PHYSICS

Graduate study and opportunities for basic research are offered in experimental and theoretical physics in the following subfields: atomic and molecular physics, biophysics, chemical physics, condensed matter physics, elementary particle physics, geophysics, laser and optical physics, nuclear physics, physics education research, plasma and space physics, quantum information science and renewable energy.

Doctoral programs in chemical physics and geophysics are offered jointly with the Department of Chemistry and with the other departments that participate in the interdepartmental geophysics program.

Course code for this program is PHYS.

Master's Degree

- Physics - Master of Science (MS) (https://catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/physics/physics-master-science-ms/)

Doctoral Degree

- Physics - Doctor of Philosophy (PhD) (https://catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/physics/physics-doctor-philosophy-phd/)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Anderson, Dana Z. (https://experts.colorado.edu/display/fisid_102371/)
Professor; PhD, University of Arizona

Ashby, Neil
Professor Emeritus; PhD, Harvard University

Aumentado, Jose
Lecturer; PhD, Northwestern University

Baker, Daniel N. (https://experts.colorado.edu/display/fisid_103264/)
Distinguished Professor; PhD, University of Iowa

Bartlett, David
Professor Emeritus; PhD, Columbia University

Beale, Paul D. (https://experts.colorado.edu/display/fisid_101602/)
Professor; PhD, Cornell University

Becker, Andreas (https://experts.colorado.edu/display/fisid_146675/)
Distinguished Professor; Dr habil, Universite Laval (Canada)

Berry, Joseph (https://experts.colorado.edu/display/fisid_131839/)
Associate Professor; PhD, Pennsylvania State University

Betterton, Meredith D. (https://experts.colorado.edu/display/fisid_125396/)
Professor; PhD, Harvard University

Bohn, John (https://experts.colorado.edu/display/fisid_111716/)
Research Professor; PhD, University of Chicago

Bolton, Daniel Ryan (https://experts.colorado.edu/display/fisid_155168/)
Associate Teaching Professor; PhD, University of Washington

Calkins, Michael Andrew (https://experts.colorado.edu/display/fisid_149720/)
Associate Professor; PhD, University of California, Los Angeles

Cao, Gang (https://experts.colorado.edu/display/fisid_157991/)
Professor; PhD, Temple University

Cary, John R. (https://experts.colorado.edu/display/fisid_105901/)
Professor; PhD, University of California, Berkeley

Chou, Chin-Wen
Lecturer; PhD, California Insitutute of Technology

Clark, Noel A. (https://experts.colorado.edu/display/fisid_101947/)
Professor; PhD, Massachusetts Institute of Technology

Coddington, Jan
Lecturer; PhD, University of Colorado Boulder

Cooper, John
Professor Emeritus; PhD, University of London

Cornell, Eric (https://experts.colorado.edu/display/fisid_100112/)
Professor Adjoint; PhD, Massachusetts Institute of Technology

Cumalat, John P. (https://experts.colorado.edu/display/fisid_105582/)
Professor; PhD, University of California, Santa Barbara

De Alwis, Senarath P. (https://experts.colorado.edu/display/fisid_103029/)
Professor Emeritus; PhD, University of Cambridge (England)

Deca, Jan (https://experts.colorado.edu/display/fisid_155664/)
Lecturer; PhD, KU Leuven (Belgium)

Degrand, Thomas A. (https://experts.colorado.edu/display/fisid_102740/)
Professor; PhD, Massachusetts Institute of Technology

Dennis, Tasshi
Lecturer; PhD, Rice University

Dessau, Daniel S. (https://experts.colorado.edu/display/fisid_107532/)
Professor; PhD, Stanford University

DeWolfe, Oliver M. (https://experts.colorado.edu/display/fisid_142992/)
Professor; PhD, Massachusetts Institute of Technology

Diddams, Scott A. (https://experts.colorado.edu/display/fisid_148274/)
Professor; PhD, University of New Mexico

Dincao, Jose Paulo (https://experts.colorado.edu/display/fisid_143731/)
Assistant Research Professor; PhD, Univ of Sao Paulo (Brazil)

Donley, Elizabeth
Lecturer; PhD, Swiss Federal Institute of Technology

Dreitlein, Joseph
Professor Emeritus; PhD, Washington University

Dubson, Michael A. (https://experts.colorado.edu/display/fisid_102266/)
Teaching Professor of Distinction, Associate Chair; PhD, Cornell University

Figueroa, Nuris (https://experts.colorado.edu/display/fisid_167396/)
Assistant Professor; PhD, Sorbonne University (France)

