

Physics

Website: <http://physics.wustl.edu/graduate>

Courses

Visit online course listings to view semester offerings for L31 Physics.

L31 Physics 500 Independent Work

Prerequisites: senior standing and apply for approval using the Physics independent study web form <https://physics.wustl.edu/independent-study>. Program and credit to be determined; maximum 6 units. Credit variable, maximum 6 units.

L31 Physics 5001 Physical Science in 12 Problems

Exercises related to general chemistry, classical mechanics, quantum mechanics, statistical mechanics, thermodynamics, and kinetics, will be solved with numerical software. Each exercise will be accompanied by a lecture, a software template solving a problem and presenting a related take-home problem. The software will allow us to focus on, and treat in a transparent fashion, physical problems without the unworldly idealizations and contrivances found in textbooks. Prerequisites: Chem 106/112A and/or Physics 192/194, and prior or concurrent enrollment in either Chem 401 or Phys 217. The lectures will be in-person however a complete set of taped lectures will also be available. A remote help session will be scheduled at a mutually agreed to time. There are no quizzes, exams or a final.

Same as L07 Chem 400

Credit 1 unit. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 501 Theoretical Physics

The first part of a two-semester course reviewing the mathematical methods essential for the study of physics. Theory of functions of a complex variable, residue theory; review of ordinary differential equations; introduction to partial differential equations; integral transforms. Prerequisite: undergraduate differential equations (Math 217), or permission of instructor.

Credit 3 units.

L31 Physics 5011 Mechanics

Motion of a point particle, rotational motion, oscillation, gravitation and central forces, Lagrangian and Hamiltonian formulation. Prerequisite: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206, Math 217, or permission of instructor.

Same as L31 Physics 411

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 502 Methods of Theoretical Physics II

Continuation of Phys 501. Introduction to function spaces; self-adjoint and unitary operators; eigenvalue problems, partial differential equations, special functions; integral equations; introduction to group theory. Prerequisite: Phys 501, or permission of instructor.

Credit 3 units.

L31 Physics 5021 Electricity and Magnetism I

Starting from Coulomb's law, the Biot-Savart law, and Faraday's law, the electrical and magnetic fields are defined and applied. Maxwell's equations are derived and their consequences, such as electromagnetic waves and relativity, are explored. Prerequisites: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206., Math 217, or permission of instructor.

Same as L31 Physics 421

Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI EN: BME T, DU, SU, TU

L31 Physics 5027 Introduction to Computational Physics

What does it mean to solve a research problem using a computer? What is the difference between "someone ran a simulation" and an interesting research result? And what skills does it take? Familiarity with a programming language is, of course, essential, but that is only the beginning. This course will focus on the methodology of computational research, touching also on topics in numerical analysis, statistics and visualization. The format will combine lectures and hands-on experience, with emphasis on research-style small-group projects. Prerequisites: Prerequisite: Physics 191 - 192 or Phys 193 - 194 or Physics 197-198 or Phys 205 - 206, Calculus, and familiarity with a programming language.

Same as L31 Physics 427

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 503 Advanced Math Methods for Physicist & Engineers I

The first semester of a two semester course presenting an organized approach to solving hard problems approximately; a self contained and general examination of asymptotics and perturbation theory; local and global analysis of differential and difference equations, summation methods, Pade theory, asymptotic expansion of integrals; emphasis calculational rather than theoretical. Continued in Physics 504.

Prerequisite: Physics 501 or an elementary knowledge of differential equations and complex variables.

Credit 3 units.

L31 Physics 5035 Nuclear and Radiochemistry Lab

Application of radiochemistry to problems in chemistry, physics, and nuclear medicine, with emphasis on particle detectors and experimental techniques. Prerequisites: 3 units of physical chemistry or quantum mechanics, or permission of instructor. Five hours of laboratory a week.

Same as L07 Chem 435

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 504 Advanced Math Methods for Physicist & Engineers II

A continuation of Physics 503. A general presentation of perturbation theory. Matched asymptotic expansions. Boundary layer theory, WKB theory, multiple scale analysis. Variational methods, integral equations. Credit 3 units.

