research potential in the proposed area of study
- A two-three page research proposal
- Performance of the candidate in the EECE 499 research-based course if taken or a proven research record through published articles
- An interview conducted with the ECE Graduate Committee (EGC) in person, by phone or over the Internet

Course Requirements for Students Holding a Bachelor's Degree

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 accelerated PhD track in Electrical and Computer Engineering. A minimum of 36 credit hours must be in approved graduate level course work and a minimum of 30 credit hours in thesis work. In addition, normally a maximum of 6 credit hours out of the 36 credits of coursework may be in tutorial courses.

The basic program of study for the accelerated PhD 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 II.

- The major area has to be in one of the ECE areas.
- Students must take at least six graduate level courses in their PhD major area.
- Students must take at least three graduate level courses in their PhD minor area.
- The minor courses have to be from one of the ECE areas.

PhD Qualifying Exam for Students Holding a Bachelor's Degree

Refer to the General University Academic Information section.

Qualifying Exam Part I: Comprehensive Exam for Students Holding a Bachelor's Degree

Comprehensive examinations are written exams taken after completing a minimum of 30 credits of course requirements for the accelerated track. Timing of the examination is set by the department/program no later than the sixth regular term of the PhD student's enrollment. Refer to the General University Academic Information section.

Residence Requirements for Students Holding a Bachelor's Degree

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 EGC, 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. Every effort will be made to screen students carefully to assure their potential and aptitude as researchers prior to acceptance. This may be accomplished by having selected students participate in ongoing research projects while they are registered undergraduates.

Admission to Candidacy for Students Holding a Bachelor's Degree

Students must be admitted to candidacy at least two terms before obtaining the PhD degree.

For admission to candidacy, students are expected to have:

- submitted a program approved by the thesis committee, EGC, MSFEA GSC and GC
- passed the oral qualifying examination
- completed at least 30 credits of graduate level courses beyond the bachelor's degree
- attained a cumulative average of at least 85 (3.7) in all courses taken beyond the bachelor's degree
- maintained good academic standing

PhD Thesis Committee

In accordance to the Lebanese Ministry of Higher Education, the thesis committee should be composed of at least five faculty members:

- Chair of the committee, advisor and at least one member from the student's department/program
- Two members must be from outside the university
- At least four committee members must be from the student's major area
- All members must hold doctoral degrees
- The advisor and at least three of the members must be of professorial rank
- The chair of the thesis committee must be a full professor and cannot be the advisor

Members of the committee are recommended by the student's thesis advisor and approved by the Graduate Committee of the ECE department, MSFEA Graduate Studies Committee and Graduate Council.

The committee approves the thesis topic and research plan, administers the oral Qualifying Exam (Part II) and conducts the thesis defense. The thesis proposal and selection of the committee should be approved at least two terms before the thesis defense.

Any changes in the committee, including the thesis advisor, must receive the approval of the EGC, MSFEA GSC and GC.

PhD Thesis Proposal

Refer to PhD Thesis Proposal under General University Academic Information section.

Qualifying Exam Part II: Defense of Thesis Proposal

Within two terms of passing the comprehensive examination, the student must take an oral qualifying examination, administered by her/his thesis committee. The defense of the PhD thesis proposal is considered part of the oral qualifying examination. In addition to reviewing the prospectus of the thesis, the nature and content of the examination are related to the student's field of research. Refer to Qualifying Exam Part II: Defense of Thesis Proposal under General University Academic Information section.

PhD Thesis

The student must submit a thesis based on the results of original and independent research. The PhD thesis is expected to make a significant contribution to the field of electrical and computer engineering. Upon its completion and after its approval by the thesis advisor, the thesis must be defended orally. Refer to PhD Thesis Format under General University Academic Information section.

PhD Thesis Defense

Refer to PhD Thesis Defense under General University Academic Information section.

Seminar Requirement

The student must register for the EECE 797 Seminar as long as s/he is enrolled in the program.

Program Completion Requirements

To earn the PhD degree in Electrical and Computer Engineering, the student must complete the following requirements:

- Have at least one journal article, based on the PhD thesis, accepted in a leading international journal in the field of specialty subjected to at least two reviews. Additionally, at least two refereed conference papers based on the thesis must have appeared in conference proceedings.
- Have a cumulative average, beyond the master's degree, of 85 (3.7) or above and be in good academic standing.
- Satisfy the course and research credit requirements.
- Pass the comprehensive and oral qualifying examinations.
- Complete and successfully defend a PhD thesis.
- Satisfy the residence requirement and all other pertinent AUB regulations.

PhD Major or Minor Areas

The PhD major or minor areas of study with their corresponding courses are the same as those listed for the master's degree (page 385).

Course Descriptions

EECE 601 Biomedical Devices and Equipment 3 cr.
The course discusses the main types of biomedical devices and equipment in terms of the physical principles underlying their operation, their operational characteristics, and their applications. The discussion includes: ultrasound systems, blood instruments, cardiac and respiratory devices and equipment, clinical laboratory equipment, radiology equipment. X-ray machines, CT scanners, PET scanners, and magnetic resonance imaging systems.*Prerequisites: BIOL 210 or BIOL 202 or PHYL 246; and EECE 210 or PHYS 228 and PHYS 228L; or consent of the instructor.*

EECE 603 Biomedical Signal and Image Processing 3 cr.
Fundamentals of digital signal processing as implemented in biomedical applications. It provides a concise treatment of the tools utilized to describe deterministic and random signals as the basis of analyzing biological signals: data acquisition, imaging, denoising and filtering, feature extraction, modeling. The course is tightly coupled with a practical component through laboratory projects. Examples include the auditory system, speech generation, electrocardiogram, neuronal circuits and medical imaging. Students should have reasonable software skills in Matlab. *Pre or co-requisites: STAT 230 and EECE 340, or STAT 233 and EECE 340 or consent of instructor.*

EECE 605 Neuromuscular Engineering 3 cr.
An introduction on the nervous system, electrophysiology and chemical kinetics. The cell membrane in the steady state: resting membrane voltage and membrane equivalent circuit. Generation and propagation of the action potential: Hodgkin-Huxley model, properties and propagation of the action potential. Synapses: neuromuscular junction, fast chemical synapses, second-messenger systems, synaptic plasticity and electrical synapses. Neurons: neuronal currents, firing patterns and signaling in dendrites. Muscle: contraction, mechanics and receptors. Control of movement: mechanics, spinal reflexes, hierarchical organization and control, locomotion, equilibrium-point hypothesis. *Prerequisites: BIOL 210 or BIOL 202 or PHYL 246, and EECE 210; or PHYS 228, PHYS 228L and MATH 202; or consent of instructor.*

EECE 612/412 Digital Integrated Circuits 3 cr.
A course on digital electronic circuits; models, current equations, and parasitics of CMOS transistors for digital design; study of CMOS inverter and logic gates, including analysis, design, simulation, layout, and verification; advanced circuit styles; sequential circuits; advanced topics: semiconductor memories, power grid, clocking strategies, data-path building blocks, deep-submicron design issues, interconnect. *Prerequisites: EECE 310 and EECE 320, or consent of instructor.*

EECE 616 Advanced Digital Integrated Circuits 3 cr.
This course covers advanced concepts in circuit design for digital VLSI systems in state of-the-art integrated circuits technologies. Emphasis is on circuit design and optimization techniques targeted for high-speed, low-power or high-density circuits. The impact of scaling, deep submicron effects, interconnect, signal integrity, power distribution/ consumption and timing on circuit design is investigated. Emerging challenges in low power/low voltage design, process variations and memory design in the nano-scale era are covered. *Prerequisite: EECE 412 or EECE 612 or consent of instructor.*

EECE 617 Reliability and Statistical Design 3 cr.
This course explores major aspects of statistical design methodologies with particular emphasis on electrical and computer engineering problems. It covers various topics in the domain of reliability, yield estimation, variance reduction methods for purposes of extreme statistics and rare fail event estimation, modeling and optimization. Case studies will be provided to analyze the manufacturability challenges of advanced circuits and the implications on low power design.

