

Physics

Chairperson: Andrew Kunz, Ph.D.

Department of Physics website (<http://www.marquette.edu/physics/>)

The Physics department at Marquette offers three majors that prepare students for graduate study, employment, professional training and diversification into a variety of other fields that require rigor and a combination of creative and analytical skills. The majors offered are Physics, Biophysics and Applied Physics. Physics students achieve a general understanding of leading edge computational, theoretical and experimental approaches to explaining diverse natural phenomena from sub atomic particles, to exotic stars and galaxies, and progress into areas as diverse as medicine, law, engineering and finance, as well as mainstream areas of physics such as particle physics, astrophysics, solid state, atomic and molecular physics. Biophysics students learn about the structures and mechanisms of living systems at the chemical, molecular, atomic and electronic levels, and become familiar with the techniques and instrumentation with which to study these. The Biophysics major is a rigorous preparation for a career in medicine or in the rapidly growing biomedical industry, or for further study and research in biophysical and biomedical sciences. Applied Physics students study a core physics curriculum along with practical and engineering techniques and applications, and carry out an intensive research or work-study program, in preparation for employment, specialist vocational training or further specialized study. Majors in the Physics department can apply for acceptance into the Disciplinary Honor Program in Physics near the end of their sophomore year. Completion of this experiential program involves six credits of independent research with a faculty member and enrollment in an accompanying seminar focused on the research skills typically found in successful scientists. Minors are offered in Physics, Astrophysics and Biophysics. In addition, together with the Graduate School of Management, the Department of Physics offers a five-year B.S./M.B.A. accelerated degree program.

- Applied Physics, BS (<https://bulletin.marquette.edu/arts-sciences/physics/applied-physics-bs/>)
- Astronomy, Minor (<https://bulletin.marquette.edu/arts-sciences/physics/astronomy-minor/>)
- Biophysics, BS (<https://bulletin.marquette.edu/arts-sciences/physics/biophysics-bs/>)
- Biophysics, Minor (<https://bulletin.marquette.edu/arts-sciences/physics/biophysics-minor/>)
- Physics, BS (<https://bulletin.marquette.edu/arts-sciences/physics/physics-bs/>)
- Physics, Minor (<https://bulletin.marquette.edu/arts-sciences/physics/physics-minor/>)

PHYS 1001 General Physics 1 (4 credits)

Newton's laws, linear motion, circular and harmonic motion, fluids, heat, kinetic theory, wave motion and sound; includes lab.

Prerequisite: High school algebra, geometry, and trigonometry or equivalent.

Level of Study: Undergraduate

Last four terms offered: 2023 Summer Term, 2022 Fall Term, 2022 Summer Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201001>)

PHYS 1002 General Physics 2 (4 credits)

Continuation of PHYS 1001. Electrostatics, DC circuits, magnetism, electromagnetic induction, light, optical instruments, interference and diffraction of light, modern physics; includes lab.

Prerequisite: PHYS 1001.

Level of Study: Undergraduate

Last four terms offered: 2023 Summer Term, 2023 Spring Term, 2022 Summer Term, 2022 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201002>)

PHYS 1003 General Physics with Introductory Calculus 1 (4 credits)

Survey of classical physics for science and engineering majors. Kinematics in one and two dimensions. Newton's laws of motion and dynamics, including rotation of rigid bodies. Energy concepts in physical systems, harmonic motion and thermodynamics with applications. A command of high school algebra, geometry and trigonometry is assumed. Requires the use of introductory calculus. Students may receive credit for only one of PHYS 1003, 1003H, 1013, or 1013H. 3 hrs. lec., 2 hrs. lab., 1 hr. dis.