Finkelstein, Noah D. (https://experts.colorado.edu/display/fisid_129919/)
Professor; PhD, Princeton University

Ford, William T. (https://experts.colorado.edu/display/fisid_102175/)
Professor Emeritus; PhD, Princeton University

Franklin, Allan D. (https://experts.colorado.edu/display/fisid_100660/)
Professor Emeritus; PhD, Cornell University

Gallagher, Michael (https://experts.colorado.edu/display/fisid_151214/)
Lecturer; PhD, University of Colorado

Gao, Xun (https://experts.colorado.edu/display/fisid_174294/)
Assistant Professor; PhD, Tsinghua University (China)

Glancy, Scott
Lecturer; PhD, University of Notre Dame

Glaser, Matthew A.
Professor Attendant Rank; PhD, University of Colorado Boulder

Goldman, Martin V. (https://experts.colorado.edu/display/fisid_100567/)
Professor Emeritus; PhD, Harvard University

Gopinath, Juliet T. (https://experts.colorado.edu/display/fisid_147075/)
Professor; PhD, Massachusetts Institute of Technology

Gorokhovsky, Vladimir
Lecturer; PhD, Russian Academy of Sciences

Gurarie, Victor Vladimir (https://experts.colorado.edu/display/fisid_129918/)
Professor; PhD, Princeton University

Gyenis, Andras (https://experts.colorado.edu/display/fisid_167223/)
Assistant Professor; PhD, Princeton University

Hall, John L. (https://experts.colorado.edu/display/fisid_103891/)
Professor Adjoint; PhD, Carnegie Institute of Technology

Halverson, Nils W. (https://experts.colorado.edu/display/fisid_134252/)
Professor; PhD, California Institute of Technology

Hamilton, Andrew J.S. (https://experts.colorado.edu/display/fisid_101517/)
Professor; PhD, University of Virginia

Hasenfratz, Anna (https://experts.colorado.edu/display/fisid_102393/)
Professor; PhD, Lorand Eotvos University, Budapest (Hungary)

Hermann, Allen M.
Professor Emeritus; PhD, Texas AM University

Hermele, Michael Aaron (https://experts.colorado.edu/display/fisid_143370/)
Professor; PhD, University of California, Santa Barbara

Hodby, Eleanor R. (https://experts.colorado.edu/display/fisid_128058/)
Senior Instructor, Faculty Fellow, Associate Teaching Professor; PhD, Oxford University

Holland, Murray John (https://experts.colorado.edu/display/fisid_105126/)
Professor; PhD, Oxford University (England)

Horanyi, Mihaly (https://experts.colorado.edu/display/fisid_102420/)
Professor; PhD, Eötvös Loránd University (Hungary)

Hough, Loren Evan (https://experts.colorado.edu/display/fisid_144904/)
Associate Professor; PhD, University of Colorado Boulder

Hume, David
Lecturer; PhD, University of Colorado Boulder

Hussein, Mahmoud I. (https://experts.colorado.edu/display/fisid_144300/)
Professor; PhD, University of Michigan Ann Arbor

Kapteyn, Henry C. (https://experts.colorado.edu/display/fisid_115334/)
Professor; PhD, University of California, Berkeley

Kaufman, Adam Micah (https://experts.colorado.edu/display/fisid_159513/)
Associate Professor Adjoint; PhD, University of Colorado Boulder

Kempf, Sascha (https://experts.colorado.edu/display/fisid_149628/)
Associate Professor; Dr habil, Technische Universität Braunschweig (Germany)

Kinney, Edward R. (https://experts.colorado.edu/display/fisid_101717/)
Professor; PhD, Massachusetts Institute of Technology

Kitching, John
Lecturer; PhD, California Institute of Techology

Knill, Emanuel
Lecturer; PhD, University of Colorado Boulder

Kunz, P. Dale
Professor Emeritus; PhD, University of Washington

Lee, Minhyea (https://experts.colorado.edu/display/fisid_145209/)
Associate Professor; PhD, University of Chicago

Lehnert, Konrad W. (https://experts.colorado.edu/display/fisid_139785/)
Professor Adjoint; PhD, University of California at Santa Barbara

Leibfried, Dietrich
Lecturer; PhD, Max-Planck Institute for Quantum Optics (Germany)

Levine, Judah (https://experts.colorado.edu/display/fisid_100654/)
Professor Adjoint; PhD, New York University

Lewandowski, Heather Jean (https://experts.colorado.edu/display/fisid_111815/)
Professor, Associate Chair; PhD, University of Colorado Boulder

