485. **Philosophy of the Social Sciences**  
Spring, 4(3-0) Three credits in philosophy at 300 level or higher or 9 credits in philosophy or 9 credits, other than basic, in social sciences or approval of department.  
Selected problems in the methodology of the behavioral sciences, including such topics as: concept formation and theory construction, explanation and insight, subjectivity and value judgements, emergence and teleology, historicism, reductionism, measurement, and statistical inference.

490. **Individual Reading**  
Fall, Winter, Spring, Summer. 1 to 4 credits. Approval of department.  
Supervised reading on a particular author or topic.

494. **Special Topics**  
Fall, Winter, Spring. 1 credit. May reenroll for a maximum of 4 credits. Juniors. Fifteen credits in philosophy or approval of instructor. Each section will examine a particular topic or author. Emphasis on discussion of student papers.

525. **Seminar in the History of Philosophy**  
Fall, Winter, Spring. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department.

530. **Seminar in Ethics**  
Winter, Spring, Summer. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department.

537. **Seminar in Logic**  
Fall, Winter, Spring. 4(3-0) May reenroll for credit. Approval of department.

541. **Seminar in Epistemology**  
Fall, Winter, Spring. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department.

545. **Seminar in Metaphysics**  
Fall, Winter, Spring. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department.

550. **Seminar in Aesthetics**  
Fall, 4(3-0) May reenroll for a maximum of 12 credits. Approval of department. The nature of aesthetic values, grounds of criticism, function of the arts, etc.

560. **Seminar in Social Philosophy**  
Spring. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department. Philosophy of law and of the state.

570. **Seminar in the Philosophy of Language**  
Fall. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department. Concrete bases of language and nature of meaning.

837. **Seminar in the Philosophy of Science**  
Fall, Winter. 4(3-0) May reenroll for a maximum of 12 credits. Approval of department.

850. **Seminar in Science**  
Fall, Winter, Spring, Summer. 1 credit. Emphasis on discussion of student papers in philosophy or approval of department. Individual study, training, or project under the direction of a faculty member. Often the training will be in the area of actual delivery of planetarium presentations.

870. **Seminar in Problems of Philosophy**  
Fall, Winter, Spring, Summer. 1 to 4 credits. May reenroll for a maximum of 12 credits. Approval of department.

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**PHYSICAL SCIENCE**

**PHS**

**College of Natural Science**

The content of course: 400, 405, 410 and 412, as well as the problems course, 880, may vary from term to term. Brochures giving detailed information about individual courses are available in the science and Mathematics Teaching Center and the Office of the Assistant Dean for Lifelong Education. These courses are primarily designed for in-service teachers and interested adults and are offered in off-campus locations.

203. **Foundations of Physical Sciences**  
Fall, Winter, Spring, Summer. 4(3-0) Primarily for elementary school teachers. Integrated descriptive course in the elements of physical science including the interrelationships among chemistry, geology, meteorology, astronomy, and physics.

400. **Physical Science for Teachers**  
Fall, Winter, Spring. 3 or 4 credits. May reenroll for a maximum of 12 credits. Teacher certification with science major or minor.

405. **Topics in Physical Science**  
Fall, Winter, Spring. 1 to 3 credits. May reenroll for a maximum of 6 credits if different topic is taken. Approval of department.

410. **Seminar on Recent Advances in Physical Science**  
Fall, Winter, Spring. 1 to 3 credits. May reenroll for a maximum of 6 credits if different topic is taken. Approval of department.

412. **Recent Advances in Earth Science**  
Fall, Winter, Spring. 1 to 3 credits. May reenroll for a maximum of 6 credits if different topic is taken. Approval of department.

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**PHYSICS**

**PHY**

**College of Natural Science**

Introductory physics courses are offered in both the lecture-recitation and the Competency-Based Instructional (CBI) format. In the latter format the students are carefully guided through each course via written materials with ample consulting time available. Both content and pace of course are flexible to suit student's needs and interests. Final grades are based on total amount of material for which student's mastery is certified. The introductory course may be grouped by the application of two criteria: the interests of the students the courses are designed to serve and the method of instruction employed.