Prerequisite: MATH 1450, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Fall Term, 2022 Summer Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201003>)

PHYS 1003H Honors General Physics with Introductory Calculus 1 (4 credits)

Survey of classical physics for science majors and engineering majors. Kinematics in one and two dimensions. Newton's laws of motion and dynamics, including rotation of rigid bodies. Energy concepts in physical systems, harmonic motion and thermodynamics with applications. A command of high school algebra, geometry and trigonometry is assumed. Requires the use of introductory calculus. As an Honors Program course, includes a more intensive research or project component. Students may receive credit for only one of PHYS 1003, 1003H, 1013 or 1013H.

Prerequisite: MATH 1450, which may be taken concurrently; admission to Marquette University Honors Program.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201003H>)

PHYS 1004 General Physics with Introductory Calculus 2 (4 credits)

A continuation of PHYS 1003. A survey of classical electromagnetic theory, with an introduction to modern physics. Electricity and magnetism: Coulomb's law, the electric field and the electric potential, circuits, Ampere's law, Faraday's law, electromagnetic waves. Classical and quantum waves, interference, optics. Students may receive credit for only one of PHYS 1004, 1004H, 1014, or 1014H. 3 hrs. lec., 2 hrs. lab., 1 hr. dis.

Prerequisite: MATH 1450; PHYS 1001, PHYS 1003, PHYS 1003H, PHYS 1013, or PHYS 1013H; MATH 1451 or MATH 1455, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Summer Term, 2022 Spring Term, 2021 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201004>)

PHYS 1004H Honors General Physics with Introductory Calculus 2 (4 credits)

A continuation of PHYS 1003. A survey of classical electromagnetic theory, with an introduction to modern physics. Electricity and magnetism: Coulomb's law, the electric field and the electric potential, circuits, Ampere's law, Faraday's law, electromagnetic waves. Classical and quantum waves, interference, optics. As an Honors Program course, includes a more intensive research or project component. Students may receive credit for only one of PHYS 1004, 1004H, 1014 or 1014H.

Prerequisite: MATH 1450; PHYS 1001, PHYS 1003, PHYS 1003H, PHYS 1013 or PHYS 1013H; MATH 1451 or MATH 1455, which may be taken concurrently; admission to Marquette University Honors Program.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term, 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201004H>)

PHYS 1007 Survey of Meteorology (3 credits)

An introduction to the science of the atmosphere as it relates to the weather of the earth, including important environmental issues such as global warming and air pollution. Topics include: atmospheric gasses, heat transfer, causes of the seasons, humidity, clouds, atmospheric stability and motions, air masses, fronts, and pressure systems, thunderstorms, tornados, hurricanes and weather forecasting.

Level of Study: Undergraduate

Marquette Core Curriculum: NSM Expanding Our Horizons

Interdisciplinary Studies: Environmental Studies

Last four terms offered: 2021 Fall Term, 2019 Fall Term, 2018 Fall Term, 2017 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201007>)

PHYS 1008 Astronomy and Space Physics (3 credits)

Physics of the solar system, stars, galaxies and the universe. Experimental methods of observational astronomy, telescopes, and space probes. Special topics such as black holes, neutron stars and quasars are covered.

Level of Study: Undergraduate

Marquette Core Curriculum: NSM Expanding Our Horizons

Last four terms offered: 2023 Spring Term, 2022 Fall Term, 2022 Spring Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201008>)

PHYS 1009 Earth and Environmental Physics (3 credits)

Impact of human activities on the environment, especially the consumption of fossil fuels. Population distribution and growth. Energy balance of the earth. Energy, land and water use, the water cycle. Effects of chemical and physical pollutants on water and the atmosphere. Course designed for non-science majors.

Level of Study: Undergraduate

Marquette Core Curriculum: NSM Expanding Our Horizons

Interdisciplinary Studies: Environmental Ethics, Environmental Studies, Peace Studies

Last four terms offered: 2023 Spring Term, 2022 Fall Term, 2022 Spring Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201009>)

PHYS 1013 Classical and Modern Physics with Calculus 1 (4 credits)

A study of motion in its various forms, translational, rotational, and vibrational, that emphasizes their underlying unity, especially the central role of energy and its conservation, and their basis in the fundamental Newtonian laws of motion and Einstein's special relativity. These ideas are used to explain thermal processes. Command of high school algebra, geometry, trigonometry is assumed. Requires the use of introductory calculus. Students may receive credit for only one of PHYS 1003, 1003H, 1013, or 1013H. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz.

