

PHYSICS (PHYS)

PHYS 50. First-Year Seminar: Time and the Medieval Cosmos. 3 Credits.

This course introduces first-year students to the basic motions of the solar system as viewed from the Earth along with the mechanical and mathematical models used to reproduce them, while exploring the history of medieval and early modern education, theology, and natural philosophy.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.

Making Connections Gen Ed: HS.

Grading Status: Letter grade.

Same as: HIST 50.

PHYS 51. First-Year Seminar: The Interplay of Music and Physics. 3 Credits.

How sound is produced in instruments, and how those sounds are used in music making. Wave motion, resonance, sound perception, scales, harmony, and music theory. Collaborative laboratory exercises to investigate the acoustics of string, woodwind, and brass instruments as well as study of the physics of keyboard and percussion instruments. Students will make instruments from found objects and perform compositions on them, and can pursue their areas of special interest in a research paper.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR, FC-AESTH or FC-NATSCI.

Making Connections Gen Ed: PL.

Grading Status: Letter grade.

Same as: MUSC 51.

PHYS 52. First-Year Seminar: Making the Right Connections. 3 Credits.

This seminar investigates the multiple roles that computers and microprocessors perform in scientific investigations and the impact of technological advances on society. Students perform experiments, take field trips to research laboratories, and gain hands-on experience with computer-based instrumentation.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.

Making Connections Gen Ed: PX.

Grading Status: Letter grade.

PHYS 53. First-Year Seminar: Handcrafting in the Nanoworld: Building Models and Manipulating Molecules. 3 Credits.

This seminar provides a general introduction to nanoscience and nanotechnology, focusing on recent advances in molecular electronics, nanomaterials, and biomedical research. Course activities include group model-building projects, presentations, and discussions of reading material.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.

Making Connections Gen Ed: PL.

Grading Status: Letter grade.

PHYS 54. First-Year Seminar: Physics of Movies. 3 Credits.

Students watch and analyze short movie clips that demonstrate interesting, unusual, or impossible physics. Group analysis emphasized.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.


Making Connections Gen Ed: PL.

Grading Status: Letter grade.

PHYS 55. First-Year Seminar: Introduction to Mechatronics. 4 Credits.

Introduction to important skills and knowledge required in the STEM fields of today and tomorrow, from academic, employment, and social perspectives. All students, regardless of their educational goals, will achieve critical introductory skills in numerical reasoning and analysis, engineering design and prototyping, computer programming and electronics, and will demonstrate proficiency and knowledge about topics that increasingly impact society, including Artificial Intelligence, Machine Learning, and Quantum Computing.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR, FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX, QI.

Grading Status: Letter grade.

PHYS 61. First-Year Seminar: The Copernican Revolution. 3 Credits.

This seminar explores the 2,000-year effort to understand the motion of the sun, moon, stars, and five visible planets. Earth-centered cosmos gives way to the conclusion that earth is just another body in space. Cultural changes accompany this revolution in thinking.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.

Making Connections Gen Ed: PL, NA, WB.

Grading Status: Letter grade.

Same as: ASTR 61.

PHYS 63. First-Year Seminar: Catastrophe and Chaos: Unpredictable Physics. 3 Credits.

Physics is often seen as the most precise and deterministic of sciences. Determinism can break down, however. This seminar explores the rich and diverse areas of modern physics in which "unpredictability" is the norm. Honors version available.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.

Making Connections Gen Ed: PL, QI.

Grading Status: Letter grade.

Same as: ASTR 63.

PHYS 89. First-Year Seminar: Special Topics. 3 Credits.

Special Topics course. Content will vary each semester.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-SEMINAR.

Grading Status: Letter grade.

PHYS 100. How Things Work. 4 Credits.

Demystifying the working of objects such as CD players, microwave ovens, lasers, computers, roller coasters, rockets, light bulbs, automobiles, clocks, copy machines, X-ray and CAT-scan machines, and nuclear reactors.

Rules & Requirements

IDEAs in Action Gen Ed: FC-CREATE or FC-NATSCI, FC-LAB.

Making Connections Gen Ed: PX.

Grading Status: Letter grade.

PHYS 101. Basic Concepts of Physics. 4 Credits.

This is an introductory physics course for non-science majors. This course focuses on basic physics concepts and connections to everyday life. Course topics include Newtonian mechanics, fluids, heat, vibrations, electricity and magnetism, light and sound, quantum phenomenon, nuclear radiation, relativity, and cosmology. Connections to everyday life and society include energy conservation, global warming, nuclear energy, the origin of the universe, pseudoscience, and the search for extraterrestrial life.

Rules & Requirements

IDEAs in Action Gen Ed: FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX.

Grading Status: Letter grade.

PHYS 102. General Physics Lecture I. 3 Credits.

Lecture portion of 104, awarded as AP credit.

Rules & Requirements

Making Connections Gen Ed: PX, QI.

Grading Status: Letter grade.

PHYS 103. General Physics Lecture II. 3 Credits.

Lecture portion of 105, awarded as AP credit.

Rules & Requirements

Making Connections Gen Ed: PX, QI.