**Lecture-Recitation Format**  
237, 238, 239, three credits each, designed primarily for students with interests in the life and earth sciences. The mathematics prerequisite is credit for or concurrent enrollment in college algebra and trigonometry (MTH 109 or 111).

247, 248, 249, four credits each, designed primarily for students with interest in the physical sciences, mathematics and engineering. The mathematics prerequisite is credit for or concurrent enrollment in calculus III with vectors (MTH 214).

291H, 292H, 293H, four credits each, designed primarily for Physics majors and others with a special interest in Physics. The mathematics prerequisite is credit for or concurrent enrollment in calculus III with vectors (MTH 214), the Honors section recommended.

**Competency Based Instructional Format**  
217H, an alternate way to earn credit in Spring, 281, 282, 283, three credits each, designed for students with interest in the natural sciences, including the life and earth sciences. The mathematics prerequisite is calculus I with analytic geometry (MTH 112).
Storage and manipulation of sound in numerical
partment of Mechanical Engineering. Demonstrations emphasized.

The courses taught via the two formats may be
be used to meet the requirements for a major in

A student may change from one group of introductory
courses to another, but may not earn credit for more than one complete sequence.

Credit may not be earned for more than one of the courses 294, 357, or 364.

100, 201, 202, 203, 301, 357, 430, and 431 cannot be used to meet the requirements for a major in

Prerequisites to nearly all the first courses in the 300-400 level course sequences are stated in terms of the Introductory Physics courses. The course selected for prerequisite is that which requires the least number of credits and the least mathematical background equal to or greater than that of the stated prerequisite. The corresponding term of any introductory courses to another, but may not cam

A-159
291A. Honors Physics IA, CBI  
Fall, Winter, Spring. 1 credit. PHY 297A, MTH 113.  
Subjects and topics as in PHY 291 and PHY 297A, generally on a more advanced level.

291B. Honors Physics IB, CBI  
Fall, Winter, Spring. 5 credits. MTH 113.  
Combined material of PHY 291 plus PHY 297A plus PHY 297A is taken in one term.

291H. Physics I  
(291H) Spring. 4(5-0) MTH 214 (honors section recommended) or concurrently.  
First of a five-term course sequence in elementary physics consisting of PHY 291, PHY 292, PHY 293, PHY 294 and PHY 295. In this sequence the principles of physics are presented in a unified manner that emphasizes modern concepts. Mechanics, including special relativity.

292A. Honors Physics IIA, CBI  
Fall, Winter, Spring. 1 credit. PHY 298A, MTH 214.  
Subjects and topics as in PHY 292 and PHY 298A, generally on a more advanced level.

292B. Honors Physics IIIB, CBI  
Fall, Winter, Spring. 5 credits. PHY 298A, MTH 214.  
Combined material of PHY 292 plus PHY 298A plus PHY 298A is covered in one term.

292H. Physics II  
(292H) Fall. 4(5-0) PHY 291H, MTH 215.  
Continuation of PHY 291H. Electricity and magnetism with some special relativity.

293A. Honors Physics IIIA, CBI  
Fall, Winter, Spring. 1 credit. PHY 299A, MTH 215.  
Subjects and topics as in PHY 293 and PHY 299A, generally on a more advanced level.

293B. Honors Physics IIIB, CBI  
Fall, Winter, Spring. 3 credits. PHY 299A, MTH 215.  
Combined material of PHY 293 plus PHY 299A plus PHY 299A is covered in one term.

293H. Physics III  
(293H) Winter. 4(5-0) PHY 292H.  
Continuation of PHY 292H. Wave physics including optics.

294. Physics IV  
Spring. 4(5-0) 293H or 299.  
Continuation of 293H. Introduction to quantum physics.

297. Principles of Physics Laboratory  
Fall, Winter. 1(0-2) PHY 281 or concurrently.  
Mechanics.

298. Principles of Physics Laboratory  
Winter, Spring. 1(0-2) PHY 282 or concurrently. PHY 297 or approval of department. Heat and thermodynamics, electricity and magnetism.

299. Principles of Physics Laboratory  
Fall, Spring. 1(0-2) PHY 293 or concurrently. PHY 297 or approval of department. Wave motion, sound, light and modern developments.

