PHYSICS

Chair: Stephen Tufte
Administrative Coordinator: Amy Timmins

Physics is the inquiry into the structure and organization of the universe. It is the study of forces and matter, of motion, of cause and effect, and of the intrinsic properties of space and time. It seeks to comprehend the essences of these things at the deepest level, and to use them to synthesize models of complex phenomena. The accomplishments of physics stand out among the highest achievements of human intellect and imagination, and as the discipline continues to evolve, the mysteries with which it deals are ever more intriguing. For a person planning a career in any field, a physics course is an ideal component of a liberal arts education. For one who seeks a career as a physicist, the breadth acquired in a liberal arts education augments and enhances the special training that physics requires.

The Department of Physics offers a complete program for students planning careers in physics, astronomy, or engineering, including a thorough preparation for graduate school or for professional engineering school. (For additional information on engineering, see Engineering.) The program is also well suited for those who plan careers in science education or in the health sciences. Special courses for students not planning a science career introduce them to the basic concepts underlying modern scientific thought.

The physics faculty have diverse interests and expertise, are active in research, and engage students in their research activities. The department is particularly active in the areas of biophysics, astrophysics, and nonlinear dynamics. Laboratory and desk space is available for majors. The faculty strive to maintain an atmosphere of creative inquiry and informal interaction with students, and to provide an environment that stimulates students to learn from each other. Physics majors sponsor campus events through the Physics Club.

Resources for Nonmajors

The department regularly offers courses geared for students majoring in disciplines outside of the mathematical and natural-sciences division. These courses include PHYS 105 Astronomy, PHYS 106 The Physics of Music and PHYS 110 Great Ideas in Physics, all of which fulfill General Education requirements in scientific and quantitative reasoning (Category B). For students in other science departments, several other courses are valuable.

It is also possible for students majoring in other disciplines to gain a broad introduction to physics by taking an introductory sequence. Introductory General Physics I (PHYS 141) and Introductory General Physics II (PHYS 142) cover classical and modern physics in one year, and utilize elementary calculus. Physics I: Motion (PHYS 151), Physics II: Waves and Matter (PHYS 152), Physics III: Electromagnetism (PHYS 251), and Physics IV: Thermodynamics and Statistical Mechanics (PHYS 252) are also calculus-based and provide a two-year introduction to physics.

Chemistry, mathematics, and biology majors planning graduate study may need to take additional physics courses beyond the introductory sequence.

Facilities

The Olin Center for Physics and Chemistry has more than 40,000 square feet of classroom, laboratory, library, and study space. Facilities and equipment used by the physics department include the following:

- Research astronomical observatory
- Lecture-demonstration theatre
- Extensive faculty research space
- Professionally staffed electronic and machine shops
- Special laboratories for acoustics, quantum optics, modern physics, phase transition studies in liquids, and biophysics using state-of-the-art optical microscopy
- Advanced physics laboratory for ongoing student projects
- Student-faculty research laboratories and conference room

The Major Program

The introductory program serves students already committed to rigorous training for a professional career in physics, as well as those who are still testing their interest in physics or engineering as a profession.

The physics curriculum is highly sequential; all students contemplating the major should seek the advice of a physics faculty member as soon as possible. Transfer students and those who declare the major after the first year should consult the department chair for guidance. Upon consultation with faculty, the complete course program for a physics major can be adapted to match the goals of each student, including opportunities to participate in overseas study programs.

Major Requirements

A minimum of 38 semester credits in physics, plus courses in mathematics, distributed as follows:

- PHYS 151 Physics I: Motion (or, with the consent of the department, PHYS 141 Introductory General Physics I)
- PHYS 152 Physics II: Waves and Matter
- PHYS 251 Physics III: Electromagnetism
- PHYS 252 Physics IV: Thermodynamics and Statistical Mechanics
- MATH 131 Calculus I
- MATH 132 Calculus II
- MATH 233 Calculus III
- MATH 235 Differential Equations
- MATH 305 Calculus IV With Applications to the Physical Sciences (For some students, including those in a 3-2 engineering program, it may be preferable to take MATH 225 Linear Algebra instead. Consult your advisor.)
- PHYS 201 Experimental Methods in the Physical Sciences
- PHYS 300 Advanced Lab and Colloquium
- PHYS 321 Quantum Physics I
- PHYS 331 Advanced Electricity and Magnetism I
- PHYS 451 Theoretical Dynamics I
- One course (2 semester credits) chosen from the following:

