PHYSICS

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Physics is the study of how and why things work — from the minute world of the atomic nucleus to the universe itself — within the context of a few fundamental laws. The goal of the physics curriculum is to acquaint students with basic natural phenomena and with the quantitative methods of experimentation and theoretical analysis through which we come to understand them. It provides an excellent preparation for students planning a technical career in physics, engineering, astronomy, or related interdisciplinary programs (biophysics, geophysics, materials science, chemical physics, etc.). In addition, physics supports the background training of biologists, chemists, environmental scientists, and computer scientists. Undertaking a liberal arts physics program enables students to become technically literate scientists who have a broad understanding of the world and can communicate well.

Overview of the Major

For most students the physics major begins in the fall of their first year with the calculus-based introductory sequence, PHYS 130 Analytical Physics I, PHYS 131 Analytical Physics II, and PHYS 232 Analytical Physics III. These three courses cover mechanics, electricity and magnetism, wave phenomena, relativity, and quantum mechanics. This is followed in the sophomore spring semester with PHYS 244 Modern Physics and PHYS 245 Modern Physics Laboratory (0.25). The junior and senior years features more advanced studies in Classical Mechanics (PHYS 374), Maxwell's Equations (PHYS 375), and Advanced Laboratory (PHYS 385 and PHYS 386, 0.25 each) . Two elective course credits complete the requirements for the major; students choose from a variety of elective options depending on their career goals. A progressive sequence of courses in mathematics supports the coursework above. Laboratory experimentation and computer-based simulations or analysis are important parts of the curriculum throughout the major. Students are encouraged to participate in research with faculty members and in off-campus research or internship programs, most often in the summer.

Intended Learning Outcomes for the Major (http://wp.stolaf.edu/curriculum-committee/physics-major-ilos)

Distinction

See Academic Honors (http://catalog.stolaf.edu/academic-regulations-procedures/academic-honors/#distinction)

Students who demonstrate excellence in physics coursework and who complete and report on an additional project, typically a research experience, will be considered for distinction in physics. The project may culminate in a public presentation on research work or a topic of current interest in physics or in a written report such as a published paper or a paper submitted for PHYS 398 Independent Research. Other activities may be eligible; check with the department chair. In seeking to honor outstanding coursework in the major, faculty members do not rely solely on grades earned, but also consider factors such as improvement and dedication. Faculty members nominate candidates who have met the additional project criterion and a majority vote is taken. Students who elect the S/U grading option for a level II or level III physics course will not be eligible for distinction in physics.

Special Programs

To obtain certification as a teacher of physical science, a physics major must take the appropriate education courses and some additional science courses. The Education Department chair should be consulted for details of the available options. The requirement for a physics elective is waived.

The computer science major (http://wp.stolaf.edu/cs) can be designed to emphasize computer hardware by inclusion of PHYS 246 Electronics.

Students interested in the engineering profession may choose from two primary options. The option currently preferred by most students is to complete a St. Olaf degree and then enter a master's degree program at an engineering school of their choice. Such a route typically takes 1.5-2 years beyond the B.A. Alternatively, we offer a cooperative five-year program with Washington University that provides a B.A. degree from St. Olaf and a B.S. in engineering from Wash U.

In recent summers, approximately 5 to 10 research positions have been available on-campus for students interested in working with physics faculty on current research projects. These projects are supported by both external and internal funds and provide a stipend for student physics participants. See the college's Collaborative Undergraduate Research and Inquiry (http://wp.stolaf.edu/curi) web page for descriptions of recent projects.

Students also may register during the year for PHYS 398 Independent Research or apply to the Oak Ridge Science Semester Program (http://stolaf.studioabroad.com/index.cfm?FuseAction=Programs.ViewProgram&Program_ID=10100). International programs that can include course work in physics are the British university programs at Aberdeen, Lancaster, and the University of East Anglia.

Recommendations for Graduate Study

Students planning on graduate work in physics, engineering, materials science or related areas should choose appropriate electives in the major and consider additional coursework in mathematics, computer science, or other sciences, depending on the field of interest. Summer research experience is strongly recommended, especially for students entering Ph.D. programs. Students pursuing masters degrees in engineering are encouraged to complete internships in their areas of interest.

Specific recommendations by field of study:

Physics: To prepare for graduate study in physics, students are advised to take Quantum Mechanics (PHYS 376) and Statistical Physics (PHYS 379) and to consider additional physics electives or math courses such as complex analysis, abstract algebra, probability, statistics, numerical analysis, and real analysis. For example, Electronics (PHYS 246) develops skills that are useful in many experimental research settings.

Materials Science: To prepare for graduate study in materials science, students are advised to take Quantum Mechanics (PHYS 376).