EECE 621 Advanced Computer Architecture 3 cr.
This course focuses on modern advancements in parallel computer architecture with emphasis on instruction level parallelism (ILP). Topics include: advanced branch prediction, data speculation, memory dependence prediction, trace caches, dynamic optimization, checkpoint architectures, latency-tolerant processors, simultaneous multithreading, speculative multithreading and virtual machines. A key component of the course is a research project in which students use architecture performance simulator to investigate novel architecture techniques. *Prerequisite: EECE 421 or consent of instructor.*

EECE 622 VLSI for Communications and Signal Processing 3 cr.
This course introduces concepts in the design and implementation of digital signal processing systems using integrated circuits. Emphasis is on the architectural exploration, design and optimization of signal processing systems for communications. Algorithm, architecture and circuit design techniques are introduced that enable joint optimization across the algorithmic, architectural and circuit domains. A key component of the course is a project in which students investigate problems in the design and implementation of low-power and high-performance communication systems. *Prerequisite: EECE 491 or EECE 691 or consent of instructor.*

EECE 623/423 Reconfigurable Computing 3 cr.
A course on reconfigurable computing systems and applications; contemporary FPGA architectures; FPGA design flows and tools; high-level synthesis; hardware/software partitioning; host, memory and peripheral interfaces; operating system support; dynamic partial reconfiguration; classical and emerging applications. Students work on a set of design assignments and a research project using appropriate FPGA development boards and tools. *Prerequisite: EECE 321 or consent of instructor.*

EECE 624 Digital Systems Testing 3 cr.
This course covers an overview of digital systems testing and testable design; test economics, fault modeling, logic and fault simulation, testability measures; test generation for combinational circuits; memory test; delay test; IDDQ test; scan design and boundary scan. *Prerequisite: EECE 320 or consent of instructor.*

EECE 625/425 Embedded Systems Design 3 cr.
A course on contemporary embedded systems design. The system design process; microcontroller architectures and programming; standard peripheral device controllers (GPIO, timers/counters, interrupts); serial interfaces (RS232, SSI/SPI, I2C, USB); displays; memory devices and DMA; IoT and network interfaces; analog/digital conversion; pulse-width modulation; motor control; embedded operating systems. Students work on a set of design assignments and a major project using appropriate microcontroller development boards and tools. *Prerequisite: EECE 321 or consent of instructor.*

EECE 626 Hardware Accelerators for Machine Learning 3 cr.
This course provides an in-depth coverage of architectural techniques used to design accelerators for training and inference in machine learning systems, with focus on recent advances towards enabling efficient processing of DNNs. It provides an overview of DNNs, discusses various hardware platforms and architectures that support DNNs, and highlights key trends in reducing the computational cost of DNNs via hardware design changes only or through joint hardware design and DNN algorithm optimizations. It also covers various development tools that enable students to quickly get started in this field, and highlights important benchmarking metrics and design considerations to be used for evaluating a plethora of DNN hardware design options. Case studies include Google's TPU, Apple's Neural Engine, Intel's Nervana processor, and ARM's Project Trillium. The course involves a semester project that focuses on developing architectures for hardware ML accelerators. *Prerequisites: EECE 490 and EECE 420 or EECE 421, or consent of instructor.*

EECE 631 Advanced Topics in Algorithms 3 cr.
This is a second course on algorithms. The aim of the course is to cover general tools from probability and convex optimization with applications to randomized algorithms, approximation algorithms, and theoretical computer science in general. Topics include: introduction to randomized algorithms, tail inequalities, probabilistic method, random walks, hashing, derandomization, introduction to approximation algorithms, basics of linear programming, algorithms for solving linear programs, linear programming relaxation and approximation algorithms, basics of semidefinite programming, semidefinite relaxation and approximation algorithms, interior point methods, and selected topics as time permits. *Prerequisites: EECE 431 or EECE 331 and STAT 230 or STAT 233 and MATH 218 or MATH 219 or consent of instructor.*

EECE 632/ 455 Cryptography and Network Security 3 cr.
This course provides an overview of encryption and network security. The topics include: classical encryption techniques, block ciphers and the data encryption standard, finite fields, advanced encryption standard, confidentiality using symmetric encryption, public-key cryptography, key management, hash and MAC algorithms, digital signatures, authentication applications, Web security, email security and IP security.

EECE 633 Data Mining 3 cr.
This course is an introduction to data mining. Data mining refers to knowledge discovery, using huge amounts of data to arrive at non-trivial conclusions. Topics will range from statistics to machine learning to database, with a focus on analysis of large data sets. The course will target at least one new data mining problem involving real data, for which the students will have to find a solution. *Prerequisite: EECE 330 or consent of instructor.*

EECE 634 Introduction to Computational Arabic 3 cr.
The course discusses computational challenges specific to the Arabic language including representation, rendering, processing, structure, interface and recognition. The course also discusses multilingual texts with Arabic, visits text processing techniques such as encoding, matching, tokenization, search, indexing and pattern matching. The course reviews the state of the art in automating Arabic language understanding. *Prerequisite: EECE 330 or consent of instructor.*

EECE 635 Theoretical Foundations of Security and Privacy 3 cr.

This course provides a rigorous framework to study security and privacy using suitable mathematical models. Such models enable the assessment of the security/privacy guarantees of a given system, including communication and computing systems and

databases. In particular, this course covers both computational and information-theoretic notions of security and privacy. Students learn various adversarial models and their corresponding information-theoretic measures, in addition to basic cryptographic principles and protocols. Topics include: the Shannon cipher system, one-time pads and perfect secrecy, semantic security and the RSA algorithm, equivocation, and guessing entropy (and other measures). A particular focus is given to the notion of differential privacy and its applications. *Prerequisite: EECE 330 and STAT 230 or STAT 233 or consent of instructor.*

EECE 636 Logic Verification and Synthesis 3 cr.
The course discusses the correctness of logic systems whether software or hardware, the basic representations of propositional logic and first order logic. It discusses how expressive and realizable different logic theories are. It covers tools that reason about the correctness of logic and that automatically synthesize logic into an implementation. *Prerequisite: EECE 330 or consent of instructor.*

EECE 637 Advanced Programming Practice 3 cr.
This is an advanced course on programming practices with a focus on verification. Teams will work in agile and extreme programming environments and will use formal specifications, design patterns and aspect-oriented programming. Projects will involve tools for source control, debugging, code building, documentation, dynamic and static verification. *Prerequisite: EECE 330 or consent of instructor.*

EECE 638 Software Testing 3 cr.
The course focuses on concepts, techniques and tools for testing software. It provides practical knowledge of a variety of ways to test software and an understanding of some of the tradeoffs between testing techniques. The topics include: software testing at the unit, module, and system levels; functional and structural testing; regression testing; mutation testing; test suite minimization and prioritization; automatic test case generation.

