

## PHYSICS DEPARTMENT

<https://www.uvm.edu/cems/physics>

An education in physics provides students with the foundation for a variety of careers. In addition to preparation for graduate study in physics and related fields, undergraduate study in physics is an excellent preparation for professional careers in engineering, management, teaching, law, and medicine.

The curriculum consists of core courses on the fundamentals of physics, such as mechanics, electromagnetism, and quantum theory. Students can then choose from an array of electives to explore subfields in physics, such as astrophysics, biological physics, condensed matter physics, general relativity, nanotechnology, quantum optics, and nuclear and particle physics.

Under the guidance of faculty members, many physics majors become active in research in their second or third year of study. For eligible students, this experience can lead to college honors with the completion of a senior thesis project.

### MAJORS

#### PHYSICS MAJORS

Physics B.S.

Physics B.A. - This major is administered by the College of Arts and Sciences

### MINORS AND CERTIFICATES

#### PHYSICS MINORS

Astronomy

Physics

Semiconductor Engineering and Physics - Undergraduate Certificate

Sustainable Energy Engineering

### GRADUATE

Physics AMP

Physics M.S.

Physics Ph.D.

See the online Graduate Catalogue for more information.

#### Astronomy Courses

##### **ASTR 1400. Exploring the Cosmos w/lab. 0 or 4 Credits.**

Introduction to the basic concepts of astronomy as well as the history of their development. Includes a laboratory component. Credit not awarded for both ASTR 1400 and ASTR 1405. Catamount Core: N2, QD.

##### **ASTR 1405. Exploring the Cosmos. 3 Credits.**

Introduction to the basic concepts of astronomy as well as the history of their development. No laboratory. Credit not awarded for both ASTR 1405 and ASTR 1400. Catamount Core: N1, QD.

##### **ASTR 1990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

##### **ASTR 2100. The Big Bang. 3 Credits.**

Ancient cosmologies, beginning of time, origin of matter, cosmic background radiation, antimatter and dark matter, the expanding universe and origin of structure. Prerequisites: ASTR 1405; MATH 1034 or equivalent.

##### **ASTR 2120. Spacecraft Astronomy. 3 Credits.**

Survey of recent astronomical satellites such as Hubble, Chandra and Fermi LAT; their design, orbital characteristics, and findings. Prerequisites: ASTR 1405; MATH 1034 or equivalent.

##### **ASTR 2140. Stars & Galaxies. 3 Credits.**

Instruments and observations. Stars and their evolution. Black holes and compact objects. The interstellar medium. Relativity and galactic structure and galaxy formation. Prerequisites: ASTR 1400 or ASTR 1405; MATH 1034 or Instructor permission. Catamount Core: N1, QD.

##### **ASTR 2160. Moons & Planets. 3 Credits.**

Celestial mechanics, formation of the stars, and planetary materials. Planets, satellites, asteroids, meteors, and comets. Planetary surfaces, interiors, and atmospheres. Origins of life. Prerequisites: ASTR 1405; MATH 1034 or equivalent.

##### **ASTR 2990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

##### **ASTR 2993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

##### **ASTR 2995. Undergraduate Research. 1-18 Credits.**

Undergraduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

##### **ASTR 3820. Modern Astrophysics. 3 Credits.**

Introduces the foundations of modern astrophysics. Builds upon the knowledge gained in an introductory astronomy course, and uses the tools gained in introductory physics courses to put astronomical ideas on more solid quantitative footing. Students will develop the mathematical and qualitative tools necessary to analyze astrophysical phenomena including orbital motion, planet-moon interactions, stellar lifecycles, and much more. Prerequisites: MATH 1224, MATH 1242, or MATH 1248; PHYS 1500 or PHYS 1600.

##### **ASTR 3990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

**ASTR 3991. Internship. 1-18 Credits.**

On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

**ASTR 3993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**ASTR 3994. Teaching Assistantship. 1-3 Credits.**

Undergraduate student service as a teaching assistant, usually in an introductory-level course in the discipline, for which credit is awarded. Offered at department discretion.

