

Physics (PHYS)

Courses primarily for undergraduates:

PHYS 101. Physics for the Nonscientist.

(3-0) Cr. 3. F.S.

Survey of the principal areas of both classical and modern physics. Emphasis on the nature of the physical universe and the application of physical principles to life in the modern world. Not suitable to meet a general physics requirement for natural science majors.

PHYS 102L. Physical Sciences for Elementary Education.

(Cross-listed with CHEM). (1-5) Cr. 3. S. Prereq: MATH 195 or MATH 140

Introduction to physics and chemistry via weekly, guided-inquiry laboratories. Topics to include states of matter and changes in states of matter, sound, light, electricity, magnetism, heat, forces and how they are related to an object's motion.

PHYS 111. General Physics.

(4-2) Cr. 5. F.S.SS. Prereq: 1 1/2 years of high school algebra, 1 year of geometry, 1 semester of trigonometry

General background in physical concepts, principles, and methods for those who do not plan advanced study in physics or engineering. Mechanics, fluids, heat and thermodynamics, vibrations, waves, sound.

PHYS 112. General Physics.

(4-2) Cr. 5. F.S.SS. Prereq: PHYS 111

General background in physical concepts, principles, and methods for those who do not plan advanced study in physics or engineering. Electricity and magnetism, ray and wave optics, topics in modern physics.

PHYS 115. Physics for the Life Sciences.

(4-0) Cr. 4. F.S. Prereq: high school: 1 1/2 yr. algebra, 1 yr. geometry, 1 semester trigonometry

Emphasis on basic physics principles applied to biological problems. Topics include mechanics, fluids, thermodynamics, heat, light, sound, electricity and magnetism. A coordinated laboratory, Physics 115 laboratory is available.

PHYS 115L. Laboratory in Physics for the Life Sciences.

(0-2) Cr. 1. F.S.

Experiments related to the elementary topics of physics for the life sciences. Mechanics, fluids, thermodynamics, heat, light, sound, electricity and magnetism.

PHYS 198. Physics of Music.

(2-2) Cr. 3. F.

Introductory level course on sound for nonphysics majors. Properties of pure tones and harmonics; human perception of sound; room acoustics; scales; production, and analysis of musical by voice, string, woodwind, brass, and percussion instruments. Not suitable to meet a general physics requirement for natural science majors

PHYS 199. Introductory Seminar.

Cr. R. F.

(1-1) Gain experience in key skills that physicists/astronomers use routinely, but are rarely explicitly taught in formal courses. Participate in faculty-led discussions on frontier areas and careers. Offered on a satisfactory-fail basis only.

PHYS 221. Introduction to Classical Physics I.

(4.5-1) Cr. 5. F.S.SS. Prereq: Credit or enrollment in MATH 166

For engineering and science majors. 3 hours of lecture each week plus 3 recitations and 1 laboratory every 2 weeks. Elementary mechanics including kinematics and dynamics of particles, work and energy, linear and angular momentum, conservation laws, rotational motion, oscillations, gravitation. Heat, thermodynamics, kinetic theory of gases; waves and sound.

PHYS 221H. Introduction to Classical Physics I: Honors.

(4.5-1) Cr. 5. F.S. Prereq: Credit or enrollment in MATH 166

For engineering and science majors. 3 hours of lecture each week plus 3 recitations and 1 laboratory every 2 weeks. Elementary mechanics including kinematics and dynamics of particles, work and energy, linear and angular momentum, conservation laws, rotational motion, oscillations, gravitation. Heat, thermodynamics, kinetic theory of gases; waves and sound.

PHYS 222. Introduction to Classical Physics II.

(4-2) Cr. 5. F.S.SS. Prereq: PHYS 221, MATH 166

3 hours of lecture each week plus 1 recitation and 1 laboratory each week. Electric forces and fields. Electrical currents; DC circuits. Magnetic forces and fields: LR, LC, LCR circuits; Maxwell's equations; ray optics and image formation; wave optics; topics in modern physics.

