Faculty of Engineering and Architecture (FEA)

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Officers of the Faculty

Fadlo R. Khuri	President of the University
Mohamed Harajli	Interim Provost, ex-officio
Alan Shihadeh	Interim Dean
Moueen Salameh	Registrar, ex-officio
Salim Kanaan	Director of Admissions, ex-officio
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Ghada Kamar Najm	Executive Officer
Alia Kazma Serhal	Student Services Officer
George Jeha	Student Services Officer
Sara Jibbaoui	Financial Officer
Suzanne Kobeisse	Accreditation Officer

Historical Background

The first programs leading to a master's degree 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 (1991-93); 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: Master of Science in Chemical Engineering and Master of Engineering with major in chemical engineering. In 2016 a Master of Science in Biomedical Engineering was introduced.

In 2007 PhD programs accepted students in three departments of FEA: Civil Engineering (PhD in Civil Engineering and a PhD in Environmental and Water Resources Engineering), Electrical and Computer Engineering (PhD in Electrical and Computer Engineering), and Mechanical Engineering (PhD in Mechanical Engineering). In 2016 a new PhD program in Biomedical Engineering was established.

Mission

The Faculty of Engineering and Architecture (FEA) at the American University of Beirut is a leading professional school in the Middle East. The FEA offers educational programs of the highest standards, advances knowledge through research and scholarly creative work of its faculty and students, and provides services to the community at large, while addressing the needs of Lebanon and the region. The FEA undergoes continuous improvement to maintain a challenging and intellectually stimulating environment, and prepares its students to be life-long learners, innovators, and professionals capable of being leaders in their chosen careers, committed to personal integrity, and civic responsibility.

Graduate Programs
Master's Degree Programs

The Faculty of Engineering and Architecture offers graduate programs of study 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 Engineering (ME), major applied energy; Master of Science in Chemical Engineering (MS); Master of Science in Construction Engineering (MS); Master of Science (MS), major biomedical engineering; and Master of Science in Energy Studies (MS). FEA also offers a Master of Science in Environmental Technology (MS) (as part of an Interfaculty Graduate Environmental Sciences Program).

In addition, a professional diploma in green technologies with majors in energy, building, 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:

Deadlines

According to the deadlines set in the Admissions section page 33 applications for admission to graduate study should be submitted online through the link https://graduateadmissions.aub.edu.lb/.

- Applications are considered complete upon receipt of at least two letters of recommendation from professors or supervisors of the applicant and an official transcript covering at least till the end of the first semester of the senior year or its equivalent.
- All applications may include an application for graduate assistantships also to be submitted online. All applications for graduate assistantships received after admission application deadlines will be considered, pending availability.

Process of Admission

- The Office of Admissions directly forwards applications for graduate admission to the program/department concerned. The graduate faculty advisor, the departmental representative on the graduate studies committee, and the chairperson consider each case individually.
- Recommendations for admission are forwarded to the FEA Graduate Studies Committee from the Dean's Office.
- The Faculty Graduate Studies Committee meets in 'special sessions for admission' and recommends applicants for admission.
- Upon confirmation of the admission list by the Graduate Studies Committee, the chair of the graduate studies committee will forward the list to the Dean who in turn will forward it to the university Office of Admissions.
- The Office of Admissions prepares and sends the admission packages.
- Students who are accepted must confirm their acceptance of admission and assistantship within one month. If a student does not respond within this time, the assistantship will be re-assigned.

Waiving of Credits

The department or program of the intended major may also recommend a waving of up to nine credits of course work for students who have completed a Bachelor of Engineering Degree (BE) and are applying for admissions to a Master of Engineering Program (ME), subject to approval by the advisor and chairperson. To apply, the student must have completed electives in advanced engineering courses (600 and above) that meet the program requirements with a grade of at least 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, he/she can only waive a maximum of 12 credits.

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 70 in each undergraduate course taken.
- If a student fails to obtain a grade of 70 in any of these undergraduate courses, the student is allowed to repeat that course only once.
- Failure to meet the requirements stipulated above 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 FEA, 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 Faculty of Engineering and Architecture offers graduate programs leading to the degree of Doctor of Philosophy (PhD) with specializations in civil engineering, electrical and computer engineering, environmental and water resources engineering, mechanical engineering, and biomedical 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 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 language proficiency requirements set for master's students.

Admission to a PhD program requires the recommendations of a department, the FEA Graduate Studies Committee, and the approval of the AUB Board of Graduate Studies.

Criteria for Admission to the Accelerated PhD Programs

To apply to the accelerated program, students must have an average in their undergraduate work of 85 or above. 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 AUB catalogue, there may be specific requirements described in the departmental sections of the catalogue.

Financial Support Available to Graduate Students

The FEA offers three types of financial assistance to the most qualified applicants to its graduate programs: fellowships, graduate research assistantships (GRA), and graduate teaching assistantships (GA).

