PHYSICS

Physics is the study of how the world works: from fiber optic communications to the CCD chips in your phone; from bridges to radio antennas; from subatomic particles to stars and galaxies; physicists study it all.

The educational objectives of the Department of Physics are:

1. To train students to become critically thinking problem solvers.
2. To develop students' mathematical, computational, and laboratory skills to understand and solve scientific problems.
3. To prepare students for entrance into the technological and non-technical work forces.

To accomplish these objectives, physics students are guided to an understanding of physical laws and their applications; students learn to think logically and develop their problem-solving abilities; students develop experimental skills and become knowledgeable in the use of instrumentation; and students receive instruction in advanced mathematical and analytical techniques and in the use of computers and numerical modelling. The applied component of the physics curriculum focuses on laser technology, applications in biology and medicine, the Earth system, and nanotechnology and materials science. Students learn the fundamental physical processes that constitute the basis of modern technology and engineering. We strongly encourage students to work with our faculty members on research ranging from astronomy to geophysics and from black holes to high energy physics. Finally, students will complete a Senior Capstone Project which is an integrative project, chosen by our students and executed with the help of a faculty mentor. Here, students will apply their classroom knowledge to concrete challenges at the forefront of physics. Past capstones, for example, have focused on quantum computing, detecting early-stage cancer, monitoring the earth's ionosphere using low-frequency radio receivers, advanced microscopy, solar flare detection, and energy absorption in ocean canyons. All physics majors automatically earn a minor in mathematics.

Whether your interest is teaching high school, working in a high-tech company, or continuing on to graduate school and a research career, our combination of a solid classroom foundation and student research will give you an outstanding starting point for your future career. Physics graduates can pursue graduate studies in any sub-field of physics and related fields such as engineering, follow industrial careers in research and development in corporate or industrial environments, or pursue professional careers in such fields as physics, engineering, computer science, finance, medicine, biology, architecture, patent/high-tech law, and science teaching, just to name a few.

Programs

The physics major is broken into two parts. First, there are a block of foundational classes that all physics majors are required to complete. In addition, by the start of their junior year, every student must select an academic track to pursue. The track you pick determines the remaining courses required by the physics major. While it is possible to change tracks later, not every course is offered annually which can make it difficult to fulfill changing major requirements.

To fulfill the physics major, students must complete the following foundation classes:

Physics Major, Foundation Classes

and one of the following tracks:

- Physics Major, General Physics Track
- Physics Major, Education Track
- Physics Major, Health Studies Track

The department also offers a 16-credit minor:

Physics Minor

Provision for Physics Advanced Placement Exam C

Students who have passed the AP Physics I exam with a score of 4 or 5 will receive credit for PHYS 1145. Students who pass the AP Physics C: Mechanics exam with a score of 4 or 5 need not take PHYS 1171 and may begin with PHYS 1172 in the spring. Students who have passed both AP Physics C: Mechanics and AP Physics C: Electricity and Magnetism exams with scores of 4 or 5 may advance directly to the sophomore physics course, PHYS 2285 Modern Physics, without taking the PHYS 1171 and PHYS 1172 prerequisites. Note: Per the general Advanced Placement policy of the University, only 4 credits are awarded toward graduation for having passed the two AP Physics C exams. Students who do not take PHYS 1171 and PHYS 1172 under this provision will need to take one additional elective in physics in order to complete the required number of credits for the major in physics.

Courses

PHYS 1071 Physics of Light, Color, and Vision **3 Credits**
Attributes: EDCG Educational Studies Cognate, MSID Magis Core: Interdisciplinary
This course explores the principles of light and its interaction with matter, focusing on the physics underlying color perception and its applications in art and technology. The course examines topics such as the nature of light as electromagnetic waves, optics, and the electromagnetic spectrum. Students will analyze the formation of colors in natural phenomena, materials, and artistic contexts, such as painting, photography, and digital media. Students will also learn how light theories evolved. Activities and demonstrations will provide opportunities to investigate light and color phenomena (e.g., illusions, diffraction), enhancing our understanding and appreciation of the visual and artistic world.

