

# PHYSICS (PHYS-UA)

## PHYS-UA 7 The Universe: Its Nature and History (4 Credits)

*Typically offered Spring*

Qualitative introduction to our understanding of the nature and evolution of the universe. Topics include the creation of the cosmos; its explosive evolution, present structure, and ultimate fate; the nature of stars and galaxies; the structure and evolution of our Milky Way; the birth, life, and eventual death of the solar system; our place and role in the universe; and the relationship of modern astronomical ideas to other cultural disciplines.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

## PHYS-UA 11 General Physics I (5 Credits)

*Typically offered Fall and Summer terms*

With PHYS-UA 12, forms a two-semester sequence that must be taken in order. Lecture and laboratory-recitation. Not open to students who have completed PHYS-UA 91 with a grade of C- or better. Offered in the fall. 5 points. Begins a two-semester introduction to physics intended primarily for preprofessional students and for those majoring in a science other than physics, although well-prepared students may wish to take the physics majors sequence PHYS-UA 91, PHYS-UA 93, PHYS-UA 94, PHYS-UA 95, and PHYS-UA 96 instead. Topics include kinematics and dynamics of particles; momentum, work, and energy; gravitation; circular, angular, and harmonic motion; mechanical and thermal properties of solids, liquids, and gases; heat and thermodynamics.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

**Prerequisites:** MATH-UA 121 with a Minimum Grade of C OR Corequisite: MATH-UA 121 OR Prerequisite: MATH-UA 131 OR AP Exam Calc AB  $\geq$  4 OR AP Exam Calc ASub  $\geq$  4 OR AP Exam Calc BC  $\geq$  4.

## PHYS-UA 12 General Physics II (5 Credits)

*Typically offered Spring and Summer*

Continuation of PHYS-UA 11. Topics include electric charge, field, and potential; magnetic forces and fields; resistive, capacitive, and inductive circuits; electromagnetic induction; wave motion; electromagnetic waves; geometrical optics; interference, diffraction, and polarization of light; relativity; atomic and nuclear structure; elementary particle physics.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

**Prerequisites:** (PHYS-UA 11 with a Minimum Grade of C- OR PHYS-UA 9011 with a Minimum Grade of C-).

## PHYS-UA 13 Observational Astronomy (4 Credits)

*Typically offered Fall and Spring*

Introduction to the theory and practice of technical amateur astronomy. The approach is hands-on, with weekly evening laboratory/observing sessions. Topics include astronomical coordinate systems, optics, how to use a telescope, and the phenomena that can be seen in the urban night sky. Observing sessions involve the use of eight-inch telescopes.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

## PHYS-UA 14 Physics and Astronomy in the Renaissance (4 Credits)

*Typically offered occasionally*

In addition to the magnificent flowering of the arts in the Renaissance, the Renaissance period was also one of extraordinary advance in science, in particular in astronomy and physics. The course will examine this advance, emanating from the scientific developments in the European and Italian centers of learning during the Renaissance and at the start of the Age of Enlightenment, in the light of prior wisdom. To set the scene, it will start with a discussion of the true or mistaken views of the ancient Greeks and their transmission by Islamic centers of learning. However, the topics will center on the 'Copernican Revolution' of Nicolas Copernicus, Tycho Brahe, Johannes Kepler, and Galileo Galilei that was the beginning of observational science and astronomy. Also included will be the truly universal scientist, engineer and artist Leonardo da Vinci, the world's first cosmologist Giordano Bruno, and Sir Isaac Newton who culminated all this development with his Laws of Mechanics and Law of Universal Gravitation.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

## PHYS-UA 15 Introduction to Cosmology (4 Credits)

*Typically offered occasionally*

This course is a technical but elementary introduction to the modern understanding of cosmology, intended for non-science students. We will cover advances in cosmology over the last 100 years, with special emphasis on more recent developments in the field. We will cover topics ranging from the early universe to galaxy formation in the present day universe, through the lens of the theory of relativity and the expanding universe. We will cover the Big Bang, the Cosmic Microwave Background, dark matter, dark energy and the associated evidence for these phenomena. Assumes a high-school level mathematics background. This course counts to the astronomy minor.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

## PHYS-UA 20 20th Cent Concepts of Space, Time, & Matter (4 Credits)

*Typically offered Fall and Spring*

The 20th century has been witness to two major revolutions in man's concepts of space, time, and matter. Einstein's special and general theories of relativity: implications of the special theory, for our understanding of the unity of space and time, and the general theory, for our understanding of the nature of gravity. Quantum mechanics: a new picture of the basic structure and interactions of atoms, molecules, and nuclei. Topics include the uncertainty principle, wave-particle duality, and the continuing search for the fundamental constituents of matter.

