

Course Catalog - Spring 2010

Physics

100 **Thinking About Physics** credit: 1 hours.

Designed for students who want to prepare for PHYS 211 by improving their conceptual and problem solving skills. Shows how to analyze physical situations, describe them mathematically, and understand the meaning of the solutions. Examples will be drawn from material that will be covered in PHYS 211. PHYS 100 and PHYS 211 may be taken concurrently. Approval of the department is required to register. Prerequisite: Credit or concurrent registration in MATH 220 or MATH 221.

101 **College Physics: Mech & Heat** credit: 5 hours.

Newton's Laws, work and energy, rotational motion, fluids, thermodynamics, and waves. A noncalculus-based course for students in the life sciences, preprofessional health programs, agriculture, and veterinary medicine. Credit is not given for both PHYS 101 and either PHYS 211 or PHYS 213. Prerequisite: Trigonometry.

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

102 **College Physics: E&M & Modern** credit: 5 hours.

Electric forces and fields, electric potential, electric circuits, magnetic forces and fields, geometrical optics, relativity, and modern physics. A noncalculus-based course for students in life sciences, preprofessional health programs, agriculture, and veterinary medicine. Credit is not given for both PHYS 102 and either PHYS 212 or PHYS 214. Prerequisite: PHYS 101.

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

110 **Physics Careers** credit: 0 hours.

Provides an understanding of how undergraduate training in physics can serve as a foundation for careers of both a traditional and non-traditional character in today's world. Includes outside speakers who are representative of the broad spectrum of possible careers after receiving a physics degree. Approved for S/U grading only.

123 **Physics Made Easy** credit: 3 hours.

Designed for students who are interested in explaining and teaching science to children at the elementary school level. A hands-on inquiry-based approach to learning is used. No math or physics background needed. Topics cover most of the National Science Education K-4 Content Standards. Students assemble and keep a science teaching tool-kit.

This course satisfies the General Education Criteria for a Physical Sciences course.

140 **How Things Work** credit: 3 hours.

Nonmathematical lecture-demonstration course for nonscience students, underscoring the generality and ubiquity of basic physical laws in understanding commonplace phenomena: musical instruments, photography, electric and electronic circuits, television, motors, engines, etc. Credit is not given to engineering majors.

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

141 **Special Problems** credit: 1 hours.

Special problems in physics: discussions and independent study. Supplement to PHYS 140. Prerequisite: Credit or concurrent registration in PHYS 140.

150 **How Nature Works** credit: 3 hours.

Nonmathematical attempt to bridge the two-culture gap; takes examples from modern physics: relativity, elementary particles, quantum theory, statistics, etc., and covers basic philosophical concepts in physics which pervade all human disciplines: model-making, dynamics, ensemble behavior, and symmetry. Lecture format.

This course satisfies the General Education Criteria for a Physical Sciences course.

151 **Special Problems** credit: 1 hours.

Special problems in physics: discussions and independent study. Supplement to PHYS 150. Prerequisite: Credit or concurrent registration in PHYS 150.

191 **Particle Physics Revolutions** credit: 1 hours.

Great discoveries in the last century in particle physics; antimatter, quarks, and neutrinos; insights and discoveries and scientists such as Einstein, Feynman, and Fermi; science vs. science fiction; learning about the subatomic world; influence of fundamental science on society.

192 **Science and Pseudoscience** credit: 1 hours.

Extra-sensory perception, alien abduction, and psychic crime-solving from the standpoint of scientific inquiry and exploration; the scientific methods, how science progresses, and the types of argumentative fallacies that pervade the pseudoscientific community; examples of good science and how the scientific method is self-correcting.

193 **Physics of Music** credit: 2 hours.

The physics of music and musical instruments; acoustical physics, propagation of sound waves, the biological physics of human hearing, and the acoustical physics associated with all types of musical instruments.

194 **Behavior of Complex Systems** credit: 1 hours.

