INDIANA UNIVERSITY

University Graduate School 2009-2010 Academic Bulletin

University Graduate School
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Physics

College of Arts and Sciences Bloomington

Chairperson
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Graduate Faculty

(An asterisk [*] denotes membership in the University Graduate School faculty with the endorsement to direct doctoral dissertations.)

Distinguished Professors
V. Alan Kostelecky*, Roger Newton* (Emeritus), Robert Pollock* (Emeritus)

Professors
Andrew D. Bacher* (Emeritus), David V. Baxter*, Robert Bent* (Emeritus), Micheal S. Berger*, John L. Challifour* (Emeritus, Mathematics), Ray Crittenden* (Emeritus), Robert R. de Ruyter*, Alex R. Dzierba* (Emeritus), Herbert Abraham Fertig*, James A. Glazier*, Charles Goodman* (Emeritus), Steven A. Gottlieb*, Richard Hake* (Emeritus), Richard Heinz* (Emeritus), Archibald Hendry* (Emeritus), Charles J. Horowitz*, Larry Lee Kesmodel*, S. Y. Lee*, Andrew Lenard* (Emeritus), Don Lichtenberg* (Emeritus), J. Timothy Londergan*, Hugh Martin* (Emeritus), Hans-Otto Meyer* (Emeritus), Daniel Miller* (Emeritus), James A. Musser*, Hermann Nann* (Emeritus), Harold Olof Ogren*, Catherine Olmer*, Gerardo Ortiz*, Roger Pynn*, William L. Schaich* (Emeritus), Peter Schwandt* (Emeritus), Brian David Serot*, William Michael Snow*, Paul E. Sokol*, James Swihart* (Emeritus), Adam P. Szczepaniak*, Richard James Van Kooten*, George Walker* (Emeritus), John Wills* (Emeritus), Scott W. Wissink*

Senior Scientists
Charles Bower* (Astronomy), Pauline Gagnon*, William Jacobs* (Emeritus), Fred Luehring, James Sowinski*, Edward Stephenson*, Daria Zieminska*

Associate Professors
John P. Carini*, Harold Evans*, Fred Lurie* (Emeritus), Mark D. Messier*, Rex Tayloe*, Jon Urheim*

Assistant Professors
John M. Beggs*, Dobrin Petrov Bossev*, Mark Harry Hess*, Chen-Yu Liu*, Sima Setayeshgar*, Matthew Shepherd*

Graduate Advisor
Professor Brian Serot*, Swain Hall West 234, (812) 855-0780

Degrees Offered

Master of Science, Master of Arts for Teachers, and Doctor of Philosophy. The department also participates in the Ph.D. programs in astrophysics, chemical physics, and mathematical physics (described elsewhere in this bulletin).

Special Departmental Requirements

(See also general University Graduate School requirements.)

Grades
B average (3.0) required. See special requirement under “Master of Science Degree” for courses numbered below 501 that are to be counted toward that degree.

Master of Science Degree

Admission Requirements
Physics P201, P202, P301, P309, P331, P332, and P340 (or equivalents); Mathematics M211-M212, M311 (or equivalents). Deficiencies must be removed without graduate credit.

Course Requirements
A total of 30 credit hours, 20 in physics, of which at least 14 credit hours must be in physics courses numbered 501 or above. Seminars, research, and reading courses may not be counted toward this 14 credit hour requirement. Physics courses numbered below 501 that are listed in this bulletin may count toward the 30 credit hour requirement only if passed with a grade of B (3.0) or above.

Thesis
Not required.

Final Examination
Written. May be taken only twice.

Master of Science in Beam Physics and Technology Degree

Admission Requirements
Same as for Master of Science degree.