301. Bohr and Einstein: The Concept of Nature in Our Day  
Fall. 3(3-0) juniors.  
Basic contemporary ideas about the natural world and their significance for man presented through study of the lives of Niels Bohr (quantum theory) and Albert Einstein (relativity theory).

304. Special Problems  
Fall, Winter, Spring. Summer. 1 to 3 credits. May repeat for a maximum of 5 credits. Approval of department.

310. Calculus Concepts in Physics, CBI  
Fall, Winter, Spring. 5 credits. PHY 297, PHY 298, PHY 299; MTH 314.  
A transition course to prepare students who had non-calculus introductory physics for upper division courses. Discussions and problems in mechanics, electricity and magnetism, wave motion and modern physics. Familiarity with non-calculus introductory physics is assumed.

357. Topics in Contemporary Physics, CBI  
Fall, Winter, Spring. 4 credits. One year of general college physics.  
Atomic and nuclear physics, cosmic rays and elementary particles, nuclear energy, new theoretical concepts. Recommended for prospective high school teachers.

364. Introduction to Modern Physics I  
Fall, Winter, Spring. 3(3-0) PHY 299, MTH 215.  
Atomic structure, wave and particle aspects of radiant energy, optical and X-ray spectra.

365. Introduction to Modern Physics II  
Fall, Winter, Spring. 3(3-0) PHY 364 or PHY 299.  
Nuclear, molecular, solid state and elementary particle physics. Special emphasis is given to applications such as reactors, superconductors, semiconductors, fusion reactions, particle accelerators, etc.

395. Physics V  
Fall. 3(3-0) PHY 293B, or PHY 294, or PHY 364.  
Continued PHY 294. Thermodynamics and statistical physics.

400H. Honors Work  
Fall, Winter, Spring. Variable credit.

404. Special Problems  
Fall, Winter, Spring. Summer. 1 to 5 credits. PHY 298 or PHY 293H; approval of department.

419. Physical Phenomena and Electronic Instrumentation I  
Winter. 4(3-3) PHY 298, PHY 299 or approval of department, MTH 215.  
Interdepartmental with Electrical Engineering. Concepts of electronics relative to uses in investigations of physical phenomena and their subsequent applications to provide reliable instrumentation. Nuclear radiation detectors, photometers and magnetometers are examples of specific topics.

420. Physical Phenomena and Electronic Instrumentation II  
Spring. 3(2-2) PHY 419.  
Noise and its characterization. Typical electronic instruments are analyzed in detail. A reliable instrument that uses a physical effect is developed by the student.

427. Intermediate Mechanics  
Fall. 3(3-0) PHY 295, MTH 310 or concurrently.  
States and dynamics of a particle and of rigid bodies; linear and non-linear oscillations; gravitation from a field point of view; transformation properties of physical quantities; introduction to mathematical techniques of theoretical physics.

428. Intermediate Mechanics  
Winter. 3(3-0) PHY 427.  
Continuation of PHY 427.

429. Advanced Mechanics  
Spring. 3(3-0) PHY 428.  
Advanced methods of theoretical mechanics; generalized coordinates, Lagrange's and Hamilton's equations; the wave equation, theories of vibrations.

430. Introduction to Radioactivity and Radioisotope Techniques  
Spring. 2(3-0) or 3(3-0) One year each of general college chemistry and physics, interdepartmental with the Department of Chemistry.  
First 7 weeks. Elementary nuclear processes and properties with emphasis on radioactivity, its measurement, and its interaction with matter. Effects of radiation on chemical and biological systems. Applications of nuclear technology, safety and environmental factors. Last 3 weeks. Fundamentals of nuclear models, reactions and decay mechanisms. Basic principles of nuclear reactors and accelerators.

431. Laboratory for Radioactivity and Radioisotope Techniques  
Spring. 310, 364 or concurrently. CEM 191, CEM 192 recommended. Interdepartmental with the Department of Chemistry.  
Introduction to nuclear instrumentation. Experimental techniques for application of radioisotopes to problems in chemistry, the life sciences, and industry.

