889. Seminar in the Philosophy of Science
Fall, Winter. 4 credits. Approval of department.

890. Graduate Reading Course
Fall, Winter, Spring, Summer. 1 to 10 credits. May re-enroll for credit. Approval of department.
Supervised reading course for advanced graduate students for more thorough investigation of special fields.

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

PHYSICAL SCIENCE

College of Natural Science

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

400. Physical Science for Teachers
Fall, Winter, Spring, Summer. 3 or 4 credits. May re-enroll for a maximum of 12 credits. Teacher certification with science major or minor.
For in-service teachers stressing process, inquiry, meaning and field experience. Topics will be generated from the classroom experiences of participants.

403. Mathematics for Teachers
Winter, Spring. 4(4-0) 402 or approval of department.
Continuation of 402.

410. Seminar on Recent Advances in Physical Science
Fall, Winter, Summer. 3(3-0)
May re-enroll for a maximum of 6 credits if different topics is taken. Approval of department.
A series of lectures by senior faculty of topics on the history, development, the most recent advances and the possible future and limits of the Physical Sciences.

411. Seminar on Man, His Universe
Fall, Winter, Spring. 3(3-0)
Approval of department.
A creative review by senior faculty from Astronomy, Biochemistry, Biophysics, Geology, Physics and Philosophy on the impact of recent space probes in developing modern concepts of the universe.

412. Seminar on Man, His Earth
Fall, Winter, Spring. 3(3-0)
Approval of department.
A summary by senior faculty from Astronomy, Anthropology, Botany, Geology, Meteorology, and Zoology of new ideas, methods, and theories employed by current researchers to unravel the mysteries of the origin of the earth, its interior, the forces developing the scenic surface features, and the evolution of life in its historical setting.

PHYSICS

College of Natural Science

Introductory physics courses are divided into four groups:
1) 237, 238, 239 (theory) and 257, 258, 259 (laboratory). These are for students who are taking at the same time, or who have taken, first year mathematics through college algebra and trigonometry.
2) 281, 282, 283 (theory) for students of the natural sciences who have taken Calculus I (MTH 115).
Students in 281, 282, 283 may take either 297, 298, 299, 299 laboratory course sequences.
3) 281A, 282A, 283A, 287, 288, 289 (theory) for students of the physical sciences, mathematics, engineering and others taking Calculus III (MTH 214). May be taken as 287 or as 282 plus 283A, as 289 or 283 plus 283A.
The self-paced sections are under combined management with 281, 282, 283, and 291A, 291B, 292A, 292B, 293A, 293B.
Students in 287, 288, 289, 290, 290 may take either 297, 298, 299 or 292, 293, 294 laboratory course sequences.
291, 292, 293, 294 (theory) for physics majors and others with a special interest in physics. Students should be taking Calculus III (MTH 214). Lecture-rectation format only.
Students in 292, 293, 294, 291A, 291B, 292A, 292B, 293A, 293B may take either 292, 293, 294, or 297, 298, 299 laboratory course sequences.

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 PHY 294, 357 or 364.

PHY 201, 205, 301, 357 and 430 cannot be used to meet the requirements for a major in physics.
All 400 level physics courses (except 430) require PHY 259 or 293B or equivalent and MTH 215 as prerequisites.

800. Problems in Physical Science
Fall, Winter, Spring, Summer. 1 to 15 credits. May re-enroll for a maximum of 15 credits. Bachelor's degree in a physical science.

PHYSICAL SYSTEMS IN AGRICULTURE AND NATURAL RESOURCES

See Agricultural Engineering

PHYSICS

College of Natural Science

Introductory physics courses are divided into four groups:
1) 237, 238, 239 (theory) and 257, 258, 259 (laboratory). These are for students who are taking at the same time, or who have taken, first year mathematics through college algebra and trigonometry.
2) 281, 282, 283 (theory) for students of the natural sciences who have taken Calculus I (MTH 115).
Students in 281, 282, 283 may take either 297, 298, 299, 299 laboratory course sequences.
3) 281A, 282A, 283A, 287, 288, 289 (theory) for students of the physical sciences, mathematics, engineering and others taking Calculus III (MTH 214). May be taken as 287 or as 282 plus 283A, as 289 or 283 plus 283A.
The self-paced sections are under combined management with 281, 282, 283, and 291A, 291B, 292A, 292B, 293A, 293B.
Students in 287, 288, 289, 290, 290 may take either 297, 298, 299 or 292, 293, 294 laboratory course sequences.
291, 292, 293, 294 (theory) for physics majors and others with a special interest in physics. Students should be taking Calculus III (MTH 214). Lecture-rectation format only.
Students in 292, 293, 294, 291A, 291B, 292A, 292B, 293A, 293B may take either 292, 293, 294, or 297, 298, 299 laboratory course sequences.