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

Fellowships, GRAs, and GAs, covering tuition and stipends are available for students at the graduate level in return for assisting faculty members in teaching and/or research for a specified number of hours per week in an academic department. Applicants are selected on the basis of their academic record and the needs of the relevant department.

Applicants opting for the non-thesis track in the following programs will not be offered graduate assistantships:

- Master of Engineering; Major: Civil Engineering
- Master of Engineering; Major: Environmental and Water Resources Engineering
- Master of Engineering; Major: Electrical Computer Engineering
- Master of Engineering; Major: Mechanical Engineering
- Master of Engineering; Major: Applied Energy
- Master of Engineering Management
- Master of Science; Major: Biomedical Engineering

Biomedical Engineering Graduate Program

Coordinator:	Dawy, Zaher (Electrical & Computer Engineering, FEA)
Co-coordinator:	Jaffa, Ayad (Biochemistry & Molecular Genetics, FM)
Coordinating Committee Members:	Darwiche, Nadine (Biochemistry & Molecular Genetics, FM)
	Khoueiry, Pierre (Biochemistry & Molecular Genetics, FM)
	Mhanna, Rami (Biomedical Engineering, FEA)
	Oweis, Ghanem (Mechanical Engineering, FEA)

Background

The Biomedical Engineering Graduate Program (BMEP) is a joint FEA 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 FEA and administered by both FEA 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 honesty.

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, remedial undergraduate courses in both sciences and engineering have been identified to cover the needed prerequisite knowledge, customized per student on a case-by-case basis. Remedial undergraduate courses do not count as credit towards the MS or PhD degree completion.

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 from a recognized institution of higher learning.

Accepted students in the thesis option are eligible to apply for Graduate Assistantship (GA) and Graduate Research Assistantship (GRA).

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 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
BMEN	600	Biomedical Engineering Applications	3
EPHD	310	Basic Biostatistics[1]	3
HUMR	314	Research Seminar	1
BMEN	672	Hospital Lab Rotation	0
BIOC	321	Nucleic Acids and Basic Genetics	1
BIOC	322	Protein Biochemistry	1
PHYL	246	Human Physiology	4
BMEN	601	Computational Modeling of Physiological Systems	3
BMEN	673L	Biomedical Engineering Lab	1
BMEN	674L	Biomedical Sciences Lab	1

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
PHYL	302	Cardiovascular Physiology	2			X
PHYL	300A	Pulmonary Physiology	1			X
EECE	601	Biomedical Engineering I	3	A1[2]	B1[2]	C1[2]
BMEN CHEN	604/ 673	Engineering of Drug Delivery Systems	3	A2		C2
EECE	603	Biomedical Signal and Image Processing	3		B2	C3
EECE EECE EECE EECE	663 or 633 or 693 or 667	System Identification or Data Mining or Neural Networks or Pattern Recognition	3		B3	
BMEN MECH	607/ 633	Biomechanics	3	A3		
BMEN MECH	603 or 634	Tissue Engineering or Biomaterials and Medical Devices	3	A4		C4
BMEN	605	Biomedical Imaging	3		B4	C5
HUMR	305	Cell and Tissue Biology	3	A5		
BIOC	325	Receptors and Signal Transduction	2		B5	
BMEN	606	Computational Genomics	1		B5	

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 joint program coordinating committee.

[1] EPHD 310 can be replaced by another advanced level statistics course based on JPCC's approval.
[2] Students are required to take two courses from the following groups depending on their focus area: {A1, A2, A3, A4}, {B1, B2, B3, B4}, and {C1, C2, C3, C4, C5}.

Master thesis for the thesis option: 6 credits master 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 Bachelor's or Master's degree in a relevant field of study from AUB or its equivalent 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 cover fully their tuition fees and that 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. Requirements also allow a maximum of three credit hours out of the 18 credits of course work as tutorial course, and include zero credit comprehensive examination preparation course and zero 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 course work and a minimum of 30 credit hours of thesis work. Requirements also allow a maximum of six credit hours out of the 36 credits of course work as tutorial courses, and include zero credit comprehensive examination preparation course and zero 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 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 course work.

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

Required core courses (21 cr.)			Credits
BMEN	600	Biomedical Engineering Applications	3
EPHD	310	Basic Biostatistics[1]	3
HUMR	314	Research Seminar	1
BIOM	385	Research Ethics	1
BMEN	671	PhD Lab Rotation[2]	2
BMEN	672	Hospital Lab Rotation	0
BMEN	675	Approved Experience	0
BIOC	321	Nucleic Acids and Basic Genetics	1
BIOC	322	Protein Biochemistry	1
PHYL	246	Human Physiology	4
BMEN	601	Computational Modeling of Physiological Systems	3
BMEN	673L	Biomedical Engineering Lab	1
BMEN	674L	Biomedical Sciences Lab	1