L31 Physics 505 Classical Electrodynamics I

Classical electromagnetism via Maxwell's equations. Electric and magnetic fields from static charge and current distributions. Mathematical techniques for solving electrostatic and magnetostatic problems. Electrostatic and magnetostatic forces and energies.

Credit 3 units.

L31 Physics 506 Classical Electrodynamics II

Time-varying electric and magnetic fields. Electromagnetic waves and radiation; simple antennas. Waveguides and effects of dispersion. Retardation effects and special relativity.

Credit 3 units.

L31 Physics 5063 Statistical Mechanics and Thermodynamics

Basic methods of classical and quantum statistical mechanics, thermodynamics, and transport theory. Prerequisite: Phys 217 or permission of instructor.

Same as L31 Physics 463

Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM

L31 Physics 507 Classical Mechanics

The culminating achievements in this classical discipline are presented: the Lagrangian and Hamiltonian formulation of the equations of motion, action principles and the Hamilton-Jacobi equation.

Applications to constrained systems, many-body systems, continuous systems and classical fields are included. Perturbation theory and general relativity are discussed briefly.

Credit 3 units.

L31 Physics 5071 Quantum Mechanics

Origins of quantum theory, wave packets and uncertainty relations, Schroedinger's equation in one dimension, step potentials and harmonic oscillators, eigenfunctions and eigenvalues, Schroedinger's equation in three dimensions, the hydrogen atom, symmetry, spin and the periodic table, approximation methods for time independent problems, quantum statistics. Prerequisite: Math 217, Physics 217, or permission of instructor.

Same as L31 Physics 471

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM EN: BME T, SU, TU

L31 Physics 5072 Solid State Physics

Crystal structures, binding energies, thermal properties, dielectrics, magnetism, free electron theory of metals, band theory, semiconductors, defects in solids. Prerequisite: Phys 471.

Same as L31 Physics 472

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 5074 Introduction to Particle Physics

Introduction to the standard model of particle physics, including symmetries, conservation laws, the weak interaction, the strong interaction, quark confinement, and some more exotic ideas such as grand unified theories. Prerequisite: Phys 217.

Same as L31 Physics 474

Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM

L31 Physics 5078 From Black Holes to the Big Bang

An introduction to general relativity. The goal will be to illustrate important features of general relativity without the full-blown mathematics of Einstein's equations by restricting attention to spherically symmetric spacetimes. Topics will include: principle of equivalence; curved spacetime; spherical stars and black holes; the Big Bang model, observational cosmology. Prereq: Physics 411 or permission of instructor.

Same as L31 Physics 478

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L31 Physics 509 Nonlinear Dynamics

The course will treat the theoretical foundations of nonlinear dynamics, and its applications to phenomena in diverse fields including physics, biology, and chemistry. Topics will include phase plane analysis, stability analysis, bifurcations, chaos, and iterated maps. Prerequisites: knowledge of multivariate calculus and ordinary differential equations at the level of Mathematics 217; and Physics 117-118 (mechanics at the level of 411 is desirable but not essential).

Credit 3 units.

L31 Physics 514 Physics of the Heart

A lecture and demonstration course which may be of particular interest to premedical and life-science students. Basic physics of the human cardiovascular system. Elasticity of vessels: properties of elastin and collagen. Energetics of the circulation: arterial and venous blood pressure, total fluid energy, gravitational potential energy, kinetic energy. Streamline flow and turbulence: effects of stenosis. Static and dynamic energy consumption of the heart: cardiac efficiency, the tension-time integral, Laplace's law, Starling's law. Metabolism of cardiac muscle. Electrophysiology: the heartbeat and cardiac arrhythmias. The physics of phonocardiograms, echocardiograms, and other non-invasive techniques for physical assessment of cardiac abnormalities, including ischemia and myocardial infarction. Models of mechanical properties: contractile element, series elastic and parallel elastic elements. Individual special projects dealing with the physics underlying cardiovascular pathophysiology are required in addition to scheduled classroom activities and lectures. Prerequisite: Permission of instructor.

