Maroun Semaan Faculty of Engineering and Architecture (MSFEA)

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Officers of the Faculty

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Lina Choueiri	Interim Provost, effective January 1, 2021 ex-officio
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Ayman Kayssi	Associate Dean
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Antoine Sabbagh	Director of Admissions, ex-officio
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Ghada Najm	Executive Officer
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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 57).

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

Biomedical Engineering Graduate Program

Coordinator:	Dawy, Zaher (Electrical & Computer 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) Mhanna, Rami (Biomedical Engineering, MSFEA) Oweis, Ghanem (Mechanical 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.

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

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

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

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 or EECE 605	Computational Neuroscience or Neuromuscular Engineering	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 633 or EECE 663 or EECE 667 or EECE 693	Data Mining or System Identification or Pattern Recognition or 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.

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 Rotation[1]	1+1
BMEN 672	Hospital Lab Rotation	0
BMEN 673L	Biomedical Engineering Lab	1
BMEN 675	Approved Experience	0
EPHD 310	Basic Biostatistics[2]	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 or EECE 605	Computational Neuroscience or Neuromuscular Engineering	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

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 603	Biomedical Signal and Image Processing	3		X	X
EECE 633 or EECE 663 or EECE 667 or EECE 693	Data Mining or System Identification or Pattern Recognition or 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 and PHYL 346, 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.

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 sub-specialties: 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).

BMEN 611 Computational Modeling in Biomechanics 3 cr.

This course provides students with a glimpse into the world of computational finite element modeling and simulation in biomechanics 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, particularly 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. In addition to skills gained in modeling and basic experimentation, the course will provide students with an opportunity to enhance vital skills in scientific writing and oral communication.

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.

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 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 Biomedical Research Techniques 1 cr.
(A, B, or C)
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

1) Can be counted as an Energy specialization course.

Buildings Specialization		Credits
PRGR 645	Building Energy System Modeling	2
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 681[1]	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.

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

1) Water Core Course

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.

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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.