In addition, students should consider Materials Engineering and Nanoscience (PHYS 362) and/or Statistical Physics (PHYS 379) and/or additional physics electives or math courses such as complex analysis, abstract algebra, probability, statistics, numerical analysis, and real analysis. For example, Electronics (PHYS 246) develops skills that are useful in many experimental research settings.

Civil Engineering: To prepare for graduate study in civil engineering, students are advised to consider Engineering Design Practicum (PHYS 360), Materials Engineering and Nanoscience (PHYS 362), Electronics (PHYS 246) and/or other physics electives, along with appropriate courses in chemistry, mathematics, and computer science.

Electrical Engineering: To prepare for graduate study in electrical engineering, students are advised to take Quantum Mechanics (PHYS 376) and Electronics (PHYS 246) and are strongly encouraged to take Statistical Physics (PHYS 379). Students should also consider Engineering Design Practicum (PHYS 360), Materials Engineering and Nanoscience (PHYS 362), and/or other physics electives, along with appropriate courses in chemistry, mathematics, and computer science.

Mechanical Engineering: To prepare for graduate study in mechanical engineering, students are advised to consider Engineering Design Practicum (PHYS 360), Materials Engineering and Nanoscience (PHYS 362), Electronics (PHYS 246) and/or other physics electives, along with appropriate courses in chemistry, mathematics, and computer science. Quantum Mechanics (PHYS 376) is strongly encouraged for students interested in nanoscale technology and engineering.

Other engineering fields: There are many fields within engineering, both within and outside the broad areas of civil, electrical, and mechanical engineering. These include acoustical engineering, aerospace engineering, biomedical engineering, and geotechnical engineering, to name a few. Engineering graduate programs are typically looking for solid preparation in areas such as physics, chemistry, mathematics, and computer programming. Some fields, such as biomedical engineering, require background in biology or other areas as well. Consult with the Engineering Advisor and specific graduate programs for further information.

Requirements

Prospective physics majors should enroll in PHYS 130 Analytical Physics I in the fall semester of their first year, along with calculus or other math course recommended by placement in Mathematics. It is possible to complete the physics major with a sophomore year start in PHYS 130; interested students should consult with the department chair or other physics faculty member. Students with AP, IB, PSEO, or significant college-level experience in physics may seek advanced placement - to start in a course beyond PHYS 130 - by consulting with the department chair.

Code	Title	Credits
PHYS 130	Analytical Physics I	1.00
PHYS 131	Analytical Physics II	1.00
PHYS 232	Analytical Physics III	1.00
PHYS 244 & PHYS 245	Modern Physics and Modern Physics Laboratory (0.25)	1.25
PHYS 374	Classical Mechanics	1.00
PHYS 375	Maxwell's Equations	1.00
PHYS 385	Advanced Physics Laboratory (0.25)	0.25
PHYS 386	Advanced Physics Laboratory (0.25)	0.25
One physics elective numbered above 120 (this is waived for students obtaining teacher certification.)		1.00
One additional physics elective numbered between 300 and 393		1.00
Total Credits		8.75

In some cases it is possible to use the PHYS 124-PHYS 125 sequence to transfer into the major; see the chair.

Remember to check the prerequisites for all courses. Mathematics prerequisites may include calculus, linear algebra, differential equations, and either partial differential equations or multivariable calculus.

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electives, along with appropriate courses in chemistry, mathematics, and computer science.

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Courses

Students planning to take a single physics course should consider PHYS 112, PHYS 124, PHYS 154, or PHYS 252. The two-semester sequence, PHYS 124-PHYS 125, makes some use of calculus and is appropriate for students needing physics to support work in another major (especially biology or chemistry).

PHYS 112: ***Introductory Astronomy***
A basic introduction to astronomy, this course concentrates on how we know what we know. Students explore questions such as "How do we measure the distance to a star?" and "How do we know the universe is expanding?" In addition to studying the solar system, stars, black holes, galaxies, and the history of the universe, students engage in observation using the department's telescopes. Offered every other year. Currently planned for 2017-18.
Prerequisite: proficiency in algebra and geometry.

PHYS 124: ***Principles of Physics I***
This two-semester in-depth course addresses topics in classical and modern physics using algebra, geometry, and some calculus. The course is well suited for students of biology or chemistry or for those desiring a thorough introduction beyond the high school level. Physics 124 takes up the Newtonian mechanics of point particles (motion, mass, force, torque, energy, momentum, and gravitation), Einstein's reexamination of space time (relativity), and nuclear physics. One laboratory per week. Offered annually in the fall semester.
Prerequisite: MATH 119 or MATH 120 or equivalent.