Credit 3 units.

L31 Physics 523 Quantum Mechanics I

Provides a rigorous introduction to quantum mechanics with an emphasis on formalism. The course begins with review of the theory of linear (state) vector spaces and the quantum theory of measurement. Topics covered include dynamics of quantized systems, the quantum theory of angular momentum, density matrix formalism, and advanced topics in quantum measurement theory.

Credit 3 units.

L31 Physics 524 Quantum Mechanics II

Review of wave mechanics, scattering theory. Measurement algebra and the foundations of nonrelativistic quantum theory. Mathematical techniques for solution, perturbation theory. Applications to atomic, molecular, nuclear, and solid state problems. Introduction to relativistic quantum theory and quantized wave fields.

Credit 3 units.

L31 Physics 529 Statistical Mechanics

Gibbs' formalism of statistical mechanics and applications to thermodynamics. Quantum statistical mechanics and degenerate matter. General theory of equilibrium including phase transitions and critical phenomena. Interacting particles including non-ideal gases, ferromagnetism, and superconductivity. Transport theory, irreversible processes.

Credit 3 units.

L31 Physics 530 Advanced Topics in Statistical Mechanics

Critical phenomena and renormalization group theory: scaling, universality, exact solutions, series expansions, computer simulations, e-expansion. Role of solitons and instantons in phase transitions. Quantum fluids: superfluidity and superconductivity. Linear response theory and disordered systems.

Credit 3 units.

L31 Physics 5322 Physical Measurement Laboratory

A variety of classical and modern experiments in physics, including five experiments in nuclear radiation. Use of computers in experiment control, data acquisition, and data analysis. Development of skills in writing lab notebooks and formal reports and giving short oral presentations on experiments. Two laboratory periods each week. Prerequisite: Physics 217 or permission of instructor; junior or senior level standing

Same as L31 Physics 322

Credit 3 units. A&S IQ: NSM, AN, WI Arch: NSM Art: NSM BU: SCI EN: TU

L31 Physics 5330 Planets and Life in the Universe

In this course, we will explore the history, methods, outcomes, and broad impacts of exoplanet research and how these are connected to our search for life beyond planet Earth. Following an engaging contextual introduction at the beginning of the lectures, topics will be presented with an accessible mathematical treatment (e.g., geometrical derivations of the two-body transit problem). Prerequisite: Physics 191 and 192 or Physics 193 and 194.

Same as L31 Physics 3330

Credit 3 units. A&S IQ: NSM, AN Art: NSM

L31 Physics 534 Magnetic Resonance

Quantum mechanical and classical aspects of paramagnetism and of nuclear and electronic magnetic resonance. Phenomenological equations of motion, spin interactions, spin temperature, thermal relaxation, dynamic polarization, multiple resonance phenomena. Credit 3 units.

L31 Physics 535 Ultrasonics

Credit 3 units.

L31 Physics 537 Kinetics of Materials

A general discussion of phase formation and phase transformation in solids and liquids. Topics include equilibrium and non-equilibrium thermodynamics, equilibrium and metastable phase diagrams, nucleation and growth, spinodal transformations, diffusion and interface limited processes, shear type transformations and order/disorder transformations. Prerequisite: A background in thermodynamics, statistical mechanics, and solid state physics. Credit 3 units.

L31 Physics 539 Structure and Diffraction in Materials

Topics of interest for the study of materials using diffraction techniques. Includes an introduction to crystallography, defects in crystals and quasicrystals, and introduction to diffraction from materials, electron microscopy of materials touching on electron optics, scanning and transmission electron microscopy and the interaction of high-energy electrons with matter, and an introduction to x-ray techniques. Prerequisite: Permission of the instructor. Credit 3 units.

L31 Physics 540 Quantum Theory of Many-Particle Systems

Develops a modern approach to quantitative microscopic description of strongly-interacting quantum many-particle systems, including the helium liquids, nuclear matter, neutron star matter, nuclei, and strongly-coupled electron systems. Emphasis is placed on the method of self-consistent Green's functions. Diagram resummation and field theoretic techniques are introduced. Applications are discussed that cover the Hartree-Fock method for atoms, Bose-Einstein condensation of atoms, etc. The microscopic basis for pairing in superfluids and superconductors is also examined. Credit 3 units.