Litos, Michael (https://experts.colorado.edu/display/fisid_158137/)
Assistant Professor; PhD, Boston University

Lucas, Andrew James (https://experts.colorado.edu/display/fisid_164180/)
Assistant Professor; PhD, Harvard University

Ludlow, Andrew
Lecturer; PhD, University of Colorado Boulder

MacLennan, Joseph E. (https://experts.colorado.edu/display/fisid_104854/)
Professor Attendant Rank, Lecturer; PhD, University of Colorado Boulder

Marino, Alysia Diane (https://experts.colorado.edu/display/fisid_146427/)
Professor; PhD, University of California, Berkeley

Mascarenhas, Angelo
Lecturer; PhD, University of Pittsburgh

McGehee, Michael D. (https://experts.colorado.edu/display/fisid_163453/)
Professor; PhD, University of California, Santa Barbara

Miller, Stanley
Professor Emeritus; PhD, University of California, Berkeley

Munsat, Tobin Leo (https://experts.colorado.edu/display/fisid_134251/)
Professor, Chair; PhD, Princeton University

Murnane, Margaret (https://experts.colorado.edu/display/fisid_115333/)
Distinguished Professor; PhD, University of California, Berkeley

Nagle, James L. (https://experts.colorado.edu/display/fisid_126784/)
Professor; PhD, Yale University

Nam, SaeWoo
Lecturer; PhD, Stanford University

Nandkishore, Rahul Mahajan (https://experts.colorado.edu/display/fisid_156417/)
Associate Professor; PhD, Massachusetts Institute of Technology

Neil, Ethan (https://experts.colorado.edu/display/fisid_153411/)
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Nesbitt, David J. (https://experts.colorado.edu/display/fisid_100333/)
Professor Adjoint; PhD, University of Colorado

Newbury, Nathan
Lecturer; PhD, Princeton University

Papp, Scott
Lecturer; PhD, University of Colorado Boulder

Parker, Scott E. (https://experts.colorado.edu/display/fisid_109685/)
Professor; PhD, University of California, Berkeley

Peleg, Orit (https://experts.colorado.edu/display/fisid_159998/)
Associate Professor; PhD, ETH Zürich (Switzerland)

Pereira Da Costa, Hugo
Lecturer; PhD, Service de Physique Nucleaire du CEA (France)

Perepelitsa, Dennis V. (https://experts.colorado.edu/display/fisid_158294/)
Associate Professor; PhD, Columbia University in the City of New York

Perkins, Katherine K. (https://experts.colorado.edu/display/fisid_124217/)
Professor Attendant Rank; PhD, Harvard University

Perkins, Thomas T. (https://experts.colorado.edu/display/fisid_124578/)
Professor Adjunct; PhD, Stanford University

Peterson, R. Jerome
Professor Emeritus; PhD, University of Washington

Piestun, Rafael (https://experts.colorado.edu/display/fisid_118538/)
Professor; PhD, Israel Instit of Tech (Israel)

Pollock, Steven J. (https://experts.colorado.edu/display/fisid_101392/)
Professor; PhD, Stanford University

Price, John C. (https://experts.colorado.edu/display/fisid_101129/)
Professor Emeritus; PhD, Stanford University

Radzihovsky, Leo (https://experts.colorado.edu/display/fisid_107484/)
Professor; PhD, Harvard University

Rankin, Patricia (https://experts.colorado.edu/display/fisid_105939/)
Professor Emerita; PhD, University of London (England)

Raschke, Markus B. (https://experts.colorado.edu/display/fisid_148716/)
Professor; PhD, Technische Universität München (Germany)

Regal, Cindy Anne (https://experts.colorado.edu/display/fisid_144184/)
Professor; PhD, University of Colorado Boulder

Rey, Ana Maria (https://experts.colorado.edu/display/fisid_146407/)
Professor Adjoint; PhD, University of Maryland College Park Campus

Reznik, Dmitry (https://experts.colorado.edu/display/fisid_147659/)
Professor; PhD, University of Illinois at Urbana–Champaign

Ritzwoller, Michael H. (https://experts.colorado.edu/display/fisid_102264/)
Professor; PhD, University of California, San Diego

Robertson, Scott H.
Professor Emeritus; PhD, Cornell University

Rogers, Charles (https://experts.colorado.edu/display/fisid_101331/)
Professor; PhD, Cornell University

Romatschke, Paul (https://experts.colorado.edu/display/fisid_149870/)
Professor; PhD, Technical Univ of Vienna (Austria)

