Colby

PHYSICS

In the Department of Physics and Astronomy.

***Chair**, Professor Robert Bluhm*
Professors Robert Bluhm, Charles Conover, and Duncan Tate; Assistant Professors Jonathan McCoy and Elizabeth McGrath; Faculty Fellow Yoshihiro Sato; Teaching Associate Lisa Lessard

Physics studies nature and how things work on levels ranging from the smallest subatomic and atomic scales, through intermediate scales describing matter in its various forms, up to the largest astrophysical scales. Physics students acquire skills in mathematical calculation, experimental measurement and instrumentation, theoretical and numerical modeling, scientific writing, and oral presentation. Flexible major and minor programs are designed to fit within a liberal arts education and to provide preparation for careers or advanced training in science, teaching, business, medical professions, and engineering. The department welcomes students from all majors and with diverse backgrounds.

The introductory course sequence, Physics 141 (or 143) and 145, provides a solid basis for further work in physics as well as preparation for medical school and advanced study in other sciences. These courses also provide excellent preparation for students who plan to enter professions such as law, teaching, and business. The intermediate and advanced course offerings in the department provide a strong background for graduate study in physics, astronomy, engineering, and interdisciplinary fields such as biophysics, environmental science, medical physics, and bioengineering.

Emphasis is placed upon independent work and cooperative research with the faculty in atomic, molecular, and optical physics, condensed-matter physics, theoretical physics, and astronomy. All faculty members have active research programs that thrive on undergraduate contributions. Research projects make use of the department's well-equipped laboratories, computer workstations, and supporting machine, electronic, and technical shops.

Students seeking a career in engineering may consider applying to an exchange program in which both a bachelor of arts and a bachelor of engineering can be earned upon successful completion of three years at Colby and two years at Dartmouth College. Students should consult with the engineering advisor before selecting their first-semester courses.

Physics 141, 145, 241, and 242 form a full introduction to classical and 20th-century physics. For students with a previous background in physics and calculus from high school, Physics 143 may be taken instead of Physics 141.

Requirements for the Physics Major

Physics majors have a lot of flexibility in choosing the courses that are most appropriate for them. Students should work closely with their advisors in selecting courses to fulfill the requirements for the major. Not all upper-level elective courses are offered every year. Physics 415, taken in the fall of the senior year, involves completing an independent project, internship, or research in physics or a related field. All students are invited to attend the colloquia presented by faculty, senior students, and visiting scientists; senior physics majors are required to participate by enrolling in Physics 401, 402. The point scale for retention of the major applies to all courses taken that can satisfy the requirements listed below. No requirements for the major may be taken satisfactory/unsatisfactory. Physics majors receive Distinction in the Major upon graduating if they have a grade point average of at least 3.5 in physics and mathematics.

Required Physics Courses (unless exempted by advanced placement)
Physics

- 141 Foundations of Mechanics (or 143 Honors Physics)
- 145 Foundations of Electromagnetism and Optics
- 241 Modern Physics I
- 242 Modern Physics II
- 401-402 Senior Physics and Astronomy Colloquium
- 415 Physics and Astronomy Research (Physics 483-484 for students completing the honors major)

Mathematics and Computer Science Courses: Choose four (unless exempted by advanced placement)

Computer Science

- 151 Computational Thinking

Mathematics

- 121 Single-Variable Calculus (or 161 Honors Calculus I)

- 122 Series and Multi-Variable Calculus (or 162 Honors Calculus II)
- 253 Linear Algebra
- 262 Vector Calculus
- 311 Ordinary Differential Equations

Elective Courses: Choose at least three. At least two must be 300-level or higher physics courses, and at least one 300-level or higher physics course must be taken at Colby.

Astronomy

- 231 Introduction to Astrophysics

Biology

- 274 Neurobiology

Chemistry

- 255 Nuclear Magnetic Resonance
- 341 Physical Chemistry

Mathematics

- 332 Numerical Analysis

Physics

- 254 Essential Electronics
- 311 Classical Mechanics
- 312 Physics of Fluids
- 321 Electricity and Magnetism
- 332 Thermodynamics and Statistical Mechanics
- 334 Experimental Atomic Physics
- 335 General Relativity and Cosmology
- 336 Condensed Matter Physics
- 338 Nuclear and Particle Physics
- 431 Quantum Mechanics

Honors in Physics

In the junior year, physics majors may apply for admission to the honors program. A 3.25 grade point average in physics and mathematics courses is normally required. Successful completion of the honors program will result in the degree being awarded "With Honors in Physics." A thesis completed as part of the Senior Scholars Program may be substituted for the honors thesis.

Requirements for the Honors Major

In addition to fulfilling the requirements for the basic physics major, students must take three additional 300-level or higher physics courses and one additional 200-level or higher mathematics course. In fulfilling these requirements, students must take at least one upper-level experimental course (Astronomy 231, Physics 254, or 334). In their senior year, they must also take Physics 483-484 Independent Honors Project in the place of Physics 415. A written honors thesis is required.