Exploration of systems with simple rules that nevertheless exhibit complex behavior. Lecture demonstrations on fractal growth, chaos, catastrophes, self-assembly, lightning, turbulence, explosions, and human rhythms. Simple computer models which exhibit regular, irregular, symmetric, and self-similar patterns and dynamics. Dynamics of isolated and coupled complex systems and mathematical tools for quantifying complex behavior.

199 **Undergraduate Open Seminar** credit: 1 to 5 hours.

Approved for both letter and S/U grading. May be repeated.

211 **University Physics: Mechanics** credit: 4 hours.

Newton's Laws, work and energy, static properties and fluids, oscillations, transverse waves, systems of particles, and rotations. Lectures with demonstrations, discussions and laboratory. For students in engineering, mathematics, physics and chemistry. Credit is not given for both PHYS 211 and PHYS 101. Prerequisite: Credit or concurrent registration in MATH 231.

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

212 **University Physics: Elec & Mag** credit: 4 hours.

Coulomb's Law, electric fields, Gauss' Law, electric potential, capacitance, circuits, magnetic forces and fields, Ampere's law, induction, electromagnetic waves, polarization, and geometrical optics. Lectures with demonstrations, discussions, and laboratory. For students in engineering, mathematics, physics, and chemistry. Credit is not given for both PHYS 212 and PHYS 102. Prerequisite: PHYS 211; credit or concurrent registration in MATH 241.

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

213 **Univ Physics: Thermal Physics** credit: 2 hours.

Introduction to the first and second laws of thermodynamics including kinetic theory of gases, heat capacity, heat engines, introduction to entropy and statistical mechanics, and introduction to application of free energy and Boltzmann factor. Lectures with demonstrations, discussions, and laboratory. For students in engineering, mathematics, physics and chemistry. Credit is not given for both PHYS 213 and PHYS 101. Prerequisite: PHYS 211; credit or concurrent registration in MATH 241.

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

214 **Univ Physics: Quantum Physics** credit: 2 hours.

Interference and diffraction, photons and matter waves, the Bohr atom, uncertainty principle, and wave mechanics. Lectures with demonstrations, discussions, and laboratory. For students in engineering, mathematics, physics, and chemistry. Credit is not given for both PHYS 214 and PHYS 102. Prerequisite: PHYS 212 (includes MATH 241 and PHYS 211).

This course satisfies the General Education Criteria for a Physical Sciences, and Quant Reasoning II course.

221 **Enrichment Mechanics** credit: 1 hours.

Supplement to PHYS 211 with a collaborative group learning approach to improving conceptual understanding and problem solving in introductory calculus-based mechanics. Intended for underprepared students who have taken PHYS 100, but other at-risk students will be admitted also. Prerequisite: PHYS 100; concurrent registration in PHYS 211.

225 **Relativity & Math Applications** credit: 2 hours.

Introduction to the theory of Special Relativity, with applications to kinematics and dynamics. Key mathematical methods as they apply to aspects of electromagnetic theory and classical mechanics, including vector analysis, series expansions, matrices, Fourier analysis, partial differentiation, three-dimensional calculus, and simple differential equations. Preference given to Physics majors and minors. Prerequisite: Credit or concurrent registration in PHYS 212.

280 **Nuclear Weapons & Arms Control** credit: 3 hours.

Beginner's-level introduction to the physics of nuclear weapons, nuclear weapon effects, delivery systems, and defenses against nuclear attack; includes presentation of current issues. Nontechnical, but about technology. Designed to assist in making informed judgments about nuclear armaments and arms control. Same as GLBL 280.

This course satisfies the General Education Criteria for a Advanced Composition course.

325 ***Mechanics and Relativity I*** credit: 3 hours.