PHYS 222H. Introduction to Classical Physics II: Honors.

(4-2) Cr. 5. F.S. Prereq: PHYS 221, MATH 166

3 hours of lecture each week plus 1 recitation and 1 laboratory each week. Electric forces and fields. Electrical currents; DC circuits. Magnetic forces and fields: LR, LC, LCR circuits; Maxwell's equations; ray optics and image formation; wave optics; topics in modern physics.

PHYS 241. Principles and Symmetries in Classical Physics I.

(4.5-1) Cr. 5. F. Prereq: Credit or enrollment in MATH 166

Covers all of mechanics; Kinematics and dynamics of particles, work and energy, linear and angular momentum, conservation laws, rotational motion, oscillations, gravitation, and extremum principles. Topics in kinetic theory, thermodynamics, waves and sound.

PHYS 241H. Principles and Symmetries in Classical Physics I, Honors..

(4.5-1) Cr. 5. F. Prereq: Credit or enrollment in MATH 166; non-physics majors must have permission

Covers all of mechanics; Kinematics and dynamics of particles, work and energy, linear and angular momentum, conservation laws, rotational motion, oscillations, gravitation, and extremum principles. Topics in kinetic theory, thermodynamics, waves and sound.

PHYS 242. Principles and Symmetries in Classical Physics II.

(4-2) Cr. 5. S. Prereq: PHYS 221 or PHYS 241, MATH 166

Electrostatics, potentials and fields, currents, fields of moving charges, the magnetic field, electromagnetic induction, DC and AC circuits, Maxwell's equations and electromagnetic waves, electric and magnetic fields in matter. Topics in optics, special relativity and modern physics.

PHYS 242H. Principles and Symmetries in Classical Physics II, Honors (Spring)..

(4-2) Cr. 5. S. Prereq: PHYS 221 or 241, MATH 166

Electrostatics, potentials and fields, currents, fields of moving charges, the magnetic field, electromagnetic induction, DC and AC circuits, Maxwell's equations and electromagnetic waves, electric and magnetic fields in matter. Topics in optics, special relativity and modern physics.

PHYS 290. Independent Study.

Cr. 1-4. Repeatable. Prereq: Permission of instructor

PHYS 298. Cooperative Education.

Cr. R. F.S.SS. Prereq: Permission of the department cooperative education coordinator; sophomore classification

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

PHYS 302. The Challenge of Contemporary Physics.

(3-0) Cr. 3. S. Prereq: Sophomore classification

A largely nonmathematical but intellectually challenging exploration of physics, which assumes no previous work in the field. Selected material from classical and modern physics establishes the conceptual framework for the study of major areas of contemporary physics, culminating in the discussion of topics at the frontier of present knowledge. Topics vary yearly and may include quarks, lasers, superconductivity, fission and fusion, solid state devices, gravitational waves, string theory, facilities, left handed materials, and quantum computing. Not suitable to meet a general physics requirement for natural science majors.

PHYS 304. Thermal Physics.

(3-0) Cr. 3. F. Prereq: PHYS 222, MATH 266

Concepts of temperature, entropy, and other characteristic thermodynamic functions, with application to macroscopic properties of matter. The laws of thermodynamics. Introduction to statistical mechanics, including quantum statistics. Application to black body radiation, crystalline vibrations, magnetic ions in solids, electronic heat capacity of metals. Phase transformations and chemical reactions. Nonmajor graduate credit.

PHYS 306. Physics of Wave Motion.

(3-0) Cr. 3. S. Prereq: PHYS 222, credit or enrollment in MATH 267

Oscillating systems including damped and forced oscillations; fluids, geometric optics, water waves, the wave equation, Fourier and Laplace transforms, non-uniform media, cylindrical and spherical waves, polarization, interference and diffraction, transmission lines, non-linear waves.

PHYS 310. Electronic Instrumentation for Experimental Physics.