**Grading:** CAS Graded

**Repeatable for additional credit:** No

## PHYS-UA 71 Introductory Experimental Physics I (2 Credits)

*Typically offered occasionally*

The first of two introductory-level laboratory courses. The objectives of these courses are to introduce essential experimental techniques including set-up and operation of basic laboratory equipment, elementary experimental design, statistics and inference, and computational data analysis. Experimental techniques are introduced in the context of classic physics experiments

**Grading:** CAS Graded

**Repeatable for additional credit:** No

**PHYS-UA 72 Introductory Experimental Physics II (2 Credits)***Typically offered occasionally*

The second of two introductory-level laboratory courses. The objectives of these courses are to introduce essential experimental techniques including set-up and operation of basic laboratory equipment, elementary experimental design, statistics and inference, and computational data analysis. Experimental techniques are introduced in the context of classic physics experiments.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 71.**PHYS-UA 73 Intermediate Experimental Physics I (2 Credits)***Typically offered occasionally*

The first of two intermediate-level laboratory courses. The objectives of these courses are to develop further the experimental techniques introduced in PHYS-UA 71 and PHYS-UA 72, and all in the context of more advanced experiments.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 72.**PHYS-UA 74 Intermediate Experimental Physics II (2 Credits)**

The second of two intermediate-level laboratory courses. The objectives of these courses are to develop further the experimental techniques introduced in PHYS-UA 71 and PHYS-UA 72, and all in the context of more advanced experiments.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 73.**PHYS-UA 91 Physics I (3 Credits)***Typically offered Fall*

Begins a three-semester introduction to physics intended for physics majors and other interested science and mathematics majors. Topics include kinematics and dynamics of particles; energy and momentum; rotational kinematics and dynamics; harmonic oscillators; gravitational fields and potentials; special relativity.

**Grading:** CAS Graded**Repeatable for additional credit:** No**PHYS-UA 93 Physics II (3 Credits)***Typically offered Spring*

Continuation of PHYS-UA 91. Topics include electrostatics; dielectrics; currents and circuits; the magnetic field and magnetic materials; induction; AC circuits; Maxwell's equations.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 91 with a Minimum Grade of C.**PHYS-UA 95 Physics III (3 Credits)***Typically offered Fall*

Topics include harmonic oscillators and resonance, coupled oscillators, normal modes, and waves; mechanical vibrations, sound and light; Fourier series and Fourier transforms; reflection, refraction, interference, and diffraction of waves; polarization. This is the third semester of a three-semester calculus-based introduction to physics and is intended for physics majors and other interested students.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 93 with a Minimum Grade of C.**PHYS-UA 106 Mathematical Physics (3 Credits)***Typically offered Spring*

Mathematical preparation for the junior and senior courses in physics. Vector analysis, Fourier series and integrals, ordinary differential equations, matrices, partial differential equations, and boundary-value problems.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 95 with a Minimum Grade of C AND (MATH-UA 123 with a Minimum Grade of C OR MATH-UA 129).**PHYS-UA 110 Electronics for Scientists I (4 Credits)***Typically offered occasionally*

Introduction to basic analog and digital electronics used in physics experiments. Concepts and devices presented in lecture are studied in the laboratory. Topics include DC and AC circuits, filters, power supplies, transistors, operational amplifiers, analog to digital converters, and digital logic.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 12 with a Minimum Grade of C OR PHYS-UA 93 with a Minimum Grade of C).**PHYS-UA 112 Advanced Experimental Physics (3 Credits)***Typically offered Fall and Spring*

Introduces the experiments and techniques of modern physics. Following a number of introductory experiments, students have at their option a variety of open-ended experiments they can pursue, including the use of microcomputers for data analysis. Experimental areas include Mossbauer effect, cosmic rays, magnetic resonance, and relativistic mass.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 123 with a Minimum Grade of C AND PHYS-UA 74 with a Minimum Grade of C) OR (SCIEN-UH 1601 with a Minimum Grade of C AND SCIEN-UH 1602 with a Minimum Grade of C AND PHYS-UA 3012 with a Minimum Grade of C).**PHYS-UA 115 Advanced Mathematical Physics (3 Credits)**

An advanced course in mathematical physics intended to prepare students for more advanced physics and engineering courses. Topics include, but are not limited to, probability theory, advanced ordinary and partial differential equations, differential geometry, complex variable theory, topology, homotopy, and group representation theory.

