Physics and Astronomy (PHY)

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Degrees awarded: M.A. in Physics; M.S. in Physics in Scientific Instrumentation; Ph.D. in Physics

The Department of Physics and Astronomy in the College of Arts and Sciences offers courses of study and research that normally lead to the Ph.D. degree. The M.A degree is awarded either to exchange students or to students on the way to the Ph.D. degree. A Master of Science in Scientific Instrumentation program is provided for those interested in instrumentation for physical research. A Master of Arts in Teaching program, from the School of Professional Development, is available for students seeking to teach physics in high schools.

Physics research is conducted in the areas of particle, nuclear, condensed matter, mesoscopic, nanoscale, device, and atomic, molecular, and optical physics on campus and at research facilities elsewhere. Brookhaven National Laboratory (BNL), located only 20 miles away, offers many unique research opportunities. A number of institutes dedicated to specific fields of research are associated with the Department. The C.N. Yang Institute for Theoretical Physics focuses on research in fundamental theory such as particle theory, neutrino physics, string theory, supersymmetry, and statistical mechanics. The Nuclear Theory Institute works on the theory of non-perturbative quantum chromodynamics and the properties of hadronic matter. A new Simons Center for Geometry and Physics initatiated by a significant private donation to the University is now in the planning stage. It will build on the historic close interaction between mathermaticians and physicists at Stony Brook. The Department has a Tandem Van de Graaff accelerator that after 40 years of nuclear research is now being converted to educational, training, and accelerator R&D efforts. The Institute for Terrestrial and Planetary Atmospheres at the School of Marine and Atmospheric Sciences offers a program in atmospheric physics. The Center for Environmental Molecular Sciences enables study of biological and environmental problems. Under the umbrella of the New York Center for Computational Science (NYCCS), the Stony Brook Center for Computational Science coordinates with the Brookhaven Computational Science Center (CSC) on their mission to develop interdisciplinary computational science at Stony Brook. It provides a focal point for the community of users of the new IBM BlueGene/L supercomputer, NY Blue. Faculty and staff make use of many off-campus facilities including the Relativistic Heavy Ion Collider at BNL, the Fermilab Tevatron Collider, the Large Hadron Collider at CERN, neutrino facilities in Japan, the Center for Functional Nanomaterials at BNL, and synchrotron light sources at BNL, Argonne National Laboratory and Lawrence Berkeley National Laboratory.

Astronomical research is conducted on both theoretical and observational topics. The group uses DOE supercomputing facilities as well as an on-site Beowulf cluster for extensive simulations of astronomical objects and nuclear astrophysical processes. Observational research investigates extragalactic and cosmological parameters, molecular clouds, stellar properties, star formation regions, and neutron stars. Stony Brook is a member of the SMARTS consortium that operates a set of telescopes at Cerro Tololo in Chile. Faculty and students are also frequent users of the National Optical Astronomy Observatories, the National Radio Astronomy Observatories, the observatories at Mauna Kea, and the millimeter wave facilities at FCRAO and IRAM. They have also received extensive time on space-based observatories, including the Hubble Space Telescope.

There are additional research possibilities for graduate students at Brookhaven National Laboratory or Cold Spring Harbor Laboratory in various areas of physics not found in the Department. Students may also find opportunities in related disciplines at Stony Brook in such programs as Medical Physics, Chemical Physics, Atmospheric and Climate Modeling, Materials Science, or Biophysics.

The entire faculty participates in teaching a rich curriculum of undergraduate, graduate, and professional development courses, including many courses on special topics of current interest. Graduate students must fulfill one year of teaching. Course requirements are kept at a minimum to allow the student to set up a flexible program. Students are encouraged to participate in research as early as possible and to begin their thesis research no later than the beginning of their third year. The typical length of time to the Ph.D. is four to six years, whereas the Master's in Scientific Instrumentation is a two-year program that involves a thesis project in instrumentation design or development.

The Department of Physics and Astronomy has been highly ranked in national surveys for the quality of its graduate program, its faculty, and the impact of its published research. It strives to make a graduate education in physics intellectually stimulating and educationally rewarding.

Research Areas

Experimental High-Energy Physics

The Stony Brook group has been in the forefront of high-energy research at many premier facilities in the United States, Europe, and Japan. A large effort is based on the Dfl experiment at the Fermilab collider, currently the highest energy accelerator in the world. The detector has been upgraded to seek new understanding of the top quark, to explore the mechanism of electroweak symmetry breaking and search for the Higgs boson, to study CP violation and mixing in the b quark system, to probe the strong QCD force in new regions, and to seek new phenomena such as supersymmetry or extra spatial dimensions. The group is also participating in the ATLAS experiment at the CERN Large Hadron Collider, expected to begin in 2008, and has built components of its calorimeter and event selection electronics. Our proximity to BNL continues to provide fruitful opportunities for research. We are working to develop a 500 GeV e+e- linear collider at a site to be determined.

The Stony Brook Nucleon Decay and Neutrino group is involved in the Super-Kamiokande, the K2K and the T2K experiments in Japan. The Super-Kamiokande detector, located deep underground in western Japan, detects neutrinos from the sun and neutrinos produced in the upper atmosphere. In 1998, the experiment discovered neutrino oscillations in the atmospheric neutrino data with a far-reaching impact in elementary particle physics. The experiment also aims to detect neutrinos from super-nova bursts. It is sensitive to a host of possible proton decay signals and has set the world's best limits on the proton decay. The K2K experiment is the first successful long baseline neutrino oscillation experiment which confirmed the discovery made by the Super-Kamiokande experiment on neutrino oscillation and refined the measurement of the neutrino mixing using accelerator-generated neutrino beams. Neutrinos were generated at the KEK laboratory on the East Coast of Japan 250 km from Super-Kamiokande and sent to the Super-Kamiokande detector. The T2K experiment is an extension of this program which will use neutrinos generated by the new JPARC accelerator. It is the first approved experiment in the world to specifically look for electron neutrino appearance from muon neutrinos, which will allow us to measure 1st and 3rd generation mixing. The group is also leading an effort to build a next-generation underground neutrino detector, UNO, in the Henderson Mine in Empire, Colorado.

The MARIACHI (Mixed Apparatus for Radar Investigation of Cosmic-rays of High Ionization) project, developed by physicists and high school teachers, utilizes an innovative technique—radar reflection from ionization—to detect and study ultra high-energy cosmic rays. MARIACHI integrates outreach education with science and involves a diverse group of scientists, educators, and students in its implementation. The scientific scope of MARIACHI includes the study of meteors, lightning, and atmospheric phenomena that can be concurrently detected and recorded by their radar reflections.

Experimental Nuclear Physics

The Stony Brook Relativistic Heavy Ion Group studies collisions of large nuclei at the highest available energies, with the intent of elucidating the properties of the quark-gluon plasma, a state in which quarks and gluons become deconfined. The group is one of the founders of the PHENIX experiment at BNL Relativistic Heavy Ion Collider. They are among the leading institutions in PHENIX having taken responsibility for the design and construction of the focal plane of the Ring-Imaging Cherenkov detector, the electronics and mechanics of the PHENIX drift chambers, the tracking software, and leadership of the overall analysis efforts of PHENIX data. This fruitful program has included the first observations of jet quenching phenomena and excess nucleon yield at high transverse momentum, both discovered by the Stony Brook group's analysis of the PHENIX data. The group has also taken on the leadership role in the upgrade of PHENIX for second-generation RHIC measurements. A new effort to understand the composition of nucleon spin was launched in 2004, and the first results on the role of the gluons in the nucleon's spin, obtained from polarized proton collisions, have been published recently. The expected large increase in polarized proton luminosity, along with the introduction of precision silicon vertex detectors for heavy quark physics (currently under development by the group) will enable the group to address many interesting questions in the field of nucleon spin in the coming years. Members of the spin group play leadership roles in all aspects of the spin physics at RHIC, and in the planning of the new Electron Ion Collider, currently under consideration by the U.S. nuclear physics community.