**ASTR 3995. Undergraduate Research. 1-18 Credits.**

Undergraduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**ASTR 4990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

**ASTR 4994. Teaching Assistantship. 1-3 Credits.**

Undergraduate student service as a teaching assistant, usually in an introductory level course in the discipline, for which credit is awarded. Offered at department discretion.

**Physics Courses****PHYS 1100. The Physics of Music. 3 Credits.**

Basic physical principles underlying the production, transmission and perception of musical sound. Vibrations, waves, elementary acoustics with applications to a wide range of musical topics. Prerequisite: High school algebra. Catamount Core: N1, QD.

**PHYS 1200. Energy and the Environment. 3 Credits.**

Forms of energy as defined in physics; sources, uses, and transformations of energy: introductory seminar will place emphasis on environmental issues. Limited use of algebra and geometry. Catamount Core: N1, QD, SU.

**PHYS 1250. Conceptual Physics. 3 Credits.**

One-semester conceptual survey. Topics selected from mechanics, electricity, magnetism and modern physics.

**PHYS 1251. Conceptual Physics w/lab. 0 or 4 Credits.**

Conceptual survey. Topics selected from mechanics, electricity, magnetism and modern physics. Laboratory content is integrated with the lecture. Catamount Core: N2, QD.

**PHYS 1400. Elementary Physics I. 0 or 4 Credits.**

Algebra-based survey of mechanics, oscillations, waves and thermal physics. Appropriate for students in health and life sciences. Counts as lecture and lab. Optional accompanying problem solving recitation section: PHYS 1410. Prerequisites: High school algebra and trigonometry. Catamount Core: N2, QD.

**PHYS 1410. Elem Physics Problem Solving I. 1 Credit.**

Accompanying lecture PHYS 1400. Co-requisite: Concurrent enrollment in PHYS 1400.

**PHYS 1450. Elementary Physics II. 0 or 4 Credits.**

Algebra-based survey of electricity, magnetism, optics and modern physics. Appropriate for students in health and life sciences. Counts as a lecture and lab. Optional accompanying problem solving recitation: PHYS 1460. Prerequisites: PHYS 1400, PHYS 1500, or PHYS 1600. Catamount Core: N2, QD.

**PHYS 1460. Elem Physic Problem Solving II. 1 Credit.**

Accompanying lecture PHYS 1450. Co-requisite: Concurrent enrollment in PHYS 1450.

**PHYS 1500. Physics for Engineers I. 0 or 4 Credits.**

Mechanics including oscillations and waves. With lab. Accompanying optional problem-solving session: PHYS 1510. Prerequisite: MATH 1234 or MATH 1242. Catamount Core: N2, QD.

**PHYS 1510. Physics Problem Solving I. 1 Credit.**

Problem-solving techniques for first semester Physics with calculus. Accompanying lecture PHYS 1500.

**PHYS 1550. Physics for Engineers II. 0 or 3 Credits.**

Electricity, magnetism, electromagnetic waves, optics. Without lab. Accompanying optional problem-solving session: PHYS 1560. Prerequisites: PHYS 1500; MATH 1248 or MATH 1242. Co-requisite: MATH 2248. Catamount Core: N1, QD.

**PHYS 1560. Physics Problem Solving II. 1 Credit.**

Problem-solving techniques for second semester Physics with calculus. Accompanying lecture PHYS 1550.

**PHYS 1600. Fundamentals of Physics I. 0 or 4 Credits.**

Calculus-based introduction to kinematics, dynamics, oscillations, thermal physics. For students in the natural sciences. With lab. Credit not awarded for both PHYS 1600 and PHYS 1500. Pre/co-requisite: Credit or concurrent enrollment in MATH 1234. Catamount Core: N2, QD.