Prerequisite: MATH 1450, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201013>)

PHYS 1013H Honors Classical and Modern Physics with Calculus 1 (4 credits)

A study of motion in its various forms, translational, rotational, and vibrational, that emphasizes their underlying unity, especially the central role of energy and its conservation, and their basis in the fundamental Newtonian laws of motion and Einstein's special relativity. These ideas are used to explain thermal processes. Command of high school algebra, geometry, trigonometry is assumed. Requires the use of introductory calculus. As an Honors Program course, includes a more intensive research or project component. Students may receive credit for only one of PHYS 1003, 1003H, 1013 or 1013H. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz. Admission to Marquette University Honors Program.

Prerequisite: MATH 1450, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201013H>)

PHYS 1014 Classical and Modern Physics with Calculus 2 (4 credits)

Continuation of PHYS 1013. Examines the development of energy as a fundamental concept, includes a study of electric and magnetic phenomena and their unification in the theory of electromagnetism. Applications are made to waves, geometric and physical optics, atomic spectra, and nuclear decay and introductory quantum mechanics including wave function and bound systems. Students may receive credit for only one of PHYS 1004, 1004H, 1014, or 1014H. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz.

Prerequisite: MATH 1450; PHYS 1001, PHYS 1003 or PHYS 1013; MATH 1451 or MATH 1455, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term, 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201014>)

PHYS 1014H Honors Classical and Modern Physics with Calculus 2 (4 credits)

Continuation of PHYS 1013H. Examines the development of energy as a fundamental concept, includes a study of electric and magnetic phenomena and their unification in the theory of electromagnetism. Applications are made to waves, geometric and physical optics, atomic spectra, and nuclear decay and introductory quantum mechanics including wave function and bound systems. As an Honors Program course, includes a more intensive research or project component. Students may receive credit for only one of PHYS 1004, 1004H, 1014 or 1014H. 3 hrs. lec., 2 hrs. lab., 1 hr. quiz. Admission to Marquette University Honors Program.

Prerequisite: MATH 1450; PHYS 1001, PHYS 1003, PHYS 1003H, PHYS 1013 or PHYS 1013H; MATH 1451 or MATH 1455, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term, 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201014H>)

PHYS 1020 Physics Laboratory Only (1 credits)

Prerequisite: Cons. of dept. ch.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Fall Term, 2022 Spring Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201020>)

PHYS 1030 Physics Lecture Only (3 credits)

Prerequisite: Cons. of dept. ch.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Fall Term, 2022 Spring Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201030>)

PHYS 1953 Discovering Physics (1 credits)

An introduction to the department and the myriad career possibilities a degree in physics opens up to a student. This includes what the student groups do and why they're useful, what careers are available to physics majors, talks from faculty members about their research, tours of sites in industry that have internships available for physics students and attendance at department colloquia.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201953>)

PHYS 1954 Communicating Physics (1 credits)

An introduction to scientific literature and literature searches. Students read, present, discuss and write overviews about journal articles and special topics. These topics could include general interest, breaking research and science ethics articles. Requires attendance at the department colloquia.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term, 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%201954>)

PHYS 2400 The Microscopic World (3 credits)

A survey, including applications, of quantum mechanics including the 1-D Schrodinger equation, the hydrogen atom and angular momentum. Atoms and the forces between them, molecules, the states of matter, kinetic theory, perfect and imperfect gases. Statistical physics: classical statistics and the Boltzmann factor, quantum statistics.