Optical Sciences

The optical sciences are among the most dynamic areas of physics with an impact on contemporary life that will continue to grow. Organized as an optics consortium, several groups in the Department share an interest in optics and offer research opportunities in atomic molecular and optical physics, physics of optoelectronic materials, and X-ray optics and microscopy. The Laser Teaching Center is a focus for the activities of many student research projects.

Atomic, Molecular, and Optical Physics and Quantum Electronics

Atomic, molecular, and optical physics and quantum electronics experimental and theoretical studies focus on the interaction of light and matter under widely different circumstances. We are exploring new topics in optical manipulation of atoms both in the quantum (deBroglie) and the classical domains. We can exert huge optical forces with non-monochromatic light, create electrostatic forces on Rydberg atoms, and produce delicate momentum changes with Raman transitions. We explore dark state physics, coherent control of momentum exchange between atoms and light fields, and entanglement between orthogonal spaces. The boundary between quantal and classical physics is especially interesting when the latter is chaotic. Some experiments have focused on hydrogen atoms excited with energetic collisions and lasers into highly excited states being driven by one or more carefully controlled microwave fields strong enough to cause ionization. In other experiments that use microwaves, carefully built macroscopic resonators are mathematically equivalent to certain mesoscopic systems of interest in low-temperature condensed-matter systems. Our recent experiments have focused on so-called *ray-splitting* phenomena. Modern laser technology allows pulses that are short compared to molecular vibrational periods, so by careful choice of their spectral content and phases, quantum chemistry can be controlled. The process exploits learning and genetic algorithms that control the behavior of fast modulators through sophisticated computing systems. Theoretical studies of Bose Einstein condensates (BEC) probe interesting new regimes of many-body physics. A new laboratory now taking shape has produced BECs and will explore BECs and correlated motion of atoms in optical lattices.

Experimental Condensed Mesoscopic, Nanoscale, and Device Physics

The Department is active in several key areas of mesoscopic, nanoscale, and solid-state device physics, including quantum computing, single-electronics, molecular electronics, and nanoscale transistors. We have developed novel ultrafast superconducting digital devices and integrated circuits based on magnetic flux quantization, and single-electronic devices using ultra-small tunnel junctions with dimensions down to 30 nm. There is also an active program in solid-state and low-temperature physics. Areas of study include semiconductors, fullerenes, phase transitions in two-dimensional solids, integer and fractional quantum Hall effect, Wigner crystallization of the two-dimensional electron gas in semiconductor heterostructures, electronic properties of electron-hole systems, and electro-optic effects in quantum wells and superlattices. There is also a project to develop self-wiring "neuromorphic" computer architectures using a hybrid of 50nm lithographic crossbars and molecular conductors as active circuit elements. Projects at the National Synchrotron Light Source at BNL include powder diffraction studies on a wide range of materials (ranging from malaria pigment to intercalated fullerenes) and exploring new methods of electron spin resonance by using the far-infrared synchrotron light and superconducting magnets. A wide variety of modern techniques for fabrication of samples is employed including molecular beam epitaxy, deposition of thin films by resistive and electron-gun evaporation and magnetron sputtering, and patterning of thin-film structures using optical lithography and direct electron-beam writing.

X-Ray Physics

X rays have a wavelength short enough that one can produce a high-resolution focus and probe the structure of materials at the atomic scale. The X-ray Optics and Microscopy group carries out research in developing high resolution X-ray optics (in partnership with the Center for Functional Nanomaterials at BNL), and using these optics for soft X-ray microscopy and spectroscopy studies of problems in biology and in environmental science (the latter as part of a Center for Environmental Molecular Science at Stony Brook). The group is also developing X-ray imaging beyond the resolution limit of lenses by reconstructing diffraction data from non-crystalline specimens. Our research primarily makes use of the National Synchrotron Light Source at BNL, but also synchrotron sources at Argonne National Laboratory and Lawrence Berkeley National Laboratory.

Atmospheric Research

Atmospheric research may be carried out within the Department and also with faculty in the Institute for Terrestrial and Planetary Atmospheres (ITPA). Our ground-based research based on measurements of stratospheric trace gases led to the first proof that the Antarctic "ozone hole" is caused by stratospheric contamination from man-made chlorofluorocarbons. Stratospheric dynamics can be studied by measuring the behavior of various inert tracers of transport, and chemistry-driven effects are studied by quantitative measurement of various species and their temporal and spatial evolution. Research in the ITPA includes advanced computer modeling or direct field studies of the chemistry and the large scale and mesoscale dynamics of atmospheres, including radiative transfer through atmospheres (the "greenhouse effect" and related phenomena), the atmospheric-ocean interchange, and the use of isotopic composition to characterize and monitor natural and anthropogenic trace gas sources and sinks in the earth's atmosphere. Close interaction of students in the department with faculty of the ITPA offers a way to participate actively in finding solutions to global-scale atmospheric-environmental problems facing the world in the 21st century. The Department of Environmental Sciences at BNL offers further opportunities for instrumentation development and laboratory and field studies of atmospheric dynamics and related topics.

Yang Institute for Theoretical Physics

Research at the C.N. Yang Institute for Theoretical Physics addresses varied topics of fundamental interest. The Institute provides students of the Department the opportunity to carry on collaborative and independent research in a wide range of areas in theoretical physics.

The currently known forces and particles of high-energy physics are referred to as the standard model, including electroweak interactions and the theory of the strong interactions, quantum chromodynamics (QCD). The leading questions of high-energy and elementary particle physics emerge from unanswered questions raised by the standard model. Among these are the origins of electroweak symmetry breaking and of the patterns of particle masses. QCD is a unique testing ground for quantum field theory because of its highly energy-dependent interactions. Recent and ongoing studies in particle physics include detailed phenomenological calculations and analyses of high-energy scattering experiments, and the development of improved theoretical methods for both quantum QCD (including nuclear scattering) and electroweak interactions. There is a tradition in the study of neutrinos, now including analyses of masses and mixing in the light of contemporary data.

Quantum field and string theories supply a language for the description of matter on the smallest scales. Supersymmetric and other field theoretic extensions of the standard model, supergravity (which was discovered at Stony Brook), and string theories are being studied and developed, with attention to both their mathematical structures and physical consequences. Of special interest are quantum mechanical descriptions of gravitation and its relations to other forces. Other directions of research involve the complementary descriptions of theories with weak and strong interactions, relying on modern techniques in mathematics, statistical mechanics, including exactly solvable models and quantum computing. Progress in statistical mechanics, string and field theory is facilitated by the many physical concepts and mathematical methods that they share.

The broad range of topics and interests represented at the YITP encourages fruitful interactions with the nuclear and condensed matter theory groups, the high-energy and nuclear experimental groups, and other groups in the Departments of Physics and Astronomy, Mathematics, and Applied Mathematics.

Nuclear Theory

Traditionally, nuclear theory was limited to the study of properties of nuclei. However, in the past decade this field has broadened into the study of strong interactions in general with applications to a wide range of phenomena such as relativistic heavy ion collisions, the properties of hadrons, and the interior of neutron stars. The primary goal of nuclear theory is to understand strong interactions starting from quantum chromodynamics (QCD), the underlying microscopic theory. We address this problem in two different ways. First, to make contact with experiment, we construct and analyze phenomenological models. We investigate effective theories for the description of hadrons at low energy; have understood the pion wind in relativistic heavy ion collisions in terms of relativistic hydrodynamics; are world experts in many body theory, which relates the properties of nuclei to the nucleon-nucleon interaction; and apply our insights to problems in astrophysics such as the structure of the interior of neutron stars and the formation of black holes. Second, we analyze QCD as a quantum field theory from different perspectives and under different and extreme conditions. We are particularly interested in nonperturbative phenomena and answer questions such as: Why do nucleons exist? What are the properties of the vacuum? What is the phase of QCD at high temperature and baryon density? What are the properties of the quark-gluon plasma that might be observed in high-energy nuclear collisions? Is QCD at high baryon density superconducting? The methods we use to answer these questions are from many areas of quantum field theory and statistical mechanics. Examples include the analysis of the statistical mechanics of instantons, development of a semiclassical theory of high-energy scattering, interpretation of gauge field fluctuations in terms of random matrix theory, and finite temperature quantum field theory. Our work has both benefited from and influenced large-scale Monte-Carlo simulations of lattice QCD by groups around the world.