L31 Physics 542 Physics of finite and infinite nuclear systems

Quantum mechanics of finite and infinite systems of protons and neutrons. Interaction between nucleons. Independent-particle model of nuclei and shell structure. Contrast with atomic shell model. Isospin symmetry. Information from weakly and strongly interacting probes of nuclei. Nuclear decay properties and some historical context. Many-particle description of nuclear systems. Single-particle versus collective phenomena. Properties of excited states. Bulk properties of nuclei. Nuclear and neutron matter. Role of different energy scales in determining nuclear properties: influence of long-range, short-

range, and medium-induced interactions. Pairing correlations in nuclear systems. Relevance of nuclear phenomena and experiments for astrophysics and particle physics. Prerequisites: Phys 318 or Phys 471, or permission of instructor

Credit 3 units. Arch: NSM

L31 Physics 543 Group Theory and Symmetries in Physics

Symmetries offer beautiful explanations for many otherwise incomprehensible physical phenomena in nature. Group theory is the underlying mathematical framework for studying symmetries, with far-reaching applications in many areas of physics, including solid-state physics, atomic and molecular physics, gravitational physics, and particle physics. We will discuss many of the fascinating mathematical aspects of group theory while highlighting its physics applications. The following topics will be covered: general properties of groups (definition, subgroups and cosets, quotient group, homo- and iso-morphism), representation theory (general group actions, direct sums and tensor products, Wigner-Eckart theorem, Young tableaux), and discrete groups (cyclicity, characters, examples), Lie groups and Lie algebra (Cartan-Weyl basis, roots and weights, Dynkin diagrams, Casimir operators, Clebsch-Gordan coefficients, classification of simple Lie algebras), space-time symmetries (translation and rotation, Lorentz and Poincare groups, conformal symmetry, supersymmetry and superalgebra), and gauge symmetries (Abelian and non-Abelian, Standard Model, Grand Unified Theories). Interested undergraduates who have taken Physics 217 or similar can register for this course with prior approval. Credit 3 units.

L31 Physics 545 Solar System Astrophysics

A survey of current topics of astronomical and astrophysical interest involving the sun, planets, and other solar system objects. The interplanetary medium and galactic process as they relate to the solar system. Theories and understanding of the origin and history of the solar system. Dating methods with applications to lunar and terrestrial ages, solar system chronology, and the age of the elements. Credit 3 units.

L31 Physics 546 Galactic Astrophysics

In these lectures, the focus is on the dynamics and statistical mechanics of a collection of stars, which is treated as a collisionless system. The course begins with a discussion of potential theory and proceeds to discuss the density and phase distributions of stars in star clusters and galaxies, thus leading to an understanding of the equilibria and stability of these systems. Topics such as Chandrasekhar's dynamical friction, galaxy formation and dark matter will constitute the final topics of discussion.

Same as L31 Physics 446

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L31 Physics 547 Intro to Elementary Particle Physics

An introduction to the "standard model" of elementary particle physics. The non-Abelian $SU(3) \times SU(2) \times U(1)$ gauge theory and its relation to phenomenology and experiments. Credit 3 units.

L31 Physics 549 Solid State Physics I

Quantum theory of phonons in solids, thermodynamical properties, band theory of solids, free-electron and tight-binding approaches to electronic structure.

Credit 3 units.

L31 Physics 550 Solid State Physics II

Band magnetism and local moments, Ising models, electron-electron and electron-phonon interactions, superconductivity.
Credit 3 units.

L31 Physics 551 Relativistic Quantum Mechanics

Introduction to Quantum Field Theory using simple 1-dimensional and/or scalar field examples. Canonical quantization and path integrals; Feynman diagrams; Lorentz group; discrete symmetries; LSZ theorem. Introduction to regularization and renormalization.
Credit 3 units.