EECE 639 Advanced Techniques and Applications in Data Mining 3 cr.
A course that covers advanced topics in data mining and recent progress in this field. Discussions will include which techniques fit best for complex applications in data mining. Mining complex data will include general text mining, Arabic text mining, social network analysis, spatial data mining, mining of the World Wide Web, stream data, time-series data and sequence data. We will also discuss recent application sectors and trends in data mining such as for the telecommunication, biological, and financial sectors. *Prerequisites: EECE 330 and one of the following: EECE 633, EECE 667 or EECE 693; or consent of instructor.*

EECE 640 Wireless Communications 3 cr.
A course that covers the fundamentals of wireless communications with emphasis on wireless channel modeling; digital modulation in wireless channels; diversity techniques; channel coding and interleaving in fading channels; adaptive equalization; multiple access techniques; the cellular concept; overview of current wireless communications systems. *Prerequisite: EECE 442 or consent of instructor.*

EECE 640L Wireless Communications Laboratory 1 cr.
A laboratory course that covers the following topics: basics of radio network planning and optimization, radio network planning for the GSM cellular system, radio network planning for the UMTS cellular system, GSM-UMTS co-existence and co-citing,

radio network planning for the WiMAX broadband system, indoor GSM drive testing measurements and analysis, outdoor GSM drive testing measurements and analysis, UMTS drive testing measurements and analysis, and measurement-based wireless channel modeling. *Prerequisite: EECE 640 or consent of instructor.*

EECE 641 Information Theory 3 cr.
In this course students study data transmission through introducing the field of information theory. The theory is introduced in a gradual fashion and students study its application to communications theory, computer science, statistics and probability theory. Covering all the essential topics in information theory, students are introduced to the basic quantities of entropy, relative entropy and mutual information to show how they arise as natural answers to questions of data compression, channel capacity, rate distortion and large deviation theory. *Prerequisite: STAT 230 or STAT 233 or EECE 442, or consent of instructor.*

EECE 642 Introduction to Coding Theory 3 cr.
This course introduces the theory of error-correcting codes with a focus on the asymptotic, algorithmic and algebraic aspects. Topics include: background material from combinatorics and algebra; Shannon's coding theorem; linear codes; coding bounds; classical algebraic codes: Hamming and Hadamard codes, Reed-Solomon codes and Justesen codes and decoding algorithms; codes from graphs: low density parity check codes, expander codes, explicit constructions and decoding algorithms; and an introduction to turbo codes.

EECE 644 Stochastic Processes, Detection, and Estimation 3 cr.
This is a graduate-level introduction to the fundamentals of detection and estimation theory involving signal and system models in which there is some inherent randomness. The concepts that we develop are extraordinarily rich, interesting and powerful, and form the basis for an enormous range of algorithms used in diverse applications. The material in this course constitutes a common foundation for work in the statistical signal processing, communication and control areas. *Prerequisites: STAT 230 and EECE 340 or STAT 233 and EECE 340 or consent of instructor.*

EECE 645 Wireless Cellular Technologies 3 cr.
A course on the evolution of cellular technologies with focus on 2G GSM technology, 3G UMTS/HSPA technology, 4G LTE technology and beyond. Topics include: cellular network fundamentals; standardization; transmitter and receiver link level designs; access and core network architectures; physical channels and signaling procedures; scheduling and radio resource management; radio network planning; multiple antenna techniques; emerging topics. *Prerequisite: EECE 640 or consent of instructor.*

EECE 646 Advanced Digital and Data Communications 3 cr.
A course that addresses digital communication principles and techniques aimed at achieving improved reliability. The course examines information measures, such as entropy and mutual information for discrete and waveform channels, source coding, channel capacity and coding theorem, linear block and cyclic codes, hard and soft decision decoding, and spread spectrum modulation. *Prerequisite: EECE 442 or consent of the instructor.*

EECE 647 Queuing Theory 3 cr.
A course that covers Poisson counting and renewal processes; Markov chains and decision theory, branching processes, birth death processes and semi-Markov processes; simple Markovian queues, networks of queues, general single and multiple-server queues, bounds and approximations.

EECE 651 Internet Engineering 3 cr.
A course that provides in-depth coverage of Internet architecture, Internet protocols and routing; discusses recent developments on the Internet such as IPv6, switching and mobility; and gives a detailed study of TCP. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 651L Internetworking Laboratory 1 cr.
This laboratory course covers the technologies and protocols of the Internet. The experiments cover IP, ARP, ICMP, UDP, TCP, DNS, routing protocols (RIP, OSPF, BGP), network address translation (NAT), dynamic host configuration (DHCP), SNMP and IP multicast. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 652 Web Server Design and Programming 3 cr.
This course concentrates on major technologies used in building web servers. It is divided into two parts: client programming and server programming. The first part includes HTML, CSS, Java Script and XML programming. The second part is based on the ASP. NET framework (both Forms and MVC) along with C#. It covers basic controls, validation, database interfacing, AJAX, sessions and cookies, file uploading and downloading, emails with attachments, securing websites, user controls and third-party controls. The course concludes with programming and interfacing with web services. The website development group-based project is a major component of the course.

EECE 653 Multimedia and Networking 3 cr.
This course covers topics in multimedia such as system requirements, performance requirements, representation and compression. Multimedia networking is emphasized by discussing multicasting, streaming, multimedia networking protocols and quality of service-based traffic management protocols. Other topics covered include synchronization, VoIP and Internet2. Multimedia networking applications are designed and implemented as student projects. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 655 Internet Security 3 cr.
The course covers topics in Internet security. It discusses security threats, vulnerabilities of protocols and the different types of attacks. Preventive and defensive mechanisms are covered, such as e-mail security, web security, IP security, network management security, wireless security, intrusion detection techniques, firewalls, VPNs and tracing the source of attacks. Student projects will be composed of implementation, simulation and research components. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 655L Network and Computer Security Laboratory 1 cr.
A laboratory that addresses advanced network and computer security topics. Experiments include the execution of attacks, the setup of intrusion detection and prevention, securing computers and wired and wireless networks, and digital forensics. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 656 Mobile Ad Hoc and Sensor Networks 3 cr.
This course covers major aspects of ad hoc and sensor networking, and tackles topics related to mobility, disconnections and battery energy consumption. The course is composed of two parts: mobile ad hoc networks (MANETs) and wireless sensor networks (WSNs). The first part provides a detailed treatment of routing protocols in MANETs, the changes to TCP to support mobility and vehicular networks. In the second part, topics covered concern information-centric routing, MAC layer provisions for energy

savings, addressing, localization, time synchronization and information dissemination. The group project gives students hands-on experience in designing protocols and applications for real sensor devices. *Prerequisite: EECE 350 or EECE 351 or consent of instructor.*

EECE 657 Wireless Security 3 cr.
A course that covers wireless network security; security challenges in wireless networks; security problems facing existing and upcoming wireless networks; security in naming, addressing, neighbor discovery and routing; and trust and privacy. *Prerequisites: EECE 350 or EECE 351 and EECE 455 or EECE 632, or consent of instructor.*

EECE 660/ MECH 653 System Analysis and Design 3 cr.
A course that outlines state-space models of discrete and continuous, linear and nonlinear systems; controllability; observability; minimality; Eigenvector and transforms analysis of linear time invariant multi-input multi-output systems; pole shifting; computer control; design of controllers and observers. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 661/ MECH 641 Robotics 3 cr.
Robotic manipulators classification and work envelope. Robot kinematics, dynamics and forces. Joints trajectory planning for end effector desired tracking and constrained motion. Control of robots using linear, nonlinear and adaptive controllers. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 662/ MECH 655 Optimal Control 3 cr.
A course on optimization theory and performance measures, calculus of variations, the maximum principle, dynamic programming, numerical techniques, LQR control systems.

EECE 663/ MECH 656 System Identification 3 cr.
This course introduces the basic mathematical tools to fit models into empirical input-output data. General time-series modeling and forecasting, such as stock prices, biological data and others. Topics include nonparametric identification methods: time and frequency response analysis; parametric identification: prediction error, 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.

EECE 664 Fuzzy Sets, Logic and Applications 3 cr.
A course that outlines fuzzy sets and related concepts; logical connectives; mapping of fuzzy sets; extension principle; fuzzy relations and fuzzy set ordering; fuzzy logic inference; applications: fuzzy control, signal processing, pattern recognition, decision-making and expert systems.

EECE 665/ MECH 654 Adaptive Control 3 cr.
A course that includes the control of partially known systems; analysis and design of adaptive control systems; self-tuning regulators; model reference adaptive control of uncertain dynamic systems; typical applications. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 667 Pattern Recognition 3 cr.
The course provides an overview of the algorithms used in machine learning. The course discusses modern concepts for model selection and parameter estimation, decision-making and statistical learning. Special emphasis will be given to regression and classification for supervised modes of learning. Students will be assigned typical machine learning problems to investigate as projects.