Prerequisite: MATH 2440 or MATH 2450; PHYS 1002, PHYS 1004 or PHYS 1014; any of which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%202400>)

PHYS 2500 Oscillations and Waves with Laboratory (4 credits)

A comprehensive study of mechanical and electromagnetic oscillators and waves as understood with ordinary differential equations. Application includes the simple harmonic oscillator, driven/damped systems and coupled oscillators, scattering-interference/diffraction. Matrix methods, eigenvectors and eigenvalues, normal modes, complex variables, Fourier transformations.

Prerequisite: PHYS 1002 or PHYS 1004 or PHYS 1014; PHYS 2400; MATH 2451, which may be taken concurrently.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%202500>)

PHYS 2929 Applied Physics Bridge to Engineering (1 credits)

Taken concurrently with approved courses offered by the Opus College of Engineering. With permission, a student may take this course in lieu of the prerequisite for the paired Engineering course. Addresses missing prerequisite content.

Prerequisite: Cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2021 Spring Term, 2020 Spring Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%202929>)

PHYS 2953 Computational Methods in Physics (1 credits)

Introduces computational methods for simulating physical systems, solving problems, analyzing and presenting data, and performing error analysis arising in physics and related fields. No prior experience with computer programming required. Programs such as Matlab or Python are used to investigate problems. Computational methods taught are used in upper-division Physics courses.

Prerequisite: Concurrent enrollment in PHYS 2400, recommended.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%202953>)

PHYS 2954 Participating in Physics (1 credits)

Designed to prepare students to apply for Research Experiences for Undergraduates (REU's), summer positions, graduate schools, full-time career employment, Teaching Assistant and Research Assistant positions. Covers development of proposal, cover letter, research statement, curriculum vitae and resumes. Builds awareness of available resources.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%202954>)

PHYS 3021 Introduction to Theoretical Astrophysics (3 credits)

Introduction to astrophysical problems, with emphasis on underlying physical principles; includes the nature of stars, equations of state, stellar energy generations, stellar structure and evolution, astrophysical neutrinos, binary stars, white dwarfs, neutron stars and pulsars and novae and supernovae.

Prerequisite: PHYS 1004 or PHYS 1014; or PHYS 1002 and cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2020 Fall Term, 2018 Fall Term, 2016 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%203021>)

PHYS 3022 Introduction to Observational Astronomy (3 credits)

Nature of the Milky Way galaxy from an observer's perspective: stellar statistics and distributions, stellar populations, spiral structure, the nucleus and halo. Nature of ordinary galaxies, galaxies in our Local Group, structure of voids and superclusters. Nature of peculiar objects: Seyfert galaxies, starburst galaxies, and quasars. Elementary aspects of physical cosmology. Introduction to techniques used in modern optical and radio astronomy with emphasis on the physical and mathematical understanding of the detection of electromagnetic radiation.

Prerequisite: PHYS 2400 and PHYS 3021; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2021 Spring Term, 2019 Spring Term, 2017 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%203022>)

PHYS 3056 Contemporary Physics Lab 1 (2 credits)

Experiments in a variety of modern physics topics. Laboratory safety and methods, scientific writing and error analysis.

Prerequisite: PHYS 2500 or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%203056>)

PHYS 3100 Classical Mechanics (3 credits)

Three-dimensional motion of a particle in both Cartesian and spherical coordinate systems. Newtonian dynamics, central forces. Lagrange's and Hamilton's formulations of analytical mechanics, angular momentum, Kepler's problem and the dynamics of a rigid body.

Prerequisite: MATH 2451; PHYS 1002, PHYS 1004 or PHYS 1014; PHYS 2500, all of which may be taken concurrently; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%203100>)

PHYS 3989 Applied Physics Immersion Experience 1 (0 credits)

For students completing a pre-approved full-time internship or co-op comprising of at least 240 hours. Placement internship in research or industry in an applied physics setting. Internships must be approved in advance. Responsibilities include relevant academic content. Grading and credits are accomplished by registering for PHYS 4989 during the following term. Fee. SNC/UNC grade assessment.

