



<b>PHYS 330</b>	<b>Principles of Environmental Physics</b>	<b>3.0; 3 cr.</b>
Scope of environmental physics, review of gas laws, transport laws, radiation environment, microclimatology of radiation, momentum transfer, heat transfer, mass transfer, steady state heat balance, crop meteorology, energy for human use, and environmental spectroscopy. Not open to physics graduate students. <i>Prerequisites: PHYS 204 and 205 or equivalent and some knowledge of calculus. Annually.</i>		
<b>PHYS 391/392</b>	<b>Graduate Tutorial</b>	<b>1–3 cr. (each)</b>
Physics 391 is usually given in the fall semester while PHYS 392 is given in the spring semester. For more than one student or if the same student is taking two tutorials at the same time the letters A, B, C will be attached to distinguish these tutorials. <i>May be repeated for credit.</i>		
<b>PHYS 395A/395B</b>	<b>Comprehensive Exam</b>	<b>0 cr.</b>
<i>Prerequisite: Consent of adviser.</i>		
<b>PHYS 399</b>	<b>MS Thesis</b>	<b>9 cr.</b>

# Doctor of Philosophy in Theoretical Physics

## Mission Statement

The PhD program in the Department of Physics is intended to produce competent independent researchers who are able to make original contributions to physical sciences. The program prepares students for careers in research, teaching, or industry and thus provides qualified scientists for Lebanon and the region. It serves the AUB mission of promoting research and participating in the advancement of knowledge.

## Admission

Admission to the PhD program is on a competitive basis. To be eligible for admission, applicants must have an excellent academic record, and demonstrate exceptional motivation and ability to pursue research in physics. The following items are required for an application:

- For the Regular Track\*: A Master's (MS) degree in Physics or related fields from an institution recognized by AUB;
- For the Accelerated Track\*: A bachelor's (BS) degree in Physics or related fields from an institution recognized by AUB;
- Three letters of recommendation;
- A score on the general part of the Graduate Record Examination (GRE), and the subject part in physics. This exam is also required by both BS and MS holders. A score on a previously taken GRE will remain valid for a period of three years;
- A score on the Test of English as a Foreign Language (TOEFL) or English Entrance Examination (EEE) that meets the university requirements (250 for computer-based TOEFL, 600 for paper based TOEFL, 97 for Internet-based TOEFL and 550 for EEE);

\*Refer to the Program of Study section under "General University Academic Information"

- A statement of purpose; and
- A recommendation for admission by the AUB Department of Physics. A departmental committee may require an interview with the applicant before giving a recommendation.

## Governance

The PhD program is proposed as a full-time 5 year program, with a maximum of 7 years permitted for its completion. The governance of the program commences with the application process.

Upon admission into the program, a graduate student is assigned an academic adviser who evaluates his/her academic background, designs a curriculum to meet the student's research interests and career goals, and advises if undergraduate courses are needed to rectify deficiencies. All of the duties of the academic adviser will be transferred to the thesis adviser chosen by the student and approved by the department. The thesis adviser must be chosen within 3 semesters from the admission to the program.

## Supervision of PhD Thesis

Academic Adviser guides and helps the student plan a course of study and recognize a thesis adviser. The thesis adviser must be a full-time professorial rank faculty member. The PhD thesis proposal and the committee should be formed at least two semesters before the thesis defense. The thesis committee should be conforming to the AUB policy and the requirement of the Lebanese Ministry of Higher Education as described in details under the PhD Thesis Committee section of the "General University Academic Information."

## Course Work

The PhD program requires the completion of at least 39 credits hours of course work for students admitted on the accelerated track (BS holders) and a minimum of 18 credit hours of course work for students admitted on the regular track (MS holders).

The required courses for students admitted on the accelerated track are: PHYS 301, 302, 303, 305, 306 and 307 (18 credits), and at least 21 credits beyond the core program, out of which one course must be in the concentration area, while the others can be taken as electives. Students may take relevant courses outside the department provided they secure departmental approval.

