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, Letter graded (A, A-, B+, etc.)

PHY 502: 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, Letter graded (A, A-, B+, etc.)

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, and 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, Letter graded (A, A-, B+, etc.)

PHY 504: 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.
3 credits, S/U grading

PHY 505: Classical Electrodynamics
Electrostatics and Magnetostatics in vacuum and medium; Green's functions; Maxwell's equations and gauge invariance; Electromagnetic wave propagation; Radiation, scattering, interference, and diffraction; Special relativity; Radiation by relativistic charges; Additional topics as time permits. Three lecture hours plus two recitation hours per week.
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

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, Letter graded (A, A-, B+, etc.)

PHY 511: Quantum Mechanics I
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, Letter graded (A, A-, B+, etc.)

PHY 512: Quantum Mechanics II
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, Letter graded (A, A-, B+, etc.)

PHY 513: Current Research
An introduction to the principles of stellar evolution. 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, 3 credits, Letter graded (A, A-, B+, etc.)

PHY 514: 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 experiments 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, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 515: 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, Letter graded (A, A-, B+, etc.)
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.

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

PHY 534: Radio Astronomy
This graduate level course covers application of superconducting radio frequency (SRF) technology to contemporary high-# accelerators: storage rings, pulsed and CW linacs, including energy recovery linacs (ERLs). The course will address physics and engineering aspects of using SRF in accelerators. It will cover beam-cavity interactions issues specific to superconducting cavities, a systems approach to designing SRF systems and engineering of superconducting cavity cryomodules. The course is intended for graduate students pursuing accelerator physics and graduate engineers and physicists who want to familiarize themselves with superconducting RF systems.

Offered

PHY 540: 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 nonequilibrium phenomena.

Fall, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

PHY 541: Advanced Statistical Mechanics
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 structure, and pulsars. Extragalactic topics include radio galaxies and jets, radio loud structure, and pulsars.

Spring, 3 credits, Letter graded (A, A-, B+, etc.)

PHY 542: Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab
This course is an introduction to the underlying principles and uses of the nearly 14,000 particle accelerators that are used worldwide in medicine, industry, and scientific research. The course is suitable for senior undergraduate and entry-level graduate students in physics and engineering or students from other fields with a particular interest in accelerator-based science.

Offered

PHY 543: Superconducting RF for High-Energy Accelerators
This graduate level course covers application of superconducting radio frequency (SRF) technology to contemporary high-# accelerators: storage rings, pulsed and CW linacs, including energy recovery linacs (ERLs). The course will address physics and engineering aspects of using SRF in accelerators. It will cover beam-cavity interactions issues specific to superconducting cavities, a systems approach to designing SRF systems and engineering of superconducting cavity cryomodules. The course is intended for graduate students pursuing accelerator physics and graduate engineers and physicists who want to familiarize themselves with superconducting RF systems.

Offered

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.

Spring, 3 credits, Letter graded (A, A-, B+, etc.)

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.

1-3 credits, Letter graded (A, A-, B+, etc.)

PHY 554: Fundamentals of Accelerator Physics
History of accelerators, basic principles including centre of mass energy, luminosity, accelerating gradient; Characteristics of modern colliders: RHIC, LEP, LHC, b-factories; Transverse motion, principles of beam cooling, Strong focusing, simple lattices; Circulating beams, synchrotron radiation; Longitudinal dynamics; Nonlinearities and resonances; Radio Frequency cavities, superconductivity in accelerators; Applications of accelerators: light sources, medical uses, Future Accelerators: eRHIC, ILC, neutrino factories, muon collider, laser plasma acceleration.

Offered

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.

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 mesoscopic physics. Both phenomenological and theoretical descriptions are discussed.

PHY 557: Elementary Particle Physics

PHY 558: Physical Biology
Topics of this course include but are not limited to: Time and space in cells; Structural basis of biology; Molecular solvation and lattice models; Chemical potential; Electrostatics, potentials, dipoles, electrochemical potentials; Poisson-Boltzmann and Born models; Acids, bases and salts; Intermolecular potentials and force fields; Phase transitions; Lattice and Ising models; Adsorption; Binding polynomials; Binding cooperativity; Semigrand ensemble, molecular machines; Molecular motors, energy conversion and transduction; Polymer theory; Flory-Huggins; Random flights; Elasticity; Helix-coil theory; Collapse transitions; Protein folding equilibrium; Protein folding kinetics; Sequence space; Protein evolution; Protein elasticity and biological mechanics of proteins; Biophysics of the cell; Proteome stabilities, aggregation, kinetics.