Grading Status: Letter grade.

PHYS 106. Inquiry into the Physical World. 4 Credits.

This course uses a hands-on/minds-on or "inquiry" approach to learning the basic concepts of physical science. Topics will include the properties of matter, electricity and magnetism, kinematics, and waves. An emphasis will be placed on examining the nature of science, your own learning, and the way in which scientists learn science.

Rules & Requirements

IDEAs in Action Gen Ed: FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX.

Grading Status: Letter grade.

PHYS 108. Climate and Energy Transitions: Understanding the Forecasts. 4 Credits.

This course examines uncertainties in projecting future fossil fuel consumption and impact on global climate by quantifying how effectively alternative power-generation and energy-storage technologies can scale to meet needs in developing and developed nations, and by understanding past and present climates. Course previously offered as GEOL 108/MASC 108.

Rules & Requirements

Making Connections Gen Ed: PX, GL.

Grading Status: Letter grade.

Same as: EMES 108.

PHYS 114. General Physics I: For Students of the Life Sciences. 4 Credits.

Basic principles of physics, including forces, energy, oscillations, sound, diffusion, and heat transfer, and applications to biological systems. Intended to meet the needs of, but not restricted to, students majoring in the life sciences. Students may not receive credit for PHYS 114 in addition to PHYS 104, 116, or 118.

Rules & Requirements

IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX, QI.

Requisites: Prerequisite, MATH 129P or 130 or 231.

Grading Status: Letter grade.

PHYS 115. General Physics II: For Students of the Life Sciences. 4 Credits.

Basic principles of physics, including fluids, electricity, magnetism, optics, quantum physics, and nuclear physics, and applications to biological systems. Intended to meet the needs of, but not restricted to, students majoring in the life sciences. Students may not receive credit for PHYS 115 in addition to PHYS 105, 117, or 119.

Rules & Requirements

IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX, QI.

Requisites: Prerequisite, PHYS 104, 114, 116, or 118.

Grading Status: Letter grade.

PHYS 118. Introductory Calculus-based Mechanics and Relativity. 4 Credits.

Mechanics of particles and rigid bodies. Newton's laws; mechanical and potential energy; mechanical conservation laws; frame-dependence of physical laws; Einstein's Theory of Relativity. Students may not receive credit for PHYS 118 in addition to PHYS 104, 114, or 116. Honors version available.


Rules & Requirements

IDEAs in Action Gen Ed: FY-LAUNCH (only designated sections), FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX, QI.

Requisites: Prerequisite, MATH 231; Pre- or corequisite, MATH 232; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

 **PHYS 119. Introductory Calculus-based Electromagnetism and Quanta. 4 Credits.**

Unification of the laws of electricity and magnetism; electromagnetic waves; the particle-wave duality; fundamental principles and applications of quantum mechanics. Students may not receive credit for PHYS 119 in addition to PHYS 105, 115, or 117. Honors version available.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FY-LAUNCH (only designated sections), FC-NATSCI or FC-QUANT, FC-LAB.

Making Connections Gen Ed: PX, QI.

Requisites: Prerequisite, PHYS 118 or PHYS 118H; Pre- or corequisite, MATH 233; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 128. Modern Physics. 3 Credits.

Special relativity theory, black body radiation, photons and electrons; wave particle duality. Elements of atomic theory, nuclei and fundamental particles. Three lecture hours a week.

Rules & Requirements

Requisites: Prerequisite, PHYS 117 (or PHYS 105 by permission of the instructor); co-requisite, PHYS 128L.

Grading Status: Letter grade.

PHYS 128L. Modern Physics Laboratory. 1 Credits.

Selected modern physics experiments. Written research reports and oral presentations. Three laboratory hours a week.

Rules & Requirements

Requisites: Pre- or corequisite, PHYS 128.

Grading Status: Letter grade.

PHYS 131. Energy: Physical Principles and the Quest for Alternatives to Dwindling Oil and Gas. 3 Credits.

A quantitative exploration of the physical principles behind energy development and use within modern civilization, the stark impact of depleted fossil fuel reserves, and alternative sources.

Rules & Requirements

Making Connections Gen Ed: PX, QI.

Requisites: Corequisite, PHYS 131L.

Grading Status: Letter grade.

PHYS 131L. Energy: Physical Principles and the Quest for Alternatives to Dwindling Oil and Gas. 1 Credits.

Explore renewable and nonrenewable energy sources. Three laboratory hours per week.

Rules & Requirements

Requisites: Corequisite, PHYS 131.

Grading Status: Letter grade.

PHYS 132. Science and Society. 3 Credits.

A description of the scientific community and how scientists relate to such sociotechnical issues as the space program, the arms race, the energy problem, computer technology, medical technology, and pseudosciences.

Rules & Requirements

Grading Status: Letter grade.

PHYS 133. How Bio Works. 3 Credits.

Physics of biology and biotechnology. Life as an assembly of molecular machines that manipulate DNA, replicate cells, propel bacteria, and contract muscles. Nanotechnology for DNA biotechnology and microscale fluid chips.