Examines kinematics and dynamics. Special relativity, Newtonian kinematics and dynamics in three dimensions, behavior of systems of particles, oscillations, transient response of oscillators, nonlinear oscillators, motion in rotating frames of reference, and rigid body dynamics. Vector analysis is developed as needed. Credit is not given for both PHYS 325 and PHYS 219. Prerequisite: Credit or concurrent registration in MATH 285 and PHYS 212.

326 ***Mechanics and Relativity II*** credit: 3 hours.

Continuation of PHYS 325. Lagrangian techniques and the calculus of variations, central force motion, scattering, coupled oscillations, the wave equation in one dimension, generalized coordinates and the Hamiltonian formulation, relativistic dynamics, Euler angles and tops, non-linear and fluid dynamics. Prerequisite: PHYS 325; credit or concurrent registration in MATH 241 or MATH 380.

329 ***Atmospheric Dynamics I*** credit: 3 hours.

Same as ATMS 302. See ATMS 302.

330 ***Atmospheric Dynamics II*** credit: 4 hours.

Same as ATMS 312. See ATMS 312.

401 ***Classical Physics Lab*** credit: 3 hours.

Experiments and techniques in classical mechanics and electromagnetism. Dynamics of electrical and mechanical oscillators in the linear domain. Fourier analysis of system response. Measurements of electrostatic fields, transmission lines, waves, and radiation. Investigation of electromagnetic phenomena in dielectrics, conductors, and magnetic materials. Instruction in data analysis and report writing. Graduate credit is not given to physics graduate program majors. Prerequisite: PHYS 325.

402 ***Light*** credit: 0 to 4 hours.

Wave kinematics; geometrical optics: basic concepts, ray-tracing and matrix formalism, Gaussian imaging by thick lenses, stops, apertures, and intensity relations; interference; interference spectroscopy and coherence; diffraction: Fresnel-Kirchhoff formulation, Fraunhofer case, Fresnel case, and holography; polarized light. Lectures, laboratory, and problems. 4 undergraduate hours. 3 or 4 graduate hours (3 hours without lab). Prerequisite: MATH 285; PHYS 102 (includes PHYS 101) or PHYS 214 (includes PHYS 211 and PHYS 212).

403 ***Modern Experimental Physics*** credit: 2 to 5 hours.

Techniques and experiments in the physics of atoms, atomic nuclei, molecules, the solid state, and other areas of modern physical research. 4 or 5 hours. 5 undergraduate hours. 4 graduate hours. Prerequisite: PHYS 401; concurrent registration in PHYS 486.

404 ***Electronic Circuits I*** credit: 0 to 5 hours.

The physics of semiconductor devices; theory and application of discrete and integrated devices in linear circuits; use of operational amplifiers and feedback; regulation, oscillators, and modulation; emphasizes practical experience. Lectures, problems, and laboratory. Same as CHEM 423. 5 undergraduate hours. 4 graduate hours. Offered Spring term only. Prerequisite: PHYS 401 and PHYS 435.

405 **Electronic Circuits II** credit: 0 to 5 hours.

Continuation of PHYS 404, with particular emphasis on nonlinear devices, switching circuits, digital logic, analog to digital and digital to analog conversion, and individual projects. Lectures, problems, and laboratory. 5 undergraduate hours. 4 graduate hours. Offered Fall term only. Prerequisite: PHYS 404.

419 **Space, Time, and Matter-ACP** credit: 3 or 4 hours.

Identical to PHYS 420 except for the additional writing component including a final term paper. Same as PHIL 419. 3 undergraduate hours. 4 graduate hours. Credit is not given for both PHYS 419 and PHYS 420. Junior standing is required. Prerequisite: One physical science course; one of PHYS 214, PHIL 101, PHIL 270, PHIL 317.

This course satisfies the General Education Criteria for a Advanced Composition course.

420 **Space, Time, and Matter** credit: 2 hours.