Course Requirements
A total of 30 credit hours, including the following: proof of proficiency in undergraduate senior-level classical mechanics and electromagnetism, or passing the Classical Mechanics and Electromagnetism in Beams examination offered by the U.S. Particle Accelerator School (USPAS) with grade B or higher, P570, one course at the 500 level or above in laboratory techniques or computational methods, and a master's thesis course (P802). Four advanced courses in beam physics should be chosen from among the special topics courses P571, P671, and P672, with topics to be listed in a syllabus prepared jointly by the Department of Physics and USPAS. A grade point average of 3.0 or better must be maintained in the courses satisfying the 30 credit hour requirement. In particular, both senior-level classical mechanics and electromagnetism (or equivalents) must be passed with a grade of B (3.0) or above.

Thesis
Required.

Final Examination
Either a defense of the thesis or a written final examination is required, and should take place at Indiana University. The written examination may be substituted for the defense only with the permission of the thesis committee. The defense of the thesis will follow the same guidelines as the Master of Science thesis of the Indiana University Graduate School.

Master of Arts for Teachers Degree

Admission Requirements
8 credit hours of undergraduate physics courses.

Course Requirements
20 credit hours in physics courses numbered P300 or higher, selected from the course listings that follow (recommended: P301, P309, P331, P332, P360, P451, P453, P454), the remaining 16 credit hours in graduate education and in mathematics, astronomy, chemistry, or computer science. Candidates for the M.A.T. must obtain a teacher's certificate (or license) by the time they complete the M.A.T.

Doctor of Philosophy Degree

Admission Requirements
Same as those for Master of Science degree.

Course Requirements
A total of 90 credit hours, including two courses in one of the following six areas: accelerator physics (P671 plus one of P633, P634, P640, P641, P672), biological physics (P575 plus one of P581, P582, P583, P676), chemical physics (P615 or P557 plus one of P614, P616, P625, or P627), condensed-matter physics (P557, P615, P616, P627, P657), high-energy physics (P635, P636, P640, P641, P707, P708), mathematical physics (P607, P609, P610, P622, P625, P637, P638, P647, P665, P743), nuclear physics (P626, G630, P633, P634, P640, P641). Courses offered for the (optional) inside minor cannot be used to satisfy this requirement. A minimum of 9 credit hours per semester at the P501 level or above with a minimum 3.0 (B) grade point average is required. Mathematics courses suited to the student's fields will be specified by advisors in the Department of Physics.

Minor
The minor may be taken either inside or outside of the department. The inside minor for all majors except biological physics consists of either P621 or P625, and at least two courses, falling within at least two nonmajor areas of concentration, among six areas: accelerator physics (P570, P671, or P672), chemical or condensed-matter physics (P557, P615, P616, P657, P627), high-energy physics: P535, P635, P636, P640, P641, P707, P708), mathematical physics (P522, P607, P609, P610, P622, P625, P637, P638, P647, P665, P743), nuclear physics (P535, P537, P626, G630, P633, P634, P640, P641), biological physics (P548, P575, P581, P582, P583, P676) or electronics (P540, P541). For biological physics the inside minor consists of at least two different courses, falling within two of the six areas of concentration. Programs of study for outside minors are determined by the individual departments and typically require 9 to 12 credit hours of course work. Recommended outside fields: astronomy, chemistry, mathematics, biology, biochemistry, and scientific computing. All outside minors must be approved by the graduate advisor of the Department of Physics. Note that P535 Introduction to Nuclear and Particle Physics cannot be counted toward the inside minor for students specializing in either nuclear physics or high-energy physics. For students specializing in other fields, P535 can be counted once toward the inside minor and can be considered as a course in either nuclear physics or high-energy physics for that purpose.

Outside Minor in Physics
For students in other departments who wish an outside minor in physics, the requirement is a minimum of 9 credit hours at the 501 level or above. The grade point average for the 9 credit hours must be at least 3.0. Students who wish to complete the physics minor should bring the Nomination to Candidacy form to the Physics Academic Services Office for a signature upon completion of this requirement.

Qualifying Examination
Written. May be taken only twice. Must be taken at the end of the first year and must be passed by the end of the second year. The written examination covers the subjects of mechanics, electricity and magnetism, quantum mechanics, and thermodynamics/statistical physics at the level of first-year graduate work. Relevant courses are P506, P507, P511, P512, P521, and P556. Not attempting the qualifying examination at the required time constitutes an automatic failure.