**PHYS 1650. Fundamentals of Physics II. 0 or 4 Credits.**

Calculus-based introduction to electricity, magnetism and optics. For students in the natural sciences. Laboratory content is integrated with the lecture. Credit not awarded for both PHYS 1550 and PHYS 1650. Prerequisites: PHYS 1500 or PHYS 1600; credit or concurrent enrollment in MATH 1248. Catamount Core: N2, QD.

**PHYS 1660. Fund Phys Problem Solving II. 1 Credit.**

Problem-solving techniques for second semester Physics with calculus. Accompanying lecture PHYS 1650. Co-requisites: PHYS 1650.

**PHYS 1990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

**PHYS 2100. Experimental Physics I. 3 Credits.**

Classic physics experiments with a strong emphasis on experimental setup, data collection and analysis, error estimation, and writing/presentation of results. The laboratory work is centered around three experiments: Poisson statistics, Cavendish balance, and Kater pendulum. Prerequisite: PHYS 1650 or PHYS 1550.

**PHYS 2200. Classical Mechanics. 3 Credits.**

Newtonian dynamics of particles and systems of particles, with applications to problems of special importance, such as driven and coupled harmonic oscillators and central field trajectories. Prerequisites: PHYS 1650 or PHYS 1550; MATH 2248.

**PHYS 2500. Waves and Quanta. 0-4 Credits.**

Classical and electromagnetic waves, relativity, wave-particle phenomenology, wave mechanics, and applications of the Schrodinger equation. With laboratory. Prerequisites: PHYS 1650 or PHYS 1550. Co-requisite: MATH 2248. Catamount Core: N2, QD.

**PHYS 2990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles. Prerequisites: PHYS 2500; Department permission.

**PHYS 2993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion. Prerequisites: PHYS 2500; Department permission.

**PHYS 2995. Undergraduate Research. 1-18 Credits.**

Undergraduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion. Prerequisites: PHYS 2500; Department permission.

**PHYS 3150. Computational Physics I. 3 Credits.**

Introduction to modern computational techniques focusing on the simulation or solution of the behavior of physical systems. Examples will be drawn from classical, statistical, and quantum mechanics, electromagnetism, and chaos. Prerequisites: PHYS 1550 or PHYS 1650; MATH 2248.

**PHYS 3165. Integrated Circuit Fabrication. 0 or 4 Credits.**

Science and technology of integrated circuit fabrication. Interaction of processing with material properties, electrical performance, economy, and manufacturability. Study of unit processes used to make semiconductor chips. Prerequisite: PHYS 1550 or PHYS 1650. Cross-listed with: EE 3420.

**PHYS 3175. Microstructure & Surface Analy. 1 Credit.**

Explores the theory and practical operation of several advanced techniques to analyze the structure, composition, and surfaces of micro and nano-scale materials. Students will be fully trained as users of a Field Emission Scanning Electron Microscope (FESEM) including x-ray elemental analysis. Credit will not be given for both PHYS 3175 and PHYS 5185. Prerequisite: PHYS 2500.

**PHYS 3300. Electricity & Magnetism. 3 Credits.**

Fundamental principles of electricity and magnetism; electrostatic fields, and magnetic fields of steady currents. Electric and magnetic properties of matter and electromagnetic energy. Prerequisites: PHYS 1650 or PHYS 1550 and MATH 2248. Credit not given for more than one of PHYS 3300 or EE 3100.

**PHYS 3400. Thermal & Statistical Physics. 3 Credits.**

Thermodynamics, kinetic theory, statistical mechanics. Prerequisites: PHYS 1650 or PHYS 1550; MATH 2248.

**PHYS 3500. Quantum Mechanics I. 3 Credits.**

Introduction to nonrelativistic quantum mechanics. Schrodinger equation and applications to simple systems. Prerequisite: PHYS 2500, PHYS 2200.

**PHYS 3550. Nuclear & Elem Particle Physic. 3 Credits.**

Introduction to theoretical and experimental aspects of nuclear and elementary particle physics. Prerequisite: PHYS 2500; Junior standing.