EECE 668 Game Theory and Decision-Making 3 cr.
This course provides a set of tools, approaches and perspectives on game theory to mimic the human elements of decision-making that is best described by strategy and cooperation. Topics covered include: games of skills, games of chance, cooperative, mixed motive, zero sum, coalition and repeated games. Students will be assigned real-world examples of game theory to investigate as projects.

EECE 669/ MECH 648 Nonlinear Systems: Analysis, Stability and Control 3 cr.
A course that presents a comprehensive exposition of the theory of nonlinear dynamical systems and its control with particular emphasis on techniques applicable to mechanical systems. The course will be punctuated by a rich set of mechanical system examples, ranging from violin string vibration to jet engines, from heart beats to vehicle control, and from population growth to nonlinear flight control. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

EECE 670 Power System Planning 3 cr.
The course investigates electric energy and peak demand forecasts using weather sensitive, time curve, autoregressive and causal models; generation reliability evaluation, loss of energy expectation, energy limited units, probabilistic production costing, generating capacity expansion analysis and maintenance scheduling; operational planning, unit commitment, hydrothermal coordination; power system security classification, contingency analysis, external equivalents, optimal power flow; planning in a competitive electric power environment. *Prerequisite: EECE 471 or consent of instructor.*

EECE 671 Environmental Aspects of Energy Systems 3 cr.
A course that examines world energy resources and classifications; sources and effects of air pollution; air quality modeling, Gaussian dispersion models for pollution estimation; motor vehicle emissions and noise pollution; environmental impacts of electricity generation, pollution control systems, electromagnetic radiation, production and impacts in high-voltage applications; environmental impact assessment; basic concepts.

EECE 672 Energy Planning and Policy 3 cr.
This is a course that focuses on features of modern energy planning and policy. Topics covered include the interaction among the technological, economic, environmental and sociopolitical aspects of energy supply and use; electricity, oil and gas industries, and their market structures; elements of energy planning on the sector and national levels; energy decision-making under conditions of uncertainty; risk management in energy planning; liberalization of energy markets; case studies.

EECE 673 Power Electronics Systems and Applications 3 cr.
A course that reviews converter topologies for AC/DC, DC/AC and DC/DC; power supply applications; converter applications to motor drives; utility interface of distributed energy systems; static VAR systems; flexible AC transmission; high voltage DC; power quality control; active and passive harmonics compensation. *Prerequisite: EECE 473 or EECE 471, or consent of instructor.*

EECE 674 Energy Storage and Sustainable Systems 3 cr.
The course covers the principles of sustainable energy systems, solar radiation, solar thermal applications, the Stirling engine, fuel cells and the hydrogen cycle. Various energy storage technologies are also investigated, e.g. thermal storage, compressed air, flywheels, batteries, and ultra-capacitors. The operation principles of each application will be discussed, its current developments and future trends, and students will design an energy storage solution for a selected application. *Prerequisites: EECE 230, EECE 310 and Phys 210, or consent of instructor.*

EECE 675 PV and Wind Electric Energy Systems 3 cr.
This course seeks to impart in students a sound understanding of renewable energy systems in terms of their design, operation and economic impacts. It covers wind resource assessment and site selection; drag and lift principles; linear momentum theory; turbine characteristics; power and energy yield calculation; aspects of wind drive options: horizontal and vertical axis machines, fixed and variable speed wind turbine generators. It also covers solar resource assessment; photovoltaic cells: photo effect, P-N junction, principle of operation of PV cells, circuit models, maximum power point trackers, I-V and power characteristics, physics of shading, types and characteristics of autonomous solar energy systems, hybrid systems and grid connected systems; the economics of wind and solar energy systems. Introduction to small hydro and geothermal energy systems.

EECE 676 Modeling and Control of Electric Drives 3Cr.
A course that covers several topics related to modeling and control of electric drives. The course introduces fundamental equations related to inductance and flux variations in a rotating machine, leading to torque production. Reference frame theory and transformations are also studied for modeling purposes. Dynamic models of three-phase induction and permanent-magnet synchronous machines are derived. Basic modeling of power electronic converters for electric drives, with focus on three-phase DC/AC inverters, are introduced. Various control strategies are studied with focus on vector control and different power electronic switching schemes in electric drives. *Prerequisite: EECE 474 or EECE 473 or consent of instructor.*

EECE 677 Electric Power System Stability and Control 3 cr.
A course on synchronous machine modeling and simulation, response to small disturbances and voltage instability. Topics include Park's transformation, flux linkage, voltage and state-space equations, subtransient and transient parameters, simplified models of the synchronous machine, treatment of saturation, system reference frame, small-signal stability, power system stabilizers and bifurcation analysis. *Prerequisite: EECE 678 or consent of instructor.*

EECE 678 Advanced Power System Analysis 3 cr.
A course on optimal dispatch of generation, symmetrical components and unbalanced faults, transient stability, control of generation, state estimation in power systems and power system simulation. *Prerequisite: EECE 471 or consent of instructor.*

EECE 679 Energy Efficiency in the Power Sector 3 cr.
Topics covered in the course include: utility companies and energy supply, energy sustainability, cogeneration systems: combined heat and power (CHP) and combined cycle gas turbines (CCGT), reciprocating engines, distributed generation, demand side management, energy analysis techniques, energy audit: types and data analysis, smart grids, energy-efficient rotating machines, design and performance optimization; and case studies. *Prerequisite: EECE 370 or consent of instructor.*

EECE 680 Antennas for Wireless Communications 3 cr.
This course provides students with an understanding of the basic principles of Antenna Analysis and Design for wireless communications. The course covers an overview of the fundamental characteristics and parameters of antennas, an overview of analytical methods used to analyze and design antennas with application to some basic antenna structures such as linear antennas, loop antennas, antenna arrays and microstrip antennas. *Prerequisite: EECE 380 or consent of instructor.*

EECE 681 Advanced Antenna Design 3 cr.
This course provides students with an understanding of advanced antenna structures and presents an overview of analytical and numerical methods used to analyze and design these antenna structures. This course includes broadband antennas, frequency-independent antennas, aperture antennas, horn antennas, microstrip antennas and reflector antennas. Students will work on a research paper on a selected antenna design topic. *Prerequisite: EECE 680 or consent of instructor.*

EECE 682 Time-Harmonic Electromagnetic Fields 3 cr.
A course on time-varying and time-harmonic EM fields; electrical properties of matter; wave propagation and polarization; construction of solutions; reflection and transmission; electromagnetic theorems and principles in particular equivalence; rectangular waveguides and cavities; dielectric, circular and spherical waveguides; radiation from structures; scattering by wedges, cylinders and spheres; radiation from apertures, and perturbational and variational techniques. *Prerequisite: EECE 380 or consent of instructor.*

EECE 683 Numerical Methods in Electromagnetics 3 cr.
This course examines the principles and applications of numerical techniques for solving practical electromagnetics problems. It covers the moment methods, finite difference methods, finite element methods and hybrid methods. The course also investigates the application of the finite-volume control method in electromagnetics. *Prerequisite: EECE 682 or consent of instructor.*

EECE 684 Microwave Engineering 3 cr.
This course focuses on the analysis and design of passive microwave circuits. It covers the fundamentals for radio frequency and microwave engineering. It discusses the theories of transmission lines, waveguides, impedance matching, microwave networks, scattering parameters, power dividers, directional couplers, microwave resonators and microwave filters. The course enables students to study and analyze their own microwave network using computer-aided design tools and measurement equipment. *Prerequisite: EECE 380 or consent of instructor.*