PHYS 390	Biomedical Imaging
PHYS 400	Advanced Lab and Colloquium
PHYS 490	Undergraduate Research and Colloquium
PHYS 491	Honors Research

All majors beyond the first year are expected to attend the physics colloquium. CS 171 Computer Science I, MATH 225 Linear Algebra, and two semesters of biology and/or chemistry are recommended for all

majors. Majors planning to do graduate work should also take PHYS 380 Topics in Physics as well as MATH 345 Numerical Analysis and MATH 365 Complex Variables.

Minor Requirements

A minimum of 24 semester credits (six courses), distributed as follows:

- PHYS 151 Physics I: Motion (or, with the consent of the department, PHYS 141 Introductory General Physics I)
- PHYS 152 Physics II: Waves and Matter
- PHYS 201 Experimental Methods in the Physical Sciences
- PHYS 251 Physics III: Electromagnetism
- PHYS 252 Physics IV: Thermodynamics and Statistical Mechanics
- One course chosen from the following:

PHYS 321	Quantum Physics I
PHYS 331	Advanced Electricity and Magnetism I
PHYS 390	Biomedical Imaging
PHYS 451	Theoretical Dynamics I

Honors

Physics majors in their junior year are invited to take part in the department's honors program during the semester they are scheduled to have completed 96 semester credits, provided they have a GPA of 3.500 overall and 3.500 for all physics courses taken at Lewis & Clark. Before the end of the semester of invitation, the student selects a faculty member to supervise the research. The approved research program is completed during the senior year, and the student receives 4 semester credits in PHYS 491 Honors Research for each of the two semesters required to carry out the research. Credit in PHYS 491 Honors Research may be applied to the laboratory requirement of the physics major program. The designation of honors in physics requires approval of at least three-quarters of the physics faculty.

Faculty

Mohamed M. Anber. Assistant professor of physics. Quantum field theory, cosmology, physics beyond the standard model, gravity. PhD 2010 University of Massachusetts Amherst. MS 2004, BS 2000 Cairo University, Egypt.

Michael L. Broide. Associate professor of physics. Physics of colloids and macromolecules. Phase transitions, aggregation, pattern formation; light scattering and optical instrumentation; membrane biophysics. PhD 1988 Massachusetts Institute of Technology. MS 1981, BS 1981 University of California at Los Angeles.

Andrew Funk. Visiting assistant professor of physics. PhD 2004 University of Oregon. BA 1995 Reed College.

Bethe A. Scalettar. Professor of physics. Fluorescence microscopy, biophysics, optics, thermodynamics, quantum mechanics. PhD 1987 University of California at Berkeley. BS 1981 University of California at Irvine.

Stephen L. Tufte. Associate professor of physics, chair of the Department of Physics, coordinator of the Engineering Program. Astrophysics, experimental physics, optics. PhD 1997, MS 1989 University of Wisconsin at Madison. BA 1986 St. Olaf College.

Courses

PHYS 105 Astronomy
Faculty: Tufte, Physics Faculty
Content: For nonmajors. Present knowledge of the sun, the planets, and other objects in the solar system; of stars, star systems, galaxies, and the universe as a whole. Focus on conceptual understanding rather than on a catalog of objects. Basic laws of physics, including Newton's laws of motion and gravitation, laws governing energy and its transformations, theories of matter and radiation. How the distance, size, mass, brightness, and composition of remote objects are determined. General theory of stellar evolution including nuclear synthesis, origins of life on earth, and origin and fate of the solar system. Occasional evening observations at the Karle Observatory atop the Olin Center for Physics and Chemistry.
Prerequisites: QR 101 or equivalent. Mathematics proficiency should be sufficient for entry into precalculus.
Usually offered: Annually, spring semester.
Semester credits: 4.