Schibli, Thomas Richard (https://experts.colorado.edu/display/fisid_143464/)
Professor; PhD, Univ of Karlsruhe (Germany)

Shaheen, Sean Eric (https://experts.colorado.edu/display/fisid_153664/)
Professor; PhD, University of Arizona

Shalm, Lynden Krister (https://experts.colorado.edu/display/fisid_152367/)
Lecturer; PhD, University of Toronto

Shepard, James R.
Professor Emeritus; PhD, University of Colorado Boulder

Shi, Yuan (https://experts.colorado.edu/display/fisid_172193/)
Assistant Professor; PhD, Princeton University

Simmonds, Raymond
Lecturer; PhD, University of California, Berkeley

Slichter, Daniel
Lecturer; PhD, University of California, Berkeley

Smalyukh, Ivan (https://experts.colorado.edu/display/fisid_144757/)
Professor; PhD, Kent State University

Stenson, Kevin M. (https://experts.colorado.edu/display/fisid_128676/)
Professor, Associate Chair; PhD, University of Wisconsin–Madison

Sun, Shuo (https://experts.colorado.edu/display/fisid_165715/)
Assistant Professor; PhD, University of Maryland College Park Campus

Taylor, John
Professor Emeritus; PhD, University of California, Berkeley

Teufel, John D.
Lecturer; PhD, Yale University

Thompson, James Karl (https://experts.colorado.edu/display/fisid_144585/)
Professor Adjoint; PhD, Massachusetts Institute of Technology

Toney, Michael (https://experts.colorado.edu/individual/fisid_167235/)
Professor; PhD, University of Washington

Ullom, Joel
Lecturer; PhD, Harvard University

Ulmer, Keith A. (https://experts.colorado.edu/display/fisid_144871/)
Associate Professor; PhD, University of Colorado Boulder

Uzdensky, Dmitri Anatoljevich (https://experts.colorado.edu/display/fisid_147430/)
Professor; PhD, Princeton University

Van Schilfgaarde, Mark
Lecturer; PhD, Stanford University

Wagner, Stephen R. (https://experts.colorado.edu/display/fisid_139773/)
Professor Attendant Rank; PhD, Johns Hopkins University

Wang, Xu (https://experts.colorado.edu/display/fisid_141619/)
Lecturer; PhD, University of Wisconsin-Madison

Washburn, Brian R.
Lecturer; PhD, Georgia Institute of Technology

West, Colin G. (https://experts.colorado.edu/display/fisid_163336/)
Associate Teaching Professor; PhD, Stony Brook University

Wilcox, Bethany R. (https://experts.colorado.edu/display/fisid_156075/)
Assistant Professor; PhD, University of Colorado Boulder

Wilkerson, Donald (https://experts.colorado.edu/display/fisid_104406/)
Associate Teaching Professor; MA, University of Colorado Boulder

Wilson, Andrew
Lecturer; PhD, University of Otago (New Zealand)

Wineland, David J. (https://experts.colorado.edu/display/fisid_119931/)
Professor Adjoint; PhD, Harvard University

Ye, Jun (https://experts.colorado.edu/display/fisid_106154/)
Professor Adjoint; PhD, University of Colorado Boulder

Zabow, Gary
Lecturer; PhD, Harvard University

Zhong, Shijie (https://experts.colorado.edu/display/fisid_118396/)
Professor; PhD, University of Michigan Ann Arbor

Zimmerman, Eric (https://experts.colorado.edu/display/fisid_122809/)
Professor; PhD, University of Chicago

Courses

PHYS 5030 (3) Intermediate Mathematical Physics 1
This course and its continuation, PHYS 5040, form a survey of classical mathematical physics. Studies complex variable theory and finite vector spaces, and includes topics in ordinary and partial differential equations, boundary value problems, potential theory, and Fourier analysis.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5030
Requisites: Restricted to graduate students only.

PHYS 5040 (3) Intermediate Mathematical Physics 2
Continuation of PHYS 5030. Includes group theory, special functions, integral transforms, integral equations and calculus of variations.
Equivalent - Duplicate Degree Credit Not Granted: MATH 5040
Requisites: Restricted to graduate students only.
Recommended: Prerequisite PHYS 5030.

PHYS 5070 (3) Introduction to Computational Physics
Surveys methods and practices in programming and scientific computing for the study of physics, using the Python programming language. Core material will include data analysis and visualization, numerical solution of differential equations, working with large-scale remote computers, and general software skills such as debugging, version control, and collaborative tools. Previously offered as a special topics course.
Requisites: Restricted to graduate students only.