(2-4) Cr. 4. F. Prereq: PHYS 222; MATH 166

Common electrical instruments; power supplies; transducers; passive and active devices, analog integrated circuits, including filters and amplifiers; digital integrated circuits; signal transmission and enhancement. Nonmajor graduate credit.

PHYS 311. Intermediate Laboratory.Cr. 1-2. Repeatable. S. *Prereq: PHYS 222*

Experiments in classical and modern physics performed independently by each student. Nonmajor graduate credit.

PHYS 311T. Intermediate Laboratory for Secondary Physics Teachers.(0-6) Cr. 3. Repeatable. S. *Prereq: PHYS 112 or PHYS 222*

Experiments in classical and modern physics performed independently by each student. For students preparing for a career in high school teaching.

PHYS 321. Introduction to Modern Physics I.(3-0) Cr. 3. F. *Prereq: PHYS 222, credit or enrollment in MATH 266*

Quantum nature of matter: photons, de Broglie's postulate: wave-like properties of matter; Bohr's model of hydrogen atom; Schrodinger equations in one dimension: energy quantization; detailed solutions for potential steps, barriers and wells; one-electron atoms, spin and magnetic interactions; ground states, optical and x-ray excitations of multi-electron atoms.

PHYS 321L. Introductory Laboratory in Modern Physics I.(0-2) Cr. 1. F. *Prereq: Credit or enrollment in PHYS 321*

Experiments related to the foundations of modern physics. The dual wave and particle character of electrons and photons, statistics, interferometry and x-ray spectroscopy.

PHYS 322. Introduction to Modern Physics II.(3-0) Cr. 3. S. *Prereq: PHYS 321*

Quantum statistics; lasers; physics of molecules. Properties of solids, including electron band structure, superconductivity and magnetism. Nuclear physics, including nuclear sizes and masses, stability, decay modes, reactions, fission and fusion. Elementary particles, including strangeness, charm, and quarks. Fundamental forces of nature.

PHYS 322L. Introductory Laboratory in Modern Physics II.(0-2) Cr. 1. S. *Prereq: Credit or enrollment in PHYS 322*

Experiments related to the foundations of modern physics. Radioactive decay, elementary particles, Hall effect, quantization, spectroscopy, statistics and instrumentation.

PHYS 361. Classical Mechanics.(3-0) Cr. 3. F. *Prereq: PHYS 222, MATH 265, MATH 266*

Newtonian mechanics including forced oscillations, central forces and orbital motion, collisions, moving frames of reference, Lagrange's equations. Nonmajor graduate credit.

PHYS 362. Intermediate Mechanics.(3-0) Cr. 3. S. *Prereq: PHYS 361*

Rigid body motion; small oscillations, normal modes. Special relativity including length contraction, time dilation, simultaneity, Lorentz transformation, 4-vector covariant formalism, relativistic mechanics. Nonmajor graduate credit.

PHYS 364. Electricity and Magnetism I.(3-0) Cr. 3. F. *Prereq: PHYS 222*

Static electric and magnetic fields, potential theory; electromagnetism, Maxwell's equations. Nonmajor graduate credit.

PHYS 365. Electricity and Magnetism II.(3-0) Cr. 3. S. *Prereq: PHYS 364*

Relativistic electromagnetic theory; radiation and propagation of electromagnetic waves; interaction with matter. Nonmajor graduate credit.

PHYS 389. Junior Seminar.

Cr. R. S.

Recommended for all junior physics majors. Career opportunities: graduate school programs and application, job placement, alternative careers, basic skills needed for the job market competition. Offered on a satisfactory-fail basis only.