433. Geometrical Optics  
Fall. 4(3-3) PHY 295, PHY 299 or approval of department, MTH 215.  
Geometrical optics including Fermat's Principle, reflection, refraction, mirrors, thin lenses, thick lenses, aberrations, and the effects of apertures and stops.

439. Physical Optics  
Winter. 4(3-3) PHY 295, PHY 299 or approval of department, MTH 215.  
Physical optics including Huygens-Fresnel Principles, interference, diffraction, and coherence. Additional topics will be selected from Fourier transforms of wave forms, convolution, diffraction and image formation, spatial filtering, holography, and polarization.

447. Electricity and Magnetism I  
Winter. 4(4-0) 18 credits in PHY 291 and above.  
Advanced study of electromagnetic phenomena; electrostatic potentials from Laplace's and Poisson's equations; effects of dielectric and magnetic materials; magnetic fields and potentials; induced e.m.f. Maxwell's equations; electromagnetic radiation and waves.

448. Electricity and Magnetism II  
Spring. 4(4-0) PHY 447.  
Continuation of PHY 447.
497. Introduction to Elementary Physics
498. Introduction to Nuclear Physics

457G. Advanced Physics Laboratory (General)
Fall. 3(1-6) 15 credits in PHY 291 and above including PHY 295 and PHY 299.
Experiments in modern physics of historical interest and in general physics research techniques. Emphasizes experimental methods and proper treatment of data. Independent work encouraged.

457N. Advanced Physics Laboratory (Nuclear)
Winter of even-numbered years. Spring of odd-numbered years. 3(1-6) 15 credits in PHY 291 and above including PHY 295 and PHY 299.
Experiments in nuclear physics. Detection of nuclear radiation and determination of nuclear properties. Emphasizes research methods and proper treatment and interpretation of data. Independent work encouraged.

457S. Advanced Physics Laboratory (Solid State)
Spring of even-numbered years, Winter of odd-numbered years. 3(1-6) 15 credits in PHY 291 and above including PHY 295 and PHY 299.
Experiments in low temperature and solid state physics. Emphasizes research methods and proper treatment and interpretation of data. Independent work encouraged.

491. Introduction to Quantum Mechanics I
Fall. 3(3-0) PHY 294 or PHY 364; MTH 319 or concurrently.
Schrödinger wave equation and its applications; angular momentum; one electron atoms; absorption and emission of radiation; atomic and molecular structure.

492. Introduction to Quantum Mechanics II
Winter. 3(3-0) PHY 349. Continuation of PHY 491.

493. Introduction to Quantum Mechanics III
Spring. 3(3-0) PHY 492. Continuation of PHY 492.

496. Introduction to Solid State Physics
Winter. 3(3-0) PHY 364 or PHY 294.
Crystal structure and binding, lattice dynamics, thermal properties, free-electron and band models of metals and semiconductors, magnetism, optical properties, superconductivity, lattice defects.

497. Introduction to Elementary Particle Physics
Fall. 3(3-0) PHY 294 or PHY 364 or PHY 491.
Relativistic kinematics, invariance principles. Phenomenological analysis of elementary particle interactions with matter. Weak, electromagnetic and strong interactions. High energy accelerators and techniques in experimental high energy physics.

498. Introduction to Nuclear Physics
Spring. 3(3-0) PHY 294 or PHY 364 or PHY 491.
Interactions of nuclear radiations with matter; properties of nuclei; alpha, beta, gamma decay; nuclear models; nuclear reactions and elementary applications of scattering theory; reactors accelerators; introduction to high-energy physics.

500. Research Methods
Fall, Winter, Spring. 2(0-6)
May be repeated for a maximum of 6 credits. Beginning graduate students. Interdepartmental with the Department of Astronomy and Astrophysics. Problems and techniques of current research by taking part in the design and setup of experiments, data taking and reduction; study and practice of theoretical methods. Areas of study: solid state and molecular structure, nuclear, elementary particles, astronomy, astrophysics.

817. Techniques of Theoretical Physics
Fall. 3(3-0) Graduate students; approval of department.
Application of quantum systems to physical problems; basic concepts in theoretical formulation of quantum mechanical systems; solution of physical problems using Green's Functions, the delta function, series, integral transforms.

