Department of Physics

Chairperson:	Isber, Samih T.
Professors:	*Bitar, Khalil M.; Chamseddine, Ali H.; El Eid, Mounib F.; Isber, Samih T.; Klushin, Leonid I.; Sabra, Wafic A.; Tabbal, Malek D.
Visiting Professor	Mavromatis, Harry A.
Associate Professor:	Touma, Jihad R.
Assistant Professor:	Antar, Ghassan Y.
Research Associate:	Christidis, Theodore C.
Senior Lecturer:	PNasrallah, Nasrallah F.
Lecturers:	PBodakian, Berjouhi H.; PRoumieh, Mohammad A.

Graduate Program

The department provides 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, non-linear 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 nine credits of physics graduate electives. After completion of the four core courses, the student must pass a qualifying exam. The student must then select a thesis adviser who will present the thesis proposal to the physics faculty for approval. The MS degree is granted after the student defends his/her thesis successfully.

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.
Boltzmann distribution, density matrix, statistical ensembles, 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, and electromagnetic waves. *Annually.*

* On Leave
P Part time

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; introduction to relativistic quantum mechanics. *Annually.*

PHYS 309/310 Special Topics 3.0; 3 cr. (each)
May be repeated for credit. Annually.

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 205 or equivalent and some knowledge of calculus. Annually.*

PHYS 391/392 Graduate Tutorial 1–3 cr. (each)
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. *May be repeated for credit.*

PHYS 395A/395B Comprehensive Exam 0 cr.
Pre-requisite: Consent of adviser.

PHYS 399 MS Thesis 9 cr.

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 a good academic record with a minimum cumulative average of 85 or equivalent, and demonstrate exceptional motivation and ability to pursue research in physics. The following items are required for an application:

- 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, 100 for Internet-based TOEFL and 550 for EEE);
- 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 dissertation adviser chosen by the student and approved by the department. The dissertation adviser must be chosen within 3 semesters from the admission to the program.

Supervision of Research Work

A doctoral dissertation committee provides general guidance and advises the student on the research project. The committee is formed at least eight months prior to the defense of the dissertation proposal. The committee consists of four members of professorial rank, with at least one external member from outside AUB, and chaired by the student's thesis adviser.

The doctoral dissertation committee evaluates the thesis proposal and the thesis research and dissertation.

Course Work

The PhD program requires the completion of at least 30 credits of courses. These include the following required courses: PHYS 301, 302, 303, 305, 306 and 307 (18 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.

Comprehensive Exam and Proposal Defense

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 a written comprehensive examination to determine whether he/she has acquired the background necessary to continue in the PhD program.

After choosing a dissertation adviser, the student must formulate, submit and defend a doctoral research proposal to demonstrate a capacity to pursue and complete a doctoral research project.

Candidacy

To achieve PhD candidacy, the student must

- complete the four graduate courses: PHYS 301, 302 303 and 305 with a cumulative average of 85 or above;
- pass the written PhD qualifying exam upon completion of a minimum of 15 credits of graduate course work including the four above-mentioned courses;
- complete the course program with a minimum of 30 credit hours graduate course work after the BS degree, and with a cumulative average of 85 or above; and
- submit and defend a dissertation proposal not later than 5 semesters after admission to the graduate program.

PhD Dissertation and Thesis Defense

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

Residency Requirement

Students admitted to the PhD program must

- remain in residence for one full academic year (2 consecutive semesters) as full-time students, preferably teaching in the department;
- register for a minimum of 6 semesters of full tuition; and
- complete all requirements for the PhD degree within a maximum time limit of 7 years. Extension requires approval of the Board of Graduate Studies.

Graduation Requirements

A student is granted the PhD degree upon approval of his/her PhD dissertation by the dissertation 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 dissertation 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 30 credits after the BS) within 6 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 dissertation adviser within 3 semesters of starting the graduate study program;
- Defend the PhD dissertation proposal within 5 semesters and advance to candidacy within 6 semesters of starting the graduate study program; and
- Present his/her research work by submitting his/her dissertation to the dissertation committee and defending it in a public session. The total length of the PhD should not exceed 7 years.

Financial Support

Graduate assistantships covering tuition fees and stipends are awarded to PhD students as they are admitted into the program. Stipends are sufficient to cover living expenses in Beirut. PhD students in their fourth and fifth years are eligible for grants for participation in international conferences. In return, students help in teaching undergraduate labs and recitations of introductory courses. Their duties also include help in proctoring and correcting exams.

Graduate Course Program

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.

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.

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.

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.

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 311 Astrophysics I 3.0; 3 cr.
Stars: observational properties, population, spectra analysis, Stellar matter: atomic Processes, equation of state including degeneracy effects, Stellar structure: Differential equations of stellar structure, radiative and convective energy transport, Thermonuclear reactions nuclear fusion processes, Stellar evolution: discussion of the evolutionary phases of stars, Stellar stability and pulsations, Final stages of Stars: supernovae, white dwarfs, neutron stars and black holes, Star formation.

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.
Differential manifolds. Tangent vectors. Vectors and tensor fields. Lie derivatives. Differential forms. Affine connections: covariant derivatives. Curvature and torsion Tensors. Principal of equivalence. Einstein filed 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 amphiphylic 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.
Renormalization and renormalization group. Group theory and the quark model. Chiral anomaly. Gauge theories and quantization. Quantum Chromodynamics. Spontaneous symmetry braking. 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 & 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 and 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-hydromagnetic (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 Comprehensive Exam 0 cr.

PHYS 495 Preparation for Dissertation Proposal 0 cr.
Research is conducted individually by the student leading to a dissertation proposal.

PHYS 499 PhD Dissertation