PHYS 398. Cooperative Education.Cr. R. F.S.SS. *Prereq: Permission of the department cooperative education coordinator; junior classification*

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

PHYS 399. Seminar on Secondary School Physics.Cr. 1-2. Repeatable, maximum of 2 credits. F. *Prereq: Permission of instructor*
Review of materials and curricula for secondary school physics presented and discussed by members of the class. Required for approval to teach physics in secondary schools.**PHYS 421. Ultrafast Laser Science and Spectroscopy.**(Dual-listed with PHYS 521). (3-0) Cr. 3. F. *Prereq: PHYS 321, PHYS 365, or equivalent with permission of instructor*

Introduction to ultrafast lasers, nonlinear optics, and their applications. Topics selected from: basic optics, atom-photon interactions, electrostatics of condensed matter, laser physics, ultrafast and nonlinear optics, ultrashort pulse generation, broadband pulse generation, time-resolved spectroscopy and instrumentation. Nonmajor graduate credit.

PHYS 426. Mathematical Methods for the Physical Sciences.(3-0) Cr. 3. F. *Prereq: Math 266 or 267*

A fast-paced course primarily for first-year graduate students in physics and chemistry. Emphasis on techniques needed for quantum mechanics and electrostatics. Functions of a complex variable and contour integration, integral transforms and applications, series methods for ordinary differential equations, Green's functions, Sturm-Liouville problems and orthogonal functions, boundary-value problems for partial differential equations. Nonmajor graduate credit.

PHYS 432. Molecular and Cell Biophysics.(Dual-listed with PHYS 532). (3-0) Cr. 3. S. *Prereq: PHYS 304 or CHEM 325.*

Quantitative description of biological systems using basic physical laws, including a brief discussion of a variety of biophysical techniques. Topics include: thermodynamics, chemical equilibrium, gene expression, structure and physical properties of nucleic acids and proteins, folding of nucleic acids and proteins, chemical kinetics, catalysis, allosteric enzymes, cell membrane structure and physical properties, and machines in cell membranes. Nonmajor graduate credit.

PHYS 450. Undergraduate Research.Cr. 1-6. Repeatable. F.S.SS. *Prereq: Permission of instructor*

Theoretical research under supervision of physics faculty.

PHYS 450L. Undergraduate Research.Cr. 1-6. Repeatable. F.S.SS. *Prereq: PHYS 311, permission of instructor*

Laboratory project under supervision of physics faculty.

PHYS 461. Physics of Biomolecules.(Dual-listed with PHYS 561). (3-0) Cr. 3. F. *Prereq: PHYS 304 or CHEM 325, BBMB 301, or permission of instructor*

Cell and Molecular Biophysics. Physical techniques used to characterize the structure, dynamics and properties of biomolecules with emphasis on single molecule techniques.

PHYS 470L. Applied Physics Laboratory.Cr. 2-5. Repeatable. F.S.SS. *Prereq: PHYS 322 and permission of instructor*

Studies in modern experimental techniques via experimentation and simulation in various areas of applied physics, e.g. superconductivity, optical spectroscopy, nuclear magnetic resonance, electron spin resonance, x-ray diffraction, and computation of electronic and structural properties of matter.

PHYS 480. Quantum Mechanics I.(3-0) Cr. 3. F. *Prereq: PHYS 322, MATH 385*

First semester of a full-year course. A systematic development of the formalism and applications of quantum mechanics. Solutions to the time independent Schrodinger equation for various one-dimensional potentials including the harmonic oscillator; operator methods; Heisenberg picture; angular momentum; the hydrogen atom; spin; symmetry properties. Nonmajor graduate credit.

PHYS 481. Quantum Mechanics II.(3-0) Cr. 3. S. *Prereq: PHYS 480*

Continuation of 480. Addition of angular momentum; charged particles in electromagnetic fields; time-independent perturbation theory; variational principles; WKB approximation; interaction picture; time-dependent perturbation theory; adiabatic approximation; scattering; selected topics in radiation theory; quantum paradoxes. Nonmajor graduate credit.

PHYS 490. Independent Study.Cr. 1-4. Repeatable, maximum of 9 credits. *Prereq: 6 credits in physics, permission of instructor*

No more than 9 credits of Phys 490 may be counted toward graduation.