L31 Physics 552 Relativistic Quantum Field Theory

Continuation of Phys 551. Path integral quantization of spin 1/2 and spin 1 fields. Quantum electrodynamics. Ward identities and renormalization. Computation of the electron anomalous magnetic moment and the Lamb shift. Non-Abelian gauge theories and their quantization. Quantum chromodynamics and asymptotic freedom. Spontaneous symmetry breaking and the Standard Model.
Credit 3 units.

L31 Physics 555 Astrophysical Plasmas

Credit 3 units.

L31 Physics 556 Stellar Astrophysics

In the second semester, the focus is on the dynamics and statistical mechanics of a collection of stars which is treated as a collisionless system. The course begins with a discussion of potential theory and proceeds to discuss the density and phase space distributions of stars in star clusters and galaxies, thus leading to an understanding of the equilibria and stability of these systems. Topics such as Chandrasekhar's dynamical friction and dark matter will constitute the final topics of discussion. This course is also available for advanced undergraduates, with the prerequisites as noted. Prerequisites: Physics 411, 421, and 463, or permission of the instructor.
Credit 3 units.

L31 Physics 557 Gravitation and Cosmology

Special relativity, equivalence principle, and fundamental experiments. Mathematics of curved spacetime. General structure of Einstein's equations. Observational tests. Applications of general relativity, relativistic stellar structure, gravitational collapse and black holes.
Credit 3 units.

L31 Physics 558 Relativistic Astrophysics

Applications of general relativity to astrophysics and cosmology. Relativistic stars, gravitational collapse and black holes; generation, propagation and detection of gravitational radiation. Cosmology, the Standard Model; physical processes in the early universe and the microwave background. Inflationary scenario. Origin of galaxies and large-scale structure. Gravitational lenses. Credit 3 units.
Credit 3 units.

L31 Physics 559 Testing Fundamental Physics with Astronomical Observations

Astronomical observations allow us to test fundamental physics laws under more extreme conditions than possible in terrestrial laboratories. In some important cases (i.e. cosmology), astronomical observations present the only way to gather empirical evidence and to formulate and subsequently test the theories. In this one-semester course, we start with a brief summary of the current theoretical framework that is used to explain the cosmos: the theory of General Relativity and the Standard Model of particle physics. Subsequently, we introduce

current astronomical observatories and discuss which fundamental physics laws they can probe. We include a detailed discussion of theoretical ideas which are being probed, and avenues for developing more precise tests with future experiments. This class is designed to be highly relevant for theoretical and experimental researchers. Previous exposure to the theory of General Relativity and quantum field theories is beneficial but not required.

Credit 3 units.

L31 Physics 560 X-ray and Gamma-ray Astrophysics

The final semester will provide an up to date coverage of x-ray and gamma-ray astronomy and astrophysics. Generation and observational techniques of energetic radiations from accreting neutron stars and black holes, supernova and supernova remnants, active galactic nuclei, interstellar and intergalactic matter, as well as related physics and model building will be discussed. The course will thus explore the most energetic phenomena in the universe and will also provide insight into diverse topics ranging from planetary exploration to dark matter and cosmology. This course is also available for advanced undergraduates, with the prerequisites as noted in 476/576.

Credit 3 units.

L31 Physics 563 Topics in Theoretical Biophysics

Application of a range of physical models to biological systems. Topics include protein folding, self-assembling molecular systems, and mechanical properties of biological materials. Background material will be provided but some exposure to statistical mechanics or thermodynamics is necessary.

Credit 3 units.

L31 Physics 565 Magnetism and Superconductivity: Basics and Applications

Fundamental and applied aspects of magnetism and superconductivity in solids. The magnetic state in transition metal, rare earth and actinide systems. Exotic forms of magnetism. Conventional, high-T_c, fullerene and organic superconductors. Josephson effect. Bose-Einstein condensation. Coexistence of magnetism and superconductivity. Applications include: SQUID sensors, permanent and superconducting magnets, bubble memories, and magnetic cooling. Prerequisite: Physics 472 or permission of instructor.