Candidacy Seminar
Must be presented after the first attempt at the qualifying examination but before the end of the fifth semester. Usually pertains to a proposed dissertation topic.

Dissertation
Result of a significant piece of original research.

Final Examination
Oral defense of dissertation.

Mathematical Physics

The Doctor of Philosophy Degree in Mathematical Physics is described elsewhere in the Bulletin.

Courses

Courses at the 300 level listed as follows may be taken for graduate credit only by M.A.T. students in physics; those at the 400 level or above are available for graduate credit to all graduate students.

Physics
P301 Physics III (3 cr.)
P309 Modern Physics Laboratory (2 cr.)
P331-P332 Theory of Electricity and Magnetism I-II (3-3 cr.)
P340 Thermodynamics and Statistical Mechanics (3 cr.)
P360 Modern Optics (3 cr.)
P410 Computing Applications in Physics (3 cr.)
P441-P442 Analytical Mechanics I-II (3-3 cr.)
P451 Atomic and Nuclear Physics Laboratory I (2 cr.)
P453 Introduction to Quantum Physics (3 cr.)
P454 Modern Physics (4 cr.)

P460 Modern Optics (3 cr.) P: P331 or consent of instructor. Physical optics and electromagnetic waves based on electromagnetic theory, wave equations; phase and group velocity; dispersion; coherence; interference; diffraction; polarization of light and of electromagnetic radiation generally; wave guides; holography; masers and lasers; introduction to optical spectroscopy.

P500 Seminar (1 cr.) Reports on current literature. Graduate students and staff participate.

P504 Practicum in Physics Laboratory Instruction (1 cr.) Practical aspects of teaching physics labs. Meets the week before classes and one hour per week during the semester to discuss goals, effective teaching techniques, grading standards, AI-student relations, and administrative procedures as applied to P201. Students enrolling in this course teach a section of P201 laboratory.

P506 Electricity and Magnetism I (4 cr.) Three hours of lectures and one hour of recitation. Development of Maxwell's equations. Conservation laws. Problems in electrostatics and magnetostatics. Introduction to the special functions of mathematical physics. Time-dependent solutions of Maxwell's equations. Motion of particles in given electromagnetic fields. Elementary theory of radiation. Plane waves in dielectric and conducting media. Dipole and quadruple radiation from nonrelativistic systems.

P507 Electricity and Magnetism II (4 cr.) Three hours of lectures and one hour of recitation. Further development of radiation theory. Fourier analysis of radiation field and photons. Scattering and diffraction of electromagnetic waves. Special relativity. Covariant formulation of electromagnetic field theory.

P508 Current Research in Physics (1 cr.) Presentations by faculty members designed to give incoming graduate students an overview of research opportunities in the department.

P511 Quantum Mechanics I (4 cr.) Three hours of lectures and one hour of recitation. Basic principles, the Schrödinger equation, wave functions, and physical interpretation. Bound and continuum states in one-dimensional systems. Bound states in central potential; hydrogen atom. Variational method. Time-independent perturbation theory.

P512 Quantum Mechanics II (4 cr.) P: P511. Three hours of lectures and one hour of recitation. Time-dependent perturbation theory. Schrödinger, Heisenberg and interaction pictures. Elementary theory of scattering. Rotations and angular momentum. Other symmetries. Nonrelativistic, many-particle quantum mechanics, symmetry and antisymmetry of wave functions, and Hartree-Fock theory of atoms and nuclei.

P521 Classical Mechanics (3 cr.) Vector and tensor analysis. Lagrangian and Hamiltonian dynamics. Conservation laws and variational principles. Two-body motion, many-particle systems, and rigid-body motion. Canonical transformations and Hamilton-Jacobi theory. Continuum mechanics with introduction to complex variables.