Rules & Requirements

Making Connections Gen Ed: PL.

Grading Status: Letter grade.

PHYS 201. Basic Mechanics. 3 Credits.

A one-semester course in statics, kinematics, simple harmonic motion, central forces, and applications from modern physics.

Rules & Requirements

Requisites: Pre- or corequisites, MATH 383 and PHYS 281L; permission of the instructor for students lacking the pre- or co-requisites.

Grading Status: Letter grade.

PHYS 211. Intermediate Electromagnetism. 3 Credits.

Electric fields and potentials, dielectrics, steady currents, magnetic flux and magnetic materials, electromagnetic induction. Emphasis on Maxwell's equations and their application to electromagnetic waves in bounded and unbounded media.

Rules & Requirements


Requisites: Prerequisites, MATH 233 and one of PHYS 105, 115, 117, 119.

Grading Status: Letter grade.

 **PHYS 231. Physical Computing. 4 Credits.**

Physical Computing is an introduction to the interaction between a computing unit and the outside world, using measurement and control. The tools for this implementation of physical computing are microcontrollers, software, sensors, a variety of analog and digital electronic components, and algorithms that anticipate and respond in ways that humans perceive as NOT inherently computerized. Honors version available.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FC-CREATE or FC-QUANT, FC-LAB, RESEARCH.

Requisites: Pre- or corequisite, PHYS 114 or 118; permission of the instructor for students lacking the pre- or corequisite.

Grading Status: Letter grade.

 **PHYS 281L. Experimental Techniques in Physics. 3 Credits.**

An introductory course centered around 8 lab experiments that include Compton scattering, interferometry, e/m, and photoelectric effect. Students use data analysis tools including MATLAB or Python, uncertainty analysis based on the GUM, and LaTeX for written reports. In this communication-intensive course, students collaborate like physicists through written and oral communication and peer review exercises aimed at general, peer, and expert audiences. They also engage with themes of diversity, equity, and inclusion in the field.

Rules & Requirements

 **IDEAs in Action Gen Ed:** FC-NATSCI, FC-LAB, COMMBEYOND.

Making Connections Gen Ed: CI.

Requisites: Prerequisite, PHYS 117 or 119; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 295. Research with Faculty Mentor I. 1-12 Credits.

Students undertake independent research with a faculty mentor. Approved learning contract required.

Rules & Requirements

IDEAs in Action Gen Ed: RESEARCH.

Making Connections Gen Ed: EE- Mentored Research.

Repeat Rules: May be repeated for credit. 12 total credits. 12 total completions.

Grading Status: Letter grade.

PHYS 311. Electromagnetism I. 3 Credits.

First semester of a two-semester sequence on electromagnetic theory and applications. This first semester is focused on electrostatic fields and potentials, magnetic fields and potentials, dielectrics, and magnetic fields in matter.

Rules & Requirements

Requisites: Prerequisites, PHYS 331 and one of PHYS 117 or 119; permission of the instructor for students lacking the requisite.

Grading Status: Letter grade.

PHYS 313. Space and Time in Physics and Philosophy. 3 Credits.

Contingent and necessary properties of space and time. The direction and flow of time. Fatalism. Effects preceding their causes.

Rules & Requirements

Grading Status: Letter grade.

PHYS 331. Numerical Techniques for the Sciences I. 4 Credits.

Applications of calculus, vector analysis, differential equations, complex numbers, and computer programming to realistic physical systems. Three lecture and two computational laboratory hours per week.

Rules & Requirements

Requisites: Prerequisite, PHYS 104, 114, 116, or 118; pre- or corequisite, MATH 383.

Grading Status: Letter grade.

PHYS 332. Numerical Techniques for the Sciences II. 4 Credits.

Modeling of celestial dynamics, nuclear physics problems, electrostatics; Monte Carlo integration in particle and theoretical physics; data modeling for physics and astronomy; gravitation, electromagnetism, fluid dynamics and quantum mechanics. Three lecture and two computational laboratory hours per week. Previously offered as PHYS 358.

Rules & Requirements

Requisites: Prerequisite, PHYS 331.

Grading Status: Letter grade.

PHYS 351. Electronics I. 4 Credits.

DC and AC circuit analysis. Diodes, transistor amplifiers, analog devices, and signal conditioning. Boolean logic and digital logic circuits. Extensive practice designing and debugging circuits.

Rules & Requirements

Requisites: Prerequisite, PHYS 105, 115, 117, or 119; permission of the instructor for students lacking the prerequisites; Pre- or corequisites, MATH 383 and PHYS 331.

Grading Status: Letter grade.

PHYS 352. Electronics II. 4 Credits.

Introduction to digital circuits: gates, flip-flops, and counters. Computers and device interconnections, converters and data acquisition. Signal analysis and digital filters. Graphical (LabVIEW) programming and computer interfacing. Individual projects and practical applications.

Rules & Requirements

Requisites: Prerequisite, PHYS 351; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 354. Quantum Mechanics, Weirdness, and Reality. 3 Credits.

An interdisciplinary course on the weirdness of quantum mechanics and the problem of interpreting it. Nonlocality, the measurement problem, superpositions, Bohm's theory, collapse theories, and the many-worlds interpretation.

