Physics

Natural Sciences Division

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Physics is the study of the most basic principles of nature that describe the world around us, from subatomic objects to the motion of everyday particles to the galaxies and beyond. Courses in physics allow students to develop a sound knowledge of these principles, as well as the analytical and experimental techniques necessary to apply them to a broad range of theoretical and experimental problems.

The Physics Curriculum

The Department of Physics offers three options for students wishing to begin their exploration of physics. Look for the ◆ symbol, which designates those courses particularly appropriate for first-year students or upperclass students new to the physics department curriculum.

Students who want a less mathematical approach to interesting subfields of physics should consider PHYS 102 (Good Nukes, Bad Nukes), PHYS 104 (Einstein), PHYS 105 (Unifying Ideas in Physics), PHYS 106 (Astronomy: Planets and Moons), PHYS 107 (Astronomy: Stars and Galaxies), PHYS 108 (Geology), or PHYS 109 (Origins). These courses are suitable for diversification in the sciences and are accessible to any Kenyon student. All contain some laboratory sessions in which students gain experience with the phenomena discussed in lectures. Usually, one or two such courses are offered each year.

The second option is PHYS 130 and 135 (General Physics I and II). PHYS 130 and 135 constitute a general survey of physics designed primarily for students who will take only one year of physics. Co-requisite courses PHYS 141 and PHYS 146 are weekly laboratories closely tied to lecture material and that make extensive use of computers for data acquisition and analysis.

The third option is PHYS 140 (Classical Physics) and PHYS 145 (Modern Physics), which, together with PHYS 240 (Fields and Spacetime), form a calculus-based introduction to the fundamentals of physics. These courses cover much the same material as PHYS 130 and PHYS 135, but are more analytical and treat a smaller number of topics in greater depth. PHYS 140 and PHYS 145 are particularly suitable for students who plan to take more physics or upper-level chemistry or mathematics courses. PHYS 140 and 145 are required for all physics courses with numbers above 220. They require concurrent enrollment in, or credit for, calculus. For first year students who have had any physics laboratory experience in high school, PHYS 110 (First Year Physics Seminar) is required as a co-requisite to PHYS 140. (For first-year students who have not had any physics laboratory component in high school or who are just starting their study of physics in college, PHYS 141 is the required co-requisite class.) For upper-class students, co-enrollment in PHYS 141 is required for PHYS 140. For the second semester, co-enrollment in PHYS 146 is required for enrollment in PHYS 145 for all students. PHYS 141 and PHYS 146 are weekly laboratories, closely tied to lecture material and that make extensive use of computers for data acquisition and analysis.

Students who have an unusually strong background in high-school physics and mathematics, or who receive high scores on the Advanced Placement C-level Physics Examination, should consider beginning their study of physics with PHYS 240 (Fields and Spacetime) and the co-requisite laboratory course PHYS 241. Placement in this course is done in consultation with the instructor and chair of the department. A student choosing this option should consider taking PHYS 110 (First Year Physics Seminar) as well.

Requirements for the Major

The minimum requirements for a major in physics consist of the following:

- PHYS 140; 110 or 141; 145; 146; 240; 241; 245; 246; 280; 281; 480; 481. PHYS 130 and 135 may be substituted for PHYS 140 and 145 with permission of the department chair.
- One additional unit selected from physics courses numbered above 320 and including at least one of PHYS 340, 350, or 360.
- MATH 111, 112, and 213, or equivalent; and either MATH 224 or 333.

Additional physics courses are encouraged. A student preparing for graduate study in physics should enroll in several advanced physics courses in addition to the minimum requirements and is encouraged to take further work in mathematics and chemistry. A student preparing for graduate study should expect to average about 2.25 units per semester. Care should be taken to satisfy the College's graduation requirement to take nine units outside of the major department.

Note: All courses in physics numbered above 220 have as prerequisites PHYS 140 and 145 and MATH 111 and 112, unless otherwise noted. PHYS 141, 146, 241, 246, 281, and 481 are laboratory courses involving substantial experimental work.

Senior Exercise

The Senior Exercise includes the presentation of a talk on a topic in physics to a department colloquium and a comprehensive written exam in physics.

Honors

Honors work in physics involves directed research on a specific topic in experimental physics, theoretical physics, or the history of physics, culminating in a written thesis, an oral presentation to a departmental colloquium, and an examination by an outside specialist.

Requirements for the Minor

The department offers two minors, physics and astronomy. Students considering one of these minors should work with a faculty member in the physics department as the minor is being planned, since some courses are not offered every year.