P522 Advanced Classical Mechanics (3 cr.) Mathematical methods of classical mechanics; exterior differential forms, with applications to Hamiltonian dynamics. Dynamical systems and nonlinear phenomena; chaotic motion, period doubling, and approach to chaos.

P535 Introduction to Nuclear and Particle Physics (3 cr.) P: P453 or equivalent. Survey of the properties and interactions of nuclei and elementary particles. Experimental probes of subatomic structure. Basic features and symmetries of electromagnetic, strong and weak forces. Models of hadron and nuclear structure. The role of nuclear and particle interactions in stars and the evolution of the universe.

P537 Neutron Physics and Scattering (3 cr.) An interdisciplinary survey of the physics of neutrons, ideas and techniques of neutron scattering. Examples taken from applications of neutron scattering in biology, chemistry, geology, materials science, and physics.

P540 Digital Electronics (3 cr.) Digital logic, storage elements, timing elements, arithmetic devices, digital-to-analog and analog-to-digital conversion. Course has lectures and labs emphasizing design, construction, and analysis of circuits using discrete gates and programmable devices.

P541 Analog Electronics (3 cr.) Amplifier and oscillator characteristics feedback systems, bipolar transistors, field-effect transistors, optoelectronic devices, amplifier design, power supplies, and the analysis of circuits using computer-aided techniques.

P548 Mathematical Methods for Biology (3 cr.) Physical principles applied to modeling biological systems to obtain analytical models that can be studied mathematically and tested experimentally.

P551 Modern Physics Laboratory (3 cr.) Graduate-level laboratory; experiments on selected aspects of atomic, condensed-matter, and nuclear physics.

P556 Statistical Physics (3 cr.) The laws of thermodynamics; thermal equilibrium, entropy, and thermodynamic potentials. Principles of classical and quantum statistical mechanics. Partition functions and statistical ensembles. Statistical basis of the laws of thermodynamics. Elementary kinetic theory.

P557 Solid State Physics (3 cr.) P: P453 or equivalent. Atomic theory of solids. Crystal and band theory. Thermal and electromagnetic properties of periodic structures.

P570 Introduction to Accelerator Physics (3 cr.) P: Approval of instructor. Overview of accelerator development and accelerator technologies. Transverse phase space motion and longitudinal synchrotron motion of a particle in an accelerator. Practical accelerator lattice design. Design issues relevant to synchrotron light sources. Basics of free electron lasers. Spin dynamics in cyclic accelerators and storage rings.

P571 Special Topics in Physics of Beams (3 cr.) P: Approval of instructor.

P575 Introduction to Biophysics (3 cr.) Physics P575 presents an introduction to Biophysics. Topics include: properties of biomolecules and biomolecular complexes; biological membranes, channels, neurons; Diffusion, Brownian motion; reaction-diffusion processes, pattern formation; sensory and motor systems; psychophysics and animal behavior, statistical inference.

P581 Modeling and Computation in Biophysics (3 cr.) Introduction to modeling and computational methods applied to phenomena in Biophysics. Topics: population dynamics; reaction kinetics; biological oscillators; coupled reaction networks; network theory; molecular motors; limit cycles; reaction diffusion models; the heart; turning instability; bacterial patterns; angiogenesis.

P582 Biological and Artificial Neural Networks (3 cr.) Biological details of neurons relevant to computation. Artificial neural network theories and models, and relation to statistical physics. Living neural networks and critical evaluation of neural network theories. Student final projects will consist of programming networks and applying them to current research topics.

P583 Signal Processing and Information Theory in Biology (3 cr.) Probability and statistics. Filtering. Correlation functions and power spectra. Time invariant and time-varying systems. Shannon Information. Coding and decoding. Processing of sensory signals and other applications to neurobiology and psychophysics.

P607 Group Representations (3 cr.) P: Consent of instructor. Elements of group theory. Representation theory of finite and infinite compact groups. Study of the point crystal, symmetric, rotation, Lorentz, and other classical groups as time permits. Normally offered in alternate years; see also MATH M607-M608.