The required courses for students admitted on the regular track are: PHYS 306 and 307 (6 credits), and at least 12 credits beyond the core program, out of which one course must be in the concentration area, while the others can be taken as electives. Students may take relevant courses outside the department provided they secure departmental approval.

## PhD Qualification Exam Part I and Part II

Upon completion of a minimum of 15 credits of graduate course work including the four core courses: PHYS 301, 302, 303 and 305 with a cumulative average of 85 or above in the core courses, the student may sit for PhD Qualification Exam Part I (written comprehensive examination) to determine a written comprehensive examination to determine whether he/she has acquired the background necessary to continue in the PhD program.

After choosing a thesis adviser, the student should pass the PhD Qualification Exam Part II; the student must formulate, submit and defend a thesis research proposal to demonstrate a capacity to pursue and complete a doctoral research project.

## Candidacy

Refer to the Admission to Candidacy section under “General University Academic Information” on page 57.

## PhD Thesis and Thesis Defense

After qualifying as a PhD candidate, the student will focus on the doctoral research. The PhD thesis is based on independent original research. The doctoral research, once completed, will be presented publicly and defended in front of the thesis committee. The thesis committee will consist of four members, all of professorial rank, with at least one member from outside AUB.

## Residence Requirements

See Residence Requirements section under “General University Academic Information” on page 50.

## Graduation Requirements

A student is granted the PhD degree upon approval of his/her PhD thesis by the thesis committee in a public session. In addition to the general graduation guidelines specified by the University, the Physics Department also requires that part of the PhD thesis work be published or accepted for publication in a refereed journal by the time of graduation.

## Timetable

A student is expected to abide by the following time table:

- Finish the graduate course work (a minimum of 39 credits after the BS) within 8 semesters of starting the graduate study program;
- Pass the qualifying exam upon completion of 15 credits, within 3 semesters of starting the graduate study program;
- Choose a thesis adviser within 3 semesters of starting the graduate study program;
- Defend the PhD thesis proposal within 6 semesters and advance to candidacy within 7 semesters of starting the graduate study program; and
- Present his/her research work by submitting his/her thesis to the thesis committee and defending it in a public session. The total length of the PhD should not exceed 7 years.



**PHYS 313**                    **Differential Geometry and General Relativity**                    **3.0; 3 cr.**  
Differential manifolds. Tangent vectors. Vectors and tensor fields. Lie derivatives. Differential forms. Affine connections: covariant derivatives. Curvature and torsion Tensors. Principal of equivalence. Einstein field equations. Schwarzschild solutions and classical test of general relativity. Weak gravitational fields. Post-Newtonian approximation.

**PHYS 314**                    **Non-equilibrium Statistical Mechanics**                    **3.0; 3 cr.**  
Phenomenological description of transport processes: diffusion, thermal conduction and brownian motion. General microscopic approaches: Liouville's and von Neumann's equations. Boltzmann's equation and H-Theorem. Linear response theory: time-dependent correlation function, Green-Kubo formula, fluctuation-dissipation theorems. Stochastic evolution: Markoff process and master equation, correspondence between Langevin and Fokker-Planck pictures, kinetics of phase transitions. *Prerequisite: PHYS 302.*

**PHYS 315**                    **Particle Cosmology**                    **3.0; 3 cr.**  
Relativistic cosmology: Friedmann equations and their solutions, Hubble diagram. Hot Big Bang model: statistical mechanics of the expanding Universe, microwave background, primordial nucleosynthesis, GUT model for baryon asymmetry. Structure formation: Newtonian perturbation theory, gauge invariant relativistic perturbation theory, the large scale structure of the Universe. Inflation theory. *Prerequisite: PHYS 313.*