PHYS 1076 Physics of Sound and Music **3 Credits**
Attributes: EDCG Educational Studies Cognate, MSID Magis Core: Interdisciplinary
Designed for the non-science major, this course examines the physical principles in the production of sound, with an emphasis on sound produced by musical instruments. Topics include the nature of wave motion as produced by vibrating strings and organ pipes, harmonic content, musical scales and intervals, and the mechanism of the hearing process. The course applies concepts to the construction and characteristics of musical instruments and to the design of auditoriums and concert halls.

PHYS 1077 Science and Technology for Future Presidents 3 Credits
Attributes: EDCG Educational Studies Cognate, MSJ1 Magis Core: Social Justice I
This interdisciplinary exploration provides introductory knowledge of the physics of sound waves and the combination of waves in music. This foundation expands into an exploration the elements of musical theory and composition, including studying the brain's perception of sound and the physiological response to music. Students will continue to study acoustics, sound engineering, and musical instrument design, including the use of specific materials, structures, and electronic components for the enhancement of sound. While this class does contain mathematical elements, class time will prioritize interactive, project-based activities that demonstrate how the physical concepts are linked to the other studied disciplines.

PHYS 1078 Nature of the Universe 3 Credits
Attributes: MSID Magis Core: Interdisciplinary
This course, intended for non-science majors, reviews the scientific field of cosmology, or the nature of the physical universe, from a historical perspective. Beginning with the ancients, the course traces the development of cosmological principles through the Greek and Egyptian era of Aristotle, C. Ptolemy, and others; the 16th and 17th centuries of Copernicus, Galileo, and Newton; and the cosmology of the 20th century based upon Einstein's theories of relativity coupled with several fundamental observations. This leads to an examination of the current model of the universe, which is based upon the Big Bang theory.

PHYS 1087 Fundamentals of Astronomy 3 Credits
This course introduces students who are not majoring in science to the principal areas, traditional and contemporary, of astronomy. Traditional topics include a historical background to astronomy, telescopes, the sun, the moon, the major and minor planets, comets, and meteors. After discussing these subjects in detail, the course covers areas appropriate to modern astronomy such as the composition and evolution of stars, star clusters, quasars, pulsars, black holes, and cosmological models.

PHYS 1089 Physics of Sport 3 Credits
Attributes: EDCG Educational Studies Cognate, MSID Magis Core: Interdisciplinary, SPEL Sports Media Elective
This course introduces concepts from science, particularly physics, by using illustrations from a wide variety of sports. For example, it explains why a baseball curves, why gears work on a bike, the speeds obtainable by a windsurfer or skier or tennis ball or arrow, how scuba divers survive, and a wide variety of other sports phenomena from football, golf, skiing, climbing, sailing, skating, baseball, scuba, fishing, sky-diving and so forth. The association of sports with motion, forces, and energy is explained by scientific reasoning and analysis. The course includes a small laboratory/experiential component that illustrates the scientific method, where various examples of sports are made quantitative, using readily available equipment.

PHYS 1090 Physics of the Atmosphere, Ocean, and Climate 3 Credits
Attributes: EDCG Educational Studies Cognate, EVME Environmental Studies Major Elective, EVNS Environmental Studies: Natural Science, EVPE Environmental Studies Elective, MSID Magis Core: Interdisciplinary
This introductory course presents the physical processes that lead to the atmospheric, oceanic, and climate phenomena we experience in our everyday lives. During the first half of the semester, students will learn how simple physics can explain the current state of the atmosphere, ocean, and climate, and during the second half of the semester, students will learn how the atmosphere, ocean, and climate undergo changes due to both Earth's natural variations and human impacts. A full-day field trip, table-top experiments, and climate models will be used to illustrate concepts from class. Only a knowledge of algebra will be assumed.

PHYS 1093 Energy and Environment 3 Credits
Attributes: EDCG Educational Studies Cognate, EVME Environmental Studies Major Elective, EVNS Environmental Studies: Natural Science, EVPE Environmental Studies Elective
This course introduces students not majoring in the natural sciences to topics relating to work, energy, and power, and explores many of the environmental consequences resulting from our use of energy. The course examines the finite nature of fossil fuels as well as many alternative energy sources including solar energy, wind, tidal, and geothermal energy, nuclear fission, and nuclear fusion. Students will use arithmetic and simple algebra.