P609 Computational Physics (3 cr.) Designed to introduce students (1) to numerical methods for quadrature, solution of integral and differential equations, and linear algebra; and (2) to the use of computation and computer graphics to simulate the behavior of complex physical systems. Topics will vary.

P610 Computational Physics II (3 cr.) Second semester of computational physics focusing on more advanced topics; e.g.: fractals, kinetic growth models, models in statistical mechanics, quantum systems and fast Fourier transforms, parallel computing.

P615-P616 Condensed Matter Physics I-II (3-3 cr.) P: P512. Mechanical, thermal, electric, and magnetic properties of solids; crystal structure; band theory; semiconductors; phonons; transport phenomena; superconductivity; superfluidity; and imperfections. Usually given in alternate years.

P621 Relativistic Quantum Field Theory I (4 cr.) P: P512. Introduction to quantum field theory, symmetries, Feynman diagrams, quantum electrodynamics, and renormalization.

P622 Relativistic Quantum Field Theory II (4 cr.) P: P621. Non-Abelian gauge field theory, classical properties, quantization and renormalization, symmetries and their roles, and nonperturbative methods.

P625 Quantum Many-Body Theory I (3 cr.) P: P512. Elements of nonrelativistic quantum field theory: second quantization, fields, Green's functions, the linked-cluster expansion, and Dyson's equations. Development of diagrammatic techniques and application to the degenerate electron gas and imperfect Fermi gas. Canonical transformations and BCS theory. Finite-temperature (Matsubara), Green's functions, and applications.

P626 Quantum Many-Body Theory II-Nuclear (3 cr.) P: P625. Continued development of nonrelativistic, many-body techniques, with an emphasis on nuclear physics: real-time, finite-temperature Green's functions, path-integral methods, Grassmann algebra, generating functionals, and relativistic many-body theory. Applications to nuclear matter and nuclei.

P627 Quantum Many-Body Theory II-Condensed Matter (3 cr.) P: P625. Continued development of nonrelativistic many-body techniques with an emphasis on condensed-matter physics:

properties of real metals, superconductors, superfluids, Ginzburg-Landau theory, critical phenomena, order parameters and broken symmetry, ordered systems, and systems with reduced dimensionality.

G630 Nuclear Astrophysics (3 cr.) P: A451-A452, P453-P454, or consent of instructor. R: A550, P611. Fundamental properties of nuclei and nuclear reactions, and the applications of nuclear physics to astronomy. The static and dynamic properties of nuclei; nuclear reaction rates at low and high energies. Energy generation and element synthesis in stars; the origin and evolution of the element abundances in cosmic rays.

P633-P634 Theory of the Nucleus I-II (3-3 cr.) P: P512. Nuclear forces, the two-nucleon problem, systematics and electromagnetic properties of nuclei, nuclear models, nuclear scattering and reactions, theory of beta-decay, and theory of nuclear matter.

P635-P636 Frontier Particle Physics I-II (3-3 cr.) This course focuses on the frontier of particle physics. Topics include Standard-Model physics, neutrino masses, tests of fundamental symmetries, anomalies, grand unified theories, higher-dimensional theories, supersymmetry, composite models, supergravities, string and superstring theory.

P637 Theory of Gravitation I (3 cr.) Introduction to the general theory of relativity, stress-energy tensor, parallel transport, geodesics, Einstein's equation, differential geometry, manifolds, general covariance, bending of light, perihelion advance. Modern cosmology: Robertson-Walker metric, equations of state, Friedmann equations, Hubble's law, redshift, cosmological constant, inflation, quintessence, cosmic microwave background, Big Bang nucleosynthesis, structure formation. See MATH M637.

P638 Theory of Gravitation II (3 cr.) Gravitation waves, Schwarzschild geometry and black holes, Kerr metric, Reissner-Nordstrom metric, extremal black holes, Penrose diagrams, Hawking radiation, Lie derivatives, isometries and Killing vectors, variational principle and the Palatini formalism, spinors in general relativity, vierbeins, gravitation as a gauge theory, quantum gravity. See MATH M638.