**PHYS 3650. Intro to Solid State Physics. 3 Credits.**

Introduction to crystal structures, reciprocal lattices, lattice vibrations. Thermal properties of solids and free electron theory of metals and semiconductors. Elementary band theory and introduction to electronic transport theory. Prerequisite: PHYS 2500.

**PHYS 3675. Semiconductor Materials/Devic. 0 or 4 Credits.**

Covers Energy band theory, effective mass, band structure and electronic properties of semiconductors. Transport of electrons and holes in bulk materials and across interfaces. MOSFETs, BJTs, pn junctions, and Schottky barriers. Experimental portion of course will cover electronic measurements of semiconductor devices. Credit not awarded for both PHYS 3675 and PHYS 5675. Prerequisites: EE 2145, EE 3410, or PHYS 3300. Cross-listed with: EE 3440.

**PHYS 3800. Intro to Cosmology. 3 Credits.**

Topics related to the expanding Universe, including: Kinematics and Dynamics of expansion (space-time curvature, Friedmann equation, etc.), Black-body radiation and the early history of the Universe, the Cosmic Microwave Background, Dark Matter, Structure formation, the Cosmological constant problem, Cosmic Inflation and the early Universe, and basic elements of General Relativity. Prerequisites: PHYS 2500, MATH 2248.

**PHYS 3990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

**PHYS 3991. Internship. 1-18 Credits.**

On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

**PHYS 3993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**PHYS 3994. Teaching Assistantship. 1-3 Credits.**

Undergraduate student service as a teaching assistant, usually in an introductory level course in the discipline, for which credit is awarded. Offered at department discretion.

**PHYS 3995. Undergraduate Research. 1-18 Credits.**

Undergraduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**PHYS 4100. Experimental Physics II. 3 Credits.**

Experiments in classical and modern physics. Prerequisites: PHYS 2500; MATH 2248; Junior standing.

**PHYS 4110. Capstone Seminar. 1 Credit.**

Capstone experience emphasizing the application of physics concepts, development of professional skills, and integration of knowledge acquired during undergraduate Physics studies. Culminating project to demonstrate personal academic and professional growth. Through customized activities, students will explore professional pathways and prepare for their post-college goals. Course complements an approved independent or group study option taken in the same semester. Prerequisites: PHYS 2100, PHYS 2500, PHYS 4100. Co-requisites: PHYS 4991, PHYS 4993, PHYS 4995, or PHYS 4996.

**PHYS 4300. Electromagnetism. 3 Credits.**

Introduction to time dependent electromagnetic fields. Maxwell's equations in vacuum and in matter. Electromagnetic waves and radiation. Prerequisite: PHYS 3300. Credit not given for more than one of PHYS 4300 or EE 241.

**PHYS 4500. Applications of Quantum Mechanics. 3 Credits.**

Applications of Quantum Mechanics including Quantum Statistical Mechanics, Time-Independent and Time-Dependent Perturbation Theory, WKB Approximation, Variational Principle and Scattering. Prerequisite: PHYS 3500.

**PHYS 4990. Special Topics. 1-18 Credits.**

See Schedule of Courses for specific titles.

**PHYS 4991. Internship. 1-18 Credits.**

On-site supervised work experience combined with a structured academic learning plan directed by a faculty member or a faculty-staff team in which a faculty member is the instructor of record, for which academic credit is awarded. Offered at department discretion.

**PHYS 4993. Independent Study. 1-18 Credits.**

A course which is tailored to fit the interests of a specific student, which occurs outside the traditional classroom/laboratory setting under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**PHYS 4994. Teaching Assistantship. 1-3 Credits.**

Undergraduate student service as a teaching assistant, usually in an introductory level course in the discipline, for which credit is awarded. Offered at department discretion.

**PHYS 4995. Undergraduate Research. 1-18 Credits.**

Undergraduate student work on individual or small team research projects under the supervision of a faculty member, for which credit is awarded. Offered at department discretion.

**PHYS 4996. Honors. 1-6 Credits.**

College honors thesis or other department/program honors, under the supervision of a faculty member. Offered at department discretion.