Prerequisite: Cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2020 Fall Term, 2019 Summer Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%203989>)

PHYS 3990 Applied Physics Immersion Experience 2 (0 credits)

For students completing a pre-approved full-time internship or co-op comprising of at least 240 hours. Placement internship in research or industry in an applied physics setting. Internships must be approved in advance. Responsibilities include relevant academic content. Grading and credits are accomplished by registering for PHYS 4990 during the following term. Fee. SNC/UNC grade assessment.

Prerequisite: Cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2021 Summer Term, 2020 Fall Term, 2019 Summer Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%203990>)

PHYS 4012 Quantum Mechanics (3 credits)

Quantum states, state vectors, observables and operators. The formal structure of quantum mechanics. Time evolution of the state vector. The Hamiltonian. Position and momentum representations, and the wave function. One-dimensional wave mechanics and the harmonic oscillator. Three-dimensional wave mechanics. Symmetry, angular momentum, and the hydrogen atom. Fermions, and bosons. Perturbation methods.

Prerequisite: MATH 2451 and PHYS 2500; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204012>)

PHYS 4031 Electricity and Magnetism (3 credits)

Electrostatics: Coulomb's law and Gauss' law. The electric field in dielectric materials. Microscopic theory of Ohm's law and steady state currents. The magnetic field, Biot-Savart law, Ampere's law, the vector potential. Magnetic materials. Electromagnetic induction, Faraday's law. Maxwell's equations and electromagnetic waves.

Prerequisite: MATH 2440 or MATH 2450; PHYS 1002, PHYS 1004, PHYS 1004H, PHYS 1014, or PHYS 1014H; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term, 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204031>)

PHYS 4034 Modern Optics (3 credits)

Applications of Maxwell's Equations to vacuum and material propagation. Both long wavelength and short wavelength limits (physical and geometric optics) are analyzed along with cavity solutions (lasers) and wave guides (microwave propagation and fiber optics).

Prerequisite: PHYS 4031 or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204034>)

PHYS 4046 The Physical Basis of Biological Structure and Function (3 credits)

The molecular processes of life occur in a complex aqueous molecular environment. Biological molecules and their environments are governed by the principles of physics. Presents physical techniques and models based on mechanics, thermodynamics, and electricity and magnetism. Shows how they apply to help characterize and understand the environments in which cells and biological molecules operate, Explains cellular and physiological processes.

Prerequisite: MATH 1410, MATH 1451 or MATH 1455; CHEM 1002; PHYS 1002, PHYS 1004, PHYS 1004H, PHYS 1014, or PHYS 1014H; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2021 Fall Term, 2019 Fall Term, 2017 Fall Term, 2015 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204046>)

PHYS 4050 Introduction to Einstein's General Theory of Relativity (3 credits)

Explores Einstein's theory in which gravity is not a force, but a property built into the fabric of the universe – the curvature of four dimensional spacetime. Overview of special relativity including spacetime diagrams, four-vectors, and the relative nature of time and distance. Introduces tensor calculus, non-Euclidean geometry, geodesics and arbitrary coordinate systems. Analyzes the Schwarzschild spacetime, planetary motion and black holes. Studies Einstein's experimentally verified predictions including topics such as perturbations in Mercury's orbit, gravitational lensing and neutron star mergers. Special topics include gravitational waves and the large-scale evolving structure of the universe.

Prerequisite: MATH 2440 or MATH 2450; PHYS 1002, PHYS 1004, PHYS 1004H, PHYS 1014, or PHYS 1014H; or cons. of instr.

Level of Study: Undergraduate

Marquette Core Curriculum: NSM Expanding Our Horizons

Last four terms offered: 2022 Spring Term, 2019 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204050>)

PHYS 4057 Contemporary Physics Lab 2 (2 credits)

Further development of experimental techniques learned in PHYS 3056. Student-led development of projects.

