DEPARTMENT OF PHYSICS AND ASTRONOMY

Introduction

Everything around you is influenced or governed by physics. Physics seeks to understand the fundamental workings of the universe, from the smallest particles like neutrinos to the vast structure of the cosmos. It unveils the underlying principles governing the world around us and serves as the cornerstone of all natural sciences, including chemistry, biology, oceanography, and geography.

The Department of Physics and Astronomy offers a range of degree tracks tailored to various interests and career paths:

- B.A. Tracks
  - Physics
  - Astronomy
  - Computational Physics
  - Energy
  - Engineering Physics
  - Medical and Biological Physics
  - Quantitative Finance
- B.S. Tracks
  - Physics
  - Astrophysics

These tracks align with diverse employment opportunities (https://www.aps.org/careers/physicists/prospects.cfm) for physics graduates, spanning high schools, government laboratories, financial institutions, medical facilities, data science, and high-tech industries.

Upon graduation, approximately 50 percent of physics bachelors transition directly into the workforce, while others pursue advanced degrees in physics, medical physics, business, law, or computer science.

Opt for a B.A. degree if you seek to blend your passion for physics with complementary disciplines such as computer science, environmental science, biophysics, medicine, engineering, or finance.

Consider a B.S. degree if you intend to pursue graduate study in physics, astronomy, or a related field, or a career practicing physics.

Advising

All majors and minors have a primary academic advisor from the Academic Advising Program (https://advising.unc.edu/). Students are encouraged to meet regularly with their advisor and review their Tar Heel Tracker each semester. The department's director of undergraduate studies and faculty advisors work with current and prospective majors by appointment (see contact information above). Faculty advisors are assigned to all physics majors and minors, and they assist students in a variety of physics related areas, including physics course planning, undergraduate research opportunities, the honors program, internships, career opportunities, and graduate school and fellowship applications. Physics majors are required to meet with their departmental advisor by appointment prior to registering for any semester beyond the fourth term in residence. Further information may be obtained from the department's website under the Undergraduate Program (http://physics.unc.edu/undergraduate-program/).

Graduate School and Career Opportunities

Employers know that physicists understand how to think and reason effectively about the world, which equips them to solve unconventional challenging problems. Over 90 percent of physics majors do something other than teach or conduct research at a university. Physics will prepare you to pursue anything from medicine to energy to business. The American Institute of Physics' Career Resources (http://aip.org/career-resources/) site and our Department site (https://physics.unc.edu/career-info/) provides useful information about the different career paths of physics bachelor's degree recipients, including who is hiring them (https://www.aip.org/statistics/multiple/).

Common job titles for our physics bachelor's degree recipients include:

- Applications Engineer
- Data Analyst
- Analyst
- Data Scientist
- Staff Engineer
- System Engineer
- Software Engineer
- Design Engineer
- High School Physics Teacher
- IT Consultant
- Lab Technician
- Research Associate
- Systems Analyst
- IT Analyst

Those who are considering going on to graduate school in physics, astronomy, and other physical science and engineering fields, should contact one of the physics advisors. Those who plan careers in health sciences, including dentistry, medicine, and veterinary medicine, should consult advisors in the Health Professions Advising Office in Hanes Hall.

Majors

- Physics Major, B.A (https://catalog.unc.edu/undergraduate/programs-study/physics-major-ba/).
  - Physics
  - Astronomy
  - Computational Physics
  - Energy
  - Engineering Physics
  - Medical and Biological Physics
  - Quantitative Finance
- Physics Major, B.S. (https://catalog.unc.edu/undergraduate/programs-study/physics-major-bs/)
  - Physics
  - Astrophysics

Minors

- Astronomy Minor (https://catalog.unc.edu/undergraduate/programs-study/astronomy-minor/)
- Physics Minor (https://catalog.unc.edu/undergraduate/programs-study/physics-minor/)

Graduate Programs

- M.S. in Physics (https://catalog.unc.edu/graduate/schools-departments/physics-astronomy/)
- Ph.D. in Physics (https://catalog.unc.edu/graduate/schools-departments/physics-astronomy/)

Professors

Rosa Tamara Branca, James Christopher Clemens, Louise A. Dolan, Joaquin Emiliano Drut, Jonathan H. Engel, Adrienne Lynn Erickcek, Charles R. Evans, Fabian Heitsch, Reyco Henning, Christian G. Iliadis, Robert Victor Janssens, Dmitri V. Khveshchenko, Nicholas M. Law, Rene Lopez, Jianping Lu, Laurie E. McNeil, Laura Mersini-Houghton, Amy Lynn Oldenburg, Lu-Chang Qin, Daniel E. Reichart, Frank Tsui, John Franklin Wilkerson, Yue Wu, Otto Z. Zhou.