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 PHY 294, 357 or 364.

PHY 201, 205, 301, 357 and 430 cannot be used to meet the requirements for a major in physics.
All 400 level physics courses (except 430) require PHY 259 or 293B or equivalent and MTH 215 as prerequisites.

201. The Science of Sound I: Rock, Bach and Oscillators
Fall, Winter. 3(4-0) or 4(4-0) Interdepartmental with the Mechanical Engineering Department.

202. The Science of Sound II
Spring. 3(2-0) or 4(4-0) 201. Interdepartmental with and administered by the Mechanical Engineering Department.

230. The Role of the Natural Sciences in Future Environments
Fall, 4(4-0) Approval of department. Interdepartmental with the departments of Entomology, Geology and Zoology and the College of Natural Science and administered by the College of Natural Science.
Physical and biological science concepts relevant to understanding of environmental issues. Options for action in areas of population size, energy and life support system. Illustrated by case studies.

237. Introductory Physics
Fall, Winter. 3(4-0) MTH 102 or 109 or 111 or concurrently.
Mechanics and heat.

238. Introductory Physics
Winter. 3(4-0) 237.
Heat, electricity and magnetism.

239. Introductory Physics
Fall, Winter. 3(4-0) 238.
Wave motion, sound, light, and modern developments.

IDC. Energy Consumption and Environmental Quality
For course description, see Interdisciplinary Courses.

257. Introductory Physics Laboratory
Fall, Winter. 1(0-2) 237 or 281, or concurrently.
Mechanics and heat.

258. Introductory Physics Laboratory
Winter, Spring. 1(0-2) 238 or 292 or concurrently.
Heat, electricity and magnetism.

259. Introductory Physics Laboratory
Fall, Spring. 1(0-2) 239 or 263 or concurrently.
Wave motion, sound, light and modern developments.

281. Basic Physics I
Fall, Winter, Spring. 3 credits—Self-paced only. MTH 112.
Static equilibrium, Newton's laws, power, harmonic motion, rotational motion.
281A. Physics IA
Fall, Winter, Spring. 1 credit—Self-paced only. MTH 115, PHY 261 or concurrently.

281B. Honors Physics IA
Fall, Winter, Spring. 1 credit—Self-paced only. MTH 115, PHY 261A or concurrently.

282. Basic Physics II
Fall, Winter, Spring. 3 credits—Self-paced only. PHY 261, or 261A, or 267, or 291A, or 291B, or 291.

282A. Basic Physics II
Fall, Winter, Spring. 3 credits—Self-paced only. PHY 261, or 291A, or 287, or 291A, or 291B, or 291.

283. Basic Physics III
Fall, Winter, Spring. 3 credits—Self-paced only. PHY 262, or 292A, or 288, or 292, or 292A or 292B.

283A. Physics IIIA
Fall, Winter, Spring. 1 credit—Self-paced only. PHY 262, or 288A, or 288, or 292, or 292A or 292B; MTH 214 or approval of department.

287. Principles of Physics
Fall, Winter, Spring. 4(5-0) MTH 115.
Mechanics.

288. Principles of Physics
Fall, Winter, Spring. 4(5-0) 287; MTH 214 or approval of department.
Heat and thermodynamics, electricity and magnetism.

289. Principles of Physics
Fall, Winter, Spring. 4(5-0) 288; MTH 214 or approval of department.
Wave motion, sound, light, and modern developments.

291. Physics I
Spring. 4(5-0) MTH 214 or concurrently.
First of a five-term course sequence in elementary physics consisting of 291, 292, 293, 394, and 395. In this sequence the principles of physics are presented in a unified manner that emphasizes modern concepts. Mechanics, including special relativity.

291A. Honors Physics IA
Fall, Winter, Spring. 1 credit—Self-paced only. MTH 115; PHY 261A or concurrently.

292. Physics II
Fall. 4(5-0) 291; MTH 215 or concurrently.
Continuation of 291. Electricity and magnetism with some special relativity.

292A. Honors Physics IIA
Fall, Winter, Spring. 1 credit—Self-paced only. MTH 214; PHY 281A, or 257, or 291A, or 291B, or 291.

292B. Honors Physics IIB
Fall, Winter, Spring. 5 credits—Self-paced only. MTH 214, PHY 291, 261A, or 287, or 292A, or 291B, or 291.

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

293A. Honors Physics IIIA
Fall, Winter, Spring. 1 credit—Self-paced only. MTH 215; PHY 282A, or 288, or 292A, or 292B.

293B. Honors Physics IIIB
Fall, Winter, Spring. 5 credits—Self-paced only. MTH 215; PHY 282 and 285A, or 288, or 292A, or 292B.