PHYS 490H. Independent Study, Honors.Cr. 1-4. Repeatable, maximum of 9 credits. *Prereq: 6 credits in physics, permission of instructor*

No more than 9 credits of Phys 490 may be counted toward graduation.

PHYS 496. Modern Optics.

(Cross-listed with E E). (3-0) Cr. 3. S. *Prereq: Credit or enrollment in PHYS 322, PHYS 365, and PHYS 480*

Review of wave and electromagnetic theory; topics selected from: reflection/refraction, interference, geometrical optics, Fourier analysis, dispersion, coherence, Fraunhofer and Fresnel diffraction, holography, quantum optics, nonlinear optics. Nonmajor graduate credit.

PHYS 498. Cooperative Education.

Cr. R. F.S.SS. *Prereq: Permission of the department cooperative education coordinator; senior classification*

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

Courses primarily for graduate students, open to qualified undergraduates:**PHYS 501. Oral Communication of Physics Seminar.**

(2-0) Cr. 1. Repeatable. F.

A practical introduction to communication methods in physics and astronomy classrooms and professional settings. For graduate physics majors only. Offered on a satisfactory-fail basis only.

PHYS 502. Introductory Research Seminar.

Cr. R. F.

(1-1) Discussion by research staff of their research areas, expected thesis research work, and opportunities in the field. For graduate physics majors only. Offered on a satisfactory-fail basis only.

PHYS 511. Condensed Matter Physics I.

(3-0) Cr. 3. S. *Prereq: PHYS 304, credit or enrollment in PHYS 481*

First semester of a full-year course. Free electron model; crystal symmetry; band theory of solids; transport properties; Fermi surface; phonons; semiconductors; crystal surfaces; magnetism; superconductivity.

PHYS 512. Condensed Matter Physics II.

(3-0) Cr. 3. F. *Prereq: PHYS 511*

Continuation of 511. Free electron model; crystal symmetry; band theory of solids; transport properties; Fermi surface; phonons; semiconductors; crystal surfaces; magnetism; superconductivity.

PHYS 521. Ultrafast Laser Science and Spectroscopy.

(Dual-listed with PHYS 421). Cr. 3. F. *Prereq: PHYS 321, PHYS 365, or equivalent with permission of instructor*

Introduction to ultrafast lasers, nonlinear optics, and their applications. Topics selected from: basic optics, atom-photon interactions, electrodynamics of condensed matter, laser physics, ultrafast and nonlinear optics, ultrashort pulse generation, broadband pulse generation, time-resolved spectroscopy and instrumentation.

PHYS 526. Particle and Nuclear Physics.

(4-0) Cr. 4. S. *Prereq: Credit or enrollment in PHYS 481*

Basic properties and structures of nuclei, hadrons, and elementary particles; weak and strong interactions; the Standard Model; accelerators and detectors; nuclear models; nuclear decay and stability; nuclear astrophysics; the Higgs mechanism; the CKM matrix; running coupling constants; relativistic heavy-ion collisions; selected topics beyond the standard model such as SUSY and grand unification.

PHYS 531. Statistical Mechanics.

(3-0) Cr. 3. S. *Prereq: PHYS 304 and credit or enrollment in PHYS 481, MATH 465, credit or enrollment in MATH 365 or MATH 426*

Thermodynamic properties of systems of many particles obeying Boltzmann, Fermi-Dirac, and Bose-Einstein statistics; microcanonical, canonical, and grand canonical ensembles and their application to physical problems; density matrices; introduction to phase transitions; renormalization group theory; kinetic theory and fluctuations.

PHYS 532. Molecular and Cell Biophysics.

(Dual-listed with PHYS 432). (3-0) Cr. 3. S. *Prereq: PHYS 304 or CHEM 325.*

Quantitative description of biological systems using basic physical laws, including a brief discussion of a variety of biophysical techniques. Topics include: thermodynamics, chemical equilibrium, gene expression, structure and physical properties of nucleic acids and proteins, folding of nucleic acids and proteins, chemical kinetics, catalysis, allosteric enzymes, cell membrane structure and physical properties, and machines in cell membranes.

