Department of Physics

Chairperson: Antar, Ghassan Y.
Professor Emeritus: Mavromatis, Harry A.
Professors: Bitar, Khalil M.; Chamseddine, Ali H.; El Eid, Mounib F.; Isber, Samih T.; Klushin, Leonid I.; Sabra, Wafic A.; Tabbal, Malek D.; Touma, Jihad R.
Associate Professors: Antar, Ghassan Y.; Christidis, Theodore C.; Kazan, Michel J.
Visiting Assistant Professor: Madi, Charbel S.
Lecturers: ^Bodakian, Berjouhi H.; ^Malaeb-Hoseiky, Ola M.;^Roumieh, Mohammad A.

The department provides courses and facilities for graduate work leading to the MS and PhD degrees. The research activities of the department include material science, condensed and soft matter physics, plasma physics, paramagnetic resonance, nonlinear dynamics, astrophysics, high energy physics, superstring theory, and quantum gravity.

MS in Physics

The MS program requires the completion of 21 credits of courses and a thesis. The courses consist of four core courses: PHYS 301, PHYS 302, PHYS 303, and PHYS 305, and 9 credits of physics graduate electives. After completion of the four core courses, the student must pass the master's Comprehensive Exam. The student must then select a thesis advisor who will present the thesis proposal to the department chair for approval. The MS degree is granted after the student defends her/his thesis successfully.

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.

^part time
Admission

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

- Degrees:
  - 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;
- GRE General Test is required as per AUB requirements. Subject GRE is required as per Physics Department requirements (No GRE is required for applicants to the MS program);
- For English, refer to the English Language Proficiency Requirements (ELPR) section in the catalogues;
- 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

Refer to Supervision of Doctoral Thesis under General University Academic Information on page 65.

Supervision of PhD Thesis

Refer to Supervision of Doctoral Thesis under General University Academic Information on page 65.

PhD Publication Requirements

Refer to PhD Publication Requirements under General University Academic Information.

Course Work

The PhD program requires the completion of at least 39 credit 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, PHYS 302, PHYS 303, PHYS 305, PHYS 306 and PHYS 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.

1 Refer to the Study Section under General University Academic Information
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, PHYS 302, PHYS 303 and PHYS 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 whether s/he has acquired the background necessary to continue in the PhD program.

After choosing a thesis advisor, 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.

For more information, refer to PhD Qualifying Exam under General University Academic Information on page 64.

Candidacy

Refer to Admission to Candidacy section under General University Academic Information on page 65.

PhD Thesis and Thesis Defense


Residence Requirements

See Residence Requirements section under General University Academic Information on page 64.

Graduation Requirements

A student is granted the PhD degree upon approval of her/his 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 timetable:

- 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 advisor 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 research work by submitting her/his thesis to the thesis committee and defending it in a public session. The total length of the PhD should not exceed 7 years.
Financial Support

The department offers, on a selective basis, substantial support which fully covers tuition and includes a monthly stipend. There are also some funds available to support participation in international conferences; these funds are awarded on a competitive basis. In return, students help in teaching undergraduate labs and recitations of introductory courses. Their duties also include help in proctoring and correcting exams.

Course Descriptions

**PHYS 301 Classical Mechanics** 3.0; 3 cr.
D'Alembert's principle, variational principles and Euler Lagrange's equations, rigid bodies and small oscillations, Hamilton's mechanics, canonical transformations and Hamilton- Jacobi theory, stability, integrable systems and chaotic motion. *Annually.*

**PHYS 302 Statistical Mechanics** 3.0; 3 cr.
Statistical ensembles, Boltzmann distribution, density matrix, Fermi-Dirac and Bose-Einstein statistics and applications, phase transitions, mean-field theory and applications. *Annually.*

**PHYS 303 Electromagnetic Theory** 3.0; 3 cr.
Boundary-value problems in electrostatics, multipoles, dielectrics, magnetostatics, time-varying fields and Maxwell's equations, electromagnetic waves. *Annually.*