PHYS 1145 General Physics for Life Sciences I 3 Credits
Corequisite: PHYS 1145L.
Designed for students in the health sciences, this algebra-based introductory physics course covers classical mechanics of rigid bodies and fluids. Topics covered include Newton's laws of motion, the conservation of energy and momentum, simple harmonic motion, basic wave properties, and static and dynamic fluids. This course stresses conceptual understanding and problem-solving skills for health science students.

PHYS 1145L General Physics for Life Sciences I Lab 1 Credit
Fee: $120 Science Lab Fee
Corequisite: PHYS 1145.
This lab course engages students in experimental measurements spanning the areas of mechanics and thermal stresses on matter, with the objective of training students in experimental measurements, data manipulation and analysis, error analysis, deductive thinking, and instrumentation, providing depth to students' understanding of the phenomena taught in PHYS 1145. Specific experimental measurements include accelerated motion, periodic motion, gravitational force, ballistics, conservation of energy, fluids, and ideal gas law. This course trains students in experimental measurements, data analysis, error analysis, deductive thinking, and instrumentation.

PHYS 1146 General Physics for Life Sciences II 3 Credits
Corequisite: PHYS 1146L.
Prerequisite: PHYS 1145.
A continuation of PHYS 1145, this course covers the basic concepts of electric forces and fields, potentials, magnetic forces and fields, induction, DC circuits, and optics. This course stresses conceptual understanding and problem-solving skills for health science students.

PHYS 1146L General Physics for Life Sciences II Lab 1 Credit
Fee: $120 Science Lab Fee
Corequisite: PHYS 1146.
This laboratory provides students with a greater understanding of electromagnetic phenomena, wave phenomena, and optics, and supports PHYS 1146. Measurements of microscopic quantities, like the charge and mass of the electron, give students an opportunity to explore the structure of matter. Other experiments involve the physics of electrical currents, electric properties of bulk matter, magnetic fields and their effect on beams, wave phenomena, and the nature of light and its interaction with optical materials. This course trains students in experimental measurements, data analysis, error analysis, deductive thinking, and instrumentation.

PHYS 1171 General Physics I **3 Credits**
Corequisite: PHYS 1171L.
Prerequisite: MATH 1141 or MATH 1171 (concurrency allowed).
This is a calculus-based introductory physics course for physics, mathematics, chemistry, and engineering majors. In it, students will cover the foundations of classical mechanics, including linear and vector motion, Newtonian mechanics, energy, momentum, rotational motion, static equilibrium, and waves. Note: Biology majors should take PHYS 1145.

PHYS 1171L General Physics I Lab **1 Credit**
Fee: $120 Science Lab Fee
Corequisite: PHYS 1171.
This lab course engages students in experimental measurements spanning the areas of mechanics and thermal stresses on matter, with the objective of training students in experimental measurements, data manipulation and analysis, error analysis, deductive thinking, and instrumentation, providing depth to students' understanding of the phenomena taught in PHYS 1171. Specific experimental measurements include accelerated motion, periodic motion, gravitational force, ballistics, conservation of energy, fluids, and rotational dynamics. This course trains students in experimental measurements, data analysis, error analysis, deductive thinking, and instrumentation.

PHYS 1172 General Physics II **3 Credits**
Corequisite: PHYS 1172L.
Prerequisites: MATH 1142 or MATH 1172 (concurrency allowed); PHYS 1171.
This course is a continuation of PHYS 1171 and covers electricity and magnetism, light, and optics. Topics covered include electric fields and their sources, magnetic fields and their sources, simple electric circuits, wave motion, reflection and refraction of light, and geometrical optics. Note: Biology majors should take PHYS 1146.

PHYS 1172L General Physics II Lab **1 Credit**
Fee: $120 Science Lab Fee
Corequisite: PHYS 1172.
This laboratory provides students with a greater understanding of electromagnetic phenomena, wave phenomena, and optics, and supports PHYS 1172. Measurements of microscopic quantities, like the charge and mass of the electron, give students an opportunity to explore the structure of matter. Other experiments involve the physics of electrical currents, electric properties of bulk matter, magnetic fields and their effect on beams, wave phenomena, and the nature of light and its interaction with optical materials. This course trains students in experimental measurements, data analysis, error analysis, deductive thinking, and instrumentation.