EECE 685 Radio Frequency (RF) Circuits Design 3 cr.
The course focuses on the analysis and design of Radio Frequency circuits and components. The course covers RF design techniques using transmission lines, strip lines, microstrip and coplanar lines. It covers the design of passive and active RF devices, including impedance transformers, amplifiers, oscillators and mixers. It provides understanding of S-parameters and signal-flow graph analysis techniques. The course enables students to get hands-on experience in RF circuit design through the use of computer-aided design tools to simulate and analyze radio frequency circuits, build them as part of a course project, and perform measurements in the lab using network and spectrum analyzers. *Prerequisites: EECE 311, EECE 340 and EECE 380; or consent of instructor.*

EECE 686 Radio-Frequency (RF) Transceiver Design (3 cr.)
This course targets the physical layer of a communication system by focusing on the interactions between the various transceiver blocks. The course addresses the design and operation of the components that reside between the signal processing unit and the antenna within the RF chain. The course also details the functional level modeling of different transceiver architectures by accounting for the gain, noise, nonlinearity, sensitivity and dynamic range. In addition, students are exposed to recent computer-aided simulation tools and measurement techniques through a set of laboratory experiments that are tailored based on the course content. As a result, the course equips the students with theoretical and practical experience in RF transceiver. *Prerequisites: EECE 380 and EECE 311; or consent of instructor.*

EECE 687/487 Radio-Frequency Integrated Circuit (RFIC) Design (3 cr.)
The course addresses the analysis and design of passive and active Radio Frequency Integrated Circuits (RFICs). The course introduces the design of on-chip lumped elements and passive RF components. In addition, it includes the design of various RF blocks such as low noise amplifiers, power amplifiers, oscillators, mixers, phase locked loops, frequency synthesizers, and switches. The course provides students with hands-on experience in the simulation of RFICs as well as the different calibration and de-embedding techniques for on-wafer measurements. As a result, the students will be equipped with essential theoretical and practical experience in RFIC design. *Prerequisites: EECE 380 and EECE 311.*

EECE 688/488 Engineering Bio-Electromagnetics 3 cr.
This course discusses the interaction between biological material and electromagnetic fields. The course introduces Bio-Electromagnetics along with its sub-divisions and reviews the fundamental properties of electromagnetic fields and their propagation characteristics in lossy biological tissues. The course then elaborates on the electromagnetic properties of biological tissues from a bioelectric perspective. Bio-Electromagnetism is then analyzed at DC, extremely low frequencies, radio frequencies, up to Terahertz frequencies and beyond. The concept of Dosimetry and the principles of energy absorption in biological tissues are then studied along the design of electromagnetic sensors and electrodes for monitoring, reception and stimulation in the human body. The human body is then analyzed as a communication channel and as a generator of electromagnetic fields. The course is concluded with an introduction to the various electromagnetic simulation tools and the corresponding measurement techniques. *Prerequisites: EECE 380 and EECE 340.*

EECE 690/490 Introduction to Machine Learning 3 cr.
The course provides an overview of machine learning theory and algorithms that learn from experience to predict or control yet to be seen instances. The course discusses the intuition and the theory of some selected modern machine learning concepts as well as practical know-how to successfully apply them to new problems. It covers topics in supervised learning such as parametric/ non-parametric, generative/ discriminative algorithms for classification and regression and in unsupervised learning for clustering, dimensionality reduction and reinforcement learning. The course also includes case studies and applications so that students can gain practice on regularization, model selection, parameter estimation, Bayesian networks, hidden Markov models, support vector machines, reinforcement learning, neural networks and deep learning. Students cannot receive credit for both EECE 664M and EECE 633 and 667. *Prerequisites: EECE 330, and MATH 218 or MATH 219, and STAT 230 or STAT 233 or consent of instructor.*

EECE 691/491 Digital Signal Processing 3 cr.
Digital Signal Processing (DSP) is at the heart of almost all modern technology. This course introduces fundamentals of DSP systems, including digital IIR and FIR filter design, sampling and reconstruction, A/D and D/A conversion, quantization, discrete-time Fourier analysis and fast convolution, spectral analysis, sample-rate conversion, filter structures and realizations, and multirate DSP and filter banks. The course also discusses applications of DSP in areas such as speech/audio processing, autonomous vehicles, and software radio. It includes a project related to DSP algorithm implementation on embedded processors. *Prerequisite: EECE 340 or consent of instructor*

EECE 691L Digital Signal Processing 3 cr.
This graduate lab is comprised of a set of lab experiments in MATLAB, C and Assembly covering a series of real-time signal processing topics. The developed laboratory material is intended to complement the digital signal processing course (EECE 691). Upon completion of the lab, students will have acquired the required knowledge and skills to develop real-time DSP systems. *Prerequisite: EECE 691 or EECE 491 or consent of instructor.*

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

EECE 693 Neural Networks 3 cr.
The course provides a comprehensive foundation to artificial neural networks and machine learning with applications to pattern recognition and data mining; learning processes: supervised and unsupervised, deterministic and statistical; clustering; single layer and multilayer perceptrons; least-mean-square, back propagation, deep learning; Al-Alaoui pattern recognition algorithms; radial basis function networks; committee machines; principal component analysis; self-organizing maps; current topics of interest.

EECE 694 Digital Image Processing 3 cr.
An introduction to multi-dimensional signal processing; digital image fundamentals; image formation and perception; image representation, coding and filtering; image enhancement in the spatial and frequency domains; image restoration; color image processing; wavelet and multi-resolution processing; image compression; morphological image processing; image segmentation; feature extraction and scene analysis; representation and description; object recognition; introduction to computer graphics and computer vision; current topics of interest.

EECE 694L Image Processing Lab 1 cr.
The EECE 694L graduate lab comprises a set of MATLAB/C++ based lab experiments in different image processing topics covering image pre- and post-processing techniques, image compression, morphological transformations, image restoration and enhancement techniques, color image processing, computer vision basics, and geographical image processing. In addition, students will be exposed to software optimizations for real time image processing using SIMD instructions. *Prerequisite: EECE 694 or EECE 603, or consent of instructor.*

EECE 695 Adaptive Filtering 3 cr.
A course that examines the fundamentals of optimal filtering and estimation, Wiener filters, linear prediction, steepest-descent and stochastic gradient algorithms; frequency-domain adaptive filters; method of least squares, recursive least squares, fast fixed order and order-recursive (lattice) filters; misadjustment, convergence and tracking analyses, stability issues, finite precision effects; connections with Kalman filtering; and nonlinear adaptive filters.

EECE 696 Applied Parallel Programming 3 cr.
This course is an introduction to parallel programming and GPU computing. Topics include GPU as part of the PC architecture; CUDA, CUDA threads and CUDA memory; floating point performance; open CL, MPI and reductions, and their implementation. The course also includes application case studies, current topics and a course case study. *Prerequisite: EECE 321 or consent of instructor.*

EECE 697/ MECH 646 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. Nonlinear control strategies (open-loop and closed-loop). Five case studies are covered during the course: car-like, cart-like, omni-directional wheeled, mobile wheeled pendulums and bike-like robots.

EECE 698/ MECH 650 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; or consent of instructor.*

EECE 699 Topics in Artificial Intelligence 3 cr.
This course focuses on some selected topics in AI related to agent and multi-agent systems, life-long learning and artificial life. Specifically, this course covers both theoretical and technical issues in reinforcement learning, transfer learning, evolutionary approaches, quantum genetic algorithms and explainable AI. The course also has a practical project for students to explore learned concepts from a contemporary lens.

EECE 731 Advanced Topics in Complexity Theory 3 cr.
The course covers advanced topics in computational complexity theory. Topics include: hierarchy theorems; relativization; non-uniform models of computations: branching programs and circuits, relations and lower bounds; alternation and the polynomial hierarchy; interactive proofs; probabilistically checkable proofs; pseudorandomness: hardness versus randomness paradigm, generators for space bounded computations, special purpose generators. *Prerequisite: EECE 631 or consent of instructor.*

EECE 732 Pseudorandomness 3 cr.
This course covers the basics of the area of pseudorandomness. Topics include: randomized complexity classes; background material from coding theory; computational indistinguishability and pseudorandom generators; hardness versus randomness: Nisan-Wigderson generator, Impagliazzo-Wigderson theorem; simple

generators: k-wise independence and small-bias spaces; unconditional generators for constant depth circuits and space-bounded computation; and randomness extractors. *Prerequisite: EECE 631 or consent of instructor.*

Special Courses and Thesis

EECE 796 Special Project
An assigned project of no more than 3 credit hours supervised by a faculty member.