Students considering graduate school in physics or astronomy are strongly encouraged to take all of the following courses: Mathematics 253, 262, 311, 352, Physics 254, 311, 321, 332, and 431.

Requirements for the Minor in Physics

Physics 141 (or 143), 145, 241, 242 (or a physics course numbered 300 or above), Mathematics 121 (or 161), 122 (or 162).

No requirements for the physics minor may be taken satisfactory/unsatisfactory.

Course Offerings

[PH115] The Shadow of the Bomb More than 60 years ago, based on a radically new understanding of the laws of nature, nuclear weapons were constructed, tested, and used in war. Nuclear weapons and associated technology have shaped scientific and political worlds since. Discusses complex scientific, technological, and environmental issues arising from understanding and using nuclear science for weapons and energy. Explains the physics of atoms and nuclei and provides background for understanding the technology of nuclear weapons and power and events surrounding them. Discussion of radiation safety, waste, and weapons proliferation. Working knowledge of algebra required; no previous study of physics assumed. *Four credit hours.* **N**

PH141f Foundations of Mechanics A calculus-based survey of classical Newtonian mechanics, including kinematics, forces, work and energy, momentum, gravity, oscillations, and waves. These topics are developed further in discussions, labs, and problem-solving assignments. May not be taken for credit if the student has earned credit for Physics 143. *Prerequisite:* A

working knowledge of high school or college calculus, or concurrent enrollment in Mathematics 121 or 161. *Four credit hours.* **N,Lb** TATE

PH143f Honors Physics An accelerated, calculus-based, introductory course on Newtonian mechanics supplemented with some coverage of additional special topics. Intended for students who have had substantial courses in physics and calculus in high school. Topics in Newtonian mechanics include kinematics, dynamics, conservation laws, oscillations, and waves. Additional topics include special relativity and nuclear physics. Students acquire knowledge in these areas and skills for solving mathematical problems and doing laboratory work. May not be taken for credit if the student has earned credit for Physics 141. *Four credit hours.* **N,Lb** BLUHM

PH145s Foundations of Electromagnetism and Optics Explores the classical foundations of electrical and magnetic forces, electromagnetic waves, and optics, emphasizing the pioneering 19th-century experimental and theoretical work culminated by Maxwell's equations. Students will learn how electrical and magnetic force fields are described mathematically, how they are interrelated, and how the interrelations lead to a wide variety of physical phenomena. These topics are developed further in discussions, labs, and problem-solving assignments. Formerly listed as Physics 142. *Prerequisite:* Physics 141 or 143. *Four credit hours.* **N,Lb** CONOVER

PH197j Introduction to Biophysics Biophysics is a rapidly growing subfield in physics that applies the tools and techniques used in physics to study biological systems. Emphasis on the ubiquitous role of physical laws in understanding how living organisms behave. Students apply concepts and skills learned in introductory physics (including force and energy) to study biological systems at the molecular and cellular levels. Additional physical quantities pertaining to biosystems, such as entropy, free energies, basic electrostatics, and statistical principles, are introduced as needed. Topics are highly interdisciplinary and include diffusion, random walks, entropic force, fluid flows, biopolymers, membranes, and self-assembly. *Prerequisite:* Physics 141 or 143 or equivalent advanced placement. *Three credit hours.* **N** SATO

PH231f Introduction to Astrophysics Listed as Astronomy 231. *Four credit hours.* **N,Lb** MCGRATH

PH241f Modern Physics I An introduction to the two central paradigms of non-Newtonian physics: Einstein's special theory of relativity and the quantum behavior of light and matter. The postulates of Einstein are presented and the consequences explored theoretically along with experimental evidence for relativity. The experimental evidence for quantum mechanics is considered from a historical perspective, beginning with Planck's quantum hypothesis for blackbody radiation through to the Bohr model of the hydrogen atom and the experimental evidence for the Schroedinger equation. Students will acquire skills in solving mathematical problems, advanced laboratory work, and scientific writing. Lecture, discussion, and laboratory. Students must be available for a self-scheduled lab outside of class time for approximately three hours every second week. *Prerequisite:* Physics 142 or 145 and Mathematics 122 or 162. *Four credit hours.* CONOVER

PH242s Modern Physics II An intermediate-level introduction to quantum mechanics and atomic physics. Topics include the Schroedinger equation, interpretation of the wave function, one-dimensional potentials, hydrogen atom, electron spin, exclusion principle, atomic structure, and atomic spectra. Lectures, discussions, and labs. Enrolled students must be available for a self-scheduled lab outside of class time for approximately three hours every second week. *Prerequisite:* Physics 241. *Four credit hours.* TATE

[PH254] Essential Electronics An introduction to modern scientific electronics, emphasizing laboratory work and including theory, problem solving, and circuit design. From simple, direct-current devices to digital integrated circuits, microcomputer instrumentation, and analog signal processing. Normally offered every other year. *Prerequisite:* Physics 142 or 145. *Four credit hours.*