P640 Subatomic Physics I (3 cr.) P: P512, C: P621. Experimental methods and theoretic description of particle and nuclear physics: applied relativistic quantum mechanics, symmetries of fundamental interactions, experimental techniques, structure of the nucleon, electromagnetic and weak interactions, elementary particles, and the Standard Model. PHYS P640 may be substituted for P633 in degree requirements.

P641 Subatomic Physics II (3 cr.) P: P640. Quarks and gluons in QCD, the parton model, strong interactions at low energies, nuclear environment and models, nuclear thermodynamics and subatomic physics in cosmology and astrophysics. PHYS P641 may be substituted for P634 in degree requirements.

P647 Mathematical Physics (3 cr.) P: P501 or P502, P521, or MATH M442. Topics vary from year to year. Integral equations, including Green's function techniques, linear vector spaces, and elements of quantum mechanical angular momentum theory. For students of experimental and theoretical physics. May be taught in alternate years by members of Departments of Physics or Mathematics, with corresponding shift in emphasis; see MATH M647.

P657 Statistical Physics II (3 cr.) Continuation of P556. Topics include advanced kinetic and transport theory, phase transitions, and nonequilibrium statistical mechanics.

P665 Scattering Theory (3 cr.) P: P506, P511. Theoretical tools for analysis of scattering experiments. Electromagnetic theory, classical and quantum particle dynamics.

P671 Special Topics in Accelerator Physics (3 cr.) P: P570, P521. Nonlinear dynamics: betatron phase space distortion due to the nonlinear forces. Methods of dealing with nonlinear perturbations. Multiparticle dynamics: microwave and coupled bunch instabilities. Physics of electron cooling and stochastic cooling. Advanced acceleration techniques: inverse free electron laser acceleration, wakefield and two-beam acceleration.

P672 Special Topics in Accelerator Technology and Instrumentation (3 cr.) P: Consent of instructor.

P676 Selected Topics in Biophysics (3 cr.) This course presents papers on current topics in Biophysics, together with key classical papers related to those topics. Student participation in discussions is essential. Each student is expected to write two essays on two of the topics presented.

P700 Topics in Theoretical Physics (cr. arr.)
P702 Seminar in Nuclear Spectroscopy (cr. arr.)
P703 Seminar in Theoretical Physics (cr. arr.)
P704 Seminar in Nuclear Reactions (cr. arr.)
P705 Seminar in High-Energy Physics and Elementary Particles (cr. arr.)
P706 Seminar in Solid State Physics (cr. arr.)
P707-P708 Topics in Quantum Field Theory and Elementary Particle Theory (3-3 cr.)

P743 Topics in Mathematical Physics (3 cr.) P: Consent of instructor. For advanced students. Several topics in mathematical physics studied in depth; lectures and student reports on assigned literature. Content varies from year to year. May be taught in alternate years by members of Departments of Physics or Mathematics, with corresponding shift in emphasis; see MATH M743.

P750 Topics in Astrophysical Sciences (1-3 cr.) A seminar in astrophysics with special emphasis on subjects involving more than one department. Examples of such topics include planetology, nucleosynthesis, nuclear cosmochronology, isotopic anomalies in meteorites, particle physics of the early universe, and atomic processes in astrophysical systems.

P782 Topics in Experimental Physics (1-4 cr.)

P790 Seminar in Mathematical Physics (cr. arr.)

P800 Research (cr. arr.) Experimental and theoretical investigations of current problems; individual staff guidance. S/F grading.

P801 Readings (cr. arr.) Readings in physics literature; individual staff guidance. S/F grading.

P802 Research (cr. arr.) Experimental and theoretical investigations of current problems; individual staff guidance. Graded by letter grade.

P803 Readings (cr. arr.) Readings in physics literature; individual staff guidance. Graded by letter grade.

Astrophysics
G750 Topics in Astrophysical Sciences (1-3 cr.)