Requirements for the Physics Minor

The program for a minor in physics consists of the following:

- PHYS 140; 110 or 141; 145; 146; 240; 241. PHYS 130 and 135 may be substituted for 140 and 145 with permission of the department chair.
- One additional unit selected from physics courses numbered above 220.

This minor is open to students with all majors, but may be especially attractive to students in disciplines that have strong ties to physics, such as chemistry, mathematics, and biology. Other combinations of introductory courses may also be acceptable. Note: All courses in physics numbered above 220 have as prerequisites PHYS 140, 141, 145, 146, and MATH 111 and 112, unless otherwise noted.

Requirements for the Astronomy Minor

The program for a minor in astronomy consists of the following:

- PHYS 130 and 135 or 140 and 145; 110 or 141; 146; 106; 107.
- An additional .5 unit selected from all physics courses (see suggestions below).

There are several options for the choice of the fifth course. PHYS 240, 241 (Fields and Spacetime) and PHYS 245, 246 (Oscillations and Waves) provide further experience with the foundations of physics (note that these two courses have prerequisites in mathematics). Students with interests in instrumentation can choose PHYS 280, 281 (Electronics). Other options may include Independent Study and Special Topics courses related to astronomy. Note that College rules prohibit a student from receiving a minor in the same department as his or her major. Thus, a physics major may not elect to minor in astronomy.

Year Course

Senior Honors

PHYS 497Y-498Y (1 unit)
Staff

This course offers guided experimental or theoretical research for senior honors candidates. Prerequisite: permission of department chair.

First-Semester Courses

Good Nukes, Bad Nukes

◆ **QR** PHYS 102 (.5 unit)
Idoine, Sullivan

Nuclear power produces needed energy, but nuclear waste threatens our future. Nuclear weapons make us strong, but dirty bombs make us vulnerable. Nuclear medicine heals us, but nuclear radiation sickens us. Radio-carbon dating tells us about the past, but challenges our religious faith. "Good Nukes, Bad Nukes" is designed to give students the scientific knowledge necessary to understand and participate in public discussions of nuclear issues. The core concepts include classification of nuclei, the types of energy (radiation) released in nuclear reactions, the interaction of that radiation with matter, including human health effects, and the design of nuclear reactors and nuclear weapons. Hands-on demonstrations and experiments will explore radioactive decay, anti-matter, transmutation of atoms, nuclear detectors, and interactions of radiation with matter. We will apply the core concepts in discussions of contemporary issues: electric power generation using nuclear energy, including its environmental effects; advances in nuclear medicine; the challenges of preventing nuclear weapons proliferation; the threat from "dirty bombs"; and dating the Creation, for example. We will also cover the history of the Manhattan Project and the use of nuclear weapons that brought an end to the Second World War. We will offer a field trip to a significant nuclear site in Ohio. This course is designed to be accessible to any Kenyon student, so there are no prerequisites.

First-Year Seminar in Physics: Biological Physics

◆ **QR** PHYS 110 (.25 unit)
Kmetko

Studying biological physics allows us to understand the role of physical principles in the world of biology. In this course, we will aim to understand the elaborate machinery of a living

cell and other amazing biological systems in terms of structure, forces, energy, and system design. We will discuss topics in current research on protein folding and nucleotide conformations, biopolymers, biomembranes, membrane transport processes, the diffusion of molecules in liquids, chemical forces and self-assembly, the propagation of nerve impulses, and we will briefly survey topics in nanotechnology and soft materials. The emphasis will be on formulating elementary concepts of probability theory, entropy, random walks, fluid dynamics and Boltzmann statistics and applying these physical concepts to biological systems.
This course will meet once each week for a combination of lectures, discussion of assigned readings, small group problem-solving sessions, demonstrations, and experimental work with biophysical techniques such as optical tweezing, electrophysiology, atomic force microscopy, electrophoresis, chromatography, spectrophotometry, dynamic light scattering, x-ray crystallography, and proteomics. The course will provide an excellent foundation for further work in physics laboratories throughout the curriculum, including experience in estimating experimental uncertainties, analyzing and graphing numerical data sets, and preparing clear, complete reports of experimental results.

This course is open only to first-year students who are concurrently enrolled in or have placed out of PHYS 140 (Classical Physics). It fulfills the concurrent laboratory requirement for PHYS 140 and serves as a solid preparation for PHYS 146 (Introduction to Experimental Physics II).