EECE 797 Seminar **0 cr.**

EECE 798 Special Topics 3 cr.
Every term.

EECE 799 Thesis **6 cr.**
Every term. Prerequisite: EECE 799T.

EECE 799T Comprehensive Exam **0 cr.**
Every term.

EECE 898 Advanced Topics in Electrical and Computer Engineering **3 cr.**

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

EECE 981 Qualifying Exam Part II: Defense of Thesis Proposal **0 cr.**
Every term. Prerequisite: EECE 980.

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

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

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

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

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

EECE 987 PhD Thesis Defense **0 cr.**
Every term. Prerequisite: EECE 981.

Department of Industrial Engineering and Management

Chairperson:	Maddah, Bacel
Professors:	Maddah, Bacel; Salameh, Moueen; Yassine, Ali
Assistant Professors:	Al-Qaisi, Saif; Azar, Jimmy; Hani, Selim; Moacdieh, Nadine; Noueihed, Maher; Tarhini, Hussein
Senior Lecturers:	Abillama, Walid; Charif, Hassan; Nehme, Nabil; Noueihed, Nazim; Saad, Youssef; Trabulsi, Samir
Lecturers:	Bdeir, Fadl; Hamade, Tarek; Itani, Bilal; Kalach, Mayssa; Khraibani, Rayan; Rahi, Khalil
Instructors:	Gharios, Nadim; Jaafar, Maysaa; Kadi, Samir; Olleik, Majd; Sfeir, Rana

General Information

The Department of Industrial Engineering and Management offers a graduate program in Engineering Management. The graduate program leading to the degree of Master of Engineering Management (MEM) provides professional training in engineering management, with emphasis on technically based organizations and applications to various engineering and related disciplines. This program addresses the specific area of management of technical activities and enterprises.

A student may pursue courses to satisfy one of the three following areas of concentration:

- Financial and Industrial Engineering (FIE)
- Project and Program Management (PPM)
- Management of Technology and Entrepreneurship (MTE)

The requirements for the Master of Engineering Management degree can be fulfilled by pursuing one of the following two options.

Non-Thesis Option

Under this option, a student is required to complete a total of 33 credits, subdivided as follows:

- Four core courses (12 credits)
- Four electives from the student's area of concentration (12 credits)
- Three free electives (9 credits)
- Seminar (0 credit)

Thesis Option

Under this option, a student is required to complete a total of 30 credits, subdivided as follows:

- Four core courses (12 credits)
- Three electives from the student's area of concentration (9 credits)
- One free elective (3 credits)
- Thesis (6 credits)
- Seminar (0 credit)

Free electives should be graduate courses (within IEM, MSFEA or any AUB program), which relate to engineering management. All free electives must be approved by the student's academic advisor. All students pursuing the FIE concentration are required to take ENMG 623 Stochastic Models and Applications. All students pursuing the PPM concentration are required to take ENMG 632 Project Planning Scheduling and Control. The ENMG 797 Special Project course can be used to satisfy the 3-credit requirement of any elective depending on the nature of the topic addressed. A flexible combination of courses not in fulfillment of either option stated above leads to no mention of an area of concentration on the student's transcript.

Requirements for Admission

In order to be eligible for admission to the MEM program, a student must have a bachelor's degree in engineering, architecture or a related field. The 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 this catalogue.

Graduates of universities other than AUB or from majors other than engineering or architecture may be required to take undergraduate prerequisite courses to make up for deficiencies.

A student is not allowed to register in the program for more than four calendar years beyond the date of his/her first registration, except with the approval of the Graduate Studies Committee of the faculty.

Dual Master's Degrees: Master of Engineering in Engineering Management and Master of Science in Energy Studies (thesis option only)

The dual master's degrees - Master of Engineering in Engineering Management and Master of Science in 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 into both programs (Master of Engineering Management and Master of Science in Energy Studies) and 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, the student may apply for the second degree no later than the end of the 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 course work in each degree program. The remaining credits include additional course work and a thesis that are credited to the dual degree. The program requires a minimum of 42 credit hours of graduate course work and 6 credits of thesis work. The coursework is distributed as follows:

- 9 credits of core Engineering 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-credit 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.**

Course Descriptions

Core Courses

ENMG 601 Management Theory 3 cr.
Nature of managerial work and the roles of the executive (informational, decisional and symbolic). Organizational configurations. Ethics in business and organizational behavior. Business strategy. Principles and practice of worker motivation. Project management and performance assessment. Effective communications in organizations. Negotiation. Power and leadership.

ENMG 602 Introduction to Financial Engineering 3 cr.
Overview of financial statements. Accounting concepts and methods. Measuring and reporting assets and equities. Alternative accounting principles. Basic financial calculations. Cost of capital calculation. Financial statement models and their use for valuation. Financial analysis of leasing.

ENMG 603 Probability and Decision Analysis 3 cr.
Framing of decision problems. Influence diagrams. Review of probability (random events and variables, probability distribution functions and so on). Decision Trees. Inverting Decision Trees (Bayes' Law). Traditional approach to assessment of error (confidences level). Decision analysis view of assessment (value of information, sensitivity). Multiple attribute decision objective. Mathematical treatment of risk, tolerance and avoidance.

ENMG 604 Deterministic Optimization Models 3 cr.
Mathematical modeling and the operation research approach. Formulation and classification of optimization models. Improving search. Formulation of linear programs (LPs). Simplex algorithms for solving LPs. Duality and sensitivity in linear programming. Multi-objective optimization and goal programming. Introduction to network flow models. Formulation of integer programs. Solution methods for integer programs. Unconstrained nonlinear programming. Introduction to constrained nonlinear programming and quadratic programming.

Elective Courses

Financial and Industrial Engineering Sequence

ENMG 611 Supply Chain Design and Management 3 cr.
The course is an introduction to supply chain management and its key issues, such as logistics, network configuration, inventory management, distribution strategies and strategic alliances. The value of information in supply chains, information technology and decision support systems for supply chain management are also covered.

ENMG 612 Advanced Supply Chain Design and Management 3 cr.
This course concentrates on the advanced quantitative and qualitative techniques used in supply chain management to achieve competitive advantage. The focus is on planning models for production, inventory and distribution in general multi-echelon multi-item systems. This course also deals with models for planning, information sharing, transportation, distribution and site selection.

ENMG 616 Advanced Optimization Techniques 3 cr.
The course is divided into four parts covering integer programming, nonlinear programming, stochastic programming and heuristic methods. Students will develop skills in modeling complex systems using mathematical programming, analyzing the structure of mathematical programs, and developing and applying the correct solution techniques.

ENMG 617 Engineering Management Statistics 3 cr.
Review of probability and probability distributions. Data description. Random samples and sampling distributions. Parameter estimation. Tests of hypotheses. Design and analysis of single-factor experiments: the analysis of variance. Design of experiments with several factors. Simple linear regression and correlation. Multi-variable regression. Nonparametric statistics.

ENMG 622 Simulation Modeling and Analysis 3 cr.
Generating discrete and continuous random variables. Discrete-event simulation. Statistical analysis of simulated data. Variance reduction techniques. Statistical validation techniques. Markov chain and Monte Carlo methods. Experience with a modern discrete-event simulation package (e.g., ARENA, SIMIO).

ENMG 623 Stochastic Models and Applications 3 cr.
Review of probability and random variables. Poisson process, renewal theory, queueing models, reliability theory, Markov chains, Brownian motion, random walks and Martingale, stochastic order relations.