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

Restricted elective courses (9 cr.)			Credits	Systems	Cyber-netics	Cardio-vascular
HUMR	305	Cell and Tissue Biology	3	X		
BIOC	325	Receptors and Signal Transduction	2		X	
BMEN	606	Computational Genomics	1		X	
PHYL	302	Cardiovascular Physiology	2			X
PHYL	300A	Pulmonary Physiology	1			X
EECE	601	Biomedical Engineering I	3	A1[3]	B1[3]	C1[3]
BMEN CHEN	604/ 673	Engineering of Drug Delivery Systems	3	A2		C2
EECE	603	Biomedical Signal and Image Processing	3		B2	C3
EECE	663 or	System Identification or	3		B3	
EECE	633 or	Data Mining or				
EECE	693 or	Neural Networks or				
EECE	667	Pattern Recognition				
BMEN	607/	Biomechanics	3	A3		
MECH	633					
BMEN	603 or	Tissue Engineering or	3	A4		C4
MECH	634	Biomaterials & Medical Devices				
BMEN	605	Biomedical Imaging	3		B4	C5

[1] EPHD310 can be replaced by another advanced level statistics course based on JPCC's approval.
[2] Students are required to take two PhD lab rotation courses where each lab rotation is 1 credit.
[3] Students are required to take two courses from the following groups depending on their focus area: {A1, A2, A3, A4}, {B1, B2, B3, B4}, and {C1, C2, C3, C4, C5}.

Free elective graduate courses: At least 6 credits additional elective courses. These courses should be taken based on the student's specific area of research as approved by the PhD thesis 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 will provide insight on 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 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, 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.

BMEN 602 Computational Modeling of Cardiovascular and Pulmonary Systems 3 cr.
The needs for better understanding of mechanics and the tools for computational modeling of Cardiovascular and Respiratory Systems in healthy and diseased conditions are constantly increasing. This is a result of the enormous advances that have been 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 Tissue Engineering 3 cr.
/CHEN675
In a world of aging population, an ever increasing demand for improvement of healthcare services and need for replacement organs and tissues is 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.

This course will provide students with an overview of the key concepts behind the main imaging modalities used in diagnostic imaging. Focus will be on explaining the physical principles and algorithms underlying X-ray imaging, computed X-ray tomography, magnetic resonance imaging, single-photon emission tomography, positron emission tomography and ultrasound imaging. The students learn the theoretical bases underlying the common forms of medical imaging as well as the limitations and the applicability of such procedures.

BMEN 606 Computational 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.

BMEN 607/ MECH633 Biomechanics 3 cr.

A course on the study of the biomechanical principles underlying the kinetics and kinematics of normal and abnormal human motion. Emphasis is placed on the interaction between biomechanical and physiologic factors (bone, joint, connective tissue, and muscle physiology and structure) in skeleto-motor function and the application of such in testing and practice in rehabilitation. The course is designed for engineering students with no previous anatomy/ physiology. *Prerequisite: CIVE 210, MECH 320 or CIVE 310; or 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 FEA and/or FM. Students may also enroll in a third elective laboratory rotation. This aims to familiarize students with potential thesis mentors and to expose them to different research environments.

BMEN 672 Hospital Lab Rotation 0 cr.

PhD students in Biomedical Engineering are required to do a lab rotation in the Biomedical 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 to 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 674L Biomedical Sciences Lab **1 cr.**
A guided laboratory course in research methods used in cell biology and physiology.

BMEN 675 Approved Experience **0 cr.**

BMEN 678 Special Topics in Biomedical Engineering **3 cr.**

BMEN 679 Special Topics in Biomedical Engineering **1 cr.**

BMEN 680 MS Comprehensive Exam **0 cr.**
Every semester.

BMEN 681 MS Thesis **6 cr.**
Every semester. Prerequisite: BMEN 680.

BMEN 690 Qualifying Exam Part I: Comprehensive Exam **0 cr.**
Every semester.

BMEN 691 Qualifying Exam Part II: Defense of Thesis Proposal **0 cr.**
Every semester. Prerequisite: BMEN 690.

BMEN 692 PhD Thesis **3 cr.**
Every semester. Taken while total required credit hours have been completed.

BMEN 693 PhD Thesis **6 cr.**
Every semester. Taken while total required credit hours have not been completed.

BMEN 694 PhD Thesis **9 cr.**
Every semester. Taken while total required credit hours have not been completed.

BMEN 695 PhD Thesis **12 cr.**
Every semester. Taken while total required credit hours have not been completed.

BMEN 696 PhD Thesis **0 cr.**
Every semester. Taken while total required credit hours have not been completed.

BMEN 697 PhD Thesis Defense **0 cr.**
Every semester. Prerequisite: BMEN 691.

BIOC 321 Nucleic Acids and Basic Genetics 15.0; 1 cr.
This course discusses the principles of nucleic acids 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 semester.*

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 semester.*

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 semester.*

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 about what it means to be an ethical and responsible researcher. *Summer semester.*

EECE 601 Biomedical Engineering I 3 cr.
This course includes an introduction to: general instrumentation configuration, 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 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 314 Research Seminar 0.32; 1 cr.
Presentation and discussion of timely research topics designated by members of the department.