294. Physics IV
Spring. 4(5-0) 263 or 289.
Continuation of 293. Introduction to quantum physics.

297. Principles of Physics Laboratory
Fall, Winter. 1(0-2) 261, or 287, or 291B or 292 or concurrently.
Mechanics.

298. Principles of Physics Laboratory
Winter, Spring. 1(0-2) 262, or 286 or 292B, or 283 or concurrently.
Heat and thermodynamics, electricity and magnetism.

299. Principles of Physics Laboratory
Fall, Spring, Summer. 1(0-2) 283, or 286, or 295B, or 294 or concurrently.
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).

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

404. Special Problems
Fall, Winter, Spring. 1 to 5 credits. 289 or 293; approval of department.
419. Physical Phenomena and Electronic Instrumentation I
Winter. 4(3-0) 289 or 293B; MTH 215. Interdepartmental with the Electrical Engineering Department.

- Concepts of electronics relative to the use in instrumentation of physical phenomena and their subsequent applications to provide reliable instrumentation. Nuclear radiation detectors, photometers and magnetometers are examples of specific topics covered.

420. Physical Phenomena and Electronic Instrumentation II
Spring. 4(3-3) 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) 299 or 293B; MTH 215.

- Statics 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) 427.

- Continuation of 427.

429. Advanced Mechanics
Spring. 3(3-0) 428.

- Advanced methods of theoretical mechanics; general coordinate; Lagrange's and Hamilton's equations; the wave equation, theory of vibrations.

430. Introduction to Radioactivity and Radioisotope Techniques
Fall, Summer. 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
Fall, Summer. 1(3-0) CEM 161; 430 concurrently. CEM 163 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.

438. Optics
Fall. 4(3-3) 289 or 293B; MTH 215.

- Geometrical optics including Fermat's Principle, reflection, refraction, mirrors, thin lenses, thick lenses, aberrations, and the effects of apertures and stops, interference.

439. Optics
Winter. 4(3-3) 438.

- Physical optics including Huygens-Fresnel Principles, diffraction; Fourier transforms of wave forms, convolution, diffraction and image formation; holography; polarization.

447. Electricity and Magnetism I
Winter. 4(4-0) Eighteen credits in physics, including 289 or 293B; MTH 215.

- 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) 447.

- Continuation of 447.

457G. Advanced Physics Laboratory (General)
Fall. 3(1-4) 15 credits in physics including 289 or 293B.

- 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. 3(1-6) 15 credits in physics including 289 or 293B.

- 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. 3(1-6) 15 credits in physics including 289 or 293B.

- 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
Fall. 3(3-0) 394 or 364; MTH 215.

- Schroedinger wave equation and its applications; angular momentum; one electron atom; moments and spin; perturbation methods; absorption and emission of radiation; atomic and molecular structure.

492. Introduction to Quantum Mechanics II
Winter. 3(3-0) 491.

- Continuation of 491.

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

- Continuation of 492.

494. Introduction to Elementary Particle Physics
Fall. 3(3-0) 394 or 404 or 491.

- Relativistic kinematics, invariance principles. Phenomenological theoretical analysis of elementary interactions with matter. Weak, electromagnetic and strong interactions. High energy accelerators and techniques in experimental high energy physics.

500. Introduction to Research Methods
Fall, Winter, Spring, Summer. 3(3-0) 428 or 448.

- May re-enroll for a maximum of 4 credits. Beginning graduate students.

- Problems and techniques of current experimental and theoretical research by taking part in the design and setup of experiments, data taking, reduction; and study and practice of theoretical methods. Areas of study are: solid state and molecular structure, nuclear, elementary particles.

817. Techniques of Theoretical Physics
Fall. 3(3-0) Graduate students or approval of department.

- Application of contour integration to physical problems; basic concepts in theoretical formulation of quantum mechanical systems; solution of physical problem using Green's Functions, the delta function, series, integral transforms.

827. Theoretical Physics I
Summer of even-numbered years. 3(3-0) 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) 448 or approval of department.

- Special relativity, Maxwell's equations, electrodynamics and electromagnetic waves.

829. Theoretical Physics III
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) 428, 491.

- The formulation of quantum mechanics, superposition principle, state vector and representations; uncertainty principles, Schroedinger equation and its solution for physical systems.

838. Quantum Mechanics II
Winter. 3(3-0) 837.

- Approximation methods, perturbation theory, applications to atomic transitions, angular momentum.

839. Quantum Mechanics III
Spring. 3(3-0) 838.

- Collision processes and scattering theory, applications; many-particle systems.

540. Symmetry in Solid State Physics
Spring. 3(3-0) Graduates or approval of department.

- Translational symmetry and Bloch's Theorem, reciprocal lattice, Brillouin zones; point groups, representations, character tables, molecular vibrations, group of the electronic vectors and band theory of solid, crystal fields.