PHYS 5130 (3) Biological Electron Microscopy: Principles and Recent Advances
Covers basic mechanisms for imaging and recent advances used in current biological research, elements of electron optics, image optimization, resolution, radiation damage, various imaging modes (TEM, HVEM, Sem, Stem, Stm), specimen quantitation and reconstruction (stereo and 3-D), microanalysis and electron diffraction. Specimen preparation treated only incidentally.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 4130

PHYS 5141 (3) Astrophysical and Space Plasmas
Covers magnetohydrodynamics and a few related areas of plasma physics applied to space and astrophysical systems, including planetary magnetospheres and ionospheres, stars, and interstellar gas in galaxies.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5140
Requisites: Restricted to Physics (PHYS) or Astronomy (ASTR) graduate students only.

PHYS 5150 (3) Introductory Plasma Physics
Includes basic phenomena of ionized gases, static and dynamic shielding, linear waves, instabilities, particles in fields, collisional phenomena, fluid equations, collisionless Boltzman equations, Landau damping, scattering and absorption of radiation in plasmas, elementary nonlinear processes, WKB wave theory, controlled thermonuclear fusion concepts, astrophysical applications and experimental plasma physics (laboratory). Department enforced prerequisite: PHYS 3310. Instructor consent required for undergraduates.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5150
Requisites: Restricted to graduate students only.

PHYS 5160 (3) Fundamentals of Optics and Lasers
Covers the basic physic of lasers. Topics include basics of optical resonators and gaussian beam propagation, stimulated emission, laser threshold conditions, laser linewidth, q-switching and mode locking of lasers, tuning of Cw lasers, and specifics of various common lasers.
Requisites: Restricted to graduate students only.

PHYS 5210 (3) Theoretical Mechanics
Variational principles, Lagrange's equations, Hamilton's equations, motion of rigid body, relativistic mechanics, transformation theory, continuum mechanics, small oscillations, Hamilton-Jacobi theory.
Requisites: Restricted to graduate students only.

PHYS 5250 (3) Introduction to Quantum Mechanics 1
Quantum phenomena, Ehrenfest theorem and relation to classical physics, applications to one-dimensional problems, operator techniques, angular momentum and its representations, bound states and hydrogen atom, and Stern-Gerlack experiment and spin and spinor wave function. Department enforced prerequisite: advanced undergraduate quantum mechanics course.
Requisites: Restricted to graduate students only.

PHYS 5260 (3) Introduction to Quantum Mechanics 2
Symmetries and conservation laws, identical particle systems, approximation techniques (including time-dependent and time-independent perturbation theories and variational techniques) and their applications, scattering theory, radiative transitions, and helium atom.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite PHYS 5250.

PHYS 5400 (3) Introduction to Fluid Dynamics
Covers equations of fluid motion relevant to planetary atmospheres and oceans and stellar atmospheres; effects of rotation and viscosity; and vorticity dynamics, boundary layers and wave motions. Introduces instability theory, nonlinear equilibration and computational methods in fluid dynamics. Department enforced prerequisite: partial differential equations or equivalent.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 5400 and ASTR 5400
Requisites: Restricted to graduate students only.

PHYS 5430 (3) Advanced Laboratory
Two lectures, one lab per week. Experiments introduce students to realities of the experimental physics so they gain a better understanding of theory and an appreciation of the vast amount of experimental work done in the physical sciences today. Department enforced prerequisites: PHYS 3330 and PHYS 3220 and PHYS 3320. Department enforced corequisites: PHYS 4410.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 4430
Requisites: Restricted to graduate students only.

PHYS 5450 (3) History and Philosophy of Physics
Discusses the epistemic question of what characterizes good physics research as well as the metaphysical question of what our best physics research tells us about the world. Topics may include case studies of physics experiments, theory choice, and scientific methodology in physics, as well as foundational metaphysical questions in statistical mechanics, quantum mechanics, special and general relativity, chance and probability, and the laws of nature.
Equivalent - Duplicate Degree Credit Not Granted: PHIL 4450 and PHIL 5450 and PHIL 5450
Requisites: Restricted to graduate students only.

PHYS 5460 (3) Teaching and Learning Physics
Learn how people understand key concepts in physics. Through examination of physics content, pedagogy and problems, through teaching, and through research in physics education, students will explore the meaning and means of teaching physics. Students will gain a deeper understanding of how education research is done and how people learn. Useful for all students, especially for those interested in physics, teaching, and education research.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 4460 and EDUC 4460 and EDUC 5460
Requisites: Restricted to graduate students only.