PHYS 2212 Circuit Analysis and Analog Systems **3 Credits**
Corequisite: PHYS 2212L.
Prerequisite: PHYS 1172.
This course introduces students to the theory and practice of basic electronics and linear/analog circuitry. Topics include Kirchhoff's laws and applications; resistor circuits; concepts of capacitive and inductive reactance; impedance calculation using vector and complex notation; DC, AC, and transient circuit behavior; operation of basic solid state devices (diodes, junction transistors, FETs, SCRs); operational amplifiers; active and passive filters; feedback techniques; and frequency dependent effects. The basic laws and theorems of circuit analysis are introduced.

PHYS 2212L Circuit Analysis and Analog Systems Lab **1 Credit**
Fee: $120 Science Lab Fee
Corequisite: PHYS 2212.
Students learn the use of basic laboratory test equipment such as the digital volt-ohm-amp meter, function generator, oscilloscope, and frequency counter. Bread boarding techniques are utilized to assemble and test various linear/analog circuits. Simulation software is introduced.

PHYS 2255 Introduction to Astrophysics **3 Credits**
Prerequisite: PHYS 2285.
This course is an introduction to modern astronomy and astrophysics. Starting from basic physical principles, we will begin with a number of practical problems in observational astronomy: the location of stars in the sky, optical telescopes and detectors, and measuring the brightness of stars and galaxies. From here, we will go on to discuss the formation, evolution, and death of stars and how these astronomical processes have influenced the world around us. Finally, we will end with a discussion of cosmological evolution from the big bang onward.

PHYS 2265 Introduction to Geophysical Fluid Dynamics **3 Credits**
Attributes: MSID Magis Core: Interdisciplinary
Prerequisite: PHYS 1172.
This course presents the field of geophysical fluid dynamics. After an overview of Earth's energy balance, students will spend the first half of the semester learning dynamics and consider how Earth's rotation alters large-scale flows in the ocean and atmosphere. After a study of the circulation of the ocean and the atmosphere, students will learn how the ocean and atmosphere couple to create the climate system, including the current climate system as well as natural and anthropogenic variations in the climate system. Students will gain experience in creating computational models of the ocean, atmosphere, and climate.

PHYS 2285 Modern Physics **3 Credits**
Prerequisite: PHYS 1172.
This course introduces modern physics, i.e., the physics of the 20th century. The basic ideas that led to the formulation of quantum mechanics together with Einstein's theories of relativity provided a means to explore many new aspects of the physical world. This course examines the discovery of quanta of energy; Einstein's Special Theory of Relativity; the Bohr model of the atom; wave mechanics, angular momentum, and spin; various aspects of quantum mechanics that explain much of the subatomic world; and aspects of atomic and nuclear physics including solid-state physics and superconductivity. The course also examines several of the major experimental observations that support and confirm these new theories. Previously PS 0285.

PHYS 2285L Modern Experimental Methods Lab **2 Credits**
Fee: $120 Science Lab Fee
Prerequisite: PHYS 2285.
This course offers lab experience in modern experimental methods and techniques. It involves lab investigation of fundamental concepts in modern physics including atomic, nuclear, solid-state, x-ray, acoustic, superconductivity, and quantum physics. Lab procedures emphasize hands-on work with basic experimental equipment such as vacuum systems, power supplies, electronics and instrumentation, detectors, diagnostic techniques, computer interfaces, data acquisition and control, hardware and software, etc. This lab course gives students maximum opportunity to work on their own with minimum supervision.

PHYS 2286 Modern Physics II: Applications of Quanta and Relativity **3 Credits**
Prerequisite: PHYS 2285.
This course applies the theory and phenomenology studied in Modern Physics (Quanta and Relativity) to a wide variety of phenomena and applications. The quantum and relativistic realm will be used to clarify topics in the structure of matter and energy from the smallest to the largest times and scales of the universe. Topics include moving from classical physics to quantum statistics, and basic structural, thermal, electronic, magnetic, and energy properties of matter up to relativistic limits. Applied topics include lasers, superconductivity, semiconductor devices, quantum optics, nanomaterials, nuclear power, applied sciences, and engineering.