PHYS 534. Symmetry and Group Theory in Physics.

(3-0) Cr. 3. S. *Prereq: Credit or enrollment in PHYS 481*

Theory of groups and group representations; introduction to both point and continuous groups, and their applications in physics.

PHYS 535. Physics of Semiconductors.

(Cross-listed with E E). (3-3) Cr. 4. *Prereq: E E 311 and E E 332*

Basic elements of quantum theory, Fermi statistics, motion of electrons in periodic structures, crystal structure, energy bands, equilibrium carrier concentration and doping, excess carriers and recombination, carrier transport at low and high fields, space charge limited current, photo-conductivity in solids, phonons, optical properties, amorphous semiconductors, heterostructures, and surface effects. Laboratory experiments on optical properties, carrier lifetimes, mobility, defect density, doping density, photo-conductivity, diffusion length of carriers.

PHYS 536. Physics of Semiconductor Devices.

(Cross-listed with E E). (3-0) Cr. 3. *Prereq: E E 535*

P-n junctions, band-bending theory, tunneling phenomena, Schottky barriers, heterojunctions, bipolar transistors, field-effect transistors, negative-resistance devices and optoelectronic devices.

PHYS 541. General Relativity.

(3-0) Cr. 3. F. *Prereq: PHYS 362, MATH 307 or MATH 317*

Tensor analysis and differential geometry developed and used to formulate Einstein field equations. Schwarzschild and Kerr solutions. Other advanced topics may include gravitational radiation, particle production by gravitational fields, alternate gravitational theories, attempts at unified field theories, cosmology.

PHYS 551. Computational Physics.

(0-4) Cr. 2. S. *Prereq: PHYS 365, credit or enrollment in PHYS 481*

Use of modern computational techniques to analyze topics in classical and modern physics. Offered on a satisfactory-fail basis only.

PHYS 561. Physics of Biomolecules.

(Dual-listed with PHYS 461). (3-0) Cr. 3. F. *Prereq: PHYS 304 or CHEM 325, BBMB 301, or permission of instructor; graduate student classification in Science/Engineering*

Cell and Molecular Biophysics. Physical techniques used to characterize the structure, dynamics and properties of biomolecules with emphasis on single molecule techniques.

PHYS 564. Advanced Classical Mechanics.

(3-0) Cr. 3. S. *Prereq: PHYS 362, MATH 426, MATH 465*

Variational principles, Lagrange's equations, Hamilton's canonical equations, canonical transformations, Hamilton-Jacobi theory, infinitesimal transformations, classical field theory, canonical perturbation theory, classical chaos.

PHYS 571. Electricity and Magnetism I.

(3-0) Cr. 3. F. *Prereq: PHYS 365, MATH 426*

Electrostatics, magnetostatics, boundary value problems, Maxwell's equations, wave phenomena in macroscopic media, wave guides.

PHYS 572. Electricity and Magnetism II.

(3-0) Cr. 3. S. *Prereq: PHYS 571*

Special theory of relativity, least action and motion of charged particles in electromagnetic fields, radiation, collisions between charged particles, multipole fields, radiation damping.

PHYS 590. Special Topics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 590A. Nuclear Physics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 590B. Condensed Matter Physics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 590C. High Energy Physics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 590D. Physics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 590E. Applied Physics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 590F. Biophysics.

Cr. arr. Repeatable. *Prereq: Permission of instructor*
Topics of current interest.

PHYS 591. Quantum Physics I.(4-0) Cr. 4. F. *Prereq: PHYS 481*

First semester of a full-year course. Postulates of quantum mechanics; time-dependent and time-independent Schrodinger equations for one-, two-, and three-dimensional systems; theory of angular momentum; Rayleigh-Schrodinger time-independent perturbation theory.