PHYS 5550 (3) Cells, Molecules and Tissues: A Biophysical Approach
Focuses on the biophysics governing the structure/function of enzymes, cells, extracellular matrix and tissue. Synthesizes ideas from molecular biology, physics, and biochemistry, emphasizing how low Reynolds number physics, not Newtonian physics, is relevant to life inside a cell.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 4550 and MCDB 4550 and MCDB 5500

PHYS 5560 (3) Introduction to Biophysics
Covers an introduction to the physics of living systems. Focuses on how living systems are able to generate order, with both physical principles and biological examples. Covers the development of quantitative models for biological systems, including estimates. Taught from a physics perspective, with biology background introduced as needed.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 4560 and MCDB 4560 and MCDB 5560
Grading Basis: Letter Grade

PHYS 5606 (3) Optics Laboratory
Consists of 13 optics experiments that introduce the techniques and devices essential to modern optics, including characterization of sources, photodetectors, modulators, use of interferometers, spectrometers and holograms, and experimentation of fiber optics and Fourier optics.
Equivalent - Duplicate Degree Credit Not Granted: ECEN 5606
Recommended: Prerequisite undergraduate optics course such as PHYS 4510.

PHYS 5730 (3) Particle Physics
Introduces the properties of elementary particles, phenomenology of particle interactions, particle detector, particle accelerators, scattering cross sections, decay rates, electron-positron annihilation, lepton scattering and hadron structure, quantum chromodynamics, electroweak interactions, symmetries and symmetry breaking.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites undergraduate courses in quantum mechanics and electricity and magnetism.

PHYS 5770 (3) Gravitational Theory (Theory of General Relativity)
Presents Einstein's relativistic theory of gravitation from geometric viewpoint; gives applications to astrophysical problems (gravitational waves, stellar collapse, etc.). Instructor consent required for undergraduates.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites PHYS 3220 and PHYS 3320.

PHYS 5840 (1-3) Selected Topics for Graduate Independent Study
Subject matter to be arranged.
Repeatable: Repeatable for up to 7.00 total credit hours. Allows multiple enrollment in term.

PHYS 5970 (3) Seminar on Physical Methods in Biology
Covers basic mechanisms and applications of physical methods used in current biological research, microprobe analysis, Eels, elementary electron and x-ray crystallography, biomedical imaging (NMR, MRI, Pet, Cat), Fourier analysis, synchrotron radiation, Exafs, neutron scattering and novel ultramicroscopy techniques. Includes lectures, student presentations, occasional demonstrations. Emphasis depends on student interest.
Equivalent - Duplicate Degree Credit Not Granted: PHYS 4970
Requisites: Restricted to graduate students only.

PHYS 6260 (3) Geometry of Quantum Fields and Strings
Focuses on differential geometric techniques in quantum field and string theories. Topics include: spinors, Dirac operators, index theorem, anomalies, geometry of superspace, supersymmetric quantum mechanics and field theory and nonperturbative aspects in field and string theories.
Equivalent - Duplicate Degree Credit Not Granted: MATH 6260
Recommended: Prerequisites MATH 6230 and PHYS 5250 and MATH 6240 and PHYS 7280.

PHYS 6610 (3) Earth and Planetary Physics 1
Examines mechanics of deformable materials, with applications to earthquake processes. Introduces seismic wave theory. Other topics include inversion of seismic data for the structure, composition and state of the interior of the Earth.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6610 and ASTR 6610
Requisites: Restricted to graduate students only.

PHYS 6620 (3) Earth and Planetary Physics 2
Covers space and surface geodetic techniques as well as potential theory. Other topics are the definition and geophysical interpretation of the geoid and of surface gravity anomalies; isostasy; post-glacial rebound; and tides and the rotation of the Earth.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6620 and ASTR 6620
Requisites: Restricted to graduate students only.

PHYS 6630 (3) Earth and Planetary Physics 3
Examines the solar system, emphasizing theories of its origin and meteorites. Highlights distribution of radioactive materials, age dating, heat flow through continents and the ocean floor, internal temperature distribution in the Earth, and mantle convection. Also covers the origin of the oceans and atmosphere.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6630 and ASTR 6630
Requisites: Restricted to graduate students only.