Philosophical examination of some fundamental concepts and theories of the physical world, such as time, matter, space, and geometry; interpretation of quantum theory. Graduate students write an additional paper. Same as PHIL 420. Credit is not given for both PHYS 420 and PHYS 419. Junior standing is required. Prerequisite: One physical science course; one of PHYS 214, PHIL 101, PHIL 270, PHIL 317.

427 **Thermal & Statistical Physics** credit: 4 hours.

Equilibrium thermodynamics, statistical mechanics, and kinetic theory of gases. A unified treatment is used in that the principles of heat and thermodynamics are discussed along with statistical postulates and the microscopic approach of introductory quantum mechanics. Designed primarily for advanced undergraduates. Credit is not given for both PHYS 427 and any of ME 404, CHEM 442, CHEM 444, MSE 500. Prerequisite: Two 400-level courses in physics.

435 **Electromagnetic Fields I** credit: 3 hours.

Static electric and magnetic fields, their interactions with electric charge and current, and their transformation properties; the effect of special relativity is incorporated. Macroscopic fields in material media are described. Prerequisite: MATH 285; PHYS 325; credit or concurrent registration in MATH 241 or MATH 380.

436 **Electromagnetic Fields II** credit: 3 hours.

Concentrates on time-dependent fields. Electromagnetic induction, Maxwell's equations, electromagnetic wave propagation in various media and structures, and electromagnetic radiation from charge and current distributions are treated. The relativistic covariance of Maxwell's equations is discussed. Prerequisite: PHYS 326 and PHYS 435.

460 **Condensed Matter Physics** credit: 4 hours.

Bonding and structure of crystals; energy bands in insulators, semiconductors, and metals; electrical conductivity; optical properties; lattice vibrations; elasticity; point defects; dislocations. Offered Fall term only. Credit is not given for both PHYS 460 and MSE 304. For engineering and science majors with junior standing.

466 **Atomic Scale Simulations** credit: 3 or 4 hours.

Same as CSE 485 and MSE 485. See MSE 485.

470 **Subatomic Physics** credit: 4 hours.

The nature and properties of nuclei and elementary particles, symmetries, interactions, nuclear models, tools and techniques of experimental subatomic physics, and applications to power generation, astrophysics, chemistry, medicine, and biology. Lecture-problem format. Offered Spring term only. Prerequisite: PHYS 485 or PHYS 486.

479 **Plasma and Fusion Science** credit: 3 hours.

Same as ECE 421 and NPRE 421. See NPRE 421.

485 **Atomic Phys & Quantum Theory** credit: 3 hours.

Introduction to the basic concepts of quantum theory which underlie modern theories of the properties of materials; elements of atomic and nuclear theory; kinetic theory and statistical mechanics; quantum theory and simple applications; atomic spectra and atomic structure; molecular structure and chemical binding. Prerequisite: CHEM 104; MATH 285; PHYS 214.

486 **Quantum Physics I** credit: 4 hours.

Atomic phenomena integrated with an introduction to quantum theory; evidence for the atomic nature of matter and the properties of the Schrodinger equation, single particle solutions in one dimension, the hydrogen atom, perturbation theory, external fields, and atomic spectroscopy of outer electrons. Prerequisite: MATH 285; PHYS 214; credit or concurrent registration in MATH 415.

487 **Quantum Physics II** credit: 4 hours.

Continuation of PHYS 486. Identical particles, spectral hyperfine structure, magnetic properties of matter, atomic spectroscopy of inner electrons, high-energy photon effects, molecular binding and spectra, emission and absorption of light, and symmetry principles. Prerequisite: PHYS 486.

496 **Intro to Physics Research** credit: 3 hours.

Presents current research topics through extensive reading, writing, and oral-presentation activities. Designed for second-semester juniors interested in pursuing physics research careers and advanced physics training. Students generally become involved in a research group at this time, leading to a full-time summer research experience. No graduate credit.

This course satisfies the General Education Criteria for a Advanced Composition course.