Associate Professors

Akaa Daniel Ayangeakaa, Andrew W. Mann, Amy Nicole Nicholson.

Assistant Professors

Gökçe Başar, Julieta Gruszko, Carl Louis Rodriguez, Wei Zhang.

Research Professor

Arthur E. Champagne.

Research Assistant Professor

Christina Redmon Inscoe.

Teaching Professor

Duane L. Deardorff.

Teaching Associate Professors

Stefan Jeglinski, Colin Wallace, Jennifer Weinberg-Wolf.

Teaching Assistant Professor

Muxin Zhang.

Adjunct Professors

Gerald N. Cecil, Steven Mark Christensen, Michael R. Falvo, Brand Fortner, Yosuke Kanai, Alfred Kleinhammes, Enrique Platin, David Clarke Radford, John Michael Shull, Gregory Clayton Sloan, Rachel Lofsky Smith, Jie Tang.

Adjunct Associate Professors

Brad Barlow, Alice Churukian, David Hill, Yueh Lee, Thomas Osburn.

Professors Emeriti

Charles V. Briscoe, Bruce Carney, Gerald N. Cecil, Wayne Christiansen, Thomas Clegg, Kian S. Dy, John P. Hernandez, Sheila Kannappan, Hugon J. Karwowski, J. Ross Macdonald, Yee Jack Ng, Nalin Parikh, James A. Rose, William J. Thompson, Sean Washburn.

ASTR–Astronomy

Undergraduate-level Courses

ASTR 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: PHYS 63.

ASTR 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.

ASTR 100L. Astronomy with Skynet: Our Place in Space. 1 Credits.
Students will use UNC's global network of "Skynet" telescopes to observe planets, moons, and other solar-system objects, star-forming regions and clusters, supernova remnants, and galaxies. Through these observations and others, we will reach a better understanding of our place in the universe, and resolve common misconceptions. Topics include: seasons, the Galilean revolution, the cosmic distance ladder, the Great Debate of 1920, dark matter in our galaxy, Hubble's law, dark energy. Previously offered as ASTR 101L.

Rules & Requirements

IDEAs in Action Gen Ed: FC-LAB.
Requisites: Pre- or corequisite, ASTR 100, 101, 102, or 103.
Grading Status: Letter grade.

ASTR 100. Understanding the Universe. 3 Credits.
Learn how astronomers study and understand the cosmos. Topics include motions of the Sun, Moon, and planets; planetary surfaces, interiors, and atmospheres; telescopes and spectroscopy; prospects for detecting and visiting life elsewhere; how stars are born, age, and die; black holes, dark matter, and gravitational radiation; the Milky Way Galaxy and galaxies beyond; the birth and fate of the expanding Universe. Optional laboratory: ASTR 100L. Optional field experience: ASTR 111.

Rules & Requirements

IDEAs in Action Gen Ed: FC-NATSCI or FC-QUANT.
Making Connections Gen Ed: PX.
Grading Status: Letter grade.

ASTR 101. Introduction to Astronomy: The Solar System. 3 Credits.
Celestial motions of the earth, sun, moon, and planets; nature of light; ground and space-based telescopes; comparative planetology; the earth and the moon; terrestrial and gas planets and their moons; dwarf planets, asteroids, and comets; planetary system formation; extrasolar planets; the search for extraterrestrial intelligence (SETI). Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FC-NATSCI or FC-QUANT.
Making Connections Gen Ed: PX.
Grading Status: Letter grade.

ASTR 102. Introduction to Astronomy: Stars, Galaxies & Cosmology. 3 Credits.
The sun, stellar observables, star birth, evolution, and death, novae and supernovae, white dwarfs, neutron stars, black holes, the Milky Way galaxy, normal galaxies, active galaxies and quasars, dark matter, dark energy, cosmology, early universe. Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FC-NATSCI or FC-QUANT.
Making Connections Gen Ed: PL.
Requisites: Prerequisite, ASTR 101; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

ASTR 103. Alien Life in the Universe. 3 Credits.
Humans have always wondered "are we alone?" From discovering life in extreme conditions on Earth, to finding thousands of exoplanets, we now know far more about this question than our ancestors. This class explores our recent understanding of planets, solar systems, where life might be, and how to find it. Optional laboratory: ASTR 100L. Optional field experience: ASTR 111.