Rules & Requirements

Making Connections Gen Ed: PH.

Requisites: Prerequisites, MATH 231 and any PHYS course numbered 100 or greater; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

Same as: PHIL 354.

PHYS 391. Senior Seminar. 1-15 Credits.

To be taken by seniors with permission of the department.

Rules & Requirements

Grading Status: Letter grade.

PHYS 395. Research with Faculty Mentor II. 1-12 Credits.

Students undertake independent research with a faculty mentor. Approved learning contract required. A research proposal and/or summary research report is required. Although not mandatory, a submission of a research proposal to an internal or external competition for funding is encouraged. Students must also present their research at an appropriate symposium, conference, or seminar.

Rules & Requirements

IDEAs in Action Gen Ed: RESEARCH.

Making Connections Gen Ed: CI, EE- Mentored Research.

Requisites: Prerequisite, PHYS 281L.

Repeat Rules: May be repeated for credit. 12 total credits. 12 total completions.

Grading Status: Letter grade.

PHYS 401. Mechanics I. 3 Credits.

Particle kinematics, central forces, planetary motions. Systems of particles, conservation laws, nonlinearity. Statics, motion of rigid bodies. Lagrange's and Hamilton's equations. Euler's equations. Vibrations and waves.

Rules & Requirements

Requisites: Pre- or corequisites, MATH 383 and PHYS 281L and 331; permission of the instructor for students lacking the requisites.

Grading Status: Letter grade.

PHYS 405. Biological Physics. 3 Credits.

How diffusion, entropy, electrostatics, and hydrophobicity generate order and force in biology. Topics include DNA manipulation, intracellular transport, cell division, molecular motors, single molecule biophysics techniques, nerve impulses, neuroscience.

Rules & Requirements

Requisites: Prerequisites, PHYS 116 and 117, or PHYS 118 and 119.

Grading Status: Letter grade.

Same as: BIOL 431, BMME 435.

 **PHYS 410. Teaching and Learning Physics. 4 Credits.**

Learning how to teach physics using current research-based methods. Includes extensive fieldwork in high school environments.

Rules & Requirements

 **IDEAs in Action Gen Ed:** HI-LEARNTA.

Making Connections Gen Ed: EE- Field Work.

Requisites: Prerequisite, PHYS 117 or 119; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 412. Electromagnetism II. 3 Credits.

Electrodynamics: Maxwell's equations and their application to electromagnetic waves, radiation, and relativity.

Rules & Requirements

Requisites: Prerequisites, PHYS 281L, 311 and 332; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 421. Introduction to Quantum Mechanics. 3 Credits.

Origins of quantum theory. Uncertainty principle. Schrödinger equation for simple systems including the hydrogen atom. Spin. Identical particles. Previously offered as PHYS 321.

Rules & Requirements

Requisites: Prerequisites, MATH 383, either MATH 347 or PHYS 331, and one of PHYS 117, or 119; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 422. Physics of the Earth's Interior. 3 Credits.

Origin of the solar system: the nebular hypothesis. Evolution of the earth and its accretionary history. Earthquakes: plate tectonics and the interior of the earth. The earth's magnetic field. Mantle convection.

Rules & Requirements

Requisites: Prerequisites, MATH 383, and either PHYS 201 and 211 or 311 and 401.

Grading Status: Letter grade.

Same as: EMES 422.

PHYS 441. Thermal Physics. 3 Credits.

Equilibrium statistical mechanics; the laws of thermodynamics, internal energy, enthalpy, entropy, thermodynamic potentials, Maxwell's relations.

Rules & Requirements

Requisites: Prerequisites, MATH 233, and PHYS 117 or 119; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

Same as: BMME 441.

PHYS 447. Quantum Computing. 3 Credits.

Recommended preparation, some knowledge of basic linear algebra. An introduction to quantum computing. Basic math and quantum mechanics necessary to understand the operation of quantum bits. Quantum gates, circuits, and algorithms, including Shor's algorithm for factoring and Grover's search algorithm. Entanglement and error correction. Quantum encryption, annealing, and simulation. Brief discussion of technologies.

Rules & Requirements

Requisites: Prerequisites, MATH 232, and PHYS 116 or 118.

Grading Status: Letter grade.

Same as: COMP 447.

PHYS 461. Introduction to Medical Physics. 3 Credits.

This class will introduce how physics principles and techniques have been applied to medical imaging and radiation therapy. Topics will include ionizing radiation and radiation safety, x-ray and computed tomography, ultrasound, magnetic resonance imaging, positron emission tomography, and radiation therapy. Topics such as the career path to become a medical physicist will also be discussed. The class will have lectures given by the instructor and guest lectures by experts and practitioners in this field.

Rules & Requirements

Requisites: Prerequisite, PHYS 117 or 119.

Grading Status: Letter grade.

PHYS 471. Physics of Solid State Electronic Devices. 3 Credits.

Properties of crystal lattices, electrons in energy bands, behavior of majority and minority charge carriers, PN junctions related to the structure and function of semiconductor diodes, transistors, display devices.