497 **Individual Study** credit: 1 to 4 hours.

Individual study at an advanced level in a subject not covered by course offerings. May be repeated. Prerequisite: Consent of instructor.

498 **Special Topics in Physics** credit: 1 to 4 hours.

Subject offerings of new and developing areas of knowledge in physics intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated in the same or separate terms if topics vary.

499 **Senior Thesis** credit: 3 hours.

Guidance in the writing of a senior thesis involving independent research (usually performed during the summer prior to the fall term). Additional activities include oral presentations of research and outside journal articles, proposal writing and reviewing, poster presentation, preparation of graduate school applications, and discussion of physics frontiers with outside experts. No graduate credit. Prerequisite: PHYS 496; completion of appropriate research activity.

This course satisfies the General Education Criteria for a Advanced Composition course.

500 **Advanced Mechanics** credit: 2 hours.

Fundamentals of classical Lagrangian and Hamiltonian mechanics, with emphasis on the relation between dynamical symmetries and constants of the motion; use of conservation laws to derive basic equations of fluid dynamics; discussion of some applications. Prerequisite: PHYS 326.

501 **Continuum Mechanics** credit: 2 hours.

Introduction to stress, strain, and waves in an elastic solid, the Euler and Navier Stokes equations, potential flow, vortex theory, viscous flows, gas dynamics, characteristics, and shock waves. Prerequisite: Credit or concurrent registration in PHYS 507.

504 **Statistical Physics** credit: 4 hours.

Single-particle distribution functions; classical and quantum mechanical systems, Boltzmann equation, virial theorem, and equations of state for gases; formal theory: ensembles, identical particles, thermodynamics of simple systems, and distribution functions; nonequilibrium problems; conservation laws and hydrodynamic equations, sound waves, and transport coefficients; plasmas, normal Fermi fluid, superfluids, and systems with internal degrees of freedom. Prerequisite: PHYS 427 and PHYS 486.

505 **Classical Electromagnetism** credit: 4 hours.

Review of Maxwell's equations followed by a relativistic formulation of the electromagnetic field and the motion of charged particles; plane and guided waves; retarded potentials; radiation from simple antennas; radiation from accelerated charged particles; synchrotron radiation, bremsstrahlung, scattering, and further topics. Prerequisite: PHYS 436.

508 **Mathematical Physics I** credit: 4 hours.

Core techniques of mathematical physics widely used in the physical sciences. Calculus of variations and its applications; partial differential equations of mathematical physics (including classification and boundary conditions); separation of variables, series solutions of ordinary differential equations and Sturm-Liouville eigenproblems; Legendre polynomials, spherical harmonics, Bessel functions and their applications; normal mode eigenproblems (including the wave and diffusion equations); inhomogeneous ordinary differential equations (including variation of parameters); inhomogeneous partial differential equations and Green functions; potential theory; integral equations (including Fredholm theory). Topics are illustrated with realistic physics problems; a broad range of illustrative examples are explored; applications are emphasized. Prerequisite: MATH 241 or MATH 380; MATH 285

509 **Mathematical Physics II** credit: 4 hours.

Continuation of PHYS 508. Further core techniques of mathematical physics widely used in the physical sciences. Complex variables; group theory in classical and quantum systems; tensors in physics; differential forms and their applications in mechanics; electromagnetism. Topics are illustrated with realistic physics problems; a broad range of illustrative examples are explored; applications are emphasized. Prerequisite: PHYS 508.

510 ***Nonlinear Dynamics*** credit: 4 hours.

Broad introduction to nonlinear dynamics of physical systems with varying degrees of complexity; surveys a variety of concepts associated with bifurcation phenomena, mappings, nonlinear oscillations, chaotic behavior, strange attractors, solitons, and topics of current interest. Prerequisite: PHYS 326.

511 ***Advanced Nonlinear Dynamics*** credit: 4 hours.