PHYS 3215 Computational Physics **3 Credits**
Prerequisite: PHYS 2285.
In this course students will learn numerical methods to solve scientific problems and to integrate the use of the computer into their research. The course will cover numerical methods to solve integrals, differential equations, partial differential equations, systems of linear equations, and to model random processes. Problems that will be solved in this class include: Laplace equation, chaotic pendulum, Schrodinger's equation, and magnetic and electric field calculations. The programming languages that will be used in this course are high level languages, such as C and C++, whose basic syntax will be taught in class.

PHYS 3222 Modern Optics **3 Credits**
Corequisite: PHYS 3222L.
Prerequisite: PHYS 2285.
Starting with a review of electromagnetic wave theory and the differential wave equation, this course covers the propagation of light from a scattering and an electromagnetic wave phenomena point of view. The course investigates superposition, polarization, interference, and diffraction in detail and discusses the photon theory of light along with the photoelectric effect. The course covers the basic theory of coherence with its contemporary application to lasers and additional selected topics in applied optical devices, stressing the application of theory to devices and observations.

PHYS 3226 Classical Mechanics **3 Credits**
Prerequisite: PHYS 1172.
The formulation of classical mechanics represents a major milestone in our intellectual and technological history as the first mathematical abstraction of physical theory from empirical observations. This achievement is rightly accorded to Isaac Newton, who first translated the interpretation of various physical observations into a compact mathematical theory. More than three centuries of experience indicate that mechanical behavior in the everyday domain can be understood from Newton's theories. Topics in this course include elementary dynamics in one and two dimensions, gravitational forces and potentials, free and forced harmonic oscillations, central fields and the motions of planets and satellites, Lagrange's and Hamilton's equations, small oscillations, and normal mode analysis. Previously PHYS 2226.

PHYS 3241 Thermal and Statistical Physics **3 Credits**
Prerequisite: PHYS 2285.
Thermodynamics, viewed primarily as the science that deals with energy transformations and the relationships between properties of systems, is a fairly modern science. As its name implies, thermodynamics deals with heat and power; originally, this now broad subject dealt almost exclusively with heat engines. This course begins with a review of the three fundamental laws of thermodynamics. Additional topics include the kinetic theory of gasses and modern statistical mechanics.

PHYS 3271 Electricity and Magnetism **3 Credits**
Prerequisites: MATH 2251, PHYS 1172.
This lecture course covers the foundations of electric and magnetic phenomena. Topics include electrostatics and the concepts of the electric field, flux, and potential; Coulomb's law and Gauss's law and their applications; vector and scalar fields and vector operators; electric energy of systems of charges; dipole fields and Laplace's equation; moving charges and currents; Ampere's law; and magnetic fields and forces.

PHYS 3324 Mathematical Methods of Physics **3 Credits**
This course provides a foundation in mathematical methods required for pursuing advanced physics courses. Two areas of focus of the course are developing a geometric perspective, and symbolic computation with Mathematica. Students apply methods often used in physics, including power series, complex functions, linear algebra, and vector analysis. Students will solve example physics equations such as heat flow, and the wave equation using curvilinear coordinates, Fourier series, Fourier transforms, Bessel functions and Legendre polynomials, and complex analysis.

PHYS 3385L Advanced Lab in Physics **3 Credits**
Fee: $120 Science Lab Fee
Prerequisite: PHYS 2285 and PHYS 2285L.
This is an advanced laboratory class that builds on the skills learned in PHYS 2285L (Modern Lab). Whereas Modern Lab emphasized working with common experimental equipment, Advanced Lab emphasizes data collection and analysis techniques, as well as introducing you to more specialized experimental equipment. Students are also be expected to take more responsibility for the planning and execution of their experiments than in previous classes.