Credit 3 units.

L31 Physics 570 Planetary Geophysics

Relationships between solar system dynamics and planetary evolution, with emphasis on orbital mechanics, gravity fields of planets and satellites, heat transfer in planetary interiors, and tidal interactions. Topics include resonant orbits and rotation rates, effects of large-body impact, volcanism on Io, and the origin of the Moon.

Same as L19 EEPS 570

Credit 3 units.

L31 Physics 576 Astrophysics

This is the first of a four-semester course in astrophysics, with two semesters of classical astrophysics of stars and stellar systems, followed by two semesters of high energy astrophysics of cosmic rays, radio, x-ray and gamma-ray astronomies. Each of these is a self-contained course and may be attended by advanced undergraduates and graduate students. In the first semester we discuss observations of stars; stellar populations; physical processes in stars; birth, evolutions, and death of stars; energy generation; nucleosynthesis; variable stars; supernovae; collapsed objects; solar neutrinos; helioseismology; and selected topics in galactic astrophysics, cosmology and exobiology. Additional reading assignments for students registered for 576.

Prerequisites: Physics 411, 421, and 463, or permission of the instructor.
Credit 3 units.

L31 Physics 581 Critical Analysis of Scientific Data

Data science" is most commonly associated with topics in computer science. But efficient algorithms, specific software packages, neural nets, etc., are only tools, and are easily misused. In a research setting, working with data is primarily an exercise in critical thinking. The purpose of this interactive, hands-on course is to learn from mistakes by making them in a safe environment. After covering/reviewing probability theory; Bayesian inference; elements of information theory and random matrix theory, the course will focus on case studies of real-world biological data, such as quantitative imaging data, next-generation sequencing (metagenomics), and neural recordings. These modules will involve critical reading of research papers and working through puzzle-based assignments. The primary modules will be supplemented by shorter presentations on topics chosen by students. Fair warning: this is explicitly NOT a course on "big data" or machine learning, although students may choose to explore some of these topics in their presentations (required for credit). Experience with MatLab or Python strongly encouraged or will need to be acquired during the course. Open to undergraduates with prior programming experience and a quantitative background (Phys 197/198, Math 203 or similar; contact instructor if unsure). Experience with data or statistics not required. Course mimics a research environment and undergraduates considering an academic research track especially encouraged. Graduate students required to pick an advance topic. Credit 3 units.

L31 Physics 582 Research Seminar

Designed to introduce students to current developments in physics and to research carried out by faculty. Topics vary each year. Each member of the department addresses issues in their particular specialty. Required of all majors and first-year graduate students. Undergraduates are advised to take this seminar in their junior year. Credit 1 unit.

L31 Physics 583 Grant Proposal Writing and Research Project Development

Introduction to grant proposal writing. Students will develop a research project and write a graduate student fellowship application based on that project. As part of the fellowship application the student will develop all supporting documents necessary for the application (i.e. curriculum vitae, budget, etc.). Twice during the course students will make an oral presentation of their project in order to get feedback from faculty and other students. Credit 1 unit.

L31 Physics 584 Computational Methods

This course provides an introduction to the computational techniques that are most widely used in both theoretical and experimental research in physics. Each lecture will use a realistic research problem to introduce the algorithms, software packages and numerical techniques that will be used by the students to develop a solution on the computer. Topics include Monte Carlo techniques, symbolic analysis with Mathematica, data acquisition software used in the laboratory, the numerical solution of quantum mechanical problems, and an introduction to general purpose frameworks based on Python. Prerequisites: Prior of concurrent enrollment in L31 471 or L31 422 or permission of the instructor. Credit 1 unit.

L31 Physics 586 Commercialization of Science and Technology

Commercialization of Science and Technology is an interdisciplinary course that investigates the issues and decisions that inventor/scientists, engineers, and entrepreneurs encounter when taking early stage scientific discoveries from the laboratory to applied use. The

course employs case studies, invited speakers, and team projects to engage graduate and professional students in interdisciplinary collaboration, idea generation and the feasibility of applying scientific discoveries in commercial marketplaces. Participants learn about the basics of commercialization and entrepreneurship and how these relate to their personal goals and scientific interests. The course is ideal for anyone interested in working as an academic, chief scientist, entrepreneur, manager, consultant, or investor. Credit 3 units.