Analysis of the dynamics of spatially extended and other complex physical systems using analytical, experimental, computational, topological, and symbolic methods; examples may involve mechanical, electrical, optical, solid state, fluid, chemical, biological, and network systems. Prerequisite: PHYS 510.

513 ***Quantum Optics & Information*** credit: 4 hours.

Experimental and core theoretical fundamentals of quantum information, using nonclassical, often counter-intuitive, features of quantum physics (including the wave-particle duality, superposition, and entanglement) to surpass the information-processing capabilities of systems restricted by classical physics. Underlying fundamental quantum phenomena, including tests of nonlocality, quantum erasers, the quantum Zeno effect, squeezed light, multi-particle interference, state transformations of the Bloch sphere (e.g., Rabi oscillations), and decoherence; quantum cryptography and teleportation; basic quantum information theory; key quantum computation algorithms and techniques for error correction; major experimental "qubit" systems. Prerequisite: Recommended: PHYS 580.

514 ***Modern Atomic Physics*** credit: 4 hours.

Rigorous survey of modern atomic, molecular, and optical physics, including a functional approach to theory and an overview of experimental techniques. Atomic structure, including fine and hyperfine structure, multi-electron atoms, and relativistic effects; interaction of single atoms with dynamic and static electromagnetic fields, taking into account hyperfine structure; ultra-cold collisions between atoms; laser cooling, evaporative cooling, and magnetic trapping; Paul and Penning traps; quantum degenerate gases; atom interferometry. Prerequisite: PHYS 427, PHYS 436, and PHYS 487.

515 ***General Relativity I*** credit: 4 hours.

Systematic introduction to Einstein's theory, with emphasis on modern coordinate-free methods of computation. Topics include: review of special relativity, modern differential geometry, foundations of general relativity, laws of physics in the presence of a gravitational field, linearized theory, and experimental tests of gravitation theories. Same as ASTR 515. Offered in alternate Fall terms. Prerequisite: PHYS 436 (includes PHYS 326).

516 ***General Relativity II*** credit: 4 hours.

Continuation of PHYS 515 with emphasis on applications to astrophysics and cosmology. Relativistic stars, gravitational collapse, black holes, gravitational waves, numerical relativity, and cosmology. Same as ASTR 516. Offered in alternate Spring terms. Prerequisite: PHYS 515.

520 ***Reactor Theory I*** credit: 4 hours.

Same as NPRE 555. See NPRE 555.

521 ***Reactor Theory II*** credit: 4 hours.

Same as NPRE 556. See NPRE 556.

522 ***Asymptotic Methods*** credit: 4 hours.
Same as MATH 559, NPRE 559, and TAM 549. See TAM 549.

540 ***Astrophysics*** credit: 4 hours.

Introduction to astrophysics and cosmology and new developments in these fields. Emphasizes basic physical concepts and principles, the key observational evidence, and illustrative calculations. Topics include relativistic cosmological models, inflation, Big-Bang nucleosynthesis, and the cosmic microwave background; formation and evolution of galaxy clusters, galaxies, and stars; formation, structure, and evolution of white dwarfs, neutron stars, and black holes; rotation- and accretion-powered pulsars, X-ray and y-ray stars, and gravitational radiation. Designed for students who want to learn about current problems and recent discoveries in astrophysics and cosmology as well as students who plan to pursue research in astrophysics. No astronomy or general relativity backgrounds are assumed. Same as ASTR 540. Prerequisite: PHYS 435; PHYS 485 or PHYS 485.

541 ***Physics of Compact Objects*** credit: 4 hours.

