Department of Physics

Professor: *Berg, Ducas (Chair), Stark*

Associate Professor: *Hu, Lannert, Quivers*

Senior Instructor in Physics Laboratory: *Bauer, Wardell, Caplan*

A major in physics involves the study of the universal principles underlying phenomena ranging from the behavior of subatomic particles to the structure of the universe. It also entails the applications of these principles to the phenomena we observe every day and to the technology used to explore the world and address people's needs. Important components of the major are: modeling, problem-solving, and developing the critical thinking skills necessary to address fundamental questions about Nature. To acquire these skills our majors engage in active inquiry in the classroom, teaching laboratories and research. In addition to preparing students for graduate study in physics or engineering, a major in physics is an excellent basis for a career in other sciences, business, public policy, medicine, law and the arts. Physics majors will also be prepared with fundamental intellectual tools to support their lifelong learning in a rapidly changing world.

Goals for the Major

The Wellesley physics major is designed to give students an effective and engaging sequence of experiences to prepare them for graduate study or any of the subsequent paths listed above. Physics courses for the first two years have laboratory components that provide hands-on training in investigating the physical world and exposure to modern equipment and analytical tools. There is also a two-term mathematical methods sequence that focuses on the link between mathematics and physics that is central to the modeling process. Our core upper-level courses cover advanced work in four fields fundamental to the understanding of the many special topics within the discipline.

Most courses meet three times weekly. If indicated, there is an additional three-hour laboratory session weekly.

PHYS 101 Einstein's Century: Physics in the Last 100 Years

Stark

NOT OFFERED IN 2010-11. In 1905, Albert Einstein published three seminal papers in the history of modern science, introducing the theory of special relativity, launching the field of quantum mechanics, and helping establish the atomic nature of matter. We will use Einstein's contributions as a springboard for an introductory exploration of the natures of light, matter, space, and time. PHYS 101 is designed for the student who may not have a strong science background, but would like an introduction to the major themes of physics in the last 100 years. In addition to lectures and demonstrations we will have readings that draw from the biographical and historical contexts in which these ideas developed. We will make use of basic high school algebra, and some trigonometry, in our work. *Not to be counted toward the minimum major or to fulfill entrance requirement for medical school.*

Prerequisite: Fulfillment of the basic skills component of the Quantitative Reasoning requirement.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: N/O Unit: 1.0

PHYS 102 Physics for Modern Living

Lannert

Will the house of the future have an LED in every socket and a hybrid car in the driveway? Or an electric car? What do you need to build a nuclear bomb? Or a nuclear reactor? What do cool roofs have to do with the greenhouse effect and night-vision goggles? This course covers physics topics with applications to current events. Stressing conceptual understanding and critical reasoning, it gives students the physics background that will help them make informed decisions and cogent arguments on matters of technology, energy policy, and public safety. We will cover topics such as energy, heat, gravity, exponential growth, light, and quantum mechanics as they apply, for instance, to fuel cells, refrigerators, satellites, nuclear reactors, LCD screens and lasers. The mathematics used will be limited to basic high school algebra and scientific notation. *Not to be counted toward the minimum major or to fulfill entrance requirement for medical school.*

Prerequisite: Fulfillment of the basic skills component of the Quantitative Reasoning requirement.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Spring Unit: 1.0

PHYS 103 The Physics of Marine Mammals

Ducas

Sperm whales can dive down thousands of feet, stay submerged for over an hour, and resurface rapidly. Many marine mammals thrive in arctic waters, sense the world around them using sound, and move with phenomenal efficiency. In this course, we will learn the physics underlying the remarkable abilities of these aquatic mammals. Marine mammal characteristics and the associated scientific topics include: diving and swimming (ideal gas law, fluids, and forces); metabolism (energy, thermodynamics, and scaling); and senses (waves, acoustics, and optics). This course represents a naturally interdisciplinary approach in connecting biology, chemistry and engineering principles to the physics we will study as we learn about these animals. The course also emphasizes the development of modeling and problem-solving techniques. Whale watch. *Not to be counted toward the minimum major or to fulfill entrance requirement for medical school.*

Prerequisite: Fulfillment of the basic skills component of the Quantitative Reasoning requirement.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall Unit: 1.0