PH311s Classical Mechanics Newton's laws, oscillatory motion, noninertial reference systems, classical gravitation, motion of rigid bodies, and Lagrangian and Hamiltonian mechanics. Lecture and discussion. *Prerequisite:* Physics 142 or 145, and Mathematics 122 or 162. *Four credit hours.* SATO

[PH312] Physics of Fluids All living things, from the smallest cells to the largest communities, are soaking in or swimming through the fluid environment of liquids and gases that covers the planet. Our understanding of fluid motion helps us build better airplanes, debate climate change, and discover new design principles in biology. We will view this subject as an exciting, interdisciplinary opportunity to see the laws of physics in action. Emphasis will be on a core set of basic concepts and mathematical tools used to describe fluids and explore a range of applications drawn from biology, chemistry, geophysics, and engineering. Formerly offered as Physics 398. *Prerequisite:* Mathematics 302 and Physics 242. *Four credit hours.*

PH321f Electricity and Magnetism A theoretical treatment of electrostatics and magnetostatics in vacuum and material media through Maxwell's equations. Lecture and discussion. *Prerequisite:* Physics 142 or 145 and Mathematics 302. *Four credit hours.* SATO

[PH332] Thermodynamics and Statistical Mechanics Examines the concepts of temperature, energy, heat, work, and entropy. Thermodynamic relations between these quantities are studied from both a microscopic and macroscopic point of view. The laws of thermodynamics are developed from an underlying statistical treatment. Topics such as heat flows, heat engines, phase transitions, chemical reactions, Bose-Einstein and Fermi-Dirac statistics, and blackbody radiation are discussed. Lecture

and discussion. Normally offered every other year. *Prerequisite:* Mathematics 122 (or 162) and either Physics 242 (may be taken concurrently) or Chemistry 342 (may be taken concurrently). *Four credit hours.*

PH334s Experimental Atomic Physics Laboratory projects in modern atomic, molecular, and optical (AMO) physics. Experiments include observing the Zeeman effect in mercury using a grating spectrometer, Doppler-free diode laser spectroscopy, and magneto-optical trapping of rubidium atoms. Through these and other projects, students will learn cutting-edge techniques of modern AMO physics. In addition they will become familiar with, and be expected to engage in, communication of results both orally and in written form. Laboratory and tutorial. Some out-of-class participation required. *Prerequisite:* Physics 242. *Three credit hours.* TATE

PH335s General Relativity and Cosmology An introduction to Einstein's general theory of relativity, including a treatment of tensor analysis, Einstein's equations, Schwarzschild metric, black holes, expansion of the universe, and cosmology. *Prerequisite:* Physics 241. *Four credit hours.* BLUHM

[PH336] Condensed Matter Physics An introduction to the properties of solid (condensed) matter. Topics may include bonding and crystal structure; diffraction of X-rays; thermal, optical, acoustical, electrical, and magnetic properties; energy band structure; and superconductivity. Students will research in more depth a chosen topic of current interest in condensed matter physics. *Prerequisite:* Physics 242. *Four credit hours.*

[PH338] Nuclear and Particle Physics Nuclear physics, including nuclear reactions and nuclear models, followed by elementary particle physics, including the quark model, leptons, and the strong and weak interactions. *Prerequisite:* Physics 242. *Four credit hours.*

PH401f, 402s Senior Physics and Astronomy Colloquium A colloquium series with presentations by visiting scientists, department faculty, and senior physics majors. Visitors and faculty present their current research. Seniors present formal oral presentations on their senior projects or honors theses. Nongraded. *One credit hour for the year.* BLUHM, MCGRATH

PH415f, 416js Physics and Astronomy Research A guided research project on a topic in physics, astronomy, or a related area. Students may choose from a range of approaches, including literature searches, analytical and computational analyses, experimental data collection and analysis, and theoretical investigation. Some project components can be conducted off campus or as part of a team project. Physics 415 is required for all senior physics majors. *One or two credit hours.* FACULTY

PH431f Quantum Mechanics Study of the structure and interpretation of quantum mechanics at an advanced level. Quantum states and observables are described in terms of abstract state vectors and operators. Students learn about representations of state vectors and operators in terms of wave functions and differential operators or the tools of linear algebra: vectors and matrices. We will approach the abstract representation of quantum objects using the concrete example of spin-systems to provide insight into the fundamental principles of quantum mechanics. Issues concerning the nature of quantum reality are examined and discussed. Problems include short proofs involving operators, state vectors, and measurement theory. A core upper-level course that should be taken by students intending to go to graduate school in physics or a related area. *Prerequisite:* Physics 242 and Mathematics 253. *Four credit hours.* CONOVER

PH483f, 484s Independent Honors Project Research conducted under the guidance of a faculty member and focused on an approved topic leading to the writing of an honors thesis. *Two to four credit hours.* FACULTY

PH483Jj Independent Honors Project *Noncredit.* CONOVER

PH491f, 492s Independent Study Individual topics or research in areas where the student has demonstrated the interest and competence necessary for independent work. *Prerequisite:* Permission of the instructor. *One to five credit hours.* FACULTY