A rigorous survey of the physical properties of black holes, white dwarfs, and neutron stars. Formation of compact objects. Equilibrium configurations, equations of state, stability criteria, and mass limits: the influence of rotation and magnetic fields. Pulsar phenomena. Black hole spacetimes. Hawking radiation. Mass flow in binary systems; spherical and disk accretion; high-temperature radiation processes; pulsar spin-up. Compact x-ray sources and x-ray bursts. Supermassive black holes in star clusters and dense galactic nuclei. Gravitational and neutrino radiation from supernova collapse and binary coalescence. Same as ASTR 541. The course does not assume any previous knowledge of astronomy or general relativity. Offered in alternate years. Prerequisite: PHYS 436.

542 ***Theoretical Stellar Physics*** credit: 4 hours.

Same as ASTR 504. See ASTR 504.

550 ***Biomolecular Physics*** credit: 4 hours.

Physical concepts governing the structure and function of biological macromolecules; general properties, spatial structure, energy levels, dynamics and functions, and relation to other complex physical systems such as glasses; recent research in biomolecular physics; physical techniques and concepts from theoretical physics emphasized. Designed for students without appreciable background in biology and chemistry. Same as BIOP 550 and MCB 550. Prerequisite: CHEM 104; PHYS 485 or PHYS 487.

552 ***Optical Spectroscopy*** credit: 4 hours.

Theoretical and experimental fundamentals of optical spectroscopy. Topics include light-matter interaction (absorption of UV, visible, IR), emission spectroscopy (fluorescence, Raman and light scattering), theoretical backgrounds of molecular electronic and vibrational transitions, modern experimental techniques, and data analysis of the optical spectroscopy experiments. A Laboratory component provides practical applications of spectroscopy applicable to a broad spectrum of disciplines, including biophysical examples. Of interest to students from a broad range of scientific disciplines, as well as to those who wish to understand recent modern literature. Prerequisite: PHYS 427 and PHYS 487.

554 ***Nonequilibrium Stat Mechanics*** credit: 4 hours.

Introduction to the mathematical description of classical and quantum stochastic systems, thoroughly addressing the tools and the mode of thinking of non-equilibrium statistical mechanics. Review of equilibrium statistical mechanics; Einstein and Smoluchowski diffusion equation; generalized moment expansion of correlation functions;

noise-induced limit cycles; time series analysis; diffusion-controlled reactions; classical dynamics under the influence of stochastic forces; observables connected with brownian transport, echoes, and hysteresis; spin-boson model. Examples from biological physics and theoretical condensed matter physics. Prerequisite: PHYS 504.

560 **Condensed Matter Physics I** credit: 4 hours.

Crystalline perfection, free-electron gas, screening, plasma oscillations, and dielectric response; Bloch electrons, Brillouin zones, and band structure; semiconductors, intrinsic and extrinsic, with applications; phonons, elasticity, and anharmonicity; ferromagnetism and second-order phase transitions; superconductivity. Prerequisite: PHYS 427 and PHYS 580.

561 **Condensed Matter Physics II** credit: 4 hours.

Hartree-Fock theory and electron-electron interactions; electron-phonon interactions; electron dynamics and transport; BCS theory of superconductivity; elastic properties; thermal properties due to anharmonicity; defects in solids. Prerequisite: PHYS 560 and PHYS 581.

563 **Phase Transitions** credit: 4 hours.

Phenomenology of phase transitions, scaling, critical behavior, and multi-criticality; Landau theory of phase transitions; renormalization group methods, including lattice models and epsilon-expansion; numerical methods; critical dynamics; selected additional topics. Prerequisite: PHYS 504.

564 **Surface Physics** credit: 4 hours.

Same as MSE 582. See MSE 582.

565 **Theory of Semicond & Devices** credit: 4 hours.

Same as ECE 535. See ECE 535.

566 **Diffraction Physics of Matls** credit: 4 hours.

Same as MSE 580. See MSE 580.

569 **Emergent States of Matter** credit: 4 hours.

Introduction to the consequences of broken symmetry in condensed matter, the emergence of novel ground states, and the nature of the excitations that arise. Specific systems covered may include superconductivity, superfluidity, Bose-Einstein condensates, the quantum Hall states, liquid crystals, biological systems and patterns in Rayleigh-Benard convection. Prerequisite: PHYS 504 and PHYS 580.