Condensed Matter Theory and Statistical Mechanics

In the last decade, new conceptual and computational tools have led to major changes in our understanding of condensed matter systems. Recent work at Stony Brook has focuses on quantum mechanical effects (i.e., superconductivity) on a macroscopic scale, quantum computing, collective phenomena in low-dimensional solids (i.e., high-temperature superconductors), the quantum Hall effect, properties of mesoscopic metals such as correlated tunneling and single-electron charging effects, and properties of nanoscale matter such as electronic properties of nanowires, single-molecule electronics, and solar energy applications. Computer simulation of solids and liquids (including problems involving interfaces, surfaces, amorphous states, nanocrystals and molecules) is being performed with density-functional theory and other theoretical methods using both a local, dedicated computer cluster and the new IBM BlueGene/L supercomputer. In statistical mechanics there is very active research into one- and two-dimensional systems where exact mathematical calculations can be made. These include studies of phase transitions, solitons, and spin diffusion. The effort spans the range from quantum field theory to computer studies.

Accelerator and Beam Physics

Research in accelerator physics is being carried out at Stony Brook and in several departments at nearby Brookhaven National Laboratory. The research covers theoretical and experimental aspects of circular and linear accelerators as well as interaction of particle beams with electromagnetic radiation, including free electron lasers. The experimental facilities include the BNL Alternating Gradient Synchrotron, the National Synchrotron Light Source, and the Relativistic Heavy-Ion Collider, also with work on radio-frequency superconducting accelerators and energy recovery linacs. Research is also being conducted on facilities such as the high-brightness Accelerator Test Facility, including investigations in high-gradient acceleration, generation of high-brightness beams, and free-electron lasers. Ph.D. and M.S.I. research at BNL may be arranged through the Center for Accelerator Physics.

Astronomy and Astrophysics

Cosmology and Extragalactic Astronomy

The cosmological and extragalactic effort combines theoretical and observational research to understand galaxy formation and evolution, and the development of large-scale structure in the universe. Theoretical efforts are aimed at interpreting the density structures uncovered by redshift surveys and have resulted in the determination of the gravitational field out to 0.5 billion light years. N-body hydrodynamics simulations of the large-scale structure are compared to the fast-growing body of data of large-scale field flows and the cosmic background radiation. Our observational efforts have focused on quasar absorption lines, which have revealed extensive galactic halos, and on the Hubble Deep field, in which the most distant objects in the universe have been found.

Millimeter Wave Astronomy and Interstellar Molecular Clouds

Stony Brook is involved in millimeter CO surveys in the galactic plane; in 1977 these first revealed the existence of giant molecular clouds. Current research focuses on determining the star formation rates in these clouds and producing high-resolution maps of the star-forming cores, and uses both infrared and millimeter wave observatories, including IRAS and the IRAM 30-meter antenna, the world's most powerful millimeter wave antenna. Extragalactic mapping of interstellar molecules like CO and CS is performed to understand the role played by giant molecular clouds in star formation and the evolution of spiral galaxies. Recently, CS emission has been detected in the luminous infrared galaxy Arp220, indicating the existence of 10 billion solar masses of dense molecular gas and extensive star formation. Mappings are also used to understand the effects of galaxy collisions on star formation and the starburst phenomenon.

Nuclear Astrophysics

Nuclear astrophysics research focuses on thermonuclear and core-collapse supernovae, neutron stars, and X-ray bursts, on the physics of dense matter, and on the development and verification and validation of algorithms for modeling these systems. Numerical simulations of these explosive events are carried out with grant support from DOE and using DOE and NASA supercomputing facilities nationwide. This work continues a long tradition of computational astrophysics at Stony Brook, including the modeling of supernovae and proto-neutron stars spectacularly confirmed by neutrino observations from 5N1987A. Other active areas of research are neutron star structure and cooling, including the effects of composition and superfluidity, and compact object mergers. Models for the dense matter equation of state developed by Stony Brook are used worldwide.

Astronomers at Stony Brook have discovered a nearby neutron star and measured its distance, temperature, and age. A major goal is to determine the radii of neutron stars combining calculations of neutron star atmospheres (employing various compositions and magnetic fields) with optical and X-ray observations (from Hubble, CHANDRA, XMM, and other instruments) of this and other neutron stars.

Modeling of thermonuclear explosions, including Type Ia supernovae and X-ray bursts, is also a major topic of research. Both the early stages and the explosion itself are being investigated with a range of simulation codes developed by Stony Brook astrophysicists in association with researchers at DOE labs and other universities. Due to the complexity of the algorithms used in our research, verification and validation of our simulation codes is also an active area of research. This process is done in participation with collaborations at the DOE labs.

Star Formation and Stellar Astronomy

Star formation research focuses on low-mass pre-main sequence (PMS) evolution and the true initial mass function. This research has demonstrated that most PMS stars are not T-Tauri objects and also that most are in binary systems. We study the early evolution of PMS stars, measure their masses, and probe the structure and composition of their circumstellar disks using state-of-the-art optical, infrared, and millimeter-wave techniques from the ground and space. We participate in a space interferometry project to study the earliest epochs of planet formation. We are actively investigating the environments of the pre-main sequence stars, using CHANDRA and XMM, to study the 10^7 K coronal gas, and using FUSE and the Hubble Space Telescope to study the stellar chromospheres, the accretion process, and circumstellar molecular hydrogen. We also study the outer atmospheres and the coronal and chromospheric activity of older cool stars using optical, ultraviolet, and X-ray spectra obtained from the ground and space observatories.

Doctoral Programs with Concentrations in Biophysics and Chemical Physics

The Department of Physics and Astronomy participates in two Ph.D. curricula in cooperation with other programs. The basic degree requirements for a student enrolled in one of these programs are the same as those for other students in physics. He or she will usually be advised to take one or more courses in the cooperating program. The written part of the preliminary (comprehensive) examination is the same as for other physics students; the oral part will ordinarily be on topics in biophysics or chemical physics. Subject to the approval of the chairs of the two programs involved, the student's research advisor may be chosen from participating members of the cooperating programs.

A student in one of these programs who expects to receive a Ph.D. from a cooperating program should consult that program's section in this bulletin for degree requirements. The cooperating programs are Biophysics: Department of Pharmacological Sciences and Department of Physiology and Biophysics; and Chemical Physics: Department of Chemistry.

Admission

For admission to graduate study in Physics and Astronomy the following, in addition to the minimum Graduate School requirements, are required:

A. A bachelor's degree in physics or a closely related field from an accredited institution;

B. A minimum grade average of B in all undergraduate coursework, and B or better in the sciences and mathematics;

C. Submission of the Graduate Record Examination (GRE) General Test (the Physics GRE subject test is also recommended);

D. Admission by the Department of Physics and Astronomy and the Graduate School.

In special cases, a student not meeting requirement A (or, in unusual cases, requirement B) may be admitted on a provisional basis, without financial support. Upon admission, the student will be informed of the requirements that must be satisfied for termination of provisional status.

Retention of students in subsequent years will depend on satisfactory academic progress.

Faculty

Einstein Professor

Yang, Chen Ning,[1] *Emeritus,* Ph.D., 1948, University of Chicago: Theoretical physics; field theory; statistical mechanics; particle physics.

University Professor

Marburger, John H., *Science Advisor to the President and Director of the Office of Science and Technology Policy,* Ph.D., 1966, Stanford University: Laser theory.

Distinguished Professors

Brown, Gerald E., Ph.D., 1950, Yale University: Theoretical physics; the many-body problem.

