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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 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.

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 num-

bered 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

Astronomy: Planets and Moons

◆ PHYS 106 (1/2 unit)
Schumacher, Turner

This course, designed primarily for non-science majors, gives an introduction to the modern understanding of the solar system, including planets,

moons, and smaller bodies (asteroids, comets, meteorites). Topics include planetary interiors, surface modification processes, planetary atmospheres, and the evolution of the solar system. Students will also attend evening laboratory sessions utilizing a variety of methods for exploring space science topics, including telescopic observations, computer simulations, and laboratory exercises. This course is complementary to PHYS 107 (Astronomy: Stars and Galaxies). Limited enrollment. No prerequisites.

First-Year Seminar in Physics: Elementary Particles

◆ PHYS 110 (1/4 unit)
Idoine

Elementary particles are the fundamental, indivisible building blocks from which all the matter in the universe is constructed. The identification of the elementary particles and the mechanisms through which they interact has been one of the great achievements of physics during the twentieth century. In this course, we will meet the elementary particles and use the "standard model" and Feynman diagrams to understand how all forces (strong, weak, gravitational, and electromagnetic) arise through exchange of field particles. We will see how quarks combine to create the vast spectrum of subatomic particles, yet are never seen individually. The emphasis will be on concepts such as symmetry and conservation laws rather than detailed mathematics. Specific topics will include the role of elementary particles in cosmology and the early universe, neutrinos, radioactive decay, scattering, the creation and destruction of matter and antimatter, grand unification theories, particle accelerators, and experimental techniques for particle physics.

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 particle detectors. 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 (1/2 unit)

Staff

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 (1/2 unit)

LaSota

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 (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)

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 (1/4 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 (1/2 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.

Electricity and Magnetism

PHYS 350 (1/2 unit)

Staff

This course covers the classical theory of the electromagnetic field. Topics include vector analysis, calculation of static fields from source distributions, time-dependent fields, electromagnetic radiation, and the electric and magnetic properties of matter. Prerequisites: PHYS 245 and MATH 213.

Research Methods for Experimental PhysicsQR PHYS 480 (1/4 unit)
Idoine

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 PhysicsQR 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 StudyPHYS 493 (1/4-1/2 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**General Physics II**◆ QR PHYS 135 (1/2 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 (1/2 unit)
Idoine

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 (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 fluo-

rescence, 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: Elementary ParticlesPHYS 210 (1/4 unit)
Idoine

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 the elementary particles will include basic forces, quarks, cosmology, neutrinos, radioactive decay, scattering, the creation and destruction of matter and antimatter, grand unification theories, particle accelerators, and experimental techniques for particle physics.

The 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 particle detectors. Students will gain experience in estimating experimental uncertainties, analyzing and graphing numerical data sets, and preparing clear, complete reports of experimental results. Prerequisites: Modern Physics (PHYS 145) or Fields and Spacetime (PHYS 240). PHYS 210 may be repeated, as topics vary from year to year.

Complex Systems in Scientific ComputingPHYS 219 (1/2 unit)
LaSota

The underlying laws governing nature are usually fairly simple, yet the phenomena of nature are often extremely complex. How can this happen? In this course we discuss several definitions of “complexity” and use computers to explore how simple rules can give rise to complex behavior. We will construct cellular automata and related models to simulate a variety of systems: the

growth of random fractals, the spread of forest fires, magnetic materials near phase transitions, the statistics of avalanches, the movements of flocks of birds, and even the formation of traffic jams. A number of common ideas and characteristics will emerge from these explorations. Since the computer is our primary tool, some knowledge of computer programming will be required. Prerequisite: MATH 218 or permission of the instructor.

Oscillations and Waves

QR PHYS 245 (1/2 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 (1/4 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 (1/4 unit)
Turner

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 (1/2 unit)
Turner

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.

Optics

PHYS 355 (1/2 unit)
Staff

The course begins with a discussion of the wave nature of light. The remainder of the course is concerned with the study of electromagnetic waves and their interactions with lenses, apertures of various configurations, and matter. Subjects include the properties of waves, reflection, refraction, interference, Fraunhofer and Fresnel diffraction, Fourier optics, and coherence theory. Prerequisite: PHYS 350 or permission of the instructor.

Thermodynamics and Statistical Mechanics

PHYS 370 (1/2 unit)
Schumacher

This introduction to classical thermodynamics and statistical mechanics focuses on how microscopic physical processes give rise to macroscopic phenomena—for example, how the

dynamics of atoms and molecules can explain the large-scale behavior of gases and how the quantum mechanical properties of electrons give rise to the properties of conductors. The concept of entropy in determining equilibrium states is another major focus. Prerequisite: PHYS 245 or permission of the instructor.

Individual Study

PHYS 494 (1/4-1/2 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 2006-07:

PHYS 360 Quantum Mechanics

PHYS 365 Atomic and Nuclear Physics

PHYS 375 Condensed Matter Physics

PHYS 493, 494 Individual Study

PHYS 497Y-498Y Senior Honors