General Physics I

◆ **QR** PHYS 130 (.5 unit)
LaSota

This course is the first course in a one-year introductory physics sequence. Topics will include Newtonian mechanics, work and energy, electric and magnetic forces, wave phenomena, and thermodynamics. When possible, examples will relate to life-science contexts. The course will be taught using a combination of lectures, in-class exercises, homework assignments, and examinations. A knowledge of calculus is not required. Prerequisites: high-school algebra and trigonometry. Co-requisite: PHYS 141.

Classical Physics

◆ **QR** PHYS 140 (.5 unit)
Idoine

This lecture course is the first in a three-semester, calculus-based introduction to physics. Topics include the kinematics and dynamics of particles and solid objects, work and energy, linear and angular momentum, gravitational, electrostatic, and magnetic forces, and usually the theory of simple, direct-current circuits. PHYS 140, 145, and 240 are recommended for students who may wish to major in physics, and are also appropriate for students majoring in other sciences and mathematics.

The course will be taught using a combination of lectures, in-class exercises, homework assignments, and examinations. Prerequisite: trigonometry. Co-requisite: (first year students) PHYS 110; (upper class students) PHYS 141; and MATH 111 or 112 taken concurrently, or equivalent. (While calculus is a co-requisite, we will develop the necessary mathematical tools in our lectures as well.) PHYS 140 is open only to first- and second-year students.

Introduction to Experimental Physics I

◆ **QR** PHYS 141 (.25 unit)
Staff

This laboratory course meets one afternoon each week and is organized around weekly experiments that demonstrate the phenomena of classical mechanics, including projectile motion, rotation, electrical circuits and fields, and conservation of energy and momentum. Lectures cover the theory and instrumentation required to understand each experiment. Experimental techniques emphasize computerized acquisition and analysis of video images to study motion. Students are introduced to computer-assisted graphical and statistical analysis of data as well as the analysis of experimental uncertainty. Enrollment is limited to sixteen students in each section. Co-requisite: PHYS 130 or 140.

Fields and Spacetime

QR PHYS 240 (.5 unit)
Kmetko

This lecture course is the third semester of the calculus-based introductory sequence in physics, which begins with PHYS 140 and PHYS 145. Topics covered include electric charge, electric and magnetic fields, electrostatic potentials, Ampere's law, electromagnetic induction, Maxwell's equations in integral form, electromagnetic waves, the postulates of the special theory of relativity, relativistic kinematics and dynamics, and the connections between special relativity and electromagnetism.

This course may be an appropriate first course for students with advanced placement in physics or two years of high-school physics; such students should contact the chair of the physics department. Prerequisites: PHYS 140 and 110 (or 141) or equivalent, and MATH 111. Co-requisite: PHYS 241.

Fields and Spacetime Laboratory

QR PHYS 241 (.25 unit)
Kmetko

This lecture and laboratory course is required for all students enrolled in PHYS 240 and is a prerequisite for all physics courses numbered above 241. The course is organized around experiments demonstrating various phenomena associated with electric and magnetic fields. Lectures cover the theory and instrumentation required to understand each experiment. Laboratory work emphasizes computerized acquisition and analysis of data, the use of a wide variety of modern instrumentation, and the analysis of experimental uncertainty. Prerequisite: PHYS 140 and 110 or 141 or equivalent. Co-requisite: PHYS 240.

Classical Mechanics

QR PHYS 340 (.5 unit)
LaSota

This lecture course begins by revisiting most of the Newtonian mechanics learned in introductory physics courses but with added mathematical sophistication. A major part of the course will be spent in understanding an alternate description to that of the Newtonian picture: the Lagrange-Hamilton formulation. The course will also cover the topics of motion in a central field, classical scattering theory, motion in non-inertial reference frames, and dynamics of rigid body rotations. Prerequisites: PHYS 245 and MATH 213.

Quantum Mechanics

QR PHYS 360 (.5 unit)
Schumacher

This course presents an introduction to theoretical quantum mechanics. Topics to be covered include wave mechanics, the Schrödinger equation, angular momentum, the hydrogen atom, and spin. Prerequisites: PHYS 245 and MATH 221.

Research Methods for Experimental Physics

QR PHYS 480 (.25 unit)
Peiris

This lecture course presents the theory, instrumentation, and statistical analysis of data needed to prepare students for the experiments performed in Experimental Physics (PHYS 481) and gives them experience in presenting physics to their peers. Topics are selected from many fields of physics and are currently drawn from nuclear physics, solid state physics, x-ray physics, optics, thermodynamics, and nuclear magnetic resonance. Understanding the physics behind the operation of detectors, analog-to-digital converters, and other modern instrumentation is stressed. Co-requisite: PHYS 481 and senior standing.