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

PHYL 246 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).*

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.*

Professional Diploma Program in Green Technologies (Pro-Green)

General Description of the Pro-Green Diploma Program

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 diploma degree programs offered are:

- Professional Diploma Program in Green Technologies; Major: Energy
- Professional Diploma Program in Green Technologies; Major: Building
- Professional Diploma Program in Green Technologies; Major: Water

The programs are offered in five universities in Lebanon and Egypt. The universities offering the diplomas in Lebanon are: American University of Beirut (AUB) and Lebanese American University (LAU). The universities offering the diplomas in Egypt are: American University of Cairo (AUC), Helwan University (HU), and Suez Canal University (SCU).

Objectives of the Green Technologies Diploma Programs

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 promote a problem-based approach among professionals pursuing green careers and careers in green industries to prepare students to meet the diverse, critical skills needed to advance in these areas.
- to develop effective, lifelong learning skills among students from different disciplines to develop expertise in green technologies related to applications in energy, water, and building.

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

- acquired an in-depth understanding of green technologies relevant to jobs in planning, design, and implementation methods for sustainable energy, building, and water technologies and industries.
- developed analysis and hands-on skills needed for development and implementation of green products and processes in the area of specialization (energy, building, or water).
- cultivated lifelong learning skills in the green technologies field through problem/project-based learning, including case studies related to real-life applications from the participants' own fields of practice.
- gained an understanding of 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. Consideration will be given to students who have BA degrees provided that they have completed the prerequisites of the courses offered in the selected specialization.

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 English Language Proficiency Requirement (ELPR). Refer to page 37 for more information.

Students should have a GPA of at least 70 out of 100 or its equivalent from recognized universities and good recommendations to be enrolled in the diploma program. Professional experience might be considered on a case-by-case basis whereby the student can register as a student not working for the diploma and still receive performance assessment in these courses.

Language Requirements

The diploma program is offered in English. The student will follow University policy regarding the English Language Proficiency Requirement (ELPR) for graduate students. Since the students are not graduate degree seekers, the English requirements are determined by requirements of similar diploma programs at the consortium institutions.

For students applying to the diploma program, a minimum score of 500 in EEE (TOEFL: CBT 240 or IBT 92) is required for admission. Applicants who are graduates of an English speaking university are exempted from the English language test. An applicant might also be required to report for an interview with the program coordinator.

ProGreen Program Structure and Degree Requirements

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

- 6 credits of core courses
- 6 credits of courses in the area of specialization including project in the area of specialization
- 4 credits for elective course as approved by project advisor/s from the list of elective courses or other courses in the specialization
- Project (equivalent to 2 credit hours)
- 0-credit Seminar/Webinar (to be registered twice)

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, Building, 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 as listed below.

Energy Specialization

PRGR	**611**	Solar Radiation and Solar Electricity using PV Technology	2 cr.
PRGR	**612**	Wind Energy: Wind Turbines and Wind Farms and Siting	1 cr.
PRGR	**613**	Energy Storage Technologies	1 cr.
PRGR	**614**	Solar Thermal Energy Conversion	1 cr.
PRGR	**615**	Biofuels	2 cr.
PRGR	**616**	Waves, Tidal, and Hydro Renewable Energy	2 cr.
PRGR	**617**	Energy Efficiency in Buildings Evaluation and Design	1 cr.
PRGR	**618**	Energy Efficiency in Agriculture Evaluation and Design	1 cr.
PRGR	**619**	Hybrid Renewable Energy Lab	1 cr.
PRGR	**620**	Energy Systems and Sustainable Environments	2 cr.
PRGR	**621**	Waste to Energy Processes and Technologies	2 cr.

PRGR	**622**	Renewable Energy Projects Evaluation and Market Analysis	1 cr.
PRGR	**623**	Energy Audit Lab	1 cr.
PRGR	**699 E**	Project	2 cr.

Building Specialization

General Green Building Modules			
PRGR	**631**	Low Energy Architecture and Passive Building Design	1 cr.
PRGR	**632**	Sustainable Building Materials	2 cr.
PRGR	**633**	Renewable Energy Systems and Energy Efficiency in Buildings	2 cr.
PRGR	**634**	Moisture and Control of Humidity in Buildings	2 cr.
PRGR	**635**	Construction and Demolition Management	1 cr.
PRGR	**636**	Modular Building Construction	1 cr.
PRGR	**637**	Green Building Basics and Building Rating Practices	2 cr.
PRGR	**638**	Sustainable Restoration of Existing Building	1 cr.
PRGR	**640**	Building Physics Lab	1 cr.
Mechanical and Electrical Engineering Modules			
PRGR	**641**	HVAC Systems for Energy Efficient Acclimatization	2 cr.
PRGR	**642**	Building Management Systems (BMS)	1 cr.
PRGR	**643**	Heat Pumps	2 cr.
PRGR	**644**	HVAC Lab	2 cr.
PRGR	**645**	Building Energy System Modeling	2 cr.
PRGR	**699 B**	Project	2 cr.