PHYS 104 Fundamentals of Mechanics with Laboratory

Quivers (Fall), Berg (Spring)

This course is a systematic introduction to Newtonian mechanics, which governs the motion of objects ranging from biological cells to galaxies. Primary concepts such as mass, force, energy, and momentum are introduced and discussed in depth. We will place emphasis on the conceptual framework and on using fundamental principles to analyze the everyday world. Topics include: Newton's Laws, conservation of energy, conservation of momentum, rotations, waves, and fluids. Concepts from calculus will be developed and used as needed. Laboratories introduce experimental approaches to these topics. Students with a strong background in mathematics or previous experience in physics should consider PHYS 107. *May not be taken in addition to*

107. May be counted toward the minimum major only if followed by Physics 108.

Prerequisite: Fulfillment of the basic skills component of the Quantitative Reasoning requirement; Corequisite: calculus at the level of MATH 115.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall, Spring, Summer Unit: 1.25

PHYS 106 Fundamentals of Electricity, Magnetism, and Optics with Laboratory

Hu (Fall), Lannert (Spring), Quivers (Spring)

This second semester of classical physics concentrates on the fundamental forces of electricity and magnetism. The electric and magnetic forces are entirely responsible for the structures and interactions of atoms and molecules, the properties of all solids, and the structure and function of biological material. Our technological society is largely dependent on the myriad applications of the physics of electricity and magnetism, e.g., motors and generators, communications systems, and the architecture of computers. After developing quantitative descriptions of electricity and magnetism, we explore the relations between them, leading us to an understanding of light as an electromagnetic phenomenon. The course will consider both ray-optics and wave-optics descriptions of light. Laboratory exercises will emphasize electrical circuits, electronic measuring instruments, optics, and optical experiments. *PHYS 106 does not normally satisfy the prerequisites for 202 or 203 and does not count toward the minimum major.*

Prerequisite: 104 and calculus at the level of MATH 115.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall, Spring Unit: 1.25

PHYS 107 Principles and Applications of Mechanics with Laboratory

Stark (Fall), Lannert (Fall), Berg (Spring)

Newtonian mechanics governs the motion of objects ranging from biological cells to galaxies. The fundamental principles of mechanics allow us to begin to analyze and understand the physical world. In this introductory calculus-based course, we will systematically study the laws underlying how and why objects move, and develop analysis techniques for applying these laws to everyday situations. Broadly applicable problem-solving skills will be developed and stressed. Topics include: forces, energy, momentum, rotations, gravity, and waves, and a wide range of applications. Laboratories focus on hands-on approaches to these topics.

Prerequisite: Fulfillment of the basic skills component of the Quantitative Reasoning requirement. Calculus at the level of MATH 115. Not open to students who have taken 104.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall, Spring Unit: 1.25

PHYS 108 Principles and Applications of Electricity, Magnetism, and Optics with Laboratory

Stark (Fall), Hu (Spring)

The electromagnetic force, one of the fundamental interactions in nature, is responsible for a remarkably wide range of phenomena and technologies, from the structures of atoms and molecules to the transmission of nerve impulses and the characteristics of integrated circuits. This introductory course begins with the study of Coulomb's law of electrostatics and progresses through investigations of electric fields, electric potential energy, magnetic fields, and Faraday's law of magnetic induction. The course culminates in the study of light, where the deep connections between electricity and magnetism are highlighted. Geometrical optics and an introduction to interference effects caused by the electromagnetic wave nature of light are covered. Laboratories, a central part of the course, provide students with hands-on experiences with electronics and electronic and optical instruments.

Prerequisite: 107 (or 104 and permission of the instructor), and MATH 116 or 120. Not open to students who have taken 106.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall, Spring Unit: 1.25

PHYS 116/CS 116 Robotic Design Studio

Berg

This first-year seminar introduces liberal arts students to the essence of engineering while designing and assembling robots out of LEGO® parts, sensors, motors, and tiny computers. Fundamental robotics skills are learned in the context of studying and modifying a simple robot known as SciBorg. Then, working in small teams, students design and build their own robots for display at a robot exhibition. These projects tie together aspects of a surprisingly wide range of disciplines, including computer science, physics, engineering, and art. *Students may register for either PHYS 116 or CS 116 and credit will be granted accordingly.*