827. Theoretical Physics I
Summer of odd-numbered years. 3(3-0) PHY 428 or approval of department.
Vector analysis, mechanics of a particle and of systems of particles. Lagrange's equations, Hamiltonian methods, rotational motion.

828. Theoretical Physics II
Summer of even-numbered years. 3(3-0) PHY 498 or approval of department.
Vector analysis, mechanics of a particle and of systems of particles. Lagrange's equations, Hamiltonian methods, rotational motion.

829. Thermal and Statistical Physics
Winter. 3(3-0) Approval of department.
Principles of thermodynamics; topics in kinetic theory; introduction to statistical mechanics.

837. Quantum Mechanics I
Fall. 3(3-0) PHY 429, PHY 491.
The formulation of quantum mechanics. Superposition principle, state vector and representations; uncertainty principle; Schrödinger equation and its solution for physical systems.

838. Quantum Mechanics II
Winter. 3(3-0) PHY 837.
Approximation methods, perturbation theory, applications to atomic transitions, angular momentum.

839. Quantum Mechanics III
Spring. 3(3-0) PHY 838.
Collision processes and scattering theory, applications; many-particle systems.

840. Symmetry in Solid State Physics
Spring of odd-numbered years. 3(3-0) Graduate or approval of department.
Translational symmetry and Bloch's Theorem, reciprocal lattice, Brillouin zones, point groups, representations, character tables, molecular vibrations, group of the wave vectors and band theory of solids, crystal fields.

847. Electromagnetic Theory I
Fall. 3(3-0) PHY 428, PHY 448.
Electrostatics, Laplace's equation, Poisson's equation, Green's theorem, solution of problems by method of images; inversion; boundary-value problems in Cartesian, spherical and cylindrical coordinates; spherical harmonics, Bessel functions.

848. Electromagnetic Theory II
Winter. 3(3-0) PHY 847.
Multipole and multipole expansions; electrostatics of macroscopic materials, dielectrics, magnetostatics, vector potential, moment, Maxwell's equations for time-varying fields, energy and momentum conservation. Plane electromagnetic waves and polarization.

849. Electromagnetic Theory III
Spring. 3(3-0) PHY 848.
Wave guides and resonant cavities, boundary-value problems. Simple radiating systems, antennas. Special relativity, concept of electromagnetic fields, Radiation by moving charges, Lienard-Wiechert potentials.

850. Ionized Gases
Fall. 3(3-0) E E 435 or PHY 448, E E 874.
Field and wave methods with Electrical Engineering and the Department of Astronomy and Astrophysics, and administered by Electrical Engineering.

857. Theoretical Mechanics I
Winter. 3(3-0)
Two-body central force problems, rigid body motion, small oscillations, Hamilton's principle, Lagrangian and Hamiltonian formalism for particles and fields, canonical transformations, relativity.

858. Theoretical Mechanics II
Spring. 3(3-0) Approval of department.
Hamiltonian formalism for particles and fields, variational methods, canonical transformations, small oscillators, classical fields, relativity.

860. General Relativity and Cosmology I
Fall of even-numbered years. 3(3-0) PHY 858 or approval of department. Interdepartmental with the Department of Astronomy and Astrophysics.
Conceptual foundations of general relativity theory; elements of tensor calculus, Riemann-Cartesian tensors, the field equations, experimental tests; special solutions; the extension to cosmology.

861. General Relativity and Cosmology II
Winter of odd-numbered years. 3(3-0) PHY 860. Interdepartmental with the Department of Astronomy and Astrophysics.
Relativistic cosmology: the model universes; steady-state theory; observational evidence and possibilities for decision among models; current problems.

867. Quantum Mechanics IV
Fall. 3(3-0) PHY 839.
Transformation theory and invariance principles; the rotation group and theory of angular momentum; Wigner-Eckart theorem and applications.