PHYS 592. Quantum Physics II.(4-0) Cr. 4. S. *Prereq: PHYS 591*

Continuation of 591. Variational theorem and WKB method; time-dependent perturbation theory and 2nd quantization of the EM field in Coulomb gauge; method of partial waves and Born approximation for scattering by central potentials; identical particles and symmetry; Dirac and Klein-Gordon equation for free particles; path integral formalism.

PHYS 599. Creative Component.Cr. arr. *Prereq: Permission of instructor*

Individually directed study of research-level problems for students electing the nonthesis M.S. degree option.

Courses for graduate students:**PHYS 611. Quantum Theory of Condensed Matter.**(3-0) Cr. 3. S. *Prereq: PHYS 512 and PHYS 681 or permission of instructor.*

Quasiparticles in condensed matter: phonons, magnons, photons, electrons. Quantum theory of interacting many body systems: Green's functions and diagrammatic techniques.

PHYS 624. Advanced Nuclear Physics.(3-0) Cr. 3. *Prereq: PHYS 526 and PHYS 592*

Microscopic few-body and many-body theory; theory of effective Hamiltonians; relativistic nuclear physics; nuclear effects in hadron-nucleus, lepton-nucleus, and nucleus-nucleus reactions.

PHYS 625. Physics of Strong Interactions.(3-0) Cr. 3. *Prereq: PHYS 681*

Quark model; Quantum Chromodynamics (QCD); perturbation methods for QCD; effective field theories for pions and nucleons; finite temperature field theories; quark-gluon plasma; phase transitions in QCD.

PHYS 637. Elementary Particle Physics I.(3-0) Cr. 3. *Prereq: PHYS 526 and PHYS 592*

First semester of a full year course. Properties of leptons, bosons, and quarks and their interactions; quantum chromodynamics, Glashow-Weinberg-Salam model, grand unification theories, supersymmetry; modern theoretical techniques and tests of the Standard Model.

PHYS 638. Elementary Particle Physics II.(3-0) Cr. 3. *Prereq: PHYS 637*

Continuation of 637. Properties of leptons, bosons, and quarks and their interactions; quantum chromodynamics, Glashow-Weinberg-Salam model, grand unification theories, supersymmetry, and superstring theory; modern theoretical techniques.

PHYS 646. Mathematical Modeling of Complex Physical Systems.

(Cross-listed with MATH). (3-0) Cr. 3. S.

Modeling of the dynamics of complex systems on multiple scales: Classical and dissipative molecular dynamics, stochastic modeling and Monte-Carlo simulation; coarse grained nonlinear dynamics, interface propagation and spatial pattern formation.

PHYS 650. Advanced Seminar.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 650A. Nuclear Physics.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 650B. Condensed Matter Physics.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 650C. High Energy Physics.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 650D. Physics.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 650E. Applied Physics.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 650F. Biophysics.

(1-0) Cr. 1. Repeatable. F.S.

Topics of current interest. Offered on a satisfactory-fail basis only.

PHYS 660. Advanced Topics in Physics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 660A. Nuclear Physics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 660B. Condensed Matter Physics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 660C. High Energy Physics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 660D. Physics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 660E. Applied Physics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 660F. Biophysics.

Cr. 1-3. Repeatable. F.S.

Courses on advanced topics and recent developments.

PHYS 681. Quantum Field Theory I.(3-0) Cr. 3. F. *Prereq: PHYS 564, PHYS 572, PHYS 592*

Quantization of fields (canonical and path integral); Feynman rules; introduction to gauge theories; Quantum Electrodynamics; radiative corrections; renormalization and renormalization group.

PHYS 682. Quantum Field Theory II.(3-0) Cr. 3. Alt. S., offered 2012. *Prereq: PHYS 681*

Continuation of 681. Systematics of renormalization; renormalization group methods; symmetries; spontaneous symmetry breaking; non-abelian gauge theories; the Standard Model and beyond; special topics.

PHYS 699. Research.

Cr. arr. Repeatable.