Rules & Requirements

IDEAs in Action Gen Ed: FC-NATSCI or FC-QUANT.
Making Connections Gen Ed: PX.
Grading Status: Letter grade.

ASTR 105. Time, Tides, and the Measurement of the Cosmos. 3 Credits.
This course is focused on medieval foundations of modern cosmology and is designed to take advantage of the opportunities available for enriched learning in England. The course is problem-based, e.g. How did people reckon calendars, time, and tides, both for navigation and daily life, before clocks and the printed word? Honors version available.

Rules & Requirements

IDEAs in Action Gen Ed: FC-KNOWING or FC-PAST.
Making Connections Gen Ed: PL, WB.
Grading Status: Letter grade.

ASTR 110. Astrophotography of the Multi-Wavelength Universe. 3 Credits.
Students will use UNC's global network of Skynet telescopes to make color images of the moon, planets, star clusters, star-forming regions, star-death regions, and galaxies. They will also use Skynet's radio telescopes to explore the invisible universe, including pulsars, supernova remnants, and supermassive black holes. Astrophotography will be our entry point to deeper explorations of the solar system; star birth, evolution, and death; galaxy formation and evolution; and black holes and Einstein's theory of relativity.

Rules & Requirements

IDEAs in Action Gen Ed: FC-CREATE or FC-NATSCI.
Making Connections Gen Ed: PL.
Requisites: Prerequisite, Any ASTR or PHYS course, or permission of the instructor.
Grading Status: Letter grade.

ASTR 111. Educational Research in Radio Astronomy. 1-3 Credits.
One-week field experience at Green Bank Observatory in West Virginia. Students observe the invisible universe using manually controlled and fully automated radio telescopes, and carry out a variety of observing projects. These target the sun, moon, Jupiter, star-forming regions, supernova remnants, pulsars, the Milky Way and Andromeda galaxies, and more distant, active galaxies and quasars. Students receive training in radio astronomy, attend research and specialty talks, and tour the observatory. Formerly offered as ASTR 111L. Permission of the instructor.

Rules & Requirements

IDEAs in Action Gen Ed: HI-INTERN.
Making Connections Gen Ed: EE- Field Work.
Grading Status: Letter grade.

ASTR 202. Introduction to Astrophysics. 3 Credits.
This introductory astrophysics course will focus on the use of classical mechanics, gravitational physics, and the physics of radiation to interpret and explain astronomical observations. Course covers stellar structure, stellar formation and evolution, galaxies, and cosmology with an emphasis on quantitative problem solving.

Rules & Requirements
Requisites: Pre- or corequisite, PHYS 119.
Grading Status: Letter grade.

ASTR 205. The Medieval Foundations of Modern Cosmology. 3 Credits.
This course will examine science as it emerged and developed in the West starting in the 13th century. We will use example problems from cosmology that are relevant today.

Rules & Requirements

IDEAs in Action Gen Ed: FC-KNOWING or FC-PAST.
Making Connections Gen Ed: PL, WB.
Grading Status: Letter grade.

ASTR 301. Stars, Galaxies, and Cosmology. 1 Credits.
Stellar observables; galaxies; novae; cosmology; the early universe. This one-credit course can be taken with ASTR 102 for students who wish to major or minor in astrophysics.

Rules & Requirements
Requisites: Pre- or corequisites, ASTR 102, and PHYS 117 or 119; Permission of the instructor for students lacking the prerequisites.
Grading Status: Letter grade.

ASTR 390. Research and Special Topics for Juniors and Seniors. 1-12 Credits.
Permission of the instructor. To be taken by honors candidates and other qualified juniors and seniors.

Rules & Requirements
Making Connections Gen Ed: QI.
Repeat Rules: May be repeated for credit. 12 total credits. 4 total completions.
Grading Status: Letter grade.

Advanced Undergraduate and Graduate-level Courses

ASTR 501. Stellar Astrophysics. 3 Credits.
An introduction to the study of stellar structure and evolution. Topics covered include observational techniques, stellar structure and energy transport, nuclear energy sources, evolution off the main-sequence, and supernovae.

Rules & Requirements
Requisites: Prerequisites, ASTR 202 or ASTR 301, MATH 383, and PHYS 331; permission of the instructor for students lacking the prerequisites.
Grading Status: Letter grade.

ASTR 502. Modern Research in Astrophysics. 3 Credits.
A capstone research experience introducing modern data-analysis techniques for large astronomical surveys. Students undertake guided research projects with a different theme each semester. The course focuses on real astrophysical discovery of new objects, events and phenomena.

Rules & Requirements
IDEAs in Action Gen Ed: FC-