888. Relativistic Quantum Mechanics
Winter. 3(3-0) PHY 867.
Relativistic equations of motion, Dirac Equation, free particle solutions and Lorentz transformation properties; interaction with electromagnetic fields; quantization of scalar, electromagnetic and Dirac fields.
889. Quantized Fields
Spring. 3(3-0) PHY 889.
Heisenberg representation, S-matrix reduction formulae, Feynman rules, quantum electrodynamics, topics from many-body theory.

877. Statistical Mechanics I
Fall. 3(3-0) Approval of department.
Necessity of statistical considerations, ensembles, probability distributions and density matrices, Liouville’s equation, equilibrium distributions, microscopic basis of thermodynamics; applications to thermodynamics of spin systems.

878. Statistical Mechanics II
Winter. 3(3-0) PHY 877.
Applications to thermodynamic properties of ideal classical and quantum gases, and to imperfect gases and interacting spin systems. Nonequilibrium distributions and transport theory, the Boltzmann equation, Kubo’s linear response theory, Onsager’s relations.

879. Statistical Mechanics III
Spring. 3(3-0) PHY 878.
Special topics chosen at discretion of instructor. Topics may include phase transitions, critical phenomena and renormalization group techniques; Green’s function and diagrammatic techniques for interacting systems.

899. Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

927. Elementary Particle Physics
Fall of even-numbered years. 3(3-0) PHY 899.
Properties of elementary particles; invariance principles and conservation laws; strong, electromagnetic, and weak interactions; pion physics.

928. Elementary Particle Physics
Winter of odd-numbered years. 3(3-0) PHY 899.
Baryon and meson resonances, unitary symmetry, dispersion relations.

929. Advanced Topics in Physics
Spring of odd-numbered years. 3(3-0) PHY 899.
Selected current topics, partial wave amplitudes and Regge poles, current algebra and weak interactions.

936. Molecular Structure and Spectra I
Fall of even-numbered years. 3(3-0) PHY 899 or concurrently.
Structure and spectra of diatomic molecules.

938. Molecular Structure and Spectra II
Winter of odd-numbered years. 3(3-0) PHY 899.
Structure and spectra of polyatomic molecules.

939. Molecular Structure and Spectra III
Spring of odd-numbered years. 3(3-0) PHY 899.
Advanced topics in vibration-rotation theory of polyatomic molecules.

947. Solid State Physics I
Fall of odd-numbered years. 3(3-0) PHY 899 and PHY 840.
Crystal symmetry, crystal bonding, lattice vibrations and specific heat; one-electron theory; Hartree-Fock equation, Brillouin zones.

942. Solid State Physics II
Winter of even-numbered years. 3(3-0) PHY 899.

949. Solid State Physics III
Spring of even-numbered years. 3(3-0) PHY 899.
Ionic crystals. Imperfections in crystals, plastic deformations, color centers. Optical properties. Rectification, transistors, selected topics.

954. Nuclear Physics I
Fall of odd-numbered years. 3(3-0) PHY 899.
Nucleon-nucleon scattering, nuclear sizes and shapes, multipole moments; shell model; collective states.

955. Nuclear Physics II
Winter of even-numbered years. 3(3-0) PHY 899.
Experimental methods and instrumentation; nuclear reactions; inelastic scattering and particle transfer.

956. Nuclear Physics III
Spring of even-numbered years. 3(3-0) PHY 899.
Many-body methods in nuclear physics; Bethe-Goldstone equation, effective interaction; nuclear models.

984. Advanced Readings in Physics or Astronomy
Fall, Winter. 3(3-0) Variable credit. Interdepartmental with the Department of Astronomy and Astrophysics.
In any one term this course will be devoted to a single topic, such as advanced quantum theory, quantum electrodynamics, specialized topics in solid state physics, statistical mechanics, relativity theory and cosmology.

985. Waves and Radiations in Plasmas
Winter of even-numbered years. 3(3-0) E E 899, Interdepartmental with the Department of Astronomy and Astrophysics and Electrical Engineering. Administered by Electrical Engineering.
Plasma oscillation; interaction, electromagnetic fields with plasma, wave propagation in magnetonic media; plasma sheath; radiation of electric source in incompressive and compressive plasmas; electrosoustic waves; magnetohydrodynamics; research topics in plasmas.

999. Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.