PHYS 125: ***Principles of Physics II***
This two-semester in-depth course addresses topics in classical and modern physics using algebra, geometry, and some calculus. The course is well-suited for students of biology or chemistry or for those desiring a thorough introduction beyond the high-school level. Physics 125 explores the character of electric and magnetic forces and fields, then takes up the extended description of matter (vibrations, waves - sound and light). Finally, both particle and wave descriptions are shown to be necessary for discussing quantum mechanics and its application to atomic physics. One laboratory meeting per week. Offered annually in the spring semester.
Prerequisites: MATH 119 or MATH 120 or equivalent and PHYS 124.

PHYS 130: ***Analytical Physics I***
This three-semester calculus-based sequence leads the student through the basic principles that account for the processes involved in baseballs, car engines, electrical power distribution systems, stereos, and black holes. It is the starting point for a major in physics and is also appropriate for majors in fields such as chemistry or mathematics who desire more mathematical depth than would be used in the two-semester PHYS 124 - PHYS 125 sequence. Physics 130 is a study of Newtonian mechanics --- motion, forces, energy, gravity, and rotation. There is one 2.5 -hour laboratory meeting per week. Offered annually in the fall semester. Counts toward computer science major.
Prerequisite: concurrent registration in (or previous completion of) MATH 119 or MATH 120 or equivalent.

PHYS 131: ***Analytical Physics II***
Physics 131, the second course in the three-semester calculus-based sequence, treats electricity, magnetism, and electromagnetic waves. There is one 2.5 hour laboratory meeting per week. Offered annually in the spring semester.
Prerequisites: PHYS 130 and concurrent registration in (or previous completion of) MATH 126 or MATH 128.

PHYS 154: ***Origins of Nuclear Weapons***
In 1945, humanity's relationship to science was forever changed by the atomic bombings of Hiroshima and Nagasaki. This course examines the scientific developments that led to these first atomic weapons, from the discovery of the nucleus to the manipulation of fission processes for the explosive release of nuclear energy. It also considers present-day weapons and nuclear power plants and discusses scientific developments in the human contexts that influenced them.
Prerequisite: high school algebra.

PHYS 232: ***Analytical Physics III***
Physics 232, the third course in the three-semester calculus-based sequence, explores special relativity, waves and oscillations, and the quantum mechanics of light and matter. There is one 2.5 hour laboratory meeting per week. Offered annually in the fall semester.
Prerequisites: PHYS 131 or permission of instructor, and concurrent registration in (or previous completion of) MATH 220.

PHYS 244: ***Modern Physics***
Quantum mechanics has changed the conceptual framework for our understanding of atoms and molecules, both as free particles and in condensed states of matter. It also guides our understanding of the nucleus and elementary particles. This course examines these discoveries and several applications they produced. Offered annually in the spring semester.
Prerequisites: PHYS 232 and concurrent registration (or previous completion of) MATH 230; concurrent registration in PHYS 245 is required.

PHYS 245: ***Modern Physics Laboratory (0.25)***
This course, meeting once a week, uses both historical experiments and open-ended investigations with modern instrumentation to examine in detail the important developments covered in PHYS 244. Offered annually in the spring semester.

PHYS 246: *Electronics*
Modern scientific work relies heavily on electronic circuitry and computation. This course examines the fundamentals of analog and digital electronics, explores the applications of discrete and integrated circuits, and introduces the broad topic of computer control of experiments. Students develop hands-on skills in circuit building, computer interfacing, and programming in LabView®. Students attend one laboratory period each week. Offered alternate years. Counts toward computer science major.
Prerequisite: PHYS 125 or PHYS 131.

PHYS 252: *Musical Acoustics*
This course offers an introduction to the physics of sound waves, the biological, physical and psychological origins of sound perception, and the synthesis of sounds and sound production in different instruments. Students explore these topics, as well as sound recording and reproduction systems, through lectures, discussions, laboratory experiments, and student presentations. Offered during Interim. Counts toward media studies concentration.
Prerequisite: proficiency in algebra and geometry. Musical experience is helpful but not required.

PHYS 294: *Academic Internship*

PHYS 298: *Independent Study*

PHYS 360: *Engineering Design Practicum*
This course gives students the opportunity to work on real world physics and engineering problems. Companies, non-profits, and other organizations provide projects relevant and important to the organizations' goals. Students work in teams to approach these projects from an engineering design perspective that emphasizes hands-on work, prototyping, and organizational skills. Offered annually during Interim.
Prerequisite: PHYS 244 or permission of the instructor.

PHYS 362: *Materials Engineering and Nanoscience*
This course introduces students to the vibrant, interdisciplinary, and growing fields of materials engineering and nanoscale science. Students focus primarily on the relationship between the structure and physical properties of materials, on length scales ranging from millimeters to nanometers. Students research articles from the peer-review literature that highlight the latest developments in the field. Students also discuss the technological and societal impacts of different materials and their applications. Students in this course are normally registered for PHYS 386 as well, in order to complete the requirements for the physics major. Offered annually in the fall semester.
Prerequisite: PHYS 374 or PHYS 375.