**Grading:** CAS Graded**Repeatable for additional credit:** No**PHYS-UA 120 Dynamics (3 Credits)***Typically offered Fall*

Topics include conservation laws, central force motion, Lagrange's and Hamilton's equations, non-inertial frames, inertia tensor, rigid body dynamics, coupled oscillators and particles, eigenvalues, eigenvectors and normal modes.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 95.

**PHYS-UA 123 Quantum Mechanics I (3 Credits)***Typically offered Fall*

Topics include: foundational experiments; wave-particle duality; wave functions; the uncertainty principle; the time-independent Schrödinger equation and its applications to one-dimensional problems and the hydrogen atom; angular momentum; spin; Hilbert Space, operators, and observables; time independent perturbation theory; atomic spectra.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 120 with a Minimum Grade of C AND PHYS-UA 106 with a Minimum Grade of C).**PHYS-UA 124 Quantum Mechanics II (3 Credits)***Typically offered Spring*

Continuation of PHYS-UA 123. Topics include the time dependent Schrödinger equation, the Schrödinger and Heisenberg description of quantum systems, time dependent perturbation theory, scattering theory, quantum statistics, and applications to atomic, molecular, nuclear, and elementary particle physics.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 123 with a Minimum Grade of C OR PHYS-UH 3012).**PHYS-UA 131 Electricity & Magnet I (3 Credits)***Typically offered Fall*

Introduction to Maxwell's equations with applications to physical problems. Topics include electrostatics, magnetostatics, the solution of the Laplace and Poisson equations, dielectrics and magnetic materials, electromagnetic waves and radiation, Fresnel equations, transmission lines, wave guides, and special relativity.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 106 with a Minimum Grade of C AND PHYS-UA 95 with a Minimum Grade of C) OR (SCIEN-UH 1601 with a Minimum Grade of C AND SCIEN-UH 1602 with a Minimum Grade of C AND MATH-UH 1020 with a Minimum Grade of C).**PHYS-UA 132 Electricity & Magnet II (3 Credits)***Typically offered occasionally*

Continuation of PHYS-UA 131, with greater depth and emphasis on more complex phenomena and applications. Topics include solutions to the Laplace and Poisson equations, dielectrics and magnetic materials, gauge invariance, plasmas, Fresnel equations, transmission lines, wave guides, and antennas.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 131 with a Minimum Grade of C.**PHYS-UA 135 Condensed Matter Physics (3 Credits)***Typically offered Spring term of odd numbered years*

This course is designed as an introduction to condensed matter physics for students with knowledge of elementary quantum mechanics. Topics include crystal structure, lattice vibrations, and the energy band theory of metals and semiconductors. Covers the electronic, magnetic, and optical properties of solids. In addition, the course may include some modern research topics such as the physics of nanostructures, soft condensed matter physics, and superconductivity.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 120 with a Minimum Grade of C.**PHYS-UA 136 Readings in Particle Physics (3 Credits)***Typically offered occasionally*

Prerequisite: PHYS-UA 105 Classical and Quantum Waves. Particle physics is the study of the very fundamental constituents of matter and of the forces between them. By its nature it is microscopic, but it also connects with astrophysics and cosmology on the largest scales. This course introduces the most important advances in elementary particle physics. It centers on journal articles in which these advances were first published, with overview lectures, original reading, discussion, and student presentations. Topics include the discovery of elementary particles in cosmic rays, antimatter, symmetries found in nature, and the invention of the Quark model of elementary particles and its experimental verification.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 106 with a Minimum Grade of C.**PHYS-UA 138 Quantum Information and Quantum Computing (4 Credits)**

Quantum mechanical systems can be thought of as information-storing, information-processing, and information transmitting systems. The theory of quantum information contains many surprising and counter-intuitive results, and holds significant potential impacts on society. Topics will include density operators, quantum communication, teleportation, quantum cryptography, entanglement and the Bell Inequalities, quantum computing, quantum algorithms, quantum error correction, quantum circuits, and experimental developments..