Experimental Physics

QR PHYS 481 (.5 unit)
Peiris

This advanced course in experimental physics includes extensive laboratory work and data analysis. Students will gain experience with nuclear detectors, x-ray diffraction and fluorescence techniques, noise reduction using phase-sensitive detection, computer data acquisition and analysis, and Fourier techniques. Prerequisites: PHYS 245, 280, and 281. Co-requisite: PHYS 480 and senior standing.

Individual Study

PHYS 493 (.25-.5 units)
Staff

The student will conduct special experimental or theoretical work on advanced topics in physics. Prerequisites: permission of instructor and department chair.

Second-Semester Courses

Origins

◆ PHYS 109 (.5 unit)
Holdener, Schumacher

Around us we see a vast, expanding universe of galaxies. The galaxies are composed of stars around some of which orbit planets. At least one of these planets in the universe is inhabited by an astoundingly complex set of living things. Where did all this come from? This course presents an overview of the formation and evolution of the universe, the solar system, planet Earth, and life on our planet. Lectures and readings will be supplemented by astronomical observations, computer simulations, and laboratory experiments (at times to be arranged.) The course has no prerequisites and is accessible to any Kenyon student.

General Physics II

◆ **QR** PHYS 135 (.5 unit)
Kmetko

This course focuses on a wide variety of physics topics relevant to students in the life sciences. Topics may include fluids, waves, optics, atomic physics, X-rays, radioactivity, nuclear physics, and particle physics. When possible, examples will relate to life-science contexts. The course will be taught using a combination of lectures, in-class exercises, homework assignments, and examinations. Prerequisites: PHYS 130. Co-requisite: PHYS 146.

Modern Physics

◆ **QR** PHYS 145 (.5 unit)
Peiris

This lecture course is a continuation of a calculus-based introduction to the physics of the twentieth century. Topics include geometrical and wave optics, special relativity, photons, photon-electron interactions, elementary quantum theory (including wave-particle duality, the Heisenberg uncertainty principle, and the time-independent Schrödinger equation), atomic physics, solid-state physics, nuclear physics, and elementary particles. PHYS 145 is recommended for students who may wish to major in physics, and is also appropriate for students majoring in other sciences or mathematics.

The course will be taught using a combination of lectures, in-class exercises, homework assignments, and examinations. Prerequisite: PHYS 140 and MATH 111 (or permission of the instructor). Co-requisite: PHYS 146 and MATH 112 taken concurrently (or equivalent). Open only to first- and second-year students.

Introduction to Experimental Physics II

◆ **QR** PHYS 146 (.25 unit)
Staff

This lecture and laboratory course is required for all students enrolled in PHYS 135 or 145, and is a pre-requisite for all physics courses numbered above 146. The course meets one afternoon each week and is organized around weekly experiments demonstrating the phenomena of waves, optics, x-rays, and atomic and nuclear physics. Lectures cover the theory and instrumentation required to understand each experiment. Experimental techniques include the use of lasers, x-ray diffraction and fluorescence, optical spectroscopy, and nuclear counting and spectroscopy. Students are introduced to computer-assisted graphical and statistical analysis of data, and the analysis of experimental uncertainty. Enrollment is limited to sixteen students in each section. Pre-requisite: PHYS 110 or 141. Co-requisite: PHYS 135 or 145.

Intermediate Seminar in Physics: Biological Physics

QR PHYS 210 (.25 unit)
Kmetko

See the course description for PHYS 110, offered in the first semester. This course will cover the same material but in greater depth, using physics learned in previous courses. As in PHYS 110, our study of biological physics will include topics on protein folding and nucleotide conformations, biopolymers, biomembranes, the role of random walks, diffusion, and entropic forces in biological systems, the physical chemistry of binding affinity and kinetics, transport processes, and chemical forces and self-assembly. There will also be a short survey of nanotechnology and soft materials.

This course will meet once each week for a combination of lectures, discussion of assigned readings, small group problem-solving sessions, demonstrations, and experimental work with biophysical techniques such as optical tweezing, electrophysiology, atomic force microscopy, electrophoresis, chromatography, spectrophotometry, dynamic light scattering, x-ray crystallography, and proteomics. The course will provide an excellent foundation for further work in physics laboratories throughout the curriculum, including experience in estimating experimental uncertainties, analyzing and graphing numerical data sets, and preparing clear, complete reports of experimental results. Prerequisites: one year of introductory physics at the college level. PHYS 210 may be repeated, as topics vary from year to year.