**PHYS 316**                    **Physics of Soft Matter**                    **3.0; 3 cr.**  
Overview: liquid crystals, polymers, colloids. Statistical mechanics of correlation and order: scattering, structure factor, response function. Application to liquid crystals: generalized elasticity, nematic-to-smectic transitions. Application to polymers: random and self-voiding walks, coil-to-globe transitions, self-organization of amphiphilic macromolecules. Application to colloids and foams. *Prerequisite: PHYS 302.*

**PHYS 317**                    **Group Theory and Symmetry in Physics**                    **3.0; 3cr.**  
Group theory: subgroups, conjugate cases, direct products. Group representation: unitary spaces, unitary representations, Schur's Lemma, orthogonality, tensor products, conjugate classes, Young tableaux. Group theory and Quantum Mechanics. Point groups: proper rotation group, crystallographic point groups. Space groups. Continuous groups: transformation groups, generators, Lie groups and algebras, Jacobi identity. Application of SU(2). Isospin. Tensor products. Tensor methods: Irreducible representations and symmetry, invariant tensors, Clebsch-Gordon decomposition. Application of Lie groups to particle classifications: SU(5) and SO(10).

**PHYS 318**                    **Standard Model of Particle Physics**                    **3.0; 3 cr.**  
Renormalization and renormalization group. Group theory and the quark model. Chiral anomaly. Gauge theories and quantization. Quantum Chromodynamics. Spontaneous symmetry breaking. Electroweak symmetry. Standard model of elementary particles. One loop structure and one loop processes.

**PHYS 319**                    **String Theory**                    **3.0; 3 cr.**  
Classical Bosonic string. Quantized Bosonic string. Conformal field theory. String perturbation theory. Classical Fermionic string. Quantized Fermionic string. Spin structures and superstring partition functions. Heterotic strings. D-branes. Orbifolds. Calabi-Yau compactification.

- PHYS 322**            **Thin Films Physics**            **3.0; 3 cr.**  
Introduction to surface and thin films physics: definitions; importance in basic research; impact on technology and society. Ultra High Vacuum Techniques and Processes: Kinetic theory concepts; Surface preparation procedures; Surface chemical composition: XPS, AES, SIMS, GIXRD. Thin film deposition: Evaporation; Plasma, laser and ion beam processing; Physical and Chemical Vapor Deposition techniques. Surface morphology and physical structure: Surface energy; reconstruction; 2-D lattices; Nucleation and growth of thin films; Microscopy techniques. Theory of surface scattering; Inelastic scattering and dielectric theory; Electron-based techniques: LEED and RHEED; RBS. Epitaxy: atomistic models and rate equations; steps, ripening and interdiffusion; HRXRD. Conduction and Magnetism in thin films; Superconductivity; Optical and mechanical properties. *Pre- or co-requisite: PHYS 302.*
- PHYS 323**            **Plasma Physics**            **3.0; 3 cr.**  
The motion of a single particle (electron or ion) subject to electromagnetic forces; fluid equations for electrons and ions; guiding center description; collisional phenomena occurring in plasmas and the resultant diffusion; propagation of high and low frequency electromagnetic waves in plasmas; description of the plasma as a single fluid; the magneto-hydrodynamic (MHD) equations; MHD instabilities and their effects on the plasma; Applications of plasma physics. *Pre- or co-requisite: PHYS 303.*
- PHYS 324**            **Electron Paramagnetic Resonance**            **3.0; 3 cr.**  
The electronic Zeeman interaction and the resonance phenomenon, Group theory-the rotation group, the spin-Hamiltonian and the spectrum, the Lanthanide 4f Group, the actinide 5f, Ions of the 3d group in intermediate Ligand Fields and some Experimental aspects of EPR. *Pre- or co-requisite: PHYS 305.*
- PHYS 490**            **Preparation for PhD Qualifying Exam Part I**            **0 cr.**
- PHYS 495**            **Preparation for Thesis Proposal**            **0 cr.**  
Research is conducted individually by the student leading to a Thesis proposal.
- PHYS 499**            **PhD Thesis**