Water Specialization

PRGR	**650**	Instrumentation	1 cr.
PRGR	**651**	Water Essentials	1 cr.
PRGR	**652**	Smart Irrigation	1 cr.
PRGR	**653**	Water Treatment	2 cr.
PRGR	**654**	Wastewater Treatment	2 cr.
PRGR	**655**	Wastewater Treatment Plant Design	1 cr.
PRGR	**656**	Water Networks Design	1 cr.
PRGR/ (CIE323)	**657**	Wastewater Networks Design	1 cr.
PRGR	**658**	Sludge Treatment	1 cr.
PRGR	**659**	Basic Operations of Wastewater Treatment Plants	1 cr.
PRGR	**660**	Water Resources Planning and Management	2 cr.
PRGR	**661**	Desalination	1 cr.
PRGR	**662**	Sustainable Water Management	2 cr.
PRGR	**663**	Liquid Waste Management	2 cr.
PRGR	**699 W**	Project	2 cr.

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:

PRGR	**670**	Life Cycle Assessment	2 cr.
PRGR	**671**	Energy Conversion and Storage	2 cr.
PRGR	**672**	Energy Systems Integration	2 cr.
PRGR	**673**	Research Skills Development - General	2 cr.
PRGR	**674**	Innovation and Knowledge Transfer I: Entrepreneurs	1 cr.
PRGR	**675**	Innovation and Knowledge Transfer I: Concept to Commercialization	1 cr.
PRGR	**676**	Global Sustainable Business Management	2 cr.
PRGR	**677**	Cost-Benefit Analysis	2 cr.
PRGR	**679**	Project Management, Risk Management and Planning	2 cr.

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 semester is 9 credits. A student who wishes to enroll in more than the maximum number of credits must petition the Faculty Graduate Studies Committee to obtain permission.

Credit Transfer

A maximum of 6 credits can be transferred from other institutions out of the 18 credits for the student to earn the Diploma from the home institution into which the student was originally admitted. This means that two-thirds of the 18-credit requirement for the diploma should be registered at the institution that will grant the degree. Normally the core courses of the program are duplicated and are offered at each of the partner institutions.

Requirements for Double Specialization

Students may enroll and earn a diploma in one or two specializations.

To fulfill the basic requirement for the double specialization, a student must complete a minimum of 12 credit hours of graduate course work over and above the requirements of the first specialization. The remaining credits include the core courses that are credited for the double specialization. The minimum total credit hours for a double specialization in green technology is 30 credit hours.

Requirements for Joint Degree in Two Specializations

This option allows students to study green technologies in two institutions and receive joint diplomas from both institutions. A student registered in one specialization in one institution can apply for a second specialization in another institution given that 12 credits over and above the 18 credits required by the first specialization are completed. The 6-credit core courses are considered common for the joint degree in two specializations.

Course Descriptions

Core Courses

PRGR 601 Green Economy, Policies and Law 3 cr.
The course covers environmental and resource economics and policy; environmental issues and regulations global sustainability and future trends; international environmental law; carbon management for green environment; the science of urban ecology; corporate environmental responsibility; green laws compliance; cost benefit analysis; environmental economics and sustainable development; green tech and finance. International climate change mitigation financing mechanisms. Best practices and case studies for successful implementation of climate change mitigation strategies locally and internationally. Introductory statistical and data modeling tools are used as basis of effective decision-making or analysis.

PRGR 602 Green Technologies System Approach to Sustainability and Management 3 cr.
The course covers green technologies applications including renewable energy sources versus conventional; solar systems: solar thermal, photovoltaic, solar concentrators, wind; biofuels and biotechnologies; water production and quality; wind; hydrogen cells; low energy architecture and energy efficient buildings; and recycling and reuse of materials, elements and components. The course also covers system approach to sustainability and management including environmental management systems and auditing; environmental impact assessment; sustainability management; sustainable operations; and project and portfolio management.

Energy Specialization Courses

PRGR 611 Solar Radiation and Solar Electricity using PV Technology 2 cr.
Solar Radiation: Components, Geometry of Earth and Sun, Geometry of collector and sun beam, Effect of Earth's atmosphere, Measurements of solar radiation. 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; Economical and sustainability aspects.

PRGR 612 Wind Energy: Wind Turbines and Wind Farms and Siting 1 cr.
The module covers the fundamentals of wind energy and the process and limitations of converting wind kinetic energy to electrical energy. It discusses the efficiency law and the governing equation of the conversion process. The module also covers the various types of wind turbines available in the commercial market along with their characteristics, and implementations' advantages and disadvantages.