PHYS 106 The Physics of Music
Faculty: Tufte
Content: This course covers the physical principles underlying musical sound. Background in the physics of vibration and the interference of waves. Resonance and standing waves as key to understanding musical instruments and the overtone series. Frequency spectrum of sound, Fourier analysis and synthesis, and the connection to timbre. Scales and harmony. Physics and psychophysics of hearing. Acoustics of rooms. Music technology including recording and reproduction, digital music, compressed formats, digital effects.
Prerequisites: QR 101 or equivalent.
Usually offered: Annually, spring semester.
Semester credits: 4.

PHYS 110 Great Ideas in Physics
Faculty: Broide, Scalettar
Content: For nonmajors. Essential concepts used to describe and understand the physical universe. Conservation of energy, second law of thermodynamics, entropy, theory of relativity, wave-particle duality of matter.
Prerequisites: QR 101 or equivalent.
Usually offered: Annually, fall and spring semester.
Semester credits: 4.

PHYS 114 The Origins of Life in the Universe
Faculty: Clifton, Loening, Safran, Tufte
Content: Processes of stellar evolution and planet formation that set the stage for life on Earth. Theories and evidence from diverse scientific disciplines on the origins of life and how physical and chemical aspects of the environment contributed to the emergence and transformations of life-forms. Scientific evaluation of the possibility of extraterrestrial life. Attention is devoted both to the processes and content of scientific discovery. Lecture, discussion, laboratory. Cross-listed with BIO 114, CHEM 114, and GEOL 114. Not applicable toward any major.
Prerequisites: QR 101 or equivalent.
Usually offered: Alternate Years, spring semester.
Semester credits: 4.

PHYS 141 Introductory General Physics I
Faculty: Physics Faculty
Content: First semester of a rigorous one-year introductory physics course aimed at life science and chemistry majors. Kinematics, vectors, force, statics, work, energy, linear and angular momentum, oscillations, fluids. Students may not earn credit for both PHYS 141 and PHYS 151. Lecture, Lab.
Prerequisites: MATH 131 (may be taken concurrently).
Usually offered: Annually, fall semester.
Semester credits: 5.

PHYS 142 Introductory General Physics II
Faculty: Physics Faculty
Content: Second semester of a rigorous one-year introductory physics course aimed at life science and chemistry majors. Electrostatics, magnetism, induced currents and fields, electrical circuits, wave motion and sound, light, optics, wave properties of matter, atomic physics, nuclear physics. Students may not earn credit for both PHYS 142 and PHYS 152. Lecture, lab.
Prerequisites: PHYS 141 or PHYS 151. MATH 131.
Usually offered: Annually, spring semester.
Semester credits: 5.

PHYS 151 Physics I: Motion
Faculty: Broide
Content: The concepts and techniques required to measure, describe, and predict the motion of objects. Kinematics; description of motion in one, two, and three dimensions. Dynamics; causes of motion, including Newton's laws of motion. Momentum, work, energy, equilibrium, gravity, rotational motion. Special relativity. Students may not earn credit for both PHYS 141 and PHYS 151. Lecture, lab.
Prerequisites: MATH 131 (may be taken concurrently).
Usually offered: Annually, fall semester.
Semester credits: 5.

PHYS 152 Physics II: Waves and Matter
Faculty: Snodgrass
Content: Oscillating phenomena in nature and the building blocks of matter. Masses on springs, pendula, waves on strings, sound waves, light waves. Optics including the action of lenses, examples of diffraction, interference. Wave-particle duality of light and the electron. Quantum mechanics, behavior of electrons in atoms, atoms in molecules, protons and neutrons in nuclei, quarks in protons and neutrons. Students may not earn credit for both PHYS 142 and PHYS 152. Lecture, Lab.
Prerequisites: PHYS 141 or PHYS 151. MATH 132 (may be taken concurrently).
Usually offered: Annually, spring semester.
Semester credits: 5.