Prerequisite: PHYS 3056 or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2010 Spring Term, 2006 Spring Term, 2005 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204057>)

PHYS 4062 Introduction to Thermodynamics (3 credits)

Fundamental concepts of thermodynamics: temperature, internal energy, entropy and thermodynamic potentials. Laws of thermodynamics, their consequences and applications. Introduction to statistical thermodynamics.

Prerequisite: MATH 2440 or MATH 2450; PHYS 2400; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Spring Term, 2020 Spring Term, 2018 Spring Term, 2016 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204062>)

PHYS 4065 Experimental Methods in Molecular Biophysics (3 credits)

An introduction to the field of biological physics which develops the science and illustrates the applications of the techniques of X-ray diffraction and spin resonance to problems of biological interest: protein structural dynamics, ion channels and transport through cell membranes.

Prerequisite: PHYS 2400 and PHYS 4031; or PHYS 4046; or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Spring Term, 2020 Spring Term, 2018 Spring Term, 2016 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204065>)

PHYS 4071 Atomic Physics (3 credits)

Quantum mechanics of one and many electron atoms. Spin, orbital, and total angular momentum. Atoms in electric and magnetic fields, the Stark effect and the Zeeman effect. Atomic transitions, symmetry and selection rules. The periodic table and shell structure. Modern spectroscopy. PHYS 4012 recommended.

Prerequisite: PHYS 2500 or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2018 Fall Term, 2016 Fall Term, 2012 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204071>)

PHYS 4072 Introduction to Nuclear and Elementary Particle Physics (3 credits)

Experimental methods in nuclear and particle physics. Theories of nuclear structure, radioactivity, decay schemes, fission and fusion models, conservation laws. Elementary particle classifications and the Standard Model.

Prerequisite: PHYS 4012.

Level of Study: Undergraduate

Last four terms offered: 2019 Fall Term, 2017 Fall Term, 2015 Fall Term, 2013 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204072>)

PHYS 4075 Introduction to Solid State Physics (3 credits)

Crystal structure of solids, the reciprocal lattice and diffraction. Lattice vibrations and thermal properties. Electrons in metals, band structure and semiconductors. The Fermi surface. Dielectric and magnetic properties of solids. Superconductivity.

Prerequisite: PHYS 2400 or cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2020 Fall Term, 2018 Fall Term, 2016 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204075>)

PHYS 4931 Topics in Contemporary Physics (3 credits)

Topics drawn from areas of current interest such as astrophysics, atmospheric physics, biophysics, condensed matter physics or particle physics.

Prerequisite: Cons. of dept. ch.

Level of Study: Undergraduate

Last four terms offered: 2017 Spring Term, 2016 Fall Term, 2016 Spring Term, 2010 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204931>)

PHYS 4953 Seminar in Physics (1 credits)

Critical analysis of the original works of scientists who have made significant contributions to Physics. May not be used as an upper division elective course for the physics major.

Prerequisite: Cons. of dept. ch.

Level of Study: Undergraduate

Last four terms offered: 2013 Spring Term, 2012 Spring Term, 2011 Spring Term, 2010 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204953>)

PHYS 4953H Honors Seminar in Physics (1 credits)

Critical analysis of the original works of scientists who have made significant contributions to Physics. As an Honors Program course, includes a more intensive research or project component. May be repeated. May not be used as an upper division elective course for the physics major.

Prerequisite: Admission to the PHYS Disciplinary Honors Program.

Level of Study: Undergraduate

Last four terms offered: 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204953H>)

PHYS 4954 Review and Preparation for Post-Graduate Life (1 credits)

Includes a review of fundamental topics in physics in order to prepare for the Physics GRE exam, focusing on practice GRE exams. Additionally, applications for graduate school and/or employment in physics are discussed.

Level of Study: Undergraduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204954>)

PHYS 4956 Undergraduate Research in Physics (1-3 credits)

Research project conducted under the direction of a faculty adviser.