547. Electromagnetic Theory I
Fall. 3(3-0) 428, 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) 847.
Multipoles and multipole expansions; electrostatics of macroscopic materials, dielectrics, magnetostrictions, vector potential, magnetic moments, Maxwell’s equations for time-varying fields, energy and momentum conservation. Plane electromagnetic waves and polarization.

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

850. Ionized Cases
Spring. 3(3-0) E E 835 or PHY 446. Interdepartmental with the Astronomy Department and Electrical Engineering and administered by Electrical Engineering. Elastic collision processes; Boltzmann equation; moment equations; basic plasma phenomena; motion of a charged particle in electric and magnetic fields; individual and collective charged particle behavior.

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) 859 or approval of department. Interdepartmental with the Astronomy Department. Conceptual foundations of general relativity theory; elements of tensor calculus; Riemann-Christoffel curvature tensor; 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) AST 860. Interdepartmental with the Astronomy Department. Relativistic cosmology: the model universe; steady-state theory; observational evidence and possibilities for decision among models; current problems.

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

868. Relativistic Quantum Mechanics
Winter. 3(3-0) 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.

869. Quantized Fields
Spring. 3(3-0) 886. Heisenberg representation, S-matrix reduction formulae, Feynman rules, quantum electrodynamics; topics from many-body theory.

877. Equilibrium Statistical Mechanics
Fall. 3(3-0) Approval of department. Ensembles, partition functions, thermodynamic potentials with applications to simple thermodynamics; topics from many-body theory.

878. Nonequilibrium Statistical Mechanics
Winter. 3(3-0) 877. Time-dependent Liouville equation, Bloch equations, and master equation, with application to relaxation processes and atomic, molecular, and nuclear systems.

879. Quantum Statistical Mechanics
Spring. 3(3-0) 878. Green’s function techniques with application to transport theory, superconductivity, magnetism.

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

891. Advanced Topics in Physics
Fall, Winter, Spring, Summer. Variable credit.

937. Molecular Structure and Spectra I
Fall. 3(3-0) 837. Study of diatomic molecules. Structure and spectra of diatomic molecules.

938. Molecular Structure and Spectra II
Winter of even-numbered years. 3(3-0) 838. Structure and spectra of polyatomic molecules.

939. Molecular Structure and Spectra III
Spring of even-numbered years. 3(3-0) 838. Advanced topics in vibration-rotation theory of polyatomic molecules.

947. Solid State Physics I
Fall. 3(3-0) 839 and 840. Crystal symmetry, crystal bonding, lattice vibrations and specific heat, one-electron theory; Hartree-Fock equation, Brillouin zones.

948. Solid State Physics II
Winter. 3(3-0) 847. Effective mass approximation. Exchange and correlation corrections. Theory of conductivity and related effects, metals and semiconductors.

949. Solid State Physics III
Spring. 3(3-0) 848. Ionic crystals. Imperfections in crystals, plastic deformations, color centers. Optical properties. Rectification, transistors, selected topics.

957. Nuclear Physics I
Fall. 3(3-0) 887. Nucleon-nucleon scattering, nuclear sizes and shapes, multiple moments; shell model; collective states.

958. Nuclear Physics II
Winter. 3(3-0) 957. Experimental methods and instrumentation; nuclear reactions; inelastic scattering and particle transfer.

959. Nuclear Physics III
Spring. 3(3-0) 958. Many-body methods in nuclear physics; Bethe-Goldstone equation; effective interaction; nuclear models.

961. Accelerator Physics
Fall. 3(3-0) 858. 858. Cyclotrons, betatrons, synchrotrons, and linear accelerators. Theory of magnetic focusing; constant gradient, alternating gradient, edge focusing; acceleration processes, longitudinal motion. Non-linear resonances, stability limits. Beam injection, extraction, and transport.

984. Advanced Readings in Physics
Fall, Winter, Spring, Summer. Variable credit.

985. General Relativity and Cosmology
Fall, Winter, Spring, Summer, or approval of department.

986. Advanced Topics in Physics
Fall, Winter, Spring. 3(3-0) or 4(4-0) or concurrent. 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.

987. Waves and Radiations in Plasmas
Fall of even-numbered years. 3(3-0) 850. Interdepartmental with the Astronomy Department and Electrical Engineering and administered by Electrical Engineering. Plasma oscillation, interaction, electromagnetic fields with plasmas, wave propagation in magnetopotic media; plasma sheath; radiation of electric source in incompressible and compressive plasmas; electromagnetic waves; magnetohydrodynamics; research topics in plasmas.

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

PHYSIOLOGY

College of Human Medicine
College of Natural Science
College of Osteopathic Medicine
College of Veterinary Medicine

240. Introductory Physiology
Fall, Spring, Summer. 4(3-0) Sophomores or approval of department. Survey of the physiology of circulatory system, excretion, nervous system and special senses, digestion, metabolism and endocrinology.