Prerequisite: Open to first-year students only.
Distribution: Natural and Physical Science
Semester: Fall Unit: 1.0

PHYS 202 Introduction to Quantum Mechanics and Thermodynamics with Laboratory

Berg

The development of quantum mechanics represented one of the most fundamental revolutions in our understanding of the natural world. Quantum mechanics forms the basis for our knowledge of atoms, molecules, and solid-state systems as well as of nuclei and fundamental particles. Thermodynamics deals with the concepts of heat and temperature and their connection to properties of matter and to processes in natural and constructed systems. This course introduces both of these important branches of physics and looks at their links by investigating such phenomena as atomic and molecular heat capacities, and the statistical basis for blackbody radiation and the second law of thermodynamics. Einstein's theory of special relativity, another cornerstone of modern physics, will also be introduced.

Prerequisite: 108, MATH 116 or 120; Corequisite: MATH 215
Distribution: Mathematical Modeling or Natural and Physical Science. Fulfills the Quantitative Reasoning overlay course requirement.
Semester: Fall Unit: 1.25

PHYS 207 Intermediate Mechanics

Hu

The basic laws of Newtonian mechanics are revisited in this course using more sophisticated mathematical tools. Special attention is paid to harmonic oscillators, central forces and planetary orbits. Newton's laws will be applied to a simple continuous medium to obtain a wave equation as an approximation. Properties of mechanical waves will be discussed. Nonlinear dynamics and chaos are introduced.

Prerequisite: 108, MATH 215; Corequisite: 216 or permission of the instructor. Not open to students who have taken 306.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Spring Unit: 1.0

PHYS 216 Mathematics for the Sciences II

Stark

When laws of nature are written in advanced mathematical forms, gradient, divergence, and curl are frequently encountered. In this course, we study these mathematical operations in the broader context of differential and integral vector calculus, with an emphasis on their physical meanings. Fourier transform and partial differential equations, which are used throughout the physical sciences, are also discussed. The course ends with an introduction to numerical methods, which is widely used in most modern scientific and engineering fields when analytical solutions to algebraic or differential equations do not exist. We use MATLAB®, a popular high-level programming language. Part of the course is similar to MATH 205, but topics closely related to physics—the theorems of Gauss and Stokes, spherical and cylindrical coordinates—are discussed in depth.

Prerequisite: MATH 215.
Distribution: Mathematical Modeling
Semester: Spring Unit: 1.0

PHYS 219 The Art of Electronics with Laboratory

Berg

NOT OFFERED IN 2010-11. We are increasingly surrounded in our lives by boxes filled with electronics, but for most people (including many scientists) the inner workings of these boxes remain obscure and mysterious. This course is intended to remove much of this mystery. The approach is practical, aimed at allowing experimental scientists to understand the electronics encountered in their research. The emphasis is on designing and building circuits. Topics include diodes, transistor amplifiers, op amps, and digital electronics including microprocessors and microcontrollers. Applications to robotics will be explored. *Two laboratories per week and no formal lectures.*

Prerequisite: 106 or 108 or permission of the instructor.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: N/O Unit: 1.25

PHYS 222 Medical Physics

Ducas

NOT OFFERED IN 2010-11. This course covers applications of physics to two important areas of medical science: the mechanisms of the human body and the design of modern diagnostic and treatment devices and techniques. We will use principles of physics from mechanics, fluids, electricity and magnetism, thermodynamics, acoustics and optics to model aspects of human structural design and performance such as respiration, circulation, muscle and nerve operation, heat regulation, hearing and vision. We will also study the principles underlying modern medical technology, such as ultrasound imaging, computer aided tomography (CT scans), magnetic resonance imaging (MRI), positron emission tomography (PET scans) and applications of lasers in diagnosis and surgery.