PHYS 3386 Quantum Physics **3 Credits**
Prerequisites: MATH 3332, PHYS 2226, PHYS 2285.
This course introduces students to the physical concepts and mathematical formulations of non-relativistic quantum mechanics. Topics include the Schrodinger wave equation, Fourier techniques and expectation values, operator formalism, angular momentum, central forces, matrix representations, and approximation methods.

PHYS 3388 Elementary Particles and Nuclear Physics **3 Credits**
Prerequisite: PHYS 3386.
This course begins with a review of elementary particles, their properties and classification, and their nuclear and electromagnetic interactions. It proceeds with the study of bound nuclear systems, conditions for nuclear stability, and radioactive decay modes. The course concludes with an examination of particle accelerators and other nuclear experimental facilities.

PHYS 4900 Special Topics (Shell) **3 Credits**
This course covers the following content: condensed matter physics, numerical analysis and computational physics, and wave phenomena and quantum phenomena. Condensed matter topics include mechanical, thermal, and electric properties of matter; magnetism; superconductivity; and magnetic resonance. Topics in numerical analysis and computational physics include solutions of differential equations, boundary value and eigenvalue problems, special functions and Gaussian quadrature, and matrix operations. Topics in wave phenomena include electric and mechanical oscillators, coupled oscillators, transverse and longitudinal waves, waves on transmission lines, and electromagnetic waves. Quantum phenomena include advanced topics in quantum mechanics with applications in the structure of nuclei, atoms, molecules, metals, crystal lattices, semiconductors, and superconductors.

PHYS 4971 Physics Research I **0-4 Credits**
This course requires theoretical, experimental, and/or computational research with a faculty member. All students interested in conducting research should obtain the consent of the professor supervising their research prior to registering for this course.

PHYS 4972 Physics Research II **0-4 Credits**
This course requires theoretical, experimental, and/or computational research with a faculty member. All students interested in conducting research should obtain the consent of the professor supervising their research prior to registering for this course.

PHYS 4973 Physics Research III **0-4 Credits**
This course requires theoretical, experimental, and/or computational research with a faculty member. All students interested in conducting research should obtain the consent of the professor supervising their research prior to registering for this course.

PHYS 4974 Physics Research IV **0-4 Credits**
This course requires theoretical, experimental, and/or computational research with a faculty member. All students interested in conducting research should obtain the consent of the professor supervising their research prior to registering for this course.

PHYS 4975 Physics Research V **0-4 Credits**
This course requires theoretical, experimental, and/or computational research with a faculty member. All students interested in conducting research should obtain the consent of the professor supervising their research prior to registering for this course.

PHYS 4976 Physics Research VI **0-4 Credits**
This course requires theoretical, experimental, and/or computational research with a faculty member. All students interested in conducting research should obtain the consent of the professor supervising their research prior to registering for this course.

PHYS 4990 Independent Study **1 or 2 Credits**
This course provides opportunities to physics majors in their junior year, and to sophomores by permission of the department Chair, to pursue independent studies in selected areas of physics, under the mentorship of a faculty member. The course aims to guide students in using the methods of scientific inquiry to explore subjects in an area of mutual interest to the student and teacher. In the process, students will get personal attention and hands-on experience, and will develop further their analytical and experimental skills.

PHYS 4998 Theoretical/Experimental Capstone **1-4 Credits**
Attributes: MWID Magis Core: Writing in the Discipline
Prerequisite: Senior standing.
This course provides opportunities for intensive investigation, experimental or theoretical, of selected topics at an advanced level under the guidance of a faculty member. Participation in this course is required of all seniors.

PHYS 4999 Theoretical/Experimental Capstone **1-4 Credits**
Attributes: MWID Magis Core: Writing in the Discipline
Prerequisite: Senior standing.
This course provides opportunities for intensive investigation, experimental or theoretical, of selected topics at an advanced level under the guidance of a faculty member. Participation in this course is required of all seniors.

Faculty

Professors

Biselli, *chair*
Winn

Associate Professors

Nazarian

Assistant Professors

Aguirre
Gozar

Visiting Assistant Professors

Multunas

Assistant Professors of the Practice

Sharp

Lecturers

Cordery
Granucci
Henry
Kuhn

Faculty Emeriti

Beal
Hadjimichael