Rules & Requirements

Requisites: Prerequisite, PHYS 117 or 119; pre- or corequisite, PHYS 211 or 311.

Grading Status: Letter grade.

PHYS 472. Chemistry and Physics of Electronic Materials Processing. 3 Credits.

Permission of the instructor. A survey of materials processing and characterization used in fabricating microelectronic devices. Crystal growth, thin film deposition and etching, and microlithography.

Rules & Requirements

Requisites: Prerequisite, CHEM 482 or PHYS 117 or 119.

Grading Status: Letter grade.

Same as: APPL 472, CHEM 472.

 **PHYS 481L. Advanced Laboratory I. 2 Credits.**

Selected physical problems to be addressed with the use of materials development, device fabrication and experiment design for evaluation.

Rules & Requirements

 **IDEAs in Action Gen Ed:** RESEARCH, COMMBEYOND.

Requisites: Prerequisites, PHYS 281L, and PHYS 351 or 352; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 491L. Materials Laboratory I. 2 Credits.

Structure determination and measurement of the optical, electrical, and magnetic properties of solids.

Rules & Requirements

Requisites: Prerequisites, APPL 470 and PHYS 351.

Grading Status: Letter grade.

Same as: APPL 491L.

PHYS 492L. Materials Laboratory II. 2 Credits.

Continuation of PHYS 491L with emphasis on low- and high-temperature behavior, the physical and chemical behavior of lattice imperfections and amorphous materials, and the nature of radiation damage.

Rules & Requirements

Requisites: Prerequisite, APPL 491L or PHYS 491L.

Grading Status: Letter grade.

Same as: APPL 492L.

PHYS 510. Seminar for Physics and Astronomy Teaching Assistants. 1 Credits.

A seminar on how students learn and understand physics and astronomy and how to teach using current research-based methods.

Rules & Requirements

Grading Status: Letter grade.

PHYS 510L. Practicum for Physics and Astronomy Undergraduate Teaching and Learning Assistants. 1 Credits.

This course is designed to accompany, or subsequently follow, the Seminar for New Physics and Astronomy Teaching and Learning Assistants (Phys 510) and is for undergraduates serving as Undergraduate Teaching Assistants (UTAs) for the Physics and Astronomy Department. UTAs who receive course credit cannot also be paid.

Rules & Requirements

Requisites: Pre- or corequisite, PHYS 510.

Repeat Rules: May be repeated for credit. 6 total credits. 6 total completions.

Grading Status: Pass/Fail.

PHYS 515. Optics. 3 Credits.

Broad coverage including ray, wave, Gaussian, and Fourier optics. Interference, diffraction, polarization, and coherence. Optical properties of materials, absorption, scattering. Fiber optics, lasers, semiconductors, imaging, and special topics. Previously offered as PHYS 415.

Rules & Requirements

Requisites: Prerequisites, PHYS 311 and 412; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 521. Applications of Quantum Mechanics. 3 Credits.

Emphasizes atomic physics but includes topics from nuclear, solid state, and particle physics, such as energy levels, the periodic system, selection rules, and fundamentals of spectroscopy.

Rules & Requirements

Requisites: Prerequisite, PHYS 421.

Grading Status: Letter grade.

PHYS 529. Introduction to Magnetic Resonance. 3 Credits.

This course will provide a broad coverage of important physics principles behind nuclear magnetic resonance (NMR) spectroscopy, especially the applications of quantum mechanics. Theoretical approaches and tools for grasping the design principles of various important NMR spectroscopic techniques will be discussed. It will show, for instance, how to use NMR spectroscopy to determine molecular structures and dynamics, and how to obtain images and functional information using magnetic resonance imaging (MRI).

Rules & Requirements

Requisites: Prerequisite, PHYS 421 or CHEM 486; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 543. Nuclear Physics. 3 Credits.

Structure of nucleons and nuclei, nuclear models, forces and interactions, nuclear reactions.

Rules & Requirements

Requisites: Prerequisite, PHYS 421; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 545. Introductory Elementary Particle Physics. 3 Credits.

Relativistic kinematics, symmetries and conservation laws, elementary particles and bound states, gauge theories, quantum electrodynamics, chromodynamics, electroweak unification, standard model and beyond.

Rules & Requirements

Requisites: Prerequisites, PHYS 412 and 421.

Grading Status: Letter grade.

PHYS 573. Introductory Solid State Physics. 3 Credits.

Crystal symmetry, types of crystalline solids; electron and mechanical waves in crystals, electrical and magnetic properties of solids, semiconductors; low temperature phenomena; imperfections in nearly perfect crystals.

Rules & Requirements

Requisites: Prerequisite, PHYS 421; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

Same as: APPL 573.

PHYS 581. Renewable Electric Power Systems. 3 Credits.

Broad and quantitative study of renewable electric power systems: wind systems, photovoltaic cells, distributed generation (concentrating solar power, microhydro, biomass), and the economics of these technologies.