PRGR 613 Energy Storage Technologies 1 cr.
In this course various energy technologies will be presented and discussed in terms of their principle of operation, system components, energy density, maintenance, and cost. The different technologies that will be addressed are: batteries, compressed air, fly-wheel storage, pumped hydro-power, super-capacitors, and superconducting magnetic energy storage.

PRGR 614 Solar Thermal Energy Conversion 2 cr.
This course provides a comprehensive analysis of solar thermal energy collection and utilization with an emphasis on the design, sizing and selection of solar thermal technologies such as: solar thermal power plants, solar water heaters, solar concentrators, solar ponds, and solar updraft towers.

PRGR 615 Biofuels 2 cr.
Course content includes studies of types, sources and processing of biodiesel, biomass, bio-methane and bioethanol, and assessing advantages, problems and principles in biofuel production. Biogas and digester design.

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 renewable 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 variety of designs for devices for extracting energy from waves, 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 1 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. Addresses integration of solar energy into boilers and condensing units of building systems and introduces optimized control strategies.

PRGR 618 Energy Efficiency in Agriculture Evaluation and Design 1 cr.
The course will address energy use and conservation in agriculture and food production systems. The course will explore energy conservation improvements through reduced fossil fuel dependency and use of renewable resources. *No prerequisites are required*.

PRGR 619 Hybrid Renewable Energy Lab 1 cr.
Photovoltaic Cells: Operating principles of PV cells, Characteristics of PV modules, Effect of Temperature and irradiance, series parallel combinations, Alignment geometry, Maximum power point tracking, and Partial shading. Wind Power: Wind turbines types, Design and operation, Physical fundamentals, Doubly-fed induction generator, Effect of wind speed on voltage and frequency, and Optimal operating point.

PRGR 620 Energy Systems and Sustainable Environments 2 cr.
This course covers a wide range of topics: (i) Worldwide importance of energy systems including their historical and current energy perspectives, concepts and applications of energy systems.

(ii) Sustainable Energy systems; approaches to energy systems analyses and sustainability metrics. Biological Carbon Capture Storage, including the following processes: soil carbon, CO2 to energy, Forests and forest ecology, Digestate from Anaerobic Digestion (AD) process, Biochar Grassland management, Biomass to oil; and (iii) Comprehensive overview of the principal types of renewable energy-including solar, thermal photovoltaics, bioenergy, hydro, tidal, wind, and wave.

PRGR 621 Waste to Energy Processes and Technologies 2 cr.
The course covers the fundamental principles of waste management, with particular emphasis on organic wastes. Waste generation and characterization, and techniques for waste collection, storage, transport, utilization (including recycling and recovery). Focus is on the application of engineering science to develop integrated waste management systems. Waste-to-energy technology: mass burning and modular combustion, refuse derived fuel systems, anaerobic digestion, composting. Comparison and benchmarking of the technologies with respect to energy efficiency, environmental impacts, costs etc. Hazardous waste generation, producer responsibility and legislation. Waste-to-energy projects implementation concepts: risk assessment; implementation process including; feasibility, siting, procurement/ownership, financing, plant construction and operations.

PRGR 622 Renewable Energy Projects Evaluation and Market Analysis 2 cr.
Renewable energy integration strategies including market development issues and challenges to large-scale deployment. Supporting policy frameworks to include national and international targets. Impacts of key factors supporting the development of renewable energy projects (e.g., economics/finance, risks, laws and regulations). Market trends/status and utilization of market information to develop strategic opportunities. Market entry and penetration strategies and contention with or removal of barriers. Current and potential future regulations/directives, protocols and research needs. Renewable energy project evaluation, market analysis and policy case studies (biomass, small hydro, solar thermal and photovoltaic, wind and so on).

PRGR 623 Energy Audit Lab 2 cr.
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 carry 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.

Building Specialization Courses
General Green Building Modules

PRGR 631 Low Energy Architecture and Passive Building Design 1 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 1 cr.
Green and recyclable building material, embodied energy, sustainable construction.

PRGR 633 Renewable Energy Systems and Energy Efficiency in Buildings 2 cr.
The module serves as the main process for a establishing a net zero energy building/ architecture by means of enabling a building to generate the electrical energy it needs from its own resources. The module thus delves into the two main building's self-energy sources; wind and solar PV. It covers the implementations of micro or mid-scale wind turbines and solar PV systems for the generation of electrical energy. The module also covers storage and grid connection mechanisms as well. Lighting efficiency and electrical installation issues.

PRGR 634 Moisture and Control of Humidity in Buildings 2 cr.
Sources of moisture and factors affecting its entry and buildup inside the 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. Moisture-caused health issues including mold formation and growth.

PRGR 635 Construction and Demolition Management 1 cr.
Building disposal techniques including deconstruction as well as selective and partial selective demolition. Design and construction for deconstruction and reuse. Sustainable waste management including recycling and reuse of waste materials and components.

PRGR 636 Modular Building Construction 1 cr.
Pre-fabrication and preassembly of building elements. Benefits of modular construction in terms of cost and time savings, and waste minimization.