570 **Subatomic Physics** credit: 4 hours.

Nuclear systematics, nucleon-nucleon interaction, shell model, and single particle and collective excitations; hadron spectroscopy, hadronic quantum numbers, quark-parton model, and hadron dynamics; weak interactions. Prerequisite: PHYS 580; concurrent registration in PHYS 581.

571 **Nuclear Physics** credit: 4 hours.

Current research in nuclear physics; topics include one or more of: photon physics, electron-nucleus scattering and nucleon structure, Few-nucleon systems and nuclear and neutron matter, nuclear astrophysics, Meson physics, Relativistic nuclear physics, heavy-ion physics, and Quarks in the nucleon and in nuclei. May be repeated.

575 **Particle Physics I** credit: 4 hours.

Basic calculations in elementary particle theory. Quantum electrodynamics, quantum chromodynamics, and the Glashow-Weinberg-Salam theory of weak and electromagnetic interactions as applied to the phenomenology of particle decays and high energy reactions. Prerequisite: PHYS 570 (in exceptional circumstances, PHYS 570 may be taken concurrently with departmental approval). Recommended (strongly): credit or concurrent registration in PHYS 582.

576 **Particle Physics II** credit: 4 hours.

Continuation of PHYS 575. Current topics in particle theory; topics change from year to year. Typically treats three or four different subjects in depth. Prerequisite: PHYS 575.

580 **Quantum Mechanics I** credit: 4 hours.

Second course in quantum mechanics. Operators, state vectors, and the formal structure of quantum theory; operator treatments of simple systems; angular momentum and vector addition coefficients; stationary state perturbation theory; introduction to scattering theory for particles without spin, partial wave analysis, and Born approximation; examples taken from atomic, nuclear, and elementary particle physics. For students with a good background in wave mechanics and atomic and molecular structure. Prerequisite: PHYS 485 or PHYS 487.

581 **Quantum Mechanics II** credit: 4 hours.

Spin and identical particles, simple many-particle systems and elements of second-quantization theory; time-dependent processes, radiative transitions, and quantization of the electromagnetic field; scattering of particles with spin; polarization; introduction to the Klein-Gordon and Dirac equations, and properties of simple relativistic systems. Prerequisite: PHYS 580.

582 **General Field Theory** credit: 4 hours.

Standard techniques of field theory as used by experimenters and theorists; relativistic quantum mechanics of a single particle; Lagrangian field theories, perturbation theory, and calculation of lowest-order processes; introduction to Feynman diagrams and higher order processes; examples taken from quantum electrodynamics, solid-state and elementary particle physics, and many-body theory. Prerequisite: PHYS 581.

583 **Advanced Field Theory** credit: 4 hours.

Quantization and Feynman path integral; gauge theories and renormalization; renormalization group with applications to particle physics and critical phenomena; approximation methods and recent developments. Prerequisite: PHYS 582.

596 **Graduate Physics Orientation** credit: 1 hours.

Introduction to Research in the Department of Physics. Advice on choosing a field of research and finding a research advisor. Faculty-presented overviews of the major areas of research available in the Physics Department. General discussions on instructional topics as well as ethics in teaching and sciences. Required of all first-year Physics Ph.D. students.

597 **Individual Study** credit: 1 to 16 hours.

Individual study in a subject not covered in course offerings may be arranged for credit by registration under this number. 2 to 16 hours for full term; 1 to 8 hours for half-term. May be repeated. Prerequisite: Consent of instructor.

598 **Special Topics in Physics** credit: 1 to 4 hours.

Subject offerings of new and developing areas of knowledge in physics intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated in the same or separate terms if topics vary.

599 **Thesis Research** credit: 0 to 16 hours.

Approved for S/U grading only. May be repeated.