Rules & Requirements

Requisites: Prerequisites, BIOL 101L, and 202 or 271; and PHYS 131, and 131L or 281L, and 201 or 401, and 211 or 311, and 351; pre- or corequisites, CHEM 261 and 481.

Grading Status: Letter grade.

PHYS 582. Decarbonizing Fuels. 3 Credits.

Assess quantitatively the feasibility of powering humanity without increasing release of climate-altering carbon dioxide and other organic greenhouse gases into the atmosphere. Can these gases be removed? Which bio-chemical-physical novelties may scale to meet growing demand and at what cost?

Rules & Requirements

Requisites: Prerequisites, BIOL 101L, and 202 or 271; and PHYS 131, and 131L or 281L, and 201 or 401, and 211 or 311, and 351; pre- or corequisites, CHEM 261 and 481.

Grading Status: Letter grade.

PHYS 585. Imaging Science: From Cells to Stars. 3 Credits.

Fundamentals of imaging as applied to biological, medical and astronomy imaging systems. Physics of radiation and particle sources, image formation and detection physics. Principles of optics, coherence, Fourier methods, statistics, especially as they cross disciplinary boundaries for new opportunities in imaging.

Rules & Requirements

Requisites: Prerequisites, MATH 233 and PHYS 118.

Grading Status: Letter grade.

PHYS 586. Introduction to Biomedical Imaging Science. 3 Credits.

This course offers an introduction to the most common biomedical imaging modalities, including Magnetic Resonance Imaging (MRI), Computed-Tomography (CT), Positron Emission Tomography (PET), Single-Photon Emission Computed Tomography (SPECT), Ultrasound, and Optical Imaging. Lectures include discussions of imaging hardware, and relevant physics, as well as pre-clinical and clinical applications.

Rules & Requirements

Requisites: Prerequisite, PHYS 119.

Grading Status: Letter grade.

PHYS 594. Nonlinear Dynamics. 3 Credits.

Interdisciplinary introduction to nonlinear dynamics and chaos. Fixed points, bifurcations, strange attractors, with applications to physics, biology, chemistry, finance.

Rules & Requirements

Requisites: Prerequisite, MATH 383; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

Same as: MATH 594.

PHYS 631. Mathematical Methods of Theoretical Physics. 3 Credits.

Linear vector spaces and matrices, curvilinear coordinates, functions of complex variables, ordinary and partial differential equations, Fourier series, integral transforms, special functions, differential forms.

Rules & Requirements

Requisites: Prerequisites, PHYS 281L and 332.

Grading Status: Letter grade.

PHYS 632. Advanced Research Analytics. 3 Credits.

Required preparation, ability to program in a high-level computer language. Permission of the instructor for students lacking the required preparation. Methods required for the analysis, interpretation, and evaluation of physics measurements and theory. Error analysis, statistical tests, model fitting, parameter estimation, Monte Carlo methods, Bayesian inference, noise mitigation, experimental design, big data, selected numerical techniques including differential equations and Fourier techniques.

Rules & Requirements

Grading Status: Letter grade.

PHYS 633. Scientific Programming. 3 Credits.

Required preparation, elementary Fortran, C, or Pascal programming. Structured programming in Fortran or Pascal; use of secondary storage and program packages; numerical methods for advanced problems, error propagation and computational efficiency; symbolic mathematics by computer.

Rules & Requirements

Requisites: Prerequisite, MATH 528 or 529, or PHYS 631 or 632.

Grading Status: Letter grade.

PHYS 660. Fluid Dynamics. 3 Credits.

The physical properties of fluids, kinematics, governing equations, viscous incompressible flow, vorticity dynamics, boundary layers, irrotational incompressible flow. Course previously offered as GEOL 560/ MASC 560.

Rules & Requirements

Requisites: Prerequisite, PHYS 401; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

Same as: EMES 560, ENVR 452.

PHYS 671L. Independent Laboratory I. 3 Credits.

Six laboratory hours a week.

Rules & Requirements

Requisites: Prerequisites, PHYS 401 and 412; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

PHYS 672L. Independent Laboratory II. 3 Credits.

Six laboratory hours a week.

Rules & Requirements

Requisites: Prerequisites, PHYS 401 and 412; permission of the instructor for students lacking the prerequisites.

Grading Status: Letter grade.

 **PHYS 691H. Senior Honor Thesis Research I. 3 Credits.**

Permission of the instructor. Readings in physics and directed research for a senior honor thesis project. Required of all candidates for graduation with honors in physics.

Rules & Requirements

 **IDEAs in Action Gen Ed: RESEARCH.**

Making Connections Gen Ed: EE- Mentored Research.

Grading Status: Letter grade.

PHYS 692H. Senior Honor Thesis Research II. 3 Credits.

Readings in physics and directed research for a senior honor thesis project. Required of all candidates for graduation with honors in physics.

Rules & Requirements

IDEAs in Action Gen Ed: RESEARCH.

Making Connections Gen Ed: EE- Mentored Research.

Requisites: Prerequisite, PHYS 691H.

Grading Status: Letter grade.

PHYS 701. Classical Dynamics. 3 Credits.