PRGR 637 Green Building Basics and Building Rating Practices 2 cr.
Assessment of building design and construction operations: Project rating systems (LEED, BREEAM, QSAS, etc.). 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.

PRGR 638 Sustainable Restoration of Existing Building 1 cr.
Energy audits, upgrade of building envelope, electric supplies, lighting, and HVAC system.

PRGR 640 Building Physics Lab 1 cr.
Hands-on evaluation and experimentation of building envelope materials and systems. Building interaction with the environment and occupants. Interaction of building enclosure with mechanical systems. Urban heat island effect.

Mechanical and Electrical Engineering Modules

PRGR 641 HVAC Systems for Energy Efficient Acclimatization 2 cr.
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. 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. ASHRAE requirements for ventilation. Personalized ventilation and personalized cooling devises.

PRGR 642 Building Management Systems (BMS) 1 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.

PRGR 643 Heat Pumps and Innovative Methods to Improve Performance with Direct Applications 2 cr.
Heat pumps in low energy and passive buildings. 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 are considered in detail. Cost effective design options.

PRGR 644 HVAC Lab 2 cr.
This course is designed to give the students "hands-on" experience with building energy systems and expose them to basic and advanced methods of measurements and data analysis to design, test, and evaluate indoor climate conditions and HVAC systems' performance under appropriate control strategies for comfort and indoor air quality. The students will be exposed to electrical HAVC instrumentation and hardware, IAQ testing equipment, tracer gas techniques for ventilation rates measurements, flow characterization measurements and air leakages and fenestration ratings. Experiments and lab projects will span a series of advanced modules on sustainable, energy-efficient HVAC and refrigeration systems as laboratory topics.

PRGR 645 Building Energy System Modeling 2 cr.
Indoor space thermal models. 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.

Water Specialization Courses

PRGR 650 Instrumentation 1 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 systems documentations, operators 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 651 Water Essentials 1 cr.
This course includes: a short history of water, patterns of water use, the urban water crisis and management, and water use in home and commercial buildings. The course covers basic information about the water and sewer utility operating environment and water sources, as well as the key issues in water demand planning. Students will learn about the history of drinking

water regulations and current regulations including the Safe Drinking Water Act and the Clean Water Act. Topics include: today's water crisis, management and best practices, an introduction to regulatory affairs and restrictions, water sources in the region and globally, commercial and domestic water use, the colors of water, our water footprint, responding to the water crisis, and new trends.

PRGR 652 Smart Irrigation 1 cr.
New technologies in irrigation aiming at water savings at the operation and management level. Soil Moisture sensors and types of irrigation controllers, determining water requirements of different plants in different environments, irrigation scheduling, operation and management technologies.

PRGR 653 Water Treatment 2cr.
Physical, chemical and biological water quality parameters determinations and standards; water treatment techniques: screens; sedimentation, thickening, coagulation/flocculation processes, filtration, and disinfection. Case studies are presented.

PRGR 654 Wastewater Treatment 2 cr.
Mass balances and hydraulic flow regimes; attached and suspended growth biological wastewater treatment systems including: activated sludge and its variations, aerated lagoons, SBR, trickling filters, RBC; basic nitrification-denitrification processes; oxygen requirements; introduction to sludge treatment and disposal; professional and ethical responsibility issues. Case studies are presented.

PRGR 655 Wastewater Treatment Plant Design 1 cr.
Analysis and design of wastewater treatment plants using commercially available software: sizing of tanks; and effluent concentration. Results visualizations and assessment. *Corequisite: PRGR 654*

PRGR 656 Water Networks Design 1 cr.
Analysis and design using commercially available software: municipal water distribution systems including pipes, reservoir, pumps and losses. Results visualizations and assessment: pressure, velocity, head losses.

PRGR 657 Wastewater Networks Design 1 cr.
Analysis and design using commercially available software: wastewater collection systems including pipes, manholes, drop manholes, wet wells, and other appurtenances. Results visualizations and assessment.

PRGR 658 Sludge Treatment 1 cr.
Sludge stabilization; Composting; Conditioning; Anaerobic digestion; Thickening; Dewatering and drying; reuse; disposal; Waste to Energy.

PRGR 659 Basic Operations of Wastewater Treatment Plant 1 cr.
Maintenance and Safety; Sampling, Sampling Methods and Parameters; Analysis and Data Handling; Management and Supervision.

PRGR 660 Water Resources Planning and Management 2 cr.
Linear programming and dynamic programming applications to water resources planning; practical water problems including allocation, quality management, reservoir operations, flood control, resources management, basin modeling and flood and drought forecasting.

PRGR 661 Desalination 2 cr.
This course will survey the commonly used thermal and membrane based desalination technologies. Fundamental thermodynamic and transport processes which govern desalination will be developed. Environmental, sustainability and economic factors which may influence the performance, affordability and more wide-spread use of desalination systems for fresh water production and reuse will be highlighted. Renewable energy technologies coupled with desalination processes will be reviewed. A team based student project will be assigned to design a reverse osmosis membrane desalination plant (brackish water, seawater, or treated sewage effluent) using conventional or alternative energy sources.