PHYS 6650 (1-3) Seminar in Geophysics
Advanced seminar studies in geophysical subjects for graduate students.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 6650 and GEOL 6650
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

PHYS 6655 (3) InSAR Processing and Interpretation
Understand the concepts and applications of interferometric synthetic aperture radar (InSAR) and differential InSAR, to include an introduction to physical geodesy and satellite techniques.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6655
Grading Basis: Letter Grade

PHYS 6670 (2) Geophysical Inverse Theory
Principles of geophysical inverse theory as applied to problems in the Earth sciences, including topography, Earth structure and earthquake locations.
Equivalent - Duplicate Degree Credit Not Granted: GEOL 6670
Requisites: Restricted to graduate students only.
Recommended: Prerequisites a course in calculus and a course in computer programming (any language).

PHYS 6940 (1) Master's Candidate for Degree
Registration intended for students preparing for a thesis defense, final examination, culminating activity, or completion of degree.

PHYS 6950 (1-6) Master's Thesis
Approved problem in theoretical or experimental physics under the direction of staff members. Intended to introduce the student to procedures in research and development work. Work of an original nature expected.
Repeatable: Repeatable for up to 6.00 total credit hours.
Requisites: Restricted to graduate students only.

PHYS 7160 (3) Intermediate Plasma Physics
Continuation of PHYS 5150. Topics vary yearly but include nonlinear effects such as wave coupling, quasilinear relaxation, particle trapping, nonlinear Landau damping, collisionless shocks, solutions; nonneutral plasmas; kinetic theory of waves in a magnetized plasma; anisotropy; inhomogeneity; radiation- ponderomotive force, parametric instabilities, stimulated scattering; plasma optics; kinetic theory and fluctuation phenomena.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 7160
Requisites: Restricted to graduate students only.
Recommended: Prerequisite PHYS 5150.

PHYS 7230 (3) Statistical Mechanics
Classical and quantum statistical theory, including study of both equilibrium and nonequilibrium systems. Topics covered include kinetic theory, degenerate gases, macrocanonical and grand canonical ensembles, and irreversible processes. Department enforced prerequisite: advanced undergraduate quantum mechanics course.
Requisites: Restricted to graduate students only.

PHYS 7240 (3) Advanced Statistical Mechanics
Introduces current research topics in statistical mechanics. Topics vary from year to year and may include phase transitions, critical phenomena, nonequilibrium phenomena, dense fluids, dynamical systems, plasma physics, or quantum statistical mechanics.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite PHYS 7230.

PHYS 7250 (3) Quantum Many Body Theory
Theory of quantum many body systems, including methods based on Green's functions, Feynman diagrams, and coherent state path integral with applications to interacting quantum gases, superconductivity and superfluidity, quantum phase transitions, quantum magnetism, quantum motion in the presence of disorder, and topological states of matter.
Requisites: Restricted to graduate students only.

PHYS 7270 (3) Introduction to Quantum Mechanics 3
Radiation theory; relativistic wave equations with simple applications; introduction to field theory and second quantization.
Requisites: Restricted to graduate students only.

PHYS 7280 (3) Advanced Quantum Theory
Quantum theory of fields, elementary particles, symmetry laws, and topics of special interest.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite PHYS 7270 or instructor consent required.

PHYS 7310 (3) Electromagnetic Theory 1
Sophisticated approach to electrostatics, boundary value problems, magnetostatics, applications of Maxwell's equations to electromagnetic wave propagation, wave guides, and resonant cavities and magnetohydrodynamics.
Requisites: Restricted to graduate students only.

PHYS 7320 (3) Electromagnetic Theory 2
Continuation of PHYS 7310. Topics include relativistic particle dynamics; radiation by moving charges; multiple fields; radiation damping and self-fields of a particle; collisions between charged particles and energy loss; radiative processes; and classical field theory.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite PHYS 7310.

PHYS 7430 (3) Soften Condensed Matter Physics
Introduces the science of liquid crystals, polymers, biological membranes, biopolymers, block copolymers, molecular monolayers, colloids, nanoparicle suspensions, emulsions, foals, gels, elastomers and other soft materials. Topics vary from semester to semester and is geared toward graduate students with diverse preparation backgrounds, including students from the Department of Physics, as well as other science and engineering departments.
Requisites: Restricted to graduate students only.

PHYS 7440 (3) Theory of the Solid State
Stresses application to the solid state of physical concepts basic to much of modern physics, single-particle approximation, and the energy-band description of electron states in solids, pseudopotential theory applied to ordered and disordered systems, dynamical behavior of electrons in solids, lattice dynamics, Hartree-Fock and random-phase approximation in solids, many-body aspects of magnetism, and superconductivity.
Requisites: Restricted to graduate students only.