Variational principles, Lagrangian and Hamiltonian mechanics. Symmetries and conservation laws. Two-body problems, perturbations, and small oscillations, rigid-body motion. Relation of classical to quantum mechanics.

Rules & Requirements

Requisites: Prerequisite, advanced undergraduate mechanics.

Grading Status: Letter grade.

PHYS 711. Electromagnetic Theory I. 3 Credits.

Electrostatics, magnetostatics, time-varying fields, Maxwell's equations.

Rules & Requirements

Requisites: Prerequisites, PHYS 631 and 632.

Grading Status: Letter grade.

PHYS 712. Electromagnetic Theory. 3 Credits.

Maxwell's equations, time-varying fields, and conservation laws. Plane EM waves, polarization, propagation, dispersive media. Wave guides and resonant cavities. Radiation from slow-moving charges. Special theory of relativity. Radiation from relativistic charges. Interaction between radiation and matter.

Rules & Requirements

Grading Status: Letter grade.

PHYS 715. Visualization in the Sciences. 3 Credits.

Computational visualization applied in the natural sciences. For both computer science and natural science students. Available techniques and their characteristics, based on human perception, using software visualization toolkits. Project course.

Rules & Requirements

Grading Status: Letter grade.

Same as: COMP 715, MTSC 715.

PHYS 721. Quantum Mechanics. 3 Credits.

Review of nonrelativistic quantum mechanics. Spin, angular momentum, perturbation theory, scattering, identical particles, Hartree-Fock method, Dirac equation, radiation theory.

Rules & Requirements

Requisites: Prerequisite, PHYS 421.

Grading Status: Letter grade.

PHYS 722. Quantum Mechanics. 3 Credits.

Review of nonrelativistic quantum mechanics. Spin, angular momentum, perturbation theory, scattering, identical particles, Hartree-Fock method, Dirac equation, radiation theory.

Rules & Requirements

Requisites: Prerequisite, PHYS 421.

Grading Status: Letter grade.

PHYS 741. Statistical Mechanics. 3 Credits.

Classical and quantal statistical mechanics, ensembles, partition functions, ideal Fermi and Bose gases.

Rules & Requirements

Requisites: Prerequisites, PHYS 701 and 721.

Grading Status: Letter grade.

PHYS 771L. Advanced Spectroscopic Techniques. 3 Credits.

Advanced spectroscopic techniques, including Rutherford backscattering-channeling, perturbed angular correlation, Raman scattering, electron paramagnetic resonance, nuclear magnetic resonance, optical absorption, and Hall effect. Two hours of lecture and three hours of laboratory a week.

Rules & Requirements

Requisites: Prerequisite, PHYS 401 or 412; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 772L. Advanced Spectroscopic Techniques. 3 Credits.

Advanced spectroscopic techniques, including Rutherford backscattering-channeling, perturbed angular correlation, Raman scattering, electron paramagnetic resonance, nuclear magnetic resonance, optical absorption and Hall effect. One hour of lecture and five hours of laboratory a week.

Rules & Requirements

Requisites: Prerequisite, PHYS 401 or 412; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 780. Advanced Materials Science. 3 Credits.

This course covers the physical fundamentals of material science with an in-depth discussion of structure formation in soft and hard materials and how structure determines material mechanical, electrical, thermal, and optical properties. Topics include amorphous and crystal structures, defects, dislocation theory, thermodynamics and phase diagrams, diffusion, interfaces and microstructures, solidification, and theory of phase transformation. Special emphasis will be on the structure-property relationships of (bio)polymers, (nano)composites, and their structure property relationships.

Rules & Requirements

Grading Status: Letter grade.

Same as: MTSC 780, BMME 780, CHEM 780.

PHYS 821. Advanced Quantum Mechanics. 3 Credits.

Advanced angular momentum, atomic and molecular theory, many-body theory, quantum field theory.

Rules & Requirements

Requisites: Prerequisite, PHYS 722.

Grading Status: Letter grade.

PHYS 822. Field Theory. 3 Credits.

Quantum field theory, path integrals, gauge invariance, renormalization group, Higgs mechanism, electroweak theory, quantum chromodynamics, Standard Model, unified field theories.

Rules & Requirements

Requisites: Prerequisite, PHYS 722.

Grading Status: Letter grade.

PHYS 823. Field Theory. 3 Credits.

Quantum field theory, path integrals, gauge invariance, renormalization group, Higgs mechanism, electroweak theory, quantum chromodynamics, Standard Model, unified field theories.

Rules & Requirements

Requisites: Prerequisite, PHYS 722.

Grading Status: Letter grade.

PHYS 824. Group Theory and its Applications. 3 Credits.

Required preparation, knowledge of matrices, mechanics, and quantum mechanics. Discrete and continuous groups. Representation theory. Application to atomic, molecular, solid state, nuclear, and particle physics.

Rules & Requirements

Grading Status: Letter grade.

PHYS 829. Principles of Magnetic Resonance. 3 Credits.**Rules & Requirements**

Requisites: Prerequisite, CHEM 781 or PHYS 721; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 831. Differential Geometry in Modern Physics. 3 Credits.