PHY 560: Advanced Accelerator Physics
Types and Components of Accelerators, Relativistic Mechanics and EM for Accelerators, Accelerator Hamiltonian and N-dimensional phase space, Poincare diagrams, Lie algebras and sympletic maps and matrices; exact parameterization of linear motion in accelerators; matrix functions, Sylvester's formula; non-linear effects, Collective instabilities & Landau Damping, Radiation damping and Excitation, natural Emittance; Spin motion in accelerators. 1-3 credits, Letter graded (A, A-, B+, etc.)

PHY 561: Biology for Physical Scientists
Topics of this course include but are not restricted to: Overview of living things; Six kingdoms, animal phyla. Physiology and organs; Chemistry of life; Noncovalent interactions; Hydrogen bonds; Solvation; Biochemistry: reactions, catalysis, ATP amino acids, nucleic acids, lipids; Cell structures: Nucleus, mitochondria, chromosomes, membranes; Basic paradigm: DNA makes RNA makes protein; How cell machines and circuits work; Cell cycle; The processes of evolution; Genetics and heredity; Diseases: how biological systems fail; How drugs are discovered; Tight-binding inhibitors; Antibodies; Current research: Cell division and cancer, genomics, bioinformatics, high throughput sequencing, systems and synthetic biology.

PHY 564: Advanced Accelerator Physics
Types and Components of Accelerators, Relativistic Mechanics and EM for Accelerators, Accelerator Hamiltonian and N-dimensional phase space, Poincare diagrams, Lie algebras and sympletic maps and matrices; exact parameterization of linear motion in accelerators; matrix functions, Sylvester's formula; non-linear effects, Collective instabilities & Landau Damping, Radiation damping and Excitation, natural Emittance; Spin motion in accelerators. 1-3 credits, Letter graded (A, A-, B+, etc.)

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 spec-troscopy, coherent transients, etc. Spring, 3 credits, Letter graded (A, A-, B+, etc.)

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, 1-3 credits, Letter graded (A, A-, B+, etc.)

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 PhD credit.

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 PhD credit. Fall, 3 credits, Letter graded (A, A-, B+, etc.)

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 PhD credit. Fall, 3 credits, Letter graded (A, A-, B+, etc.)

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 PhD credit.

Spring, 3 credits, Letter graded (A, A-, B+, etc.)

PHY 577: Physical and Mathematical Foundations of Quantum Mechanics for Teachers


In addition to the requirements for the undergraduate course PHY 307, students taking this course must prepare and present a talk on quantum physics suitable for a general (non-physics) adult audience. This course cannot be taken for credit toward the PhD degrees in Physics. Approval of the Program Director is required for taking this course for credit toward a Master Degree.

Fall, 3 credits, Letter graded (A, A-, B+, etc.)

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 PhD credit.

Spring, 3 credits, Letter graded (A, A-, B+, etc.)

PHY 579: Special Topics for Teachers

Topics of current interest to high school teachers are discussed in order 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 PhD credit.

Fall or Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
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, 1-18 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

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, 0-2 credits, Letter graded (A, A-, B+, etc.)
May be repeated 2 times FOR credit.

PHY 584: Rotation in Physical Biology

A two-semester course in which students spend at least 8 weeks in each of three different laboratories actively participating in the research of faculty associated with the Laufer Center. At least one of the rotations must be in experimental physical biology. Participants will give a research talk at the end of each eight week period.

Fall and Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)

PHY 585: Special Study

Reading course in selected topics.

Fall and Spring, 1-18 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 585: 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, 1-18 credits, Letter graded (A, A-, B+, etc.)
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, quantum optics and applications of synchrotron radiation. Required for all first-year graduate students.

Fall and Spring, 0-1 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

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 and accelerator physics. Required for all first-year graduate students.

Fall and Spring, 0-1 credits, Letter graded (A, A-, B+, etc.)
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, 0-3 credits, Letter graded (A, A-, B+, etc.)
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 or Spring, 3 credits, Letter graded (A, A-, B+, etc.)