**PHYS 305 Quantum Mechanics** 3.0; 3 cr.
Hilbert space formulation of quantum mechanics, theory of angular momentum, Euler rotation, addition of angular momenta; symmetries and conservation laws: time reversal, parity, discrete symmetry, path-integral formulation of quantum mechanics, approximation methods, identical particles, elementary scattering theory. *Annually.*

**PHYS 306 Introduction to Quantum Field Theory** 3.0; 3 cr.
Unifying quantum theory and relativity, Relativistic quantum mechanics: Klein-Gordon equation, scalar field, second quantization, Dirac's equation and Dirac's field. Interaction Fields and Feynman Diagrams, Quantization of the electromagnetic field. *Prerequisite: PHYS 305.*

**PHYS 307 Mathematical Methods of Physics** 3.0; 3 cr.
Complex Analysis: contour integration, conformal representation, Tensor analysis, Partial differential equations: heat equation, hypergeometric functions.

**PHYS 310 Special Topics** 3.0; 3 cr. (each)
*May be repeated for credit.*

**PHYS 311 Astrophysics I** 3.0; 3 cr.
PHYS 312  Astrophysics II  3.0; 3 cr.
Close binary stars and accretion disks. Physics of interstellar medium: heating, cooling, 
radiative transfer, physics of interstellar dust grains. Dynamics of stellar systems: morphology 
and dynamics of stellar populations in Galaxies, N-body simulation, spiral structure. Galaxies: 
galactic morphology, stellar content of galaxies, general properties of Galaxies. Galactic 
evolution: Formation of Galaxies, stellar populations. Expanding Universe: cosmological 
models, primeval fireball, cosmological red shift.

PHYS 313  Differential Geometry and General Relativity  3.0; 3 cr.
forms. Affine connections: covariant derivatives. Curvature and torsion Tensors. Principal of 
equivalence. 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 
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 
estility, 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, Shur'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, Yacobi 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.

PHYS 319  String Theory  3.0; 3 cr.

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 corequisite: 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-hydromagnetic (MHD) equations; MHD instabilities and their effects on the plasma; Applications of plasma physics. Pre- or corequisite: 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 corequisite: PHYS 305.

PHYS 330  Principles of Environmental Physics  3.0; 3 cr.
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. Prerequisites: PHYS 204 and PHYS 205 or equivalent, and some knowledge of calculus.

PHYS 391  Graduate Tutorial  1-3 cr. (each)
May not be repeated for credit.

PHYS 395A/395B Comprehensive Exam  0 cr.
Prerequisite: Consent of advisor.
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PHYS 399</td>
<td>MS Thesis</td>
<td>9 cr.</td>
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<tr>
<td>PHYS 480</td>
<td>Qualifying Exam Part I: Comprehensive Exam</td>
<td>0 cr.</td>
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<td><em>Every semester.</em></td>
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<tr>
<td>PHYS 481</td>
<td>Qualifying Exam Part II: Defense of Thesis Proposal</td>
<td>0 cr.</td>
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<td><em>Every semester.</em></td>
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<td>PHYS 484¹</td>
<td>PhD Thesis</td>
<td>30 cr.</td>
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<td><em>Every semester. To be taken only by regular track PhD students. Taken at first thesis registration, then registered for every subsequent semester with sequential letter annotations (A-L; 0 credits) until completion of thesis work.</em></td>
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<tr>
<td>PHYS 488¹</td>
<td>PhD Thesis</td>
<td>42 cr.</td>
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<td><em>Every semester. To be taken only by accelerated track PhD students. Taken at first thesis registration, then registered for every subsequent semester with sequential letter annotations (A-L; 0 credits) until completion of thesis work.</em></td>
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¹ The choice to register for PHYS 484 or PHYS 488 should be done in consultation with the thesis advisor to ensure that the total number of PhD thesis credits and PhD course credits are met as per AUB rules and regulations.