

# Department of Physics

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

Associate Professor: *Quivers, Hu*

Assistant Professor: *Lannert, Goldman*

Senior Instructor in Physics Laboratory: *Bauer, Wardell*

Instructor in Physics Laboratory: *Caplan*

The contemporary study of the physical universe encompasses systems ranging from the microscopic--atoms, nuclei, and elementary particles, to the very large--planets, stars and galaxies. A central theme of all branches of physics is the search for unifying principles underlying the diverse phenomena of nature. In addition to meeting the needs of students planning graduate study in physics or engineering, training in physics can also help those interested in using physics as a background for careers in other sciences, business, medicine, arts, and law. Students considering the possibility of majoring in physics should elect physics in their first year.

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*

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 one hundred 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 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 103 The Physics of Marine Mammals with Laboratory**

*Ducas*

**NOT OFFERED IN 2007-08.** Sperm whales can dive thousands of feet, stay submerged for over an hour, and resurface rapidly; no other mammal can do that and survive. 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: N/O                      Unit: 1.0

### **PHYS 104 Fundamentals of Mechanics with Laboratory**

*Quivers (Fall), Goldman (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 math or previous experience in physics should consider PHYS 107. *May not be taken in addition to 107. Not to be counted toward the minimum major.*

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      Unit: 1.25

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

*Hu, 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**

*Hu (Fall), Stark (Fall), Lannert (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**

*Ducas (Fall), Stark (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 instructor), and MATH 116 or 120. Not open to students who have taken 106 or [106X].

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Fall, Spring Unit: 1.25

**PHYS 115/CS 115 Robotic Design Studio (Wintersession)**

*Turbak (Computer Science), Anderson (Computer Science)*

In this intensive course, students are introduced to engineering principles 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, math, biology, psychology, engineering, and art. *Students may register for either PHYS 115 or CS 115 and credit will be granted accordingly. Not offered every year. Subject to Dean's Office approval.*

Prerequisite: None

Distribution: Natural and Physical Science

Semester: Wintersession Unit: 0.5

## **PHYS 202 Introduction to Quantum Mechanics and Thermodynamics with Laboratory**

*Lannert*

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 black-body radiation and the second law of thermodynamics.

Prerequisite: 108, MATH 116 or 120; Corequisite: MATH 215/[PHYS 215]

Distribution: Mathematical Modeling or Natural and Physical Science. Fulfills the Quantitative Reasoning overlay course requirement.

Semester: Fall                      Unit: 1.25

## **PHYS 203 Vibrations, Waves, and Special Relativity with Laboratory**

*Berg*

A wide range of physical systems exhibit vibrational and wave motion. Because of this universality, learning about fundamental characteristics of waves and vibrations provides insight into a tremendous number of phenomena such as the motion of strings and springs, the design of musical instruments, molecular spectra, oscillations in solids, liquids and gases, sound, and electromagnetic radiation as well as the behavior of fundamental particles. There will be an emphasis on optical applications as clear and elegant examples of wave phenomena. We will also study particular research applications such as Fourier Transform Spectroscopy and Nuclear Magnetic Resonance. The course culminates with an introduction to Einstein's Theory of Special Relativity, with a focus on explaining how this theory radically alters classical notions of space and time.

Prerequisite: 108, MATH 215/[PHYS 215]; Corequisite: PHYS 216/[MATH 216] or permission of instructor.

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Spring                      Unit: 1.25

## **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 – Gauss' and Stokes' theorems, spherical and cylindrical coordinates – is discussed in depth.

Prerequisite: MATH 215/[PHYS 215]. Not open to students who have taken this course as [MATH 216].

Distribution: Mathematical Modeling

Semester: Spring                      Unit: 1.0

## **PHYS 219 The Art of Electronics**

*Berg*

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 instructor.

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Fall                      Unit: 1.25

## **PHYS 222 Medical Physics**

*Ducas*

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 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: Spring      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**

*Berg*

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, and PHYS 216/[MATH 216].

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Fall      Unit: 1.0

### **PHYS 305 Statistical Mechanics and Thermodynamics**

*Quivers*

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 PHYS 216/[MATH 216].

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Spring      Unit: 1.0

### **PHYS 306 Advanced Classical Mechanics**

*Lannert*

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 PHYS 216/[MATH 216].

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Fall                      Unit: 1.0

### **PHYS 314 Electromagnetic Theory**

*Hu*

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, 306, and PHYS 216/[MATH 216].

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Spring                      Unit: 1.0

### **PHYS 335/BISC 335/NEUR 335 Computational Neuroscience with Laboratory**

*Goldman*

Computations by networks of neurons in the brain underlie all of our thoughts, perceptions, and memories. However, direct experimental observation of neural computations is extremely difficult. Mathematical models are increasingly used to bridge the gap between experimental measurements and hypothesized network functions. This course will focus on the use of mathematical models to describe computations performed in the nervous systems of a variety of animals. Topics will range from single neuron biophysics to the analysis of circuits thought to underlie sensory perception and memory. Each topic will be introduced by background lectures, followed by student-led presentations of primary literature and construction of a computer model of the system studied. Lab will introduce students to computer programming of mathematical models in MATLAB® and the neuron-simulator NEURON. *Students may register for either PHYS 335, BISC 335, or NEUR 335 and credit will be granted accordingly.*

Prerequisite: 104/107 and either BISC 213 or 106/[106X]/108; or permission of instructor. No programming experience is required. Not open to first-year students.

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: Fall                      Unit: 1.25

### **PHYS 349 Applications of Quantum Mechanics with Laboratory**

**NOT OFFERED IN 2007-08.** 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. Two lectures and one laboratory per week.

Prerequisite: 302 or CHEM 333

Distribution: Mathematical Modeling or Natural and Physical Science

Semester: N/O                      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

**ASTR 110wL** Fundamentals of Astronomy with Laboratory

**ASTR 311** Elements of Astrophysics

**ASTR 315** Seminar. Topics in Astrophysics

**EXTD 160** Introduction to Engineering Science

### **Directions for Election**

**A major in physics** should ordinarily include: 107, 108, 202, 203, 302, 305, 306, and 314. MATH 215 [PHYS 215] and PHYS 216/[MATH 216] are additional requirements. 219 and 349 are strongly recommended. One unit of another laboratory science is recommended.

**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/[PHYS 215] and PHYS 216/[MATH 216] are also required.

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.

**Engineering**

Students interested in engineering should consult the course listings in Extradepartmental and enroll in EXTD 160.

**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.

**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.