PHYS 201 Experimental Methods in the Physical Sciences
Faculty: Tufte
Content: Experimental methods and instrumentation in the physical sciences. Design experiments, construct instrumentation, make measurements, and analyze and interpret data in order to reach meaningful conclusions. Discussion and use of modern experimental techniques including analog and digital electronics, many types of sensors, computerized data acquisition, and spectroscopy (atomic, fluorescence, and infrared). Final student-designed project provides opportunities for interdisciplinary investigations.
Prerequisites: PHYS 141 or PHYS 151.
Corequisites: PHYS 142 or PHYS 152.
Restrictions: Sophomore standing required.
Usually offered: Annually, spring semester.
Semester credits: 4.

PHYS 205 Deep Space Astronomy
Faculty: Physics Faculty
Content: Introduction to cosmology. Cosmological models throughout history. Interplay between observations and basic principles: looking out in space and back in time. Development of modern cosmology from Newton through Einstein, including the theories of special and general relativity. Properties of light and gravitation, stars, stellar evolution, black holes, galaxies, and the large-scale structure of the universe. Present-day observations and models: Hubble space telescope, big bang, microwave background radiation, and cosmological red shift. In-depth discussion of the standard (Einstein-DeSitter) model. The ultimate fate of the universe. For majors and nonmajors.
Prerequisites: PHYS 105, PHYS 110, PHYS 141 or PHYS 151. Prior introductory physics or astronomy. Comfort with mathematics at the level of elementary functions is requested.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, fall semester.
Semester credits: 4.

PHYS 251 Physics III: Electromagnetism
Faculty: Tufte
Content: Introduction to electricity, magnetism, and their interactions. Electric fields and electric potentials. Phenomena of capacitance, currents, circuits. Forces on moving charges described in terms of the magnetic field. Effects of time-varying electric and magnetic fields, in both vacuum and matter: induction, alternating current circuits, electromagnetic waves.
Prerequisites: PHYS 151. MATH 233 (may be taken concurrently).
Restrictions: Sophomore standing required.
Usually offered: Annually, fall semester.
Semester credits: 4.

PHYS 252 Physics IV: Thermodynamics and Statistical Mechanics
Faculty: Physics Faculty
Content: The phenomena of heat from macroscopic and microscopic viewpoints. Temperature, equilibrium, thermal energy, internal energy, heat flow, entropy, extraction of work from engines. Phenomena described macroscopically by the laws of thermodynamics and microscopically by densities of accessible states, probabilities, ensembles, distribution functions. Application to the condensed states of matter and transport phenomena.
Prerequisites: PHYS 152.
Restrictions: Sophomore standing required.
Usually offered: Annually, spring semester.
Semester credits: 4.

PHYS 300 Advanced Lab and Colloquium
Faculty: Broide, Tufte
Content: Experiments of a significant historical nature or emphasizing important laboratory techniques. Students design and conduct two experiments per semester. Attendance at weekly physics colloquium required.
Prerequisites: PHYS 201.
Restrictions: Sophomore standing required.
Usually offered: Annually, fall and spring semester.
Semester credits: 2.

PHYS 321 Quantum Physics I
Faculty: Snodgrass
Content: First semester of an upper-division modern physics and quantum mechanics course. Bohr atom, DeBroglie waves, orbitals, Zeeman effect, spectroscopy, wave packets, Schrodinger equation in one dimension, eigenfunctions and eigenvalues, operators, harmonic oscillator, Schrodinger equation in three dimensions, angular momentum, hydrogen atom.
Prerequisites: MATH 235. MATH 305. PHYS 152.
Restrictions: Sophomore standing required.
Usually offered: Annually, fall semester.
Semester credits: 4.

PHYS 331 Advanced Electricity and Magnetism I
Faculty: Physics Faculty
Content: Mathematical theory of static electromagnetic fields in vacuum. The forces due to electric charges and currents in terms of electric and magnetic vector fields. The derivation of electric and magnetic fields from scalar and vector potential fields. Boundary-value techniques for the solution of the equations of LaPlace and Poisson: potential fields in the presence of various configurations of charges and currents. The summary of all aspects of electromagnetism in terms of Maxwell's equations.
Prerequisites: MATH 233. PHYS 251. MATH 235.
Restrictions: Sophomore standing required.
Usually offered: Annually.
Semester credits: 4.