L31 Physics 589 Selected Topics in Physics I

From time to time, additional courses are offered in specialized physics topics of current interest, such as group theory, general relativity, advanced hydrodynamics, boundary-value problems, celestial mechanics, astrophysics, and so on. Credit variable, maximum 3 units.

L31 Physics 590 Selected Topics in Physics II

From time to time, additional courses are offered in specialized topics of current interest such as group theory, general relativity, advanced hydrodynamics, boundary-value problems, celestial mechanics, astrophysics, etc. Credit variable, maximum 3 units.

L31 Physics 593 Introduction to Methods in Physics

Five hours per week of tutorial training in modern experimental and/or theoretical methods in physics. Instruction by faculty members or, with faculty supervision and assistance, by graduate teaching interns who are enrolled in and earning credit for Phys 597-598. A maximum of 3 units of this course may be counted toward the requirement of 36 units of course credit for the Ph.D. degree. Credit variable, maximum 3 units.

L31 Physics 594 Introduction to Methods in Physics

Five hours per week of tutorial training in modern experimental and/or theoretical methods in physics. Instruction by faculty members or, with faculty supervision and assistance, by graduate teaching interns who are enrolled in and earning credit for Phys 597-598. A maximum of 3 units of this course may be counted toward the requirement of 36 units of course credit for the Ph.D. degree. Credit variable, maximum 3 units.

L31 Physics 595 Research

The department regularly conducts seminars for review of current progress in research. Fields in which it is active : (a) Space Physics and Astrophysics, (b) Nuclear Physics, (c) Theoretical Physics, (d) Condensed Matter and Magnetic Resonance, (e) Applications of Ultrasound to medical, biological, and physical problems. This course does not count toward the requirement of 36 units of course credit for the Ph.D. degree. Credit variable, maximum 9 units.

L31 Physics 596 Research

The department regularly conducts seminars for review of current progress in research. Fields in which it is active : (a) Space Physics and Astrophysics, (b) Nuclear Physics, (c) Theoretical Physics, (d) Condensed Matter and Magnetic Resonance, (e) Applications of Ultrasound to medical, biological, and physical problems. This course does not count toward the requirement of 36 units of course credit for the Ph.D. degree. Credit variable, maximum 9 units.

L31 Physics 597 Supervised Teaching of Physics

Supervised instructional experience as graduate teaching intern. Under faculty supervision, a teaching intern may earn credit in Phys 597-598 by (a) instructing graduate students who are taking Phys 593-594, or (b) instructing undergraduates who are taking Phys 241-242 or 341-342, or (c) as a Graduate Teaching Fellow or Assistant, instructing and evaluating work of undergraduate or graduate students in classroom or laboratory physics courses, or (d) instructional activity connected with journal club, group seminars, special short courses, observatory lectures, etc. Five or more contact hours per week with student(s) being instructed plus associated preparation and evaluation.

Credit 1 unit.

L31 Physics 598 Supervised Teaching of Physics

Supervised instructional experience as a graduate teaching intern. Under faculty supervision, a teaching intern may earn credit in Phys 597-598 by (a) instructing graduate students who are taking Phys 593-594, or (b) instructing undergraduates who are taking Phys 241-242 or 341-342 or 441-442, or (c) as a Graduate Teaching Fellow or Assistant, instructing and evaluating work of undergraduate or graduate students in classroom and laboratory physics courses, or (d) instructional activity connected with journal club, group seminars, special short courses, observatory lectures, etc. Five or more contact hours per week with student(s) being instructed, plus associated preparation and evaluation.

Credit 1 unit.

L31 Physics 883 Master's Continuing Student Status

L31 Physics 884 Doctoral Continuing Student Status

L31 Physics 885 Masters Nonresident

L31 Physics 886 Doctoral Nonresident