Grannis, Paul D., *Emeritus*, Ph.D., 1965, University of California, Berkeley: Experimental high-energy physics.

Jacak, Barbara, *Spokesperson of the PHENIX Collaboration since 2006*, Ph.D., 1984, Michigan State University: Experimental nuclear physics; relativistic heavy ions.

Kirz, Janos, *Emeritus*, Ph.D., 1963, University of California, Berkeley: X-ray optics and microscopy; synchrotron radiation.

Likharev, Kostantine K., Ph.D., 1979, Moscow State University, Russia: Mesoscopic physics.

McCoy, Barry M.,[1] Ph.D., 1967, Harvard University: Theoretical physics; statistical mechanics.

Shuryak, Edward, Ph.D., 1974, Institute of Nuclear Physics, Novosibirsk, Russia: Theoretical nuclear physics.

Sprouse, Gene D., *Editor in Chief, American Physical Society*, Ph.D., 1968, Stanford University: Atomic and nuclear spectroscopy with trapped radioactive atoms.

Sterman, George,[1] *Director of Yang Institute for Theoretical Physics*, Ph.D., 1974, University of Maryland: Theoretical physics.

Van Nieuwenhuizen, Peter,[1] Ph.D., 1971, University of Utrecht, Netherlands: Theoretical physics; quantum field theory.

Distinguished Service Professor

Paul, Peter, *Emeritus*, Ph.D., 1959, University of Freiburg, Germany: Experimental nuclear physics.

Distinguished Teaching Professors

Hemmick, Thomas, Ph.D., 1989, University of Rochester: Experimental nuclear physics; relativistic heavy ions.

Metcalf, Harold J., Ph.D., 1967, Brown University: Atomic physics; laser cooling and trapping; atom optics; precision stark spectroscopy; lasers and optics.

Professors

Allen, Philip B. Ph.D., 1969, University of California, Berkeley: Theoretical condensed matter physics.

Aronson, Meigan, Ph.D., 1988, University of Illinois at Urbana: Experimental condensed matter.

Averin, Dmitrii V., Ph.D., 1987, Moscow State University, Russia: Theoretical condensed matter physics.

Courant, Ernest D.,[1] *Emeritus,* Ph.D., 1943, University of Rochester: Theoretical physics; high-energy accelerator design.

DeZafra, Robert L., *Emeritus,* Ph.D., 1958, University of Maryland: Atmospheric sciences; remote sensing, stratospheric dynamics, and trace constituent measurements; millimeter-wave spectroscopy.

Drees, Klaus Axel, Ph.D., 1989, University of Heidelberg, Germany: Experimental nuclear physics; relativistic heavy ions.

Engelmann, Roderich, Ph.D., 1966, University of Heidelberg, Germany: Experimental high-energy physics.

Feingold, Arnold, *Emeritus,* Ph.D., 1952, Princeton University: Theoretical nuclear physics.

Finocchiaro, Guido, *Emeritus,* Ph.D., 1957, University of Catania, Italy: Experimental high-energy physics.

Goldhaber, Alfred S.,[1] Ph.D., 1964, Princeton University: Theoretical physics; nuclear theory; particle physics.

Goldman, Vladimir J., Ph.D., 1985, University of Maryland: Experimental condensed matter physics.

Gurvitch, Michael, Ph.D., 1978, Stony Brook University: Experimental condensed matter physics.

Jacobsen, Chris, *Undergraduate Program Director,* Ph.D., 1988, Stony Brook University: X-ray microscopy and holography.

Jung, Chang Kee, Ph.D., 1986, Indiana University: Experimental high-energy physics.

Kahn, Peter B., *Emeritus,* Ph.D., 1960, Northwestern University: Theoretical physics; nonlinear dynamics.

Koch, Peter M., *Chair*, Ph.D., 1974, Yale University: Experimental atomic physics; quantum chaos; nonlinear dynamics.

Korepin, Vladimir,[1] Ph.D., 1977, Leningrad University, Russia: Theoretical physics.

Kuo, Thomas T.S., Ph.D., 1964, University of Pittsburgh: Nuclear theory.

Lanzetta, Kenneth M., Ph.D., 1988, University of Pittsburgh: Formation and evolution of galaxies; evolution of the intergalactic medium.

Lattimer, James M., Ph.D., 1976, University of Texas: Nuclear, nutrino, and high-energy astrophysics; supernovae, neutron stars, dense matter; grain formation; isotopic anomalies in meteorites.

Lee, Linwood L., *Emeritus,* Ph.D., 1955, Yale University: Experimental nuclear physics.

Lukens, James, Ph.D., 1968, University of California, San Diego: Experimental condensed matter physics.

Marx, Michael D., Ph.D., 1974, Massachusetts Institute of Technology: Experimental high-energy physics.

McCarthy, Robert L., Ph.D., 1971, University of California, Berkeley: Experimental high-energy physics.

McGrath, Robert L., *Vice President for Brookhaven Affairs,* Ph.D., 1965, University of Iowa: Experimental nuclear physics.

Mendez, Emilio E., *Director, Center for Functional Nanomaterials, BNL.*, Ph.D., 1979, Massachusetts Institute of Technology: Experimental condensed matter physics.

Mihaly, Laszlo, *Graduate Program Director*, Ph.D., 1977, Eotvos Lorand University, Budapest, Hungary: Experimental condensed matter physics.

Rijssenbeek, Michael, Ph.D., 1979, University of Amsterdam, Netherlands: Experimental high-energy physics.

Rocek, Martin,[1] Ph.D., 1979, Harvard University: Theoretical physics: supersymmetry and supergravity.

Shrock, Robert,[1] Ph.D., 1975, Princeton University: Theoretical physics; gauge theories; statistical mechanics.

Siegel, Warren,[1] Ph.D., 1977, University of California, Berkeley: Theoretical physics; strings.

Simon, Michal, Ph.D., 1967, Cornell University: Infrared astronomy; physics of the interstellar medium; star formation; solar astronomy.

Smith, John,[1] Ph.D., 1963, University of Edinburgh, Scotland: Theoretical physics; elementary particle physics.

Stephens, Peter W., Ph.D., 1978, Massachusetts Institute of Technology: Experimental condensed matter physics.

Swartz, Clifford E., *Emeritus,* Ph.D., 1951, University of Rochester: Experimental high-energy physics; school curriculum revision.

Verbaarschot, Jac, Ph.D., 1982, University of Utrecht, Netherlands: Theoretical nuclear physics.

Walter, Fredrick M., Ph.D., 1981, University of California, Berkeley: Stellar astrophysics, including X-ray optical and infrared photometry and spectroscopy; RS CV objects; pre-main sequence objects.

Weisberger, William,[1] *Emeritus*, Ph.D., 1961, MIT: Theoretical physics.

Yahil, Amos, Ph.D., 1970, California Institute of Technology: Galaxies; clusters of galaxies; physical cosmology; accretion processes; stellar collapse; supernovae; nuclear astrophysics.

Zahed, Ismail, Ph.D., 1983, Massachusetts Institute of Technology: Theoretical nuclear physics.

Associate Professors

Abanov, Alexander, Ph.D., 1997, University of Chicago: Theoretical condensed matter physics.

Evans, Aaron, Ph.D., 1996, University of Hawaii: Near-infrared and millimeter-wave astronomy; evolution and collisions of galaxies.

Gonzalez-Garcia,[1] Concha, Ph.D., 1991, Universidad de Valencia, Spain: Theoretical elementary particle physics.

Graf, Erlend H., Ph.D., 1967, Cornell University: Experimental low-temperature physics.

Hobbs, John, Ph.D., 1991, University of Chicago: Experimental high-energy physics.

McGrew, Clark, Ph.D., 1994, University of California Irvine: Experimental high-energy physics.

Mould, Richard A., *Emeritus,* Ph.D., 1957, Yale University: Theoretical physics; general relativity; quantum theory of measurements.

Peterson, Deane M., Ph.D., 1968, Harvard University: Stellar atmospheres; radiative transfer; optical interferometry; stellar imaging.