Prerequisite: 104/107 in addition to BISC [213] or 106/[106X]/108, Mathematics at the level of MATH 115 or higher, or by permission of the instructor.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: N/O Unit: 1.0

PHYS 250 Individual Study

Prerequisite: Open by permission to students who have taken 107.
Distribution: None
Semester: Fall, Spring Unit: 1.0

PHYS 250H Individual Study

Prerequisite: Open by permission to students who have taken 107.
Distribution: None
Semester: Fall, Spring Unit: 0.5

PHYS 302 Quantum Mechanics

Lannert

This course provides a comprehensive development of the principles of non-relativistic quantum mechanics, the fundamental theory of electrons, atoms, and molecules. Quantum mechanics governs the building blocks of all matter, and yet fundamentally challenges our physical intuition, which is based on the behavior of everyday macroscopic objects. Topics include the postulates of quantum mechanics, the Schrödinger equation, operator theory, the Heisenberg uncertainty principle, the hydrogen atom, and spin.

Prerequisite: 202, 203 or 207, and 216
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall Unit: 1.0

PHYS 305 Statistical Mechanics and Thermodynamics

Ducas

Modern statistical mechanics builds from the quantum nature of individual particles to describe the behavior of large and small systems of such particles. In this course, we will derive the fundamental laws of thermodynamics using basic principles of statistics and investigate applications to such systems as ideal and real atomic and molecular gases, radiating bodies, magnetic spins, and solids. We will study Bose-Einstein and Fermi-Dirac statistics and learn about exciting new developments, such as Bose-Einstein condensation and ultra-cold Fermi gases. We will cover additional applications of statistical mechanics in the fields of biology, chemistry, and astrophysics.

Prerequisite: 202 and 216
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Spring Unit: 1.0

PHYS 306 Advanced Classical Mechanics

Hu

The basic laws of Newtonian mechanics are revisited in this course using advanced mathematical tools such as differential equations and linear algebra. Special attention is paid to central forces, planetary orbits, oscillations, and rigid body dynamics. In addition, Hamilton-Lagrange mechanics, an alternative to Newtonian mechanics, nonlinear dynamics, and chaos are introduced.

Prerequisite: 203 and 216. Not open to students who have taken 207.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Fall Unit: 1.0

PHYS 310 Experimental Physics with Laboratory

NOT OFFERED IN 2010-11. OFFERED IN 2011-12. This course will cover the design and execution of experimental measurements in physical systems, and the analysis and presentation of data. Laboratory experiments will illustrate the use of electronic, mechanical, and optical instruments to investigate fundamental physical phenomena, such as the properties of atoms and nuclei and the nature of radiation. The course will also entail an introduction to laboratory electronics and computer-based data analysis techniques.

Prerequisite: 202
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: N/O. Offered In 2011-12. Unit: 1.25

PHYS 311/ASTR 311 Elements of Astrophysics

McLeod (Astronomy)

NOT OFFERED IN 2010-11. Astrophysics is the application of physics to the study of the universe. We will use elements of mechanics, thermodynamics, electromagnetism, quantum mechanics, special relativity, and nuclear physics to investigate selected topics such as planets, the life stories of stars and galaxies, dark matter, and the origin of the universe. Our goals will be to develop insight into the physical underpinnings of the natural world, and to develop a "universal toolkit" of practical astrophysical techniques that can be applied to the entire celestial menagerie. These tools include scaling analysis, numerical solutions to complex problems, and other research approaches advanced in professional literature. *Students may register for either ASTR 311 or PHYS 311 and credit will be granted accordingly. Normally offered in alternate years.*

Prerequisite: PHYS 202 and 203 or 207
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: N/O Unit: 1.0

PHYS 314 Electromagnetic Theory

Quivers

Richard Feynman once said, "From a long view of the history of mankind—seen from, say, ten thousand years from now—there can be little doubt that the most significant event of the nineteenth century will be judged as Maxwell's discovery of the laws of electrodynamics. The American Civil War will pale into provincial insignificance in comparison with this important scientific event of the same decade." In this course we will study the classical theory of electromagnetic fields and waves as developed by Maxwell. Topics include boundary value problems, electromagnetic radiation and its interaction with matter, and the connection between electrodynamics and relativity.

Prerequisite: 108, 207 or 306, and 216.
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Spring Unit: 1.0

PHYS 349 Applications of Quantum Mechanics with Laboratory

Stark

Quantum mechanical techniques such as perturbation theory and the numerical solutions to the Schrödinger equation will be developed. Applications to problems in atomic, molecular, and condensed matter physics will be studied both theoretically and experimentally.

