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 particles 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 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 become familiar with the phenomena discussed in lectures.

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 fewer topics in greater depth. PHYS 140 and PHYS 145 are particularly suitable for students who plan to take more physics (physics majors or minors) 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 upperclass 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 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.

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. 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.

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.

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 1/2 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

Einstein
◆ **QR** PHYS 104 (1/2 unit)
Schumacher

Almost a hundred years ago, Albert Einstein helped to launch a far-reaching revolution in physics. His relativity theories are justly famous; but he also made amazing discoveries about quantum mechanics and the statistical properties of matter and radiation. This course will focus on Einstein's life, his scientific contributions, and his role in the creation of modern physics. We will find that his insights are significant, not just for microscopic particles or for distant galaxies, but for the phenomena of everyday life. Lectures, discussions, and readings (including Einstein's own works) will be supplemented by laboratory experiments (at times to be arranged). The course will have some mathematical content—simple algebra and geometry—but should be accessible to any Kenyon student. No prerequisites. Enrollment limited.

First-Year Seminar in Physics: Observational Astronomy
PHYS 110 (1/4 unit)
Turner

Astronomy is a physicist's playground; the study of the universe depends on nearly every subdiscipline of physics, from subatomic particles to universal gravitation. Unlike physicists, however, who can use active experimental techniques to probe nature—changing conditions and looking at how those changes affect outcomes in an experiment—astronomers must rely on purely observational techniques to probe the universe. Consequently, astronomers have become quite adept at making observations over the entire electromagnetic spectrum, as well as observations using the various types of subatomic particles that manage to penetrate Earth's protective magnetic field and atmosphere. In this course, we will explore some of those techniques, particularly visible wavelength imaging and spectroscopy, primarily through hands-on observational projects supplemented as necessary by lecture and reading assignments. This course will meet one night a week, often at the observatory, with additional opportunities for making project observations available during the semester as weather conditions allow. Specific techniques employed in the course

may include astrophotography, digital imaging, electronic spectroscopy, computer modeling, and computer simulation. This 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 Physics 140 (Classical Physics). It fulfills the concurrent laboratory requirement for Physics 140 and serves as a solid preparation for Physics 146 (Introduction to Experimental Physics II).

General Physics I
◆ **QR** PHYS 130 (1/2 unit)
Staff

This course is the first course in a one-year introductory physics sequence. Topics will include Newtonian mechanics, including 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 (1/2 unit)
Sullivan

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 include weekly homework assignments and three exams. 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, or by permission of the instructor.

Introduction to Experimental Physics I
◆ **QR** PHYS 141 (1/4 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 (1/2 unit)
Idoine

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 (1/4 unit)
Idoine

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 (1/2 unit)
Schumacher

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
PHYS 360 (1/2 unit)
Sullivan

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 (1/4 unit)
Sullivan

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 (1/2 unit)
Turner

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 (1/4-1/2 units)
Staff

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

Second-Semester Courses

Astronomy: Stars and Galaxies
◆ PHYS 107 (1/2 unit)
Schumacher, Turner

Accessible to all students, this course surveys current knowledge of the physical nature of stars and galaxies. Topics include: the sun and other stars, the evolution of stars, interstellar matter, the end products of stellar evolution (including pulsars and black holes), the organization of stellar systems such as clusters and galaxies, and finally the large-scale structure and evolution of the universe itself. Evening laboratory sessions will include telescopic observing, laboratory investigations of light and spectra, and computer modeling and simulation exercises. This course is complementary to PHYS 106 (Astronomy: Planets and Moons). No prerequisites.

General Physics II
◆ **QR** PHYS 135 (1/2 unit)
Schumacher

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, and 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 (1/2 unit)
Idoine

This lecture course is 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. There will be two or three midterm exams and weekly problem assignments. Prerequisite: PHYS 140 and MATH 111 (or permission of the instructor). Co-requisite: PHYS 146 and MATH 112 taken concurrently (or equivalent).

Introduction to Experimental Physics II
◆ **QR** PHYS 146 (1/4 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: Observational Astronomy
PHYS 210 (1/4 unit)
Turner

Astronomy is a physicist's playground; the study of the universe depends on nearly every subdiscipline of physics, from subatomic particles to universal gravitation. Unlike physicists, however, who can use active experimental techniques to probe nature—changing conditions and looking at how those changes affect outcomes in an experiment—astronomers must rely on purely observational techniques to probe the universe. Consequently, astronomers have become quite adept at making observations over the entire electromagnetic spectrum, as well as observations using the various types of subatomic particles that manage to penetrate Earth's protective magnetic field and atmosphere. In this course, we will explore some of those techniques, particularly visible wavelength imaging and spectroscopy,

primarily through hands-on observational projects supplemented as necessary by lecture and reading assignments. This course will meet one night a week, often at the observatory, with additional opportunities for making project observations available during the semester as weather conditions allow. Specific techniques employed in the course may include astrophotography, digital imaging, electronic spectroscopy, computer modeling, and computer simulation. This 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 will go beyond the first-year seminar (Physics 110) in depth of coverage and in reliance on physics learned in previous courses. Prerequisites: Physics 145 (Modern Physics) or Physics 240 (Fields and Spacetime). PHYS 210 may be repeated three times.

Oscillations and Waves
QR PHYS 245 (1/2 unit)
La Sota

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 (1/4 unit)
Staff

This lecture and 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 (1/4 unit)
Greenslade

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. The course begins with the study of logic circuits and continues with other digital circuits. Analog electronics is then investigated using discrete and integrated circuits. Prerequisites: PHYS 145. Co-requisites: PHYS 281 and MATH 112.

Electronics Laboratory
QR PHYS 281 (1/2 unit)
Greenslade

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
PHYS 365 (1/2 unit)
Idoine

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
PHYS 375 (1/2 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 nanostructures. 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 (1/4-1/2 unit)
Staff

The student may 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 2005-06:

PHYS 350 Electricity and Magnetism
PHYS 355 Optics
PHYS 370 Thermodynamics and Statistical Mechanics
PHYS 493, 494 Individual Study
PHYS 497-498 Senior Honors