PHYS 332 Advanced Electricity and Magnetism II
Content: Mathematical theory of static and dynamic electromagnetic fields, including electromagnetic fields in matter. The contribution of induced charges and currents to the electric and magnetic fields in matter. The prediction of electromagnetic waves from Maxwell's equations. The propagation of these waves in vacuum, bulk matter, and waveguides. The radiation of accelerated charges.
Prerequisites: PHYS 331.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years.
Semester credits: 4.

PHYS 380 Topics in Physics
Faculty: Physics Faculty
Content: Application of physics concepts and techniques to the understanding of specific systems. Topic chosen from the following: astrophysics, atomic physics, molecular spectroscopy, solid state physics, optics, fluids, particle physics, cosmology. May be repeated once with a change of topic.
Prerequisites: PHYS 252.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, spring semester.
Semester credits: 2-4.

PHYS 390 Biomedical Imaging
Faculty: Scalettar
Content: This course introduces several cutting-edge imaging techniques used in science and medicine and explores some of the physics underlying these techniques. Concepts are explored through lectures, readings, and hands-on, out-of-class activities. Elementary concepts from fields of physics including electromagnetism, optics, and modern physics are used to explain microscopy, endoscopy, ultrasound, CAT scans, and magnetic resonance imaging.
Prerequisites: PHYS 142 or 152.
Usually offered: Annually, spring semester.
Semester credits: 4.

PHYS 400 Advanced Lab and Colloquium
Faculty: Broide, Tufte
Content: Experiments of a significant historical nature or emphasizing important laboratory techniques. Students design and conduct two experiments per semester. Attendance at weekly physics colloquium required.
Prerequisites: PHYS 300.
Restrictions: Sophomore standing required.
Usually offered: Annually, fall and spring semester.
Semester credits: 2.

PHYS 421 Quantum Physics II
Faculty: Snodgrass
Content: Continuation of PHYS 321. Interactions of electrons with electromagnetic fields, matrices, spin, addition of angular momenta, time-independent perturbation theory, helium spectra, fine structure of atoms, molecules, time-dependent perturbation theory, radiation.
Prerequisites: PHYS 321.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years.
Semester credits: 4.

PHYS 451 Theoretical Dynamics I
Faculty: Physics Faculty
Content: Precise mathematical formulations of the idealized physical systems of classical mechanics and the physical interpretation of mathematical solutions. Linear oscillating systems, the two-body problem, rotating and accelerated reference frames, rotation of extended bodies, theory of scattering. Newtonian methods, methods of Lagrange and Hamilton, phase space analysis.
Prerequisites: MATH 235. PHYS 151.
Restrictions: Sophomore standing required.
Usually offered: Annually, spring semester.
Semester credits: 4.

PHYS 452 Theoretical Dynamics II
Faculty: Physics Faculty
Content: The calculus of variations, Lagrangian and Hamiltonian mechanics, canonical transformations, Poisson brackets, nonlinear dynamics, introduction to the theory of chaos. Development of physics through minimum principles and generalized systems of coordinates, conjugate relationships between positions and momenta, and between energy and time, as these relate to the connections between the classical and quantum mechanical descriptions of the world. Phase-space notion of an attractor, characterization of strange attractors. Time series and dimensional analyses for describing chaotic systems.
Prerequisites: PHYS 451.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years.
Semester credits: 4.

PHYS 490 Undergraduate Research and Colloquium
Faculty: Physics Faculty
Content: Advanced research supervised by a sponsoring faculty member. Students conduct a preliminary literature survey; demonstrate thoughtful planning; and develop a tractable research plan, stating objectives, possible methodology, and realistic time schedule. Attendance at weekly physics colloquium required.
Prerequisites: PHYS 201.
Restrictions: Sophomore standing and consent required.
Usually offered: Annually.
Semester credits: 4.

PHYS 491 Honors Research
Faculty: Physics Faculty
Content: Supervised research toward completing a project and a research-quality paper to qualify for honors in physics on graduation. Students conduct an exhaustive literature search of a research problem, perform an extensive experimental or theoretical investigation, and prepare a comprehensive report of the findings. May be repeated once in the senior year.
Prerequisites: None.
Restrictions: By invitation only.
Usually offered: Annually, fall and spring semester.
Semester credits: 4.