Dynamical Systems in Scientific Computing

QR PHYS 218 (.5 unit)
Sullivan

The advent of widespread computing power has led to a revolution in our understanding of the natural world. Using computer models, scientists in all disciplines have been able to explore systems that are mathematically intractable. Surprising commonalities among systems have been discovered that have led to new ways of classifying phenomena and to a strong interdisciplinary perspective.

In this class, students will get hands on experience in numerical exploration using new techniques applied to many areas of science. Students will write C programs to solve ordinary differential equations and to model electrical circuits, orbital motion, and chemical reaction rates. Cellular automata models will be used to explore fluid dynamics, crystal growth, and species competition in the environment. Neural network techniques will be applied to pattern recognition. The Monte Carlo method will give us a way to explore systems containing randomness, including a model of magnetic behavior in solids. In every case, students will implement these techniques in the C programming language and build their programming skills. Prerequisites: MATH 118 or demonstrated competence in C programming.

Oscillations and Waves

QR PHYS 245 (.5 unit)
LaSota

The topics of oscillations and waves serve to unify many subfields of physics. This course begins with a discussion of damped and undamped, free and driven, mechanical and electrical oscillations. Oscillations of coupled bodies and normal modes of oscillations are studied along with the techniques of Fourier analysis and synthesis. We then consider waves and wave equations in continuous and discontinuous media, both bounded and unbounded. The course may also treat properties of the special mathematical functions that are the solutions to wave equations in various coordinate systems. Prerequisite: PHYS 240 or equivalent or permission of instructor. Co-requisites: PHYS 246 and MATH 213.

Oscillations and Waves Laboratory

QR PHYS 246 (.25 unit)
LaSota

This laboratory course is required for all students enrolled in PHYS 245 and is a prerequisite for all physics courses numbered above 246. The course is organized around experiments demonstrating oscillations and waves in mechanical, acoustical, and electrical systems. Lectures cover the theory and instrumentation required to understand each experiment. Laboratory work emphasizes computerized acquisition and analysis of data, the use of a wide variety of modern instrumentation, and the analysis of experimental uncertainty. Co-requisite: PHYS 245.

Electronics

QR PHYS 280 (.25 unit)
Idoine

This lecture course covers the physics behind modern electronic components, such as transistors, FETs, and operational amplifiers, as well as the design and analysis of digital and analog circuits. Prerequisites: PHYS 145 and MATH 112. Co-requisite: PHYS 281.

Electronics Laboratory

QR PHYS 281 (.5 unit)
Idoine

This laboratory course is required for the physics major and is a prerequisite for PHYS 481. The course meets for two afternoons each week and is organized around experiments in which students design, test, and analyze both digital and analog electronic circuits. Students will become familiar with the use of a wide variety of electronic devices, including logic gates, analog-to-digital converters, transistors, FETs, and operational amplifiers. Independent laboratory projects allow students to combine and expand upon what they have learned to create new circuits of their own design. Co-requisite: PHYS 280.

Atomic and Nuclear Physics

QR PHYS 365 (.5 unit)
Schumacher

This course covers applications of quantum mechanics to atomic, nuclear, and molecular systems. Topics to be covered include atomic and molecular spectra, the Zeeman effect, nuclear structure and reactions, cosmic rays, scattering, and perturbation theory. Prerequisite: PHYS 360.

Condensed Matter Physics

QR PHYS 375 (.5 unit)
Sullivan

Modern field theories may find their inspiration in the quest for understanding the most fundamental forces of the universe, but they find crucial tests and fruitful applications when used to describe the properties of the materials that make up our everyday world. In fact, these theories have made great strides in allowing scientists to create new materials with properties that have revolutionized technology and our daily lives. This course will include: crystal structure as the fundamental building block of most solid materials; how crystal lattice periodicity creates electronic band structure; the electron-hole pair as the fundamental excitation of the "sea" of electrons; and Bose-Einstein condensation as a model for superfluidity and superconductivity. Additional topics will be selected from the renormalization group theory of continuous phase transitions, the interaction of light with matter, magnetic materials, and nano-structures. There will be a limited number of labs, at times to be arranged, on topics such as crystal growth; X-ray diffraction as a probe of crystal structure; specific heat of metals at low temperatures; and spectroscopic ellipsometry. Prerequisite: PHYS 245.

Individual Study

PHYS 494 (.25-.5 unit)
Staff

The student will conduct special experimental or theoretical work on advanced topics in physics. Prerequisites: permission of instructor and department chair.

The following courses will be offered in 2007-08:

PHYS 107 Astronomy: Stars and Galaxies
PHYS 291 Complex Systems in Scientific Computing
PHYS 350 Electricity and Magnetism
PHYS 355 Optics
PHYS 370 Thermodynamics