ENMG 624 Financial Engineering I: Portfolios and Risk Management 3 cr.
Basic theory of interest. Fixed-income securities yield, duration convexity and immunization. Term structure of interest rates. Expectation, liquidity and market segmentation explanations of the term structure. Applied interest rate analysis: capital budgeting, optimal portfolios, dynamic cash flow processes, optimal management, the Harmony Theorem, valuation of a firm. Mean-variance portfolio theory. Introduction to expected utility theory. Introduction to general pricing theory. *Prerequisite: ENMG 602 or INDE 301, or consent of instructor.*

ENMG 625 Financial Engineering II: Derivatives 3 cr.
Derivative securities: forwards, futures and swaps; models of asset dynamics; options theory; interest rate derivatives. General cash flow streams: optimal portfolio growth, general investment evaluation. *Prerequisite: ENMG 602 or INDE 301, or consent of instructor.*

Project and Program Management Sequence

ENMG 631 Pre-Project Planning and Feasibility Analysis 3 cr.
Assimilation of client needs. Market assessment studies. Impact of laws and regulations on the facility program. Surveys of project area infrastructure conditions. Investigation of site conditions. Project scope validation. Project cost and revenue estimation. Project life-cycle analysis. Financial planning. Financial feasibility framework design and analysis.

ENMG 632 Project Planning Scheduling and Control 3 cr.
Extended overview of project management. Basic planning and scheduling concepts. Project participants and roles. Project management applications and growth. Project team formation. Dealing with time. Project planning and costing. Advanced scheduling techniques. Integrated project cost-time control.

ENMG 633 Advanced Topics in Project Management 3 cr.
Planning and scheduling under constraints. Trade-off analysis in a project environment. Project cost control from a client's perspective. Project risk management. Managing the international project. Determinants of project success. Lessons learned in project management. Strategic planning in project management. Modern developments in project management.

ENMG 635 Project Deliverance and Contracts 3 cr.
Overview of project organizations. The design-build project delivery approach. The build-operate-transfer project delivery approach. Innovative delivery approaches, financial schemes and associated contracts. Allocation of risks in contracts. Bidding phase characteristics. Components of the proposal package. Evaluation of the commercial, financial and technical components. Contract formation and agreement closure.

ENMG 642 Lean Engineering Concepts 3 cr.
This course focuses on the emerging concept of lean performance in the construction industry. Topics covered include the origin of lean concepts, application to the design process, implementation in construction, contracting for lean performance and value improving practices (e.g., benchmarking, constructability and value management).

ENMG 644 Agile Software Project Management 3 cr.
The main objectives of this course are to enable the student to understand the fundamental principles underlying software management and economics. The course provides a quick overview of traditional software development and management strategies. This will be contrasted with iterative and incremental agile methods.

ENMG 645 Program and Portfolio Management 3 cr.
This course presents a view of managing projects from an organizational perspective. The main areas of discussion will be strategic alignment, the role of effectively managing organizational assets through an enterprise project management office, portfolio management and program management. Using specific examples and a case study approach, students will explore the importance of using organizational strategies to align projects and apply practices to create portfolios of programs and projects to efficiently leverage organizational assets.

Management of Technology and Entrepreneurship Sequence

ENMG 654 Technology-Based Entrepreneurship 3 cr.
An introduction to general theories, principles, concepts and practices of entrepreneurship and intrapreneurship. The entrepreneurial perspective, developing the entrepreneurial plan, initiating entrepreneurial ventures, growth and development of entrepreneurial ventures and contemporary challenges in entrepreneurship are discussed. The course includes case study analysis and group projects.

ENMG 655 Management of Technology 3 cr.
Management of technology at both the national and organizational level and its contribution to the generation of national wealth. Engineering, science and management principles contributing to the development of a successful framework for managing technology within an organization, nationally or internationally. Introduction to technological innovations. Planning and forecasting. Socio-economic changes.

ENMG 656 Management of Technological Innovations 3 cr.
Strategic management of technology-based innovation within the firm. Assessing the innovative capabilities of the firm. Managing the corporate R&D function. Managing the interfaces between functional groups in the development process. Managing the new business development function in the firm. Building distinctive technology-based competencies and competitive advantages. Technological leadership versus followership in competitive strategy.

ENMG 659 Introduction to System Dynamics 3 cr.
An introduction to the field of system dynamics as a discipline and a set of tools for understanding and dealing with complexity in systems. Students will learn how to collaboratively translate knowledge about a system or problem into a conceptual model, and to simulate the model in order to test hypotheses about system behavior.

ENMG 661 Strategic Management of Technology 3 cr.
The organization as a whole and its interaction with its environment. The corporation as it undergoes the process of a global transformation. Mergers, acquisitions, outsourcing, downsizing and privatization. Framework of analysis for the identification of central issues and problems usually faced in strategic management. Understanding the effect of present and future environments on the corporation's welfare.

ENMG 663 Product Design and Development 3 cr.
This class provides students with a holistic perspective that includes the design, analysis and management of complex engineered systems/products. Topics covered include marketing research, integrated system/subsystem/component design, production planning, manufacturing strategy, supply chain management, innovation and entrepreneurship.

ENMG 698 Special Topics in Engineering Management 3 cr.

ENMG 700 Seminar 0 cr.
All students are required to register for the seminar during each fall term.

ENMG 797 Special Project in Engineering Management 3 cr.
A supervised study that may involve special research in the student's area of concentration.

ENMG 800 Comprehensive Exam 0 cr.
A capstone exam covering core engineering management concepts.

ENMG 798 Thesis 6 cr.

Department of Mechanical Engineering

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

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.

In addition, an online graduate diploma in building energy systems is offered in the Department of Mechanical Engineering for professionals who seek to enhance their knowledge and experience in the field.

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)

Graduate Diplomas

The department of Mechanical Engineering offers the following program:

- Online Graduate Diploma in Building Energy Systems

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:

CMPS	354	The Finite Element Method
CMPS	350	Discrete Models for Differential Equations
CMPS	373	Parallel Computing
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: MECH611 (Computational Modeling in Biomechanics), 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), MECH657 (Vehicle Dynamics and 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	PV and Wind Electric 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:	El-Meouchi, Chadia; Habchi, Carine; 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 41).

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 3.2 or 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
ENST305/ ECON333/ MECH674	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**
ENMG 645	Program and Portfolio Management	3
DCSN 330	Project Management	3
ENMG 661	Strategic Management	3
ENMG 698	Special Topics in Engineering Management	3
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
MFIN356:	Financial Markets in ME Region	

List B	Energy Science and Technology Courses	Credits
ENHL314	Environmental Management Systems	3
CHEM 324E	Electrochemistry	3
CHEM 331	Chemical Instrumentation for Environmental Analysis	3
CHEM 352C	Renewable Energy	3
CHEN619	Sustainability Science: Human and Environmental Interaction	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	PV and Wind Electric 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 51).

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 C+ or 70. If a student fails to obtain a grade of C+ or 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 51).

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

The dual master's degrees - Master of Engineering in Engineering Management and Master of Science in 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)**
ENST305/ ECON333/ Energy Economics and Policy MECH674	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**	

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.*

ENST305/ ECON333/MECH674 Energy Economics and Policy
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 ENST305 and MECH 674 or ECON 333.*

ENST 310 Advanced Energy Economics 3.0, 3 cr.
This class provides students with a holistic perspective that includes the design, analysis and management of complex engineered systems/products. Topics covered include marketing research, integrated system/subsystem/component design, production planning, manufacturing strategy, supply chain management, innovation and entrepreneurship.

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.

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** **3.0, 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 **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.

Graduate Diploma in Building Energy Systems (GDBES)

The online Graduate Diploma in Building Energy Systems aims to equip the students with the following:

- Ability to identify how through an integrated building design approach, modification on envelop material, construction, orientation, mechanical systems for heating and cooling can be greatly reduced or eliminated
- Qualitative and quantitative analysis tools for evaluating energy performance of new and existing buildings including materials, envelope, heating, cooling, and ventilation systems that provide occupant comfort and good air quality
- Stimulated thinking about approaches for integration of renewable energy sources and systems into buildings and processes
- Understanding of the impact of energy economics, energy policies and regulatory frameworks on improving energy performance of systems, processes and buildings.