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 123.**PHYS-UA 140 Thermal & Statistical Physics (3 Credits)***Typically offered Spring*

Topics include relation of entropy to probability and energy to temperature; the laws of thermodynamics; Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics; equations of state for simple gases and chemical and magnetic systems; and elementary theory of phase transitions.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 106 with a Minimum Grade of C.**PHYS-UA 150 Astrophysics (4 Credits)***Typically offered Fall of odd numbered years*

Introduction to modern astrophysical problems with an emphasis on the physical concepts involved?radio, optical, and X-ray astronomy; stellar structure and evolution; white dwarfs, pulsars, and black holes; and galaxies, quasars, and cosmology.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 12 with a Minimum Grade of C OR PHYS-UA 95 with a Minimum Grade of C OR PHYS-UH 3012).**PHYS-UA 170 General Relativity (3 Credits)***Typically offered Spring term of even numbered years*

This course provides an introduction to general relativity, stressing physical phenomena and their connection to experiments and observations. Topics include special relativity, gravity as geometry, black holes, gravitational waves, cosmology, Einstein equations.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 120 with a Minimum Grade of C.

**PHYS-UA 180 Introduction to Fluid Dynamics (4 Credits)***Typically offered Spring*

Fluid dynamics is the branch of physics that describes motions of fluids as varied as the flow of blood in the human body, the flight of an insect or the motions of weather systems on Earth. The course introduces the key concepts of fluid dynamics: the formalism of continuum mechanics, the conservation of mass, energy and momentum in a fluid, the Euler and Navier-Stokes equations, viscosity and vorticity. These concepts are applied to study classic problems in fluid dynamics, such as potential flow around a cylinder, the Stokes flow, the propagation of sound and gravity waves and the onset of instability in shear flow.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (MATH-UA 123 with a Minimum Grade of C OR MATH-UA 394 with a Minimum Grade of C OR MATH-SHU 151).**PHYS-UA 210 Computational Physics (4 Credits)***Typically offered Fall*

Introduction to computational physics, with an emphasis on fields of current research interest where numerical techniques provide unique physical insight. Topics are chosen from various branches of physics, including numerical solution of ordinary and partial differential equations, eigenvalue problems, Monte Carlo methods in statistical mechanics, field theory, dynamical systems, and chaos.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** PHYS-UA 106 with a Minimum Grade of C OR (SCIEN-UH 1601 with a Minimum Grade of C AND SCIEN-UH 1602 with a Minimum Grade of C AND MATH-UH 2010 with a Minimum Grade of C AND Restriction: Cumulative Grade Point Avg.**PHYS-UA 800 Special Topics in Physics: (4 Credits)***Typically offered Spring*

Prerequisite: mastery of geometry and intermediate algebra. Counts toward departmental minors but not the major. Intended for students who are attracted to the major because of the challenging concepts of contemporary physics and cosmology, whereas the first two years of the major are devoted to classical dynamics and electromagnetism. Topics include quantum entanglement, quantum information, black holes, gravitational radiation, and the big bang.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (MATH-UA 123 with a Minimum Grade of C OR MATH-UA 222).**PHYS-UA 997 Independent Study (4 Credits)***Typically offered Fall*

Prerequisite: permission of the director of undergraduate studies. 2 to 4 points per term.

**Grading:** CAS Graded**Repeatable for additional credit:** Yes**PHYS-UA 9011 General Physics I (5 Credits)**

This course begins a two-semester introduction to physics (lecture and laboratory-recitation) intended primarily for preprofessional students and for those majoring in a science other than physics. Topics include kinematics and dynamics of particles; momentum, work, and energy; gravitation; circular, angular, and harmonic motion; mechanical and thermal properties of solids, liquids, and gases; heat and thermodynamics.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** MATH-UA 121.**PHYS-UA 9012 General Physics II (5 Credits)**

This course is an introduction to electricity and magnetism, light, geometrical and wave optics. Many concepts from General Physics I will be used in this course such as: position, velocity, acceleration, force, Newton's laws of motion, work and energy. The course uses high school algebra, geometry and trigonometry, vectors and vector arithmetic, and some calculus. Calculus will be used in class but sparingly on exams. The algebra, geometry, and trig are absolutely essential. If some time has elapsed since your last math course, or you feel a lack of confidence in this area, you are strongly urged to study math intensively before we get too deeply into the physics course. The course has lecture, online homework and laboratory portions.

**Grading:** CAS Graded**Repeatable for additional credit:** No**Prerequisites:** (PHYS-UA 11 OR PHYS-UA 9011).