Prerequisite: Cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term, 2022 Fall Term, 2022 Spring Term, 2021 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204956>)

PHYS 4956H Honors Undergraduate Research (1-3 credits)

Experimental or theoretical research in an area of contemporary physics under the guidance of a physics faculty member who has expertise in that area. Successful completion includes a summary paper and an oral presentation to the regular physics faculty. As an Honors Program course, includes a more intensive research or project component. May be repeated. May not be used as an upper division elective course for the physics major., Jr. stndg.; admission to the PHYS Disciplinary Honors Program.

Prerequisite: Cons. of instr.

Level of Study: Undergraduate

Last four terms offered: 2020 Spring Term, 2019 Fall Term, 2018 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204956H>)

PHYS 4989 Applied Physics Immersion Experience 1 - Grading Period (1 credits)

Full-time co-op or internship grading period. Grading for preceding co-op work assignment is accomplished by completing a report on the work assignment, a report on academic material related to the work assignment and other materials, as required. Grading is completed during the term following the work assignment. S/U grade assessment.

Prerequisite: PHYS 3989.

Level of Study: Undergraduate

Last four terms offered: 2021 Spring Term, 2019 Fall Term, 2018 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204989>)

PHYS 4990 Applied Physics Immersion Experience 2 - Grading Period (1 credits)

Full-time co-op or internship grading period. Grading for preceding co-op work assignment is accomplished by completing a report on the work assignment, a report on academic material related to the work assignment and other materials, as required. Grading is completed during the term following the work assignment. S/U grade assessment.

Prerequisite: PHYS 3990.

Level of Study: Undergraduate

Last four terms offered: 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204990>)

PHYS 4995 Independent Study in Physics (1-3 credits)

Faculty-supervised, independent study/research of a specific area or topic in Physics. May not be used as an upper division elective course for the physics major.

Prerequisite: Cons. of dept. ch.

Level of Study: Undergraduate

Last four terms offered: 2020 Spring Term, 2012 Spring Term, 2011 Spring Term, 2008 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204995>)

PHYS 4997 Physics Exploration Capstone (2 credits)

Students propose and develop an independent project incorporating material you learned in the physics curriculum. The project must include a measurement of a physical system, and a theoretical prediction of the results. The project chosen can be any system, subject to budgetary constraints, but should target physics beyond the introductory level. In addition to the project, a written report and an oral presentation are required.

Prerequisite: Sr. stndg.

Level of Study: Undergraduate

Last four terms offered: 2023 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204997>)

PHYS 4999 Senior Thesis (2 credits)

Independent research under the guidance of physics faculty. The topic may be chosen from any area of physics. Successful completion of the course includes a written thesis on the research and an oral presentation. May not be used as an upper division elective course for the physics major.; cons. of a regular physics faculty member.

Prerequisite: Sr. stndg. and cons. of dept. ch.

Level of Study: Undergraduate

Last four terms offered: 2017 Fall Term, 2015 Fall Term, 2014 Fall Term, 2013 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%204999>)

PHYS 5012 Quantum Mechanics (3 credits)

Quantum states, state vectors, observables and operators. The formal structure of quantum mechanics. Time evolution of the state vector. The Hamiltonian. Position and momentum representations, and the wave function. One-dimensional wave mechanics and the harmonic oscillator. Three-dimensional wave mechanics. Symmetry, angular momentum, and the hydrogen atom. Fermions, and bosons. Perturbation methods.

Level of Study: Graduate

Last four terms offered: 2022 Fall Term, 2021 Fall Term, 2020 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205012>)

PHYS 5031 Electricity and Magnetism (3 credits)

Electrostatics: Coulomb's law and Gauss' law. The electric field in dielectric materials. Microscopic theory of Ohm's law and steady state currents. The magnetic field, Biot-Savart law, Ampere's law, the vector potential. Magnetic materials. Electromagnetic induction, Faraday's law. Maxwell's equations and electromagnetic waves.