Assistant Professors

Calder, Alan, Ph.D., 1997, Vanderbilt University: Observational astronomy.

Dawber, Matthew, Ph.D., 2003, Cambridge University: Experimental condensed matter physics.

Deshpande, Abhay, Ph.D., 1995, Yale University: Nucleon spin and heavy ion physics.

Durst, Adam, Ph.D., 2002, Massachusetts Institute of Technology: Theoretical condensed matter physics.

Fernandez-Serra, Maria, Ph.D., 2005, Cambridge University: Theoretical condensed matter physics.

Perez, Gilad,[1] Ph.D., 2003, Weizmann Institute of Science: Theoretical physics.

Rastelli, Leonardo,[1] Ph.D., 2000, Massachusetts Institute of Technology: String theory.

Schneble, Dominik A, Ph.D., 2002, University of Konstanz: Experimental atomic physics; ultracold quantum gases.

Teaney, Derek, Ph.D., 2001, Stony Brook University: Nuclear theory.

Weinacht, Thomas, Ph.D., 2000, University of Michigan: Quantum optics and atomic physics.

Zingale, Michael A., Ph.D., 2000, University of Chicago: Computational astrophysics.

Research Faculty

Patel, Vijay, Ph.D., 2001 Stony Brook University: Experimental condensed matter physics.

Semenov, Vasili, Ph.D., 1975, Moscow State University, Russia: Experimental condensed matter physics.

Swesty, Douglas F., Ph.D., 1993, Stony Brook University: Computational and nuclear astrophysics.

Yanagisawa, Chiaki, Ph.D., 1981, University of Tokyo, Japan: Experimental high-energy physics.

Adjunct Faculty

Abbamonte, Peter, Ph.D., 1999, University of Illinois: Condensed matter physics.

Aronson, Samuel, *Director of Brookhaven National Laboratory*, Ph.D, 1968, Princeton University: Experimental nuclear physics.

Ben-Zvi, Ilan, Ph.D., 1967, Weizmann Institute, Israel: Accelerator and beam physics.

Bergeman, Thomas, Ph.D., 1971, Harvard University: Theoretical atomic physics; interaction of light and matter; laser cooling; Bose condensation.

Creutz, Michael,[1] Ph.D., 1970, Stanford University: Lattice gauge theory.

Davenport, James, Ph.D., 1976, University of Pennsylvania: Theoretical condensed matter physics.

Dawson, Sally,[1] Ph.D., 1981, Harvard University: High-energy theory.

Dierker, Steven, Ph.D., 1983, University of Illinois: Experimental solid state physics.

DiMauro, Louis, Ph.D., Experimental atomic physics.

Forman, Miriam, Ph.D., 1972, Stony Brook University: Cosmic rays.

Geller, Marvin, Ph.D., 1969, Massachusetts Institute of Technology: Atmospheric physics.

Johnson, Peter, Ph.D., 1978, Warwick University: Experimental solid state physics.

Kao, Chi-Chang, Ph.D., 1988, Cornell University: Condensed matter physics.

Ku, Wei, Ph.D., 2000, University of Tennessee: Theoretical condensed matter physics.

Lee-Franzini, Juliet, Ph.D., 1960, Columbia University: Experimental high-energy physics.

Litvinenko, Vladimir, Ph.D., 1989, Institute of Nuclear Physics, Novosibirsk, Russia: Accelerator physics and free electron lasers.

Maslov, Sergei, Ph.D., 1996, Stony Brook University: Theoretical condensed matter physics.

Peggs, Steven, Ph.D., 1981, Cornell University: Accelerator physics.

Sayre, David, Ph.D., 1951, Oxford University: X-ray physics.

Sivaramakrishnan, Anand, Ph.D., 1983, University of Texas at Austin: Astronomical adaptive optics.

Spira, Robert, Physics high school teacher.

Svoboda, Karel, Ph.D., 1994, Harvard University: Experimental biophysics.

Takai, Helio, Ph.D., 1986, Rio de Janeiro: Experimental particle and heavy ion physics.

Tolpygo, Sergei, Ph.D., 1984, Institute of Solid State Physics of the Russian Academy of Sciences: Mesoscopic physics.

Tsvelik, Alexei, Ph.D., 1980, Kurchatov Institute of Atomic Energy, Moscow, Russia: Theoretical condensed matter physics.

Vogelsang, Werner,[1] Ph.D., 1993, University of Dortmund: Theory YITP.

Zhu, Yimei, Ph.D., 1987, Nagoya University: Condensed matter physics.

Affiliated Faculty

Wang, Jin, Ph.D., 1991, University of Illinois, Biology of physics.

Number of teaching, graduate, and research assistants, Fall 2007: 183

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[1] Member, C.N. Yang Institute for Theoretical Physics

Degree Requirements

Requirements for the M.A. Degree in Physics

A. Satisfactory performance in a program of studies (30 graduate credits) approved by the Department; normally such a program would include graduate seminars, classical mechanics, electrodynamics, and quantum mechanics;

B. Minimum grade point average of 3.0 in all graduate courses taken at Stony Brook;

C. Either passing the graduate comprehensive examination at the master's level or completion of a master's project.

Requirements for the M.S. Degree with Specialization in Scientific Instrumentation (MSI)

A candidate for the master's degree with concentration in instrumentation will be required to demonstrate a certain level of knowledge of physics (by written and/or oral examination), to take certain required and elective courses, and to complete both a major and minor project. The curriculum is designed to meet the needs of students learning about the design, construction, and testing of sophisticated instrument systems. The degree holder will not be a super-technician but a professional scientist trained in both physics and measurement techniques.

A. A student shall demonstrate proficiency in undergraduate physics at the level of the courses PHY 335 (Junior Laboratory I) and 405 (Advanced Quantum Physics). Students need to have demonstrated knowledge in two of three areas: Nuclear and Particle Physics (covered in PHY 431), Condensed Matter Physics (PHY 472), or Laser and Atomic Physics (PHY 452). This can be done (1) by acceptance by the Master's in Scientific Instrumentation Committee of courses taken as an undergraduate, (2) by written examination, or (3) by passing the courses appropriate to a student's background;

B. A course about research instrumentation (PHY 514);

C. Two semesters each of graduate lab (PHY 515, 516) and graduate seminar (PHY 598, 599);

D. Students shall work as teaching assistants in an undergraduate laboratory for at least one semester (being a TA in PHY 445 may satisfy the requirement of taking the second semester of graduate lab [PHY 516]);

E. Thirty credits (minimum) of graduate courses (500 level or above), including a minor project and a master's thesis are required. This thesis must describe a major piece of work in scientific instrumentation and must be in a form acceptable to the Graduate School. It need not be original research in the same sense as a Ph.D. thesis, but it should be the result of an effort consistent with a full year of full-time work. The thesis should present an improvement of the state of the art in some area, the development of a sophisticated and/or automated apparatus, or some other significant laboratory project, and be defended before a committee;

F. Students shall work as teaching assistants in an undergraduate laboratory for at least one semester;

G. Students shall acquire those technical skills deemed necessary by their thesis supervisors. These must include, but are not limited to, machining capability and computer literacy.

Each student will be assigned a committee of three faculty members and will be required to meet frequently with them. It is expected that close communication among all the faculty and students involved will foster spirit, expose problems, and generally contribute to success.

For further information on this program, contact Professor Harold Metcalf.

Requirements for the Ph.D. Degree

A. Completion of the following core courses with a grade of B or better: 501, 505, 506, 511, 512, 540. A student can skip one or more of these courses by sufficiently good performance in the corresponding parts of a placement examination given at the beginning of each fall semester;

B. Completion of required courses; each of the courses listed below must be passed with a minimum grade of B:

1. PHY 598 and PHY 599 Graduate Seminars. These courses are normally taken during the first year of graduate study, one per semester in either order.

2. PHY 515 Methods of Experimental

Research. This course must be taken not later than the fourth semester of residence.