Upon successful completion of the GDBES, students are able to:

- Determine energy demands in buildings and processes for meeting needs of power, cooling ventilation, and heating in different climates and building functions
- Identify how through an integrated building design approach, modification on envelop material, construction, orientation, mechanical systems for heating and cooling can be greatly reduced or eliminated
- Perform analysis, develop and recommend enhanced performance technical solutions for meeting energy demands and air quality requirements in buildings and systems as applicable
- Use analysis tools to assess economic, building standards, and policy aspects that can help in expanding renewable energy resources use in systems, processes, buildings and their market.

Admissions Requirements

The student should meet the university's minimum requirement for admission to a graduate degree program. The student should have an undergraduate bachelor's degree in engineering (BE or its equivalent) with an average of at least 75 percent in the last two years of study (or standardized equivalent from other institutions of higher learning). In addition, an applicant who does not meet the minimum undergraduate average requirement but appears to have reasonable potential for academic success, for example as manifested by relevant practical experience or high scores on relevant standardized exam (e.g. GRE exam), may be admitted based on the recommendation of the faculty.

A student cannot be admitted simultaneously to the online GDBES program and the MMEAE program.

Degree Requirements:

The online GDBES will require the successful completion of 12 credits of course work as follows:

- 6 credits of mandatory courses
- 6 credits of elective courses as offered by the program

Credit Summary

Course	Credits
Core Courses	6
Elective courses	6
Total number of credits required for graduation	**12**

Required Core Courses		Credits
MECH 673E	Energy Efficient, High Indoor Air Quality Buildings	3
MECH 674E	Energy Economics and Policy	3
Elective Courses		**Credits**
MECH 671E	Renewable Energy Potential, Technology, and Utilization in Buildings	3
MECH 672E	Modeling Energy Systems	3
MECH 677E	Refrigeration and Heat Pumps	3
MECH 680E	Innovation and Knowledge Transfer In Renewable and Building Services Systems	3
MECH 682E	Principles of Integrative Building Design, Construction, and Operation for Sustainability	3

Features of Online Delivery Courses

The course must comply with the AUB online course design standards.

The course has frequent formative and summative assessment using a mix of low stakes and high stakes activities that enhance student learning and permit continuous and prompt evaluation of student work.

The GDBES includes a comprehensive face-to-face exam which carries a weight of at least 30% of the overall grade of the course.

Graduation Requirements

To be eligible for graduation, the student must:

- Pass all four courses with a minimum grade of 70/100 (C+) in any course.
- Attain a cumulative course average of 80 (3.2) or above, over the four courses.
- Transfer of Credits to Regular Master Program
- The student can transfer up to 12 online credits taken towards the GDBES into the full regular MMEAE program. The number of transferred credits counts towards the grand total of 12 credits that a student with a Bachelor of Engineering degree is allowed to transfer.
- The student must obtain an overall course grade of 80 (3.2) to be able to transfer the course.

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 GPA of 3.2 or a 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 (3.7 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 41).

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 69).

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 70).

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 71).

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
ENMG 604	Deterministic Optimization Models
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

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 611, 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 657, 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 (3.7) 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 434).

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 (3.7) 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 611/ BMEN611 Computational Modeling of Biomechanics
This course is open to engineering, science and medical students wanting a glimpse into the world of computational finite element modeling and simulation to investigate and solve biomedical problems. Students will take a journey through the processes involved in producing a computational finite element model in the biomedical field; starting at construction of model geometry from medical imaging data (CT/MRI), through to model creation, simulation and visualization using finite element analysis software (ANSYS Workbench). Students will also be exposed to a selection of experimental lab techniques in biomechanics and physiology to acquire data required for model development and validation. In pursuit of developing an appreciation for the areas covered, the course will incorporate a mix of theory, demonstrations, practice, real-world modeling applications and research seminars. *Prerequisites: MATH 201 and consent of instructor.*

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, 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 or EECE 231.*

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 **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 **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 **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 231, EECE 312 and MECH 436; or EECE 230 and EECE 460.*

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

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

MECH 655 **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 **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 or ENST 300.*

MECH 672 Modeling Energy Systems 3 cr.
A course that covers indoor space thermal models. The course also deals with the analysis and modeling of building energy systems involving applications of thermodynamics, economics, heat transfer, fluid flow and optimization. The use of modern computational tools to model thermal performance characteristics of components of HVAC systems

including chillers, recovery systems, flow control devices, heat exchanges, solar panels, dehumidification systems, boilers, condensers, cooling towers, fans, duct systems, piping systems and pumps. The course will use 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 310 or equivalent.*

MECH 674/ ENST305/ECON 333 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 ENST 305 or 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 9 cr.
Prerequisite: MECH 799T or MECH 799TR.

MECH 796 Special Projects in Mechanical Engineering
An assigned project of no more than 3 credit hours supervised by a faculty member.

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.

Online Courses

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

This course has the same catalogue description as the MECH 671 course but follows the online delivery format.

MECH 672E Modeling Energy Systems 3 cr.

This course has the same catalogue description as the MECH 672 course but follows the online delivery format.

MECH 673E Energy Efficient, High Indoor Air Quality Buildings 3 cr.

This course has the same catalogue description as the MECH 673 course but follows the online delivery format.

MECH 674E Energy Economics and Policy 3 cr.

This course has the same catalogue description as the MECH 674 course but follows the online delivery format.

MECH 677E Refrigeration and Heat Pumps 3 cr.

This course has the same catalogue description as the MECH 677 course but follows the online delivery format.

MECH 680E Innovation and Knowledge Transfer in Renewable and Building Service Systems 3 cr.

A course designed to help students understand theory and practice for investing in and managing green ventures while exercising corporate social responsibility, sustainability within the organization and in the external environment. The course will develop knowledge and exposure to sustainable business concepts. Students will learn how to initiate, manage and implement a sustainable innovative project by collaboratively working on a venture which will be written up and presented at the end of the semester. The course will cover the management process required to transform an innovative idea into a commercial opportunity or business proposition. It will detail the stages and processes involved in the management and commercialization of intellectual property (IP). Students from all disciplines will be involved in the creation of knowledge in the form of intellectual property. Students will be provided with a fundamental understanding of how to manage the development of IP and transfer this asset to the Knowledge Economy. The module will examine some success stories and the address the requirements to manage and protect intellectual property rights (IPR) in areas such as renewable energy integration in buildings, HVAC applications, and smart building services. The potential routes to commercialization and the following key business feasibility questions will be considered: Can the product be made? Will someone buy it and is it possible to make a profit? This course will provide an essential grounding in matters relating to the exploitation of IP for students interested in both academic and industrial careers.

MECH 682E Principle of Integrative Building Design, Construction and Operation for Sustainability **3 cr.**

This course centers on issues surrounding the integration of passive design principles into conceptual and practical building design sing basic design rules, simulation tools and conservation measures and protocols as means to improve building energy performance. Topics include: i) Building loads from envelop characteristics/materials including fenestration, building orientation and window location, type and area/shading and associated direct solar gains, people schedules/activities, lighting, infiltration; ii) building indoor requirements of thermal comfort and air quality; iii) passive design practices. Impact on building inherent load of passive design interventions including envelop, fenestration, shading orientation, shape, energy storage, trombe wall, natural and mixed ventilation, and other potential practices will be studied. Open source software is used to model a base building in regional climate and impact of various measures on energy performance and comfort requirements inside the building. The full building simulation is performed using case study occupancy data, equipment, lights, and building envelope. Energy conservation is then applied to deduce possible savings, their economic value and contribution to reduced greenhouse gas emissions and a sustainable building design.