Level of Study: Graduate

Last four terms offered: 2023 Spring Term, 2022 Spring Term, 2021 Spring Term, 2020 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205031>)

PHYS 5034 Modern Optics (3 credits)

Applications of Maxwell's Equations to vacuum and material propagation. Both long wavelength and short wavelength limits (physical and geometric optics) are analyzed along with cavity solutions (lasers) and wave guides (microwave propagation and fiber optics).

Level of Study: Graduate

Last four terms offered: 2022 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205034>)

PHYS 5046 The Physical Basis of Biological Structure and Function (3 credits)

The molecular processes of life occur in a complex aqueous molecular environment. Biological molecules and their environments are governed by the principles of physics. Presents physical techniques and models based on mechanics, thermodynamics, and electricity and magnetism. Shows how they apply to help characterize and understand the environments in which cells and biological molecules operate, Explains cellular and physiological processes.

Level of Study: Graduate

Last four terms offered: 2021 Fall Term, 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205046>)

PHYS 5050 Introduction to Einstein's General Theory of Relativity (3 credits)

Explores Einstein's theory in which gravity is not a force, but a property built into the fabric of the universe – the curvature of four dimensional spacetime. Overview of special relativity including spacetime diagrams, four-vectors, and the relative nature of time and distance. Introduces tensor calculus, non-Euclidean geometry, geodesics and arbitrary coordinate systems. Analyzes the Schwarzschild spacetime, planetary motion and black holes. Studies Einstein's experimentally verified predictions including topics such as perturbations in Mercury's orbit, gravitational lensing and neutron star mergers. Special topics include gravitational waves and the large-scale evolving structure of the universe.

Level of Study: Graduate

Last four terms offered: 2022 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205050>)

PHYS 5062 Introduction to Thermodynamics (3 credits)

Fundamental concepts of thermodynamics: temperature, internal energy, entropy and thermodynamic potentials. Laws of thermodynamics, their consequences and applications. Introduction to statistical thermodynamics.

Level of Study: Graduate

Last four terms offered: 2022 Spring Term, 2020 Spring Term, 2012 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205062>)

PHYS 5065 Experimental Methods in Molecular Biophysics (3 credits)

An introduction to the field of biological physics which develops the science and illustrates the applications of the techniques of X-ray diffraction and spin resonance to problems of biological interest: protein structural dynamics, ion channels and transport through cell membranes.

Level of Study: Graduate

Last four terms offered: 2022 Spring Term, 2020 Spring Term, 2012 Spring Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205065>)

PHYS 5071 Atomic Physics (3 credits)

Quantum mechanics of one and many electron atoms. Spin, orbital, and total angular momentum. Atoms in electric and magnetic fields, the Stark effect and the Zeeman effect. Atomic transitions, symmetry and selection rules. The periodic table and shell structure. Modern spectroscopy.

Level of Study: Graduate

Last four terms offered: 2023 Spring Term, 2021 Spring Term, 2018 Fall Term, 2010 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205071>)

PHYS 5072 Introduction to Nuclear and Elementary Particle Physics (3 credits)

Experimental methods in nuclear and particle physics. Theories of nuclear structure, radioactivity, decay schemes, fission and fusion models, conservation laws. Elementary particle classifications and the Standard Model.

Level of Study: Graduate

Last four terms offered: 2019 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205072>)

PHYS 5075 Introduction to Solid State Physics (3 credits)

Crystal structure of solids, the reciprocal lattice and diffraction. Lattice vibrations and thermal properties. Electrons in metals, band structure and semiconductors. The Fermi surface. Dielectric and magnetic properties of solids. Superconductivity.

Level of Study: Graduate

Last four terms offered: 2022 Fall Term, 2020 Fall Term, 2018 Fall Term

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205075>)

PHYS 5931 Topics in Contemporary Physics (3 credits)

Topics drawn from areas of current interest, such as: astrophysics, atmospheric physics, condensed matter physics or particle physics.

Level of Study: Graduate

Schedule of Classes (<https://bulletin.marquette.edu/class-search/?details&code=PHYS%205931>)