3. Two advanced courses, each in an area outside that of the student's thesis research, chosen from a list of courses approved for this purpose.

C. Passing of the written comprehensive examination. This is offered at the beginning of each semester and generally draws from courses beyond the core listed in paragraph A above. It must be passed in the student's fourth semester of study at Stony Brook or earlier;

D. Passing an oral examination on a broad range of topics relevant to the student's intended area of thesis research. The oral examination should be passed before the beginning of the fifth semester of residency.

E. Acceptance of graduate student by an advisor for thesis work;

F. Teaching experience at least equivalent to that obtained in a one-year appointment as a teaching assistant, usually carried out in the first year;

G. Advancement to candidacy for the Ph.D. The Department's recommendation to the Graduate School for advancement to candidacy is based on the satisfactory completion of all requirements listed above;

H. Research, dissertation, and passing the dissertation examination;

I. At least one year of residence.

Courses

PHY 501 Classical Mechanics

Analytical classical mechanics including Lagrangian and Hamiltonian formulations and the Hamilton-Jacoby theory. Variational principles, symmetries, and conservative laws. Selected advanced problems such as parametric and nonlinear oscillations, planetary motion, classical theory of scattering, rigid body rotation, and deterministic chaos. Basic notions of elasticity theory and fluid dynamics.
Fall, 3 credits, ABCF grading

PHY 503 Methods of Mathematical Physics I

A selection of mathematical techniques useful for physicists. Topics are selected from: linear algebra, complex variables, differential equations, asymptotic analysis, special functions, boundary value problems, integral transforms, perturbation theory as applied to linear and nonlinear systems. This course should be taken by entering graduate students seeking enrichment in these areas.
Fall and spring, 3 credits, ABCF grading

PHY 504 Methods of Mathematical Physics II

A selection of advanced mathematical techniques useful for physicists. Topics are selected from: integral equations, group theory, conformal field theory, advanced statistics, stochastic methods, modern geometry, topology, Green functions, variational calculus. This course is offered to graduate students with special interest in mathematical methods.
Fall and spring, 3 credits, ABCF grading

PHY 505 Classical Electrodynamics I

First course in a two-part sequence. Electrostatics and magneostatics in vacuum and matter; electromagnetic induction, Maxwell's equations and gauge invariance; electromagnetic waves. Additional topics as time permits. Vector analysis, eigenfunction expansions, and Green functions will be introduced and used.
Fall, 3 credits, ABCF grading

PHY 506 Classical Electrodynamics II

Second course in a two-part sequence. Maxwell's equations are applied to electromagnetic waves in materials and at interfaces between media. Electromagnetic radiation by moving charges. Special relativity. Additional topics as time permits.
Spring, 3 credits, ABCF grading

PHY 510 Introduction to Nonlinear Dynamics

This course concentrates on developing the tools used to analyze models of dynamical systems associated with physical phenomena, such as coupled electrical mechanical, chemical, and biological oscillators, amplitude equations, symplectic maps, etc. There is a discussion of the basic theorems, as well as methods used to derive perturbation solutions for differential equations and maps using the method of normal forms.
Fall or spring, 3 credits, ABCF grading

PHY 511 Quantum Mechanics I

First course in a two-part sequence. Topics include basic quantum physics and mathematical apparatus; application to one-dimensional examples and simple systems. Symmetries, angular momentum, and spin. Additional topics as time permits.
Fall, 3 credits, ABCF grading

PHY 512 Quantum Mechanics II

Second course in a two-part sequence, covering variational principles, perturbation theory, relativistic quantum mechanics, quantization of the radiation field, many-body systems. Application to atoms, solids, nuclei and elementary particles, as time permits.
Spring, 3 credits, ABCF grading

PHY 514 Current Research Instruments

In a series of distinct units, various members of the experimental research faculty describe the nature of their work, explain the major principles of their laboratory instruments, discuss how these instrument systems function, and conduct tours of their laboratories showing the apparatus in action. The student becomes familiar with most of the experimental research instrumentation in the Department.
Fall or spring, 3 credits, S/U grading

PHY 515 Methods of Experimental Research I

An experimental course required for all graduate students. The goal of the course is to provide firsthand experience with the nature of experimental work. For students oriented toward theory, the course gives a background for reading and evaluating experimental papers. The course is based on classic measurements in nuclear, particle, atomic, condensed matter physics, and astronomy. Students can gain experience in handling cryogenic liquids, vacuum systems, lasers, pulse counting and coincidence methods, resonance measurements, and electronic instrumentation, such as lock-in amplifiers, particle detectors, coincidence counters, computer control, etc. Numerical analysis of data, presentation of results in written, graphic, and oral form, and meaningful comparison of experiments and theory are part of the course. Working alone or with, at most, one partner, each student must do one experiment from each of four different groups.
3 credits, ABCF grading
May be repeated for credit

PHY 517 Laboratory Course in Astronomical Techniques

A course designed to introduce the theory, design, and operation of modern astronomical instrumentation and to familiarize the student with the use of telescopes. Current astronomical techniques will be discussed with emphasis on methods of observational measurements and reduction of data. Emphasis is given on optical techniques appropriate for wavelengths shorter than one micron. Extensive laboratory and observing exercises may be expected.
Spring, alternate years, 3 credits,
ABCF grading

PHY 521 Stars

A study of the atmospheres, interiors, and evolution of stars. The contact between theory and observations is emphasized. Stellar atmospheres in hydrostatic and radiative equilibrium described. Models for the calculation of stellar spectra are discussed. Stellar winds are studied. Next, theoretical studies of stellar interiors and evolution, including equations of state, energy transport, and nuclear energy generation, are developed. Structures of main sequence, red giant, pre-main sequence, and white dwarves are studied and compared to observations. The evolution of single stars up to supernovae and the peculiar evolution of close binary systems are also studied.
Fall, alternate years, 0-3 credits,
ABCF grading

PHY 522 Interstellar Medium

A study of the interstellar medium with emphasis on physical processes. Topics include kinetic theory, equation of transfer, spectral lines, non-thermal emission, ionization effects of dust, and formation and spectroscopy of molecular clouds. The components of the interstellar medium and the interactions between them are discussed in detail, as well as the process of star formation.
Spring, alternate years, 0-3 credits,
ABCF grading

PHY 523 Galaxies
A basic course on the observational and theoretical aspects of the content, morphology, kinematics, and dynamics of galaxies. Topics include the size, shape, and location of the sun in the Milky Way; stellar populations; the disk and spheroidal components; galactic rotation; distance determination in the Milky Way and to external galaxies; galaxy classification and the Hubble Law. Theoretical topics center on stellar dynamics, including potential theory; stellar orbits; and spiral structure. The course also includes a brief introduction to cosmology.
Fall, alternate years, 0-3 credits,
ABCF grading

PHY 524 Cosmology
A basic course on cosmology: Hubble expansion, Friedmann universes, age of the universe, microwave background radiation, big-bang nucleosynthesis, inflation, growth of gravitational instabilities and galaxy formation, correlation functions, local density and velocity perturbations, and dark matter.
Prerequisite: PHY 523 or permission of instructor
Spring, alternate years, 0-3 credits,
ABCF grading

PHY 533 High Energy Astrophysics
Physical processes that occur at high temperatures and pressures, including X-ray and gamma ray emission, cosmic rays, bremsstrahlung, synchrotron, inverse Compton radiation, and gravitational radiation. Topics also include stellar and galactic accretion processes and jets, including relativistic effects and superluminal expansion. We discuss applications to stellar coronae, supernova remnants, X-ray binaries, pulsars, and compact extragalactic objects.
Fall or spring, alternate years, 0-3 credits,
ABCF grading