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, 1-3 credits, Letter graded (A, A-, B+, etc.)

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.
**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.

**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. PHY 610/611 or equivalent is prerequisite.

**PHY 622: String Theory I**
This course is intended for graduate students who have familiarity with gauge & quantum field theory. Topics will be selected from: Free bosonic & spinning strings and heterotic & Green-Schwarz superstrings; conformal field theory; tree-level and one-loop amplitudes; partition functions; spacetime supersymmetry and supergravity; compactification & duality; winding & 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. PHY 610/611 or equivalent is prerequisite.

**PHY 623: String Theory II**
This course is intended for graduate students who have familiarity with gauge & quantum field theory. Topics will be selected from: free bosonic & spinning strings and heterotic & Green-Schwarz superstrings; conformal field theory; tree-level and one-loop amplitudes; partition functions; spacetime supersymmetry and supergravity; compactification & duality; winding & 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. PHY 610/611 or equivalent is prerequisite.

**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.

**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.

**PHY 665: Journal Club in Computational Biology**
The goal of this course is for students to hone critical reading and analytic skills through discussions of literature in the area of Computational Biology. Participants take turn being a #discussion leader# who informally guides the group through a peer-reviewed manuscript for which all Journal Club members will have to read in advance of the meeting. Meetings in the Spring semester will include in Person Training (IPT) in Responsible conduct of Research and Scholarship (RCRS) on topics that comprise (1) Integrity in Scholarship, (2) Scientific Misconduct, (3) Mentoring, (4) Ownership and Authorship, (5) Plagiarism, (6) Data Management, (7) Journalism and Science, (8) Human Subjects, and (9) Laboratory Animals.

**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.

**PHY 667: Seminar in Theoretical Physics**
A weekly series of research seminars presented by visiting scientists as well as by the faculty. Required every semester of all astronomy graduate students.

**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.

**PHY 670: Seminar in Theoretical Physics**
This seminar discusses current topics in cosmology. Each semester consists of a formal talk followed by an informal discussion of active areas of cosmology research.

**PHY 673: Seminar in Cosmology**
This seminar discusses current topics in cosmology. Each semester consists of a formal talk followed by an informal discussion of active areas of cosmology research.

**PHY 674: Seminar in Nuclear Physics**
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.

**PHY 675: Seminar in Solid-State Physics**
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.

**PHY 676: Seminar in Solid-State Physics**
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.

**PHY 677: Atomic, Molecular and Optical Physics Seminar**
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.

**PHY 678: Atomic, Molecular and Optical Physics Seminar**
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.

**PHY 680: Special Topics in Theoretical Physics**
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.
PHY 682: Special Topics in Solid-State Physics
Fall and
Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 683: Special Topics in Astronomy
Fall and
Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 684: Special Topics in Nuclear Physics
Fall and
Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 685: Special Topics in Mathematical Physics
Fall and
Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 686: Special Topics in Elementary Particles
Fall and
Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
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.
1-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 688: Special Topics in Astrophysics
Fall and
Spring, 1-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.

PHY 689: Colloquium
Fall and
Spring, 0-1 credits, S/U grading
May be repeated for credit.

PHY 690: Dissertation Research on Campus
Independent research for Ph.D. degree candidates. Open only to students who have advanced to candidacy (G5). Major portion of research must take place on SBU campus, at Cold Spring Harbor, or at the Brookhaven National Lab.
Fall, Spring, and
Summer, 1-9 credits, S/U 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 off Campus - Domestic
Prerequisite: Must be advanced to candidacy (G5). Major portion of research will take place off-campus, but in the United States and/or U.S. provinces. Please note, Brookhaven National Labs and the 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, 1-9 credits, S/U grading
May be repeated for credit.

PHY 700: Dissertation Research off Campus - International
Prerequisite: Must be advanced to candidacy (G5). Major portion of research will take place outside of the United States 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 insurance. If they are to be covered by another insurance plan they must file a waiver the second week of classes. The charge will only be removed if other plan is deemed comparable.
All international students must receive clearance from an International Advisor.
Spring, 1-9 credits, S/U grading
May be repeated for credit.

PHY 800: SUMMER RESEARCH
May be repeated for credit.