PHYS 374: *Classical Mechanics*
This course is an analytical and computational study of Newtonian mechanics, including the harmonic oscillator, central force motion, non-linear oscillators, chaos, and an introduction to the Lagrangian formulation. Students use computers extensively. Offered annually in the fall semester.
Prerequisites: PHYS 232 and MATH 230.

PHYS 375: *Maxwell's Equations*
This course utilizes integral and vector calculus in a thorough and analytic examination of classical electromagnetic theory and the physical laws on which it is based. Topics include electric and magnetic fields, macroscopic interaction of electromagnetism with matter, and the propagation of electromagnetic waves in various media. Students in this course are normally registered for PHYS 385 as well, in order to complete the requirements for the physics major. Offered annually in the spring semester.
Prerequisites: PHYS 232, MATH 230, and one of the following: MATH 226, MATH 330, CSCI 251, or similar course upon approval of the department chair.

PHYS 376: *Quantum Mechanics*
Students investigate Quantum Theory, in which a particle's behavior is described through a statistically-interpreted wave function rather than through the concepts of Newtonian mechanics. Topics include an examination of the conceptual framework of Quantum Mechanics, solution of the Schrodinger Equation for systems such as the harmonic oscillator and the hydrogen atom, and approximation methods for treating more complex systems and the interaction of radiation with matter. Students in this course are normally registered for PHYS 386 as well, in order to complete the requirements for the physics major. Offered annually in the fall semester.
Prerequisites: PHYS 244, PHYS 374, and one of the following: MATH 226, MATH 330, CSCI 251, or similar course upon approval of the department chair.

PHYS 379: *Statistical Physics*
How do macroscopic variables (e.g. energy, pressure) develop through the collision or interaction of microscopic objects? Why is the spread of disease in an orchard similar to a piece of iron becoming magnetized? Students study classical and quantum gases, followed by magnets and phase transitions (Ising Model, percolation, renormalization) and employ both analytical and computer methods (Monte-Carlo sampling, simulations, molecular dynamics). Offered alternate years.
Prerequisite: PHYS 244.

PHYS 385: *Advanced Physics Laboratory (0.25)*
Experiments in the areas of mechanics, electricity and magnetism, and materials science. Emphasis is on the development of good laboratory techniques, analytical skills, and the ability to work independently. Each 0.25-course registration averages one afternoon of work each week. Offered annually in the spring semester.

PHYS 386: *Advanced Physics Laboratory (0.25)*
Experiments explore various aspects of quantum physics. Emphasis is on the development of good laboratory techniques, analytical skills, and the ability to work independently. Each 0.25-course registration averages one afternoon of work each week. Offered annually in the fall semester.

PHYS 390: *Selected Topics*
In-depth study of particular topics in physics in a full-semester format. Topics are based on student interest and available staff. Recently taught courses include solid state physics, cosmology, stellar evolution, and general relativity.
Prerequisites: PHYS 244 and MATH 230.

PHYS 392: *Short Topics in Physics (0.50)*
In-depth study of particular topics done in a half-semester format. Topics are based on student interest and available staff. Generally offered as a pair of half-courses in one semester but students may enroll in only one. Recently topics include general relativity and cosmology.
Prerequisite: PHYS 244 and MATH 230.

PHYS 394: *Academic Internship*

PHYS 396: *Directed Undergraduate Research*
This course provides a comprehensive research opportunity, including an introduction to relevant background material, technical instruction, identification of a meaningful project, and data collection. The topic is determined by the faculty member in charge of the course and may relate to his/her research interests. Offered based on department decision. May be offered as a 1.00 credit course or .50 credit course.
Prerequisite: determined by individual instructor.

PHYS 398: *Independent Research*

PHYS 399: *Senior Seminar (0.25)*
Seniors and faculty members study topics of current interest. Discussions are based on journal articles, other readings, library research, and presentations by faculty, participants, or visitors. P/N only. Available on request. May be repeated if topic is different.
Prerequisites: PHYS 374 and PHYS 375.

Faculty

Chair, 2017-2018
Jason J. Engbrecht
Associate Professor of Physics
positron and antimatter physics; robotics

Prabal Adhikari
Visiting Assistant Professor of Physics
large Nc QCD; QCD in a magnetic field

Alden Adolph
Instructor in Physics

Brian Borovsky
Associate Professor of Physics
surface science; friction and contact mechanics; micro/nanoscale applied physics

James A. Demas (on leave)
Associate Professor of Biology and Physics
neuronal biophysics; sensory circuits; retinal neurophysiology

Anne M. Gothmann
Assistant Professor of Environmental Studies and Physics

Amy Kolan
Professor of Physics
mathematical physics; statistical mechanics

Amy E. Larsen
Assistant Professor of Physics
condensed matter physics

David Nitz
Professor of Physics
quantum mechanics; atomic physics