PHY 534 Radio Astronomy
Topics covered include continuum and spectral-line radio astronomy. Within the Milky Way Galaxy topics include the interstellar medium, the physics and kinematics of molecular clouds, star formation in giant molecular clouds, chemistry of molecular clouds, galactic structure, spiral structure, and pulsars. Extragalactic topics include radio galaxies and jets, radio loud quasars, molecular and atomic gas in galaxies, luminous infrared galaxies, the missing mass problem in spiral galaxies, and cosmic microwave background radiation. Radio astronomy measurement techniques for single telescopes and aperture synthesis techniques are also covered, although the emphasis is on scientific results.
Fall or spring, alternate years, 0-3 credits,
ABCF grading

PHY 540 Statistical Mechanics
Brief review of thermodynamics, principles of physical statistics, systems of non-interacting particles: Boltzmann, Fermi-Dirac, and Bose-Einstein statistics. Applications to ideal gases, electrons and phonons in solids, and black body radiation. Approximate treatment of non-ideal gases. First-order and second-order phase transitions. Ising model, transfer matrix, and renormalization group approach. Fluctuations in thermal equilibrium, fluctuation-dissipation theorem, brief review of non-equilibrium fluctuations. Basic notions of ergodicity, classical, and quantum chaos.
Spring, 0-3 credits, ABCF grading

PHY 541 Advanced Statistical Mechanics
Topics are selected from cluster expansions, elementary theory of quantum fluids, phase transitions, transfer matrix, Ising and ferroelectric models, polymers and membranes, disordered systems, and fluctuation and non-equilibrium phenomena.
Fall, 0-3 credits, ABCF grading

PHY 551 Nuclear Physics I
Nucleon structure, conservation laws, and the static quark model; nuclear force and the two nucleon system; bulk properties of nuclear matter, charge distribution, spin, isospin, mass, alpha decay, nuclear fission; electromagnetic and weak interaction; collective motion; microscopic models of the nucleus; nuclear matter under extreme conditions, high rotational states, heavy ion physics at RHIC, nuclear astrophysics.
Summer, 0-3 credits, ABCF grading

PHY 552 Nuclear Physics II
Nucleon-nucleon scattering and effective range approximation; the nucleon-nucleon interaction calculated from meson exchange; effective forces between nucleons in nuclei and nuclear matter; the renormalization group approach to these interactions; Fermi-liquid theory of the nuclear many-body problem; thermodynamics of hadrons at high temperature; RHIC physics with heavy ions including transition from hadrons to quark gluon plasma, restoration of chiral symmetry, equation of state, initial conditions, thermodynamics of hadrons at high temperature.
0-3 credits, ABCF grading

PHY 555 Solid-State Physics I
This course concentrates on the basic notions of solid-state physics, treated mostly within the single-particle approximation. Main topics include: crystal lattices and symmetries, reciprocal lattice and state counting, phonons, electron energy band theory, bonding and cohesion (semi-quantitatively), electron dynamics and electron transport in metals and semiconductors, screening, optical properties of solids, and an introduction to superconductivity and magnetism.
Fall, 0-3 credits, ABCF grading

PHY 556 Solid-State Physics II
The course focuses on the many-particle aspects of solid-state physics addressing classical topics such as superconductivity and the transport properties of disordered conductors, as well as more modern subjects including the fractional quantum Hall effect, dissipative quantum mechanics, and problems of mesoscoptic physics. Both phenomenological and theoretical descriptions are discussed.
Spring, 0-3 credits, ABCF grading

PHY 557 Elementary Particle Physics
Introduction to elementary particle physics. Symmetries and invariance in particle physics. The properties of particles in terms of quarks and leptons and their interactions. An introduction to the electroweak and for strong interactions. Interactions at high energies. Interactions between particles and matter, experiments in particle and experimental results. Survey of particle accelerators.
Fall or spring, 0-3 credits, ABCF grading

PHY 562 Lasers and Modern Optics
Introduction to the theory of lasters including resonance conditions, normal modes, optical cavities, and elementary quantum mechanics. Description of types of lasers, methods of control, limitations of power, precision, wavelength, etc. Applications to research and industry. Throughout the course, there will be many problems that involve writing computer programs to solve simple differential equations and model different aspects of laser operation. Not for satisfying physics Ph.D. breadth course requirements.
Fall, every year, 0-3 credits, ABCF grading

PHY 565 Quantum Electronics I: Atomic Physics
Quantum electronics is a synthesis of quantum physics and electrical engineering, and is introduced in two independent semesters. A description of simple atoms and molecules and their interaction with radiation includes atoms in strong and/or weak external fields, two-photon spectroscopy, superradiance, Rydberg states, lasers and laser spectroscopy, coherent transients, etc.
Spring, 0-3 credits, ABCF grading

PHY 566 Quantum Electronics II: Quantum Optics
Quantum electronics is a synthesis of quantum physics and electrical engineering, and is introduced in two independent semesters. This course focuses on the quantum properties of light. The quantized electromagnetic field and its correlations are used to understand nonclassical states from various sources such as two-level atoms and nonlinear systems interacting with radiation fields.
Fall, 0-3 credits, ABCF grading

PHY 570 Introductory Physics Revisited for Teachers
This seminar allows students to explore the fine points of topics normally covered in high school physics. Not for Ph.D. credit.
Spring, 3 credits, ABCF grading

PHY 571 Electromagnetic Theory for Teachers
The course reviews vector calculus and develops Maxwell's equations relating electric and magnetic fields to their sources. Applications for time-independent fields are developed for solving boundary value problems and the interactions of fields in bulk matter. An oral presentation of a relevant topic suitable for a high-school class is required. Not for Ph.D. credit.
Fall, 3 credits, ABCF grading

PHY 573 Mechanics for Teachers
The Newtonian formulation of classical mechanics is reviewed and applied to more advanced problems than those considered in introductory physics. The Lagrangian and Hamiltonian methods are then derived from the Newtonian treatment and applied to various problems. An oral presentation of a relevant topic suitable for a high-school class is

required. Not for Ph.D. credit.
Fall, 3 credits, ABCF grading

PHY 576 Thermodynamics and Statistical Mechanics for Teachers
This course consists of two parts. Those relations among the properties of systems at thermal equilibrium that are independent of a detailed microscopic understanding are developed by use of the first and second laws of thermodynamics. The concepts of temperature, internal energy, and entropy are analyzed. The thermodynamic potentials are introduced. Applications to a wide variety of systems are made. The second portion of the course, beginning with the kinetic theory of gases, develops elementary statistical mechanics, relates entropy and probability, and treats simple examples in classical and quantum statistics. An oral presentation of a relevant topic suitable for a high-school class is required. Not for Ph.D. credit.
Spring, 3 credits, ABCF grading

PHY 578 Quantum Physics for Teachers
The concepts, historical development, and mathematical methods of quantum mechanics. Topics include Schroedinger's equation in time-dependent and time-independent forms, and one- and three-dimensional solutions, including the treatment of angular momentum and spin. Applications to simple systems, especially the hydrogen atom, are stressed. An oral presentation of a relevant topic suitable for a high-school class is required. Not for Ph.D. credit.
Spring, 3 credits, ABCF grading

PHY 579 Special Topics for Teachers
Topics of current interest to high school teachers are discussed to bring the teachers up to date on the latest developments in various areas of research. Examples could include the standard model of particle physics, nanofabrication techniques, atomic force microscopy, etc. Not for Ph.D. credit.
Fall or spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 580 Special Research Projects
Research under the direction of a faculty member. Not open to Ph.D. candidates.
Fall and spring, 0-18 credits, ABCF grading
May be repeated for credit

PHY 581 Astrophysics
An introduction to some areas of astrophysics. Topics are selected from stellar structure and evolution, stellar atmospheres, interstellar matter, planetary atmospheres, galactic dynamics, high-energy astrophysics and cosmology, laboratory astronomical techniques.
0-3 credits, ABCF grading

PHY 582 Optics Rotation
Optical science students experience three- to eight-week periods in each of several appropriate research groups. At the end of each period a report is required that describes the topics studied or project done. May not be taken for credit more than two semesters.
Fall and spring, 2 credits, ABCF grading
May be repeated once for credit