Applications to electrodynamics, general relativity, and nonabelian gauge theories of methods of differential geometry, including tensors, spinors, differential forms, connections and curvature, covariant exterior derivatives, and Lie derivatives.

Rules & Requirements

Requisites: Prerequisites, PHYS 701, 711, and 712.

Grading Status: Letter grade.

PHYS 832. General Theory of Relativity. 3 Credits.

Differential geometry of space-time. Tensor fields and forms. Curvature, geodesics. Einstein's gravitational field equations. Tests of Einstein's theory. Applications to astrophysics and cosmology.

Rules & Requirements

Requisites: Prerequisite, PHYS 831; permission of the instructor for students lacking the prerequisite.

Grading Status: Letter grade.

PHYS 861. Nuclear Physics. 3 Credits.

Nuclear reactions, scattering, nuclear structure, nuclear astrophysics.

Rules & Requirements

Requisites: Prerequisites, PHYS 543 and 721.

Grading Status: Letter grade.

PHYS 862. Nuclear Physics. 3 Credits.

Overview of Standard Model of particle physics. Fundamental symmetries and weak interactions. Neutrino physics. Particle-astrophysics and cosmology.

Rules & Requirements

Requisites: Prerequisites, PHYS 543 and 721.

Grading Status: Letter grade.

PHYS 871. Solid State Physics. 3 Credits.

Topics considered include those of PHYS 573, but at a more advanced level, and in addition a detailed discussion of the interaction of waves (electromagnetic, elastic, and electron waves) with periodic structures, e.g., X-ray diffraction, phonons, band theory of metals and semiconductors.

Rules & Requirements

Requisites: Prerequisite, PHYS 421; equivalent experience for students lacking the prerequisite.

Grading Status: Letter grade.

Same as: MTSC 871.

PHYS 872. Solid State Physics II. 3 Credits.

Topics considered include quantum and thermal fluctuations, and thermodynamics of phase transitions in a broad variety of condensed matter systems, their kinetic theory and hydrodynamics, novel materials (two-dimensional electron gas, graphene, topological insulators and superconductors, Dirac/Weyl/nodal line semimetals), condensed matter applications of modern field-theoretical methods (path integral, renormalization group, holography).

Rules & Requirements

Requisites: Prerequisite, PHYS 871.

Grading Status: Letter grade.

Same as: MTSC 872.

PHYS 873. Theory of the Solid State. 3 Credits.

Calculation of one-electron energy band structure. Electron-hole correlation effect and excitons. Theory of spin waves. Many-body techniques in solid state problems including theory of superconductivity.

Rules & Requirements

Requisites: Prerequisite, PHYS 722.

Grading Status: Letter grade.

PHYS 883. Current Advances in Physics. 3 Credits.

Permission of the instructor. In recent years, elementary particle physics, amorphous solids, neutrinos, and electron microscopy have been among the topics discussed.

Rules & Requirements

Grading Status: Letter grade.

PHYS 885. Introductory Graduate Seminar in Physics and Astronomy. 1 Credits.

Introduction to skills needed for success in graduate courses and research, including practice using general-purpose mathematical/computational tools, assessment of the research landscape and research project design, preparing a proposal, and participating in peer review. Professional development topics such as ethics and etiquette, time management, and career planning are also covered.

Rules & Requirements

Grading Status: Letter grade.

PHYS 893. Seminar in Solid State Physics. 1-21 Credits.

Research topics in condensed-matter physics, with emphasis on current experimental and theoretical studies.

Rules & Requirements

Grading Status: Letter grade.

PHYS 895. Seminar in Nuclear Physics. 1-21 Credits.

Current research topics in low-energy nuclear physics, especially as related to the interests of the Triangle Universities Nuclear Laboratory.

Rules & Requirements

Grading Status: Letter grade.

PHYS 896. Seminar in Particle Physics. 1-21 Credits.

Symmetries, gauge theories, asymptotic freedom, unified theories of weak and electromagnetic interactions, and recent developments in field theory.

Rules & Requirements

Grading Status: Letter grade.

PHYS 897. Seminar in Theoretical Physics. 1-21 Credits.

Topics from current theoretical research including, but not restricted to, field theory, particle physics, gravitation, and relativity.

Rules & Requirements

Grading Status: Letter grade.

PHYS 899. Seminar in Professional Practice. 1-21 Credits.

Required preparation, Ph.D. written exam passed. The role and responsibilities of a physicist in the industrial or corporate environment and as a consultant.

Rules & Requirements

Grading Status: Letter grade.

PHYS 901. Research. 1-21 Credits.

10 or more laboratory or computation hours a week.

Rules & Requirements

Grading Status: Letter grade.

PHYS 992. Master's (Non-Thesis). 3 Credits.

Rules & Requirements

Repeat Rules: May be repeated for credit.

PHYS 993. Master's Research and Thesis. 3 Credits.

Rules & Requirements

Repeat Rules: May be repeated for credit.

PHYS 994. Doctoral Research and Dissertation. 3 Credits.

Fall or spring. Staff.

Rules & Requirements

Repeat Rules: May be repeated for credit.