Prerequisite: 302 or CHEM 333
Distribution: Mathematical Modeling or Natural and Physical Science
Semester: Spring Unit: 1.25

PHYS 350 Research or Individual Study

Prerequisite: Open by permission to juniors and seniors.
Distribution: None
Semester: Fall, Spring Unit: 1.0

PHYS 350H Research or Individual Study

Prerequisite: Open by permission to juniors and seniors.
Distribution: None
Semester: Fall, Spring Unit: 0.5

PHYS 360 Senior Thesis Research

Prerequisite: By permission of department. See Academic Distinctions.
Distribution: None
Semester: Fall, Spring Unit: 1.0

PHYS 370 Senior Thesis

Prerequisite: 360 and permission of department.
Distribution: None
Semester: Fall, Spring Unit: 1.0

Related Courses

Attention Called

MATH 215 Mathematics for the Sciences I

Requirements for the Major

For students for entered the College in the Fall of 2009 or later a major in physics should ordinarily include: 107, 108, 202, 207, 302, 305, 310, and 314. MATH 215 and PHYS 216 are additional requirements. 219 and 349 are strongly recommended. One unit of another laboratory science is recommended.

For students for entered the College prior to the Fall of 2009 a major in physics should ordinarily include: 107, 108, 202, 203, 302, 305, 306, and 314. MATH 215 and PHYS 216 are additional requirements. 219 and 349 are strongly recommended. One unit of another laboratory science is recommended.

All students who wish to consider a major in physics or a related field are urged to complete the introductory sequence (107 and 108) as soon as possible, preferably in the first year. A strong mathematics background is necessary for advanced courses. It is suggested that students complete MATH 115 and 116 or 120 in their first year and the MATH 215-PHYS 216 sequence no later than their second year. All students majoring in physics are urged to develop proficiency in the use of one or more computer languages.

Requirements for the Minor

For students for entered the College in the Fall of 2009 or later a minor in physics (six units) should ordinarily include: 104 or 107, 108, 202, 207, 302 and one other unit at the 300 level (350 cannot be counted as the other 300-level unit). MATH 215 and PHYS 216 are also required.

For students for entered the College prior to the Fall of 2009 a minor in physics (six units) should ordinarily include: 104 or 107, 108, 202, 203, 302 and one other unit at the 300 level (350 cannot be counted as the other 300-level unit). MATH 215 and PHYS 216 are also required.

Honors

The only route to honors in the major is writing a thesis and passing an oral examination. To be admitted to the thesis program, a student must have a grade point average of at least 3.5 in all work in the major field above the 100-level; the department may petition on her behalf if her GPA in the major is between 3.0 and 3.5. See Academic Distinctions.

Teacher Certification

Students interested in obtaining certification to teach physics in the Commonwealth of Massachusetts should consult the chairs of the education and physics departments.

Transfer Credit

In order to obtain Wellesley credit for any physics course taken at another institution, during the summer or the academic year, approval must be obtained from the chair of the department prior to enrolling in the course. There is a limit of one physics course for which transfer credit may be given. In general, courses from two-year colleges will not be accepted at any level. These restrictions normally apply only to courses taken after matriculation at Wellesley. Transfer students wishing to obtain credit for physics courses taken prior to matriculation at Wellesley should consult the chair of the department.

Advanced Placement and Exemption Examinations

If a student has a strong physics background (AP, IB physics credits or the equivalent) and wishes to be exempted from our introductory courses for the purpose of enrolling in a higher-level physics course, she must pass an exemption examination administered by the department. Sample examinations are available from the department. Students may not receive more than two units of credit for the introductory physics sequence. For example, a student who enrolls in both PHYS 107 and 108 will not also receive AP or IB credit.

Engineering

Students interested in engineering should consult the course listings in Extradepartmental and enroll in EXTD 160, Introduction to Engineering. This course is intended to be a gateway experience for possible subsequent engineering studies such as the engineering certificates from the Olin College of

Engineering. The Special Academic Programs section contains a description of these certificates that represent groups of engineering courses at Olin designed to complement a major at Wellesley. Additional information about taking courses at Olin can be found online at crossreg.olin.edu. Students also have opportunities to take courses at MIT via the Wellesley-MIT exchange program.