PHY 585 Special Study
Reading course in selected topics.
Fall and spring, 0-18 credits, ABCF grading
May be repeated for credit

PHY 595 Master's Degree Thesis Research
Independent research for master's degree students. Open only to those approved by individual faculty for thesis work.
Fall and spring, 0-18 credits, ABCF grading
May be repeated for credit

PHY 598 Graduate Seminar I
Special research topics centered on monographs, conference proceedings, or journal articles. Topics include solid-state physics, atomic physics, and quantum optics. Required for all first-year graduate students.
Fall and spring, 0-1 credits, ABCF grading

PHY 599 Graduate Seminar II
Special research topics centered on monographs, conference proceedings, or journal articles. Topics include elementary particles, nuclear physics, galactic and extragalactic astronomy, and cosmology. Required for all first-year graduate students.
Fall and spring, 0-1 credits, ABCF grading
May be repeated for credit

PHY 600 Practicum in Teaching
This course provides hands-on experience in teaching. Activities may include classroom teaching, preparation and supervision of laboratory experiments, exams, homework assignments, and projects.
Fall and spring, 0-2 credits, ABCF grading
May be repeated for credit

PHY 610 Quantum Field Theory I
Quantization of relativistic fields: Lorentz and gauge symmetries, relativistic spin, the S-matrix and scattering; the standard model; perturbation theory, renormalization and effective field theories; path integrals and relations to condensed matter physics.
Fall, 0-3 credits, ABCF grading

PHY 611 Quantum Field Theory II
Quantization of relativistic fields: Lorentz and gauge symmetries, relativistic spin, the S-matrix and scattering; the standard model; perturbation theory, renormalization and effective field theories; path integrals and relations to condensed matter physics.
Spring, 0-3 credits, ABCF grading

PHY 612 Theoretical Particle Physics
Applications of quantum field theory to interactions between elementary particles. Topics are chosen from perturbative quantum chromodynamics, the standard electro-weak model, lattice field theory, grand unified models, supersymmetry, and current research problems.
Fall, 0-3 credits, ABCF grading

PHY 620 Modern General Relativity
General theory of relativity; tensor analysis, Einstein's field equations, experimental tests, black holes, gravitational waves, cosmology. May also include topics such as spinor methods, conformal invariance, and introduction to string theory or supergravity.
Fall or spring, 0-3 credits, ABCF grading

PHY 621 Advanced Quantum Field Theory
Proofs of renormalizability and unitarity on non-Abelian gauge theories using modern methods of Becchi-Rouet-Store-Tyutin (BRST) symmetry; descent equations for anomalies; classical instantons and their quantum corrections, including integration over zero modes; background field methods, other topics if time permits.
Prerequisite: PHY 610/611 or equivalent
Fall or spring, 0-3 credits, ABCF grading

PHY 622 String Theory I
This course is intended for graduate students who have familiarity with guage and quantum field theory. Topics will be selected from: Free bosonic and spinning strings and heterotic and Green-Schwarz superstrings; conformal field theory; tree-level and one-loop amplitudes; partition functions; spacetime supersymmetry and supergravity; compactification and duality; winding and Kaluza-Klein modes; 11-dimensional supergravity; branes in supergravity; D-branes in string theory; T-duality; M-theory; complex geometry and Calabi-Yau manifolds; string field theory; other advanced topics if time permits.
Prerequisite: PHY 610/611 or equivalent
Fall or spring, 0-3 credits, S/U grading

PHY 623 String Theory II
This course is intended for graduate students who have familiarity with gauge and quantum field theory. Topics will be selected from: free bosonic and spinning strings and heterotic and Green-Schwarz superstrings; conformal field theory; tree-level and one-loop amplitudes; partition functions; spacetime supersymmetry and supergravity; compactification and duality; winding and Kaluza-Klein modes; 11-dimensional supergravity; branes in supergravity; D-branes in string theory; T-duality; M-theory; complex geometry and Calabi-Yau manifolds; string field theory; other advanced topics if time permits.
Prerequisite: PHY 610/611 or equivalent
Fall or spring, 0-3 credits, S/U grading

PHY 655 Advanced Graduate Seminar in Theoretical Physics
A weekly seminar on advanced theoretical concepts. The discussion starts with a graduate student presentation and it is conducted under the guidance of a faculty supervisor.
0-3 credits, S/U grading
May be repeated for credit

PHY 664 Astronomy Journal Club
Presentation of preliminary research results and current research problems by students and faculty. Required every semester of all astronomy graduate students.
Fall and spring, 0-1 credits, S/U grading
May be repeated for credit

PHY 666 Cool Stars
A weekly seminar concentrating on observational and theoretical studies of cool stars and related objects. Emphasis is on ongoing research and recent results in this area. Speakers include faculty, students, and visitors. Topics anticipated in the near future include results from the Hubble Space Telescope and ROSAT. Students registering

for one credit will be expected to present at least one seminar.
Prerequisite: Permission of instructor
Fall and spring, 0-1 credits, S/U grading
May be repeated for credit

PHY 668 Seminar in Astronomy
A weekly series of research seminars presented by visiting scientists as well as by the faculty. Required every semester of all astronomy graduate students.
Fall and spring, 0-1 credits, S/U grading
May be repeated for credit

PHY 669 Nuclear Astrophysics Seminar
A weekly seminar concentrating on topics in nuclear astrophysics, including dynamics of supernova collapse, structure and evolution of neutron stars, equation of state, the role of neutrinos in nucleosynthesis, etc.
Fall and spring, 0-1 credits, S/U grading
May be repeated for credit

PHY 670 Seminar in Theoretical Physics
Fall and spring, 0-1 credits, S/U grading

PHY 672 Seminar in Elementary Particle Physics
Fall and spring, 0-1 credits, S/U grading

PHY 674 Seminar in Nuclear Physics
Fall and spring, 0-1 credits, S/U grading

PHY 676 Seminar in Solid-State Physics
Fall and spring, 0-1 credits, S/U grading

PHY 678 Atomic, Molecular, and Optical Physics Seminar
Fall and spring, 0-1 credits, S/U grading

PHY 680 Special Topics in Theoretical Physics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 681 Special Topics in Statistical Mechanics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 682 Special Topics in Solid-State Physics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 683 Special Topics in Astronomy
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 684 Special Topics in Nuclear Physics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 685 Special Topics in Mathematical Physics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 686 Special Topics in Elementary Particles
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 687 Topics in Biological Physics
The "Topics" courses in the 680 sequence do not have specific description, since the subject matter within the broadly defined topic may change from one semester to the next.
0-3 credits, ABCF grading

PHY 688 Special Topics in Astrophysics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 690 Special Topics in Atomic and Optical Physics
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

PHY 698 Colloquium
Fall and spring, 0-1 credits, S/U grading
May be repeated for credit

PHY 699 Dissertation Research On Campus
Independent research for Ph.D. degree candidates.
Prerequisite: Must be advanced to candidacy (G5); major portion of research must take place on SB campus, at Cold Spring Harbor, or at Brookhaven National Lab
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

PHY 700 Dissertation Research Off Campus–Domestic
Prerequisite: Must be advanced to candidacy (G5); major portion of research will take place off campus, but in the U.S. and/or U.S. provinces (Brookhaven National Lab and Cold Spring Harbor Lab are considered on campus); all international students must enroll in one of the graduate student insurance plans and should be advised by an International Advisor
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

PHY 701 Dissertation Research Off Campus–International
Prerequisite: Must be advanced to candidacy (G5); major portion of research will take place outside the U.S. and/or U.S. provinces; domestic students have the option of the health plan and may also enroll in MEDEX; international students who are in their home country are not covered by mandatory health plan and must contact the Insurance Office for the insurance charge to be removed; international students who are not in their home country are charged for the mandatory health insurance (if they are to be covered by another insurance plan, they must file a waiver by the second week of classes; the charge will only be removed if the other plan is deemed comparable); all international students must receive clearance from an International Advisor
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

PHY 800 Summer Research
0 credit, S/U grading
May be repeated