PRGR 662 Sustainable Water Management 1 cr.
Strategies for water management at the project and field scale including water shortage management, irrigation strategies, water harvesting, non-conventional water sources for agriculture, groundwater recharge, and catastrophe protection, and flood management; techniques, methods, and strategies for agricultural, domestic, industrial, and municipal water conservation and sustainable use in dry lands.

PRGR 663 Liquid Waste Management 1 cr.
This course focuses on management techniques of liquid waste disposal from domestic, commercial and industrial effluents. Methods for managing waste collection, recycling, and transportation of nonhazardous and hazardous materials will be studied. The effect of this waste on the environment will be assessed according to the legislation. Design strategies and calculations will also be discussed for the different types of waste. Cost analysis of the different processes will also be highlighted.

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 packages 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 and selected industrial processes and products.

PRGR 671 Energy Conversion and Storage 2 cr.
Fundamentals of renewable energy processes: heat engines (thermo-mechanical, thermo-chemical, electrochemical, and photoelectric processes and technologies); on-shore and off-shore energy conversion; innovative energy storage devices; energy carriers, synthesized fuels. Emphasis is on advanced energy technologies, energy efficiency, systems performance and minimization of environmental impacts. Introduction to principles of multiple sources of renewable energies. Deployment of energy storage technologies: technical and economic advantages of energy storage; electricity storage systems; characteristics of energy storage

techniques, and; comparison of the different storage techniques Renewable energy deployment in transport. Supply chains of liquid and gaseous transportation fuels; alternative transportation technologies and infrastructure for advanced future transportation systems (land, water and air); environmental and social impact assessments. Models/tools for estimating the energy consumption and emissions in different transportation systems; evaluation of external impact factors and means of reducing pollution and optimizing energy consumption.

PRGR 672 Energy Systems Integration 2 cr.
Develop choice awareness of energy resources and methods for energy demand and supply characterization (including forecasting). Laws and regulations for local energy production. Micro-generation, cogeneration, tri-generation, and poly-generation systems; energy flows, low-carbon/renewable energy systems, energy systems integration, and bases for sustainable energy systems. Methods and tools for hybrid energy systems integration to provide specified service loads (viz., electricity, heating, and cooling). Energy infrastructure; centralized vs. decentralized systems; on-shore and offshore systems. Energy demand and supply modeling: simulation, econometric and other forms of parameter estimation, input-output modeling, and integrated systems modeling and optimization.

PRGR 673 Research Skills Development - General 1 cr.
Objective of this module is to enable learners to develop critical research skills, including requisite skills for clear and concise communication of research plans, research progress and findings to experts in their respective area thought more efficient use of software and commonly used resources. Focus is on structured inquiry from experiments and/or data collection and analysis, rather than hypothesis or theory to be tested. The module processes will integrate knowledge gained from all other modules in the program, to develop the rationale for research, set out research objectives and methods, analyze and interrogate data, and draw validated conclusions.

PRGR 674 Innovation and Knowledge Transfer I: Entrepreneurs 1 cr.
The Innovation and Knowledge Transfer modules will provide an introduction to the area of Innovation and Entrepreneurship in the context of the Knowledge Economy. Initial focus will be on the entrepreneurial process in the journey from identification of the innovative idea through to the launch of a successful business. It will identify the key factors influencing success along the way. Concepts will be explored by way of case studies and question and answer sessions with successful entrepreneurs, telling their real-life success stories. The emphasis of the module will be to create an awareness of how innovative ideas can lead to commercial opportunities and identify the entrepreneurial qualities required to convert these ideas into viable business propositions.

PRGR 675 Innovation and Knowledge Transfer I: Concept to Commercialization 1 cr.
This 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 begin by examining some success stories and then addresses the requirements to manage and protect intellectual property rights (IPR) in areas such as ICT, Life Sciences, Engineering, Food and Energy. The potential routes to commercialization and the key business feasibility questions will be considered.

PRGR 676 Global Sustainable Business Management 1 cr.
The deliverables of this module will require team projects and participants will be graded via continuous assessment. The aim of this module is 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.

PRGR 677 Cost-Benefit Analysis 2 cr.
Introduction, conceptual and microeconomic foundations of cost-benefit analysis. Valuation of costs and benefits across time through discounting; dealing with uncertainty. Shadow price of foreign exchange, financial and economic analysis of investment projects. Case studies.

PRGR 679 Project Management, Risk Management and Planning 2 cr.
The abilities to propose, plan, execute and close a project are essential qualities of every manager. This proposal aims to help the student to develop the skill required from every project manager. It will also address common risk management and contingency planning. This should be delivered in accordance with internationally recognized global project management standard bodies, such as PMI, to aid the students who wish to become certified project managers.