PHYS 7450 (3) Theory of Solid State 2
Second semester of condensed matter physics, covers topics in soft condensed matter physics, liquid crystals, semiconductors, Quantum Hall effect, Fractional Quantum Hall effect, superconductivity and other topics at the discretion of the instructor.
Requisites: Restricted to graduate students only.

PHYS 7550 (3) Atomic and Molecular Spectra
Covers theory of atomic structure and spectra, including coupling of angular momenta, tensor operators, energy levels, fine and hyperfine structure, transition probabilities, Zeeman and Stark effects. Molecular spectra: electronic, vibrational, and rotational states. Rotation matrices, symmetric top.
Requisites: Restricted to graduate students only.

PHYS 7560 (3) Quantum Optics
Covers quantum optical and atomic systems including topics such as: coherent and squeezed states, theory of optical coherence, atom-radiation interaction, optical Bloch equations, open quantum systems, dynamics on the Bloch sphere, resonance fluorescence, beam-splitters and interferometry, entanglement and quantum information.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites PHYS 3220 and PHYS 4410.

PHYS 7570 (3) Quantum Information and Computing
Covers the foundations of quantum information and computing. Includes bits and qubits, entanglement, quantum algorithms, and quantum error correction. More advanced topics selected from: Quantum Shannon theory, quantum communication and networks, quantum-enhanced measurements, and quantum simulation. Department enforced prerequisite: PHYS 5250.
Requisites: Restricted to graduate students only.

PHYS 7650 (3) Nonlinear and Nano-Optics
Covers the field of ultrafast optics including both experimental and theoretical aspects. Topics include: description of ultrashort optical pulses, propagation of pulses including dispersion and nonlinearity, their integration, measurement and manipulation and their use in applications including spectroscopy.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites PHYS 4510 or PHYS 5160.

PHYS 7660 (3) Ultrafast Optics
Covers the field of ultrafast optics including both experimental and theoretical aspects. Topics include description of ultrashort optical pulses, propagation of pulses including dispersion and nonlinearity, their generation, measurement and manipulation and their use in applications including spectroscopy. Department enforced prerequisite: PHYS 5160, or PHYS 4510, or ECEN 5645.
Requisites: Restricted to graduate students only.
Grading Basis: Letter Grade

PHYS 7730 (3) Theory of Elementary Particles
Systematics of elementary particles, leptons, quarks,gauge bosons, symmetries and symmetry breaking, scattering cross sections, decay rates, electron-positron annihilation, lepton scattering and hadron structure, quantum chromodynamics, electroweak interactions, gauge theories.
Requisites: Restricted to graduate students only.

PHYS 7810 (1-3) Special Topics in Physics
Various topics not normally covered in the curriculum; offered intermittently depending on student demand and availability of instructors.
Repeatable: Repeatable for up to 7.00 total credit hours. Allows multiple enrollment in term.
Requisites: Restricted to graduate students only.

PHYS 7820 (3) Topics in Scientific Writing
Teaches strategies used in scientific writing with emphasis on problem statement, audience analysis and principles of sound argument; reviews and reinforces essential writing skills, stressing the need for careful and strategic revision; provides experience in writing academic and professional communications; presentation skills and proposal writing. Most appropriate for students beginning to write journal articles, Comps II paper, or dissertation chapter.
Requisites: Restricted to graduate students only.

PHYS 7830 (1) Plasma Seminar
One credit 'journal club' style course covering current and significant historical advances in plasma physics research. Each week the class is assigned a journal article to read in advance of the meeting and one student is selected (on a rotating basis) to present a synopsis and lead a round-table discussion. Cannot be used for minimum credit hour requirements of graduate program. See also PHYS 7810 and PHYS 7820. May be repeated for a total of 7 credit hours.
Repeatable: Repeatable for up to 7.00 total credit hours. Allows multiple enrollment in term.
Grading Basis: Letter Grade

PHYS 7840 (1-3) Selected Topics for Graduate Independent Study
Subject matter to be arranged.
Repeatable: Repeatable for up to 7.00 total credit hours. Allows multiple enrollment in term.

PHYS 7850 (1-3) Selected Topics for Graduate Independent Study
Subject matter to be arranged. May be repeated for a total of 7 credit hours.
Repeatable: Repeatable for up to 7.00 total credit hours. Allows multiple enrollment in term.

PHYS 8990 (1-10) Doctoral Dissertation
All doctoral students must register for not fewer than 30 hours of dissertation credit as part of the requirements for the degree. For a detailed discussion of doctoral dissertation credit, refer to the Graduate School section.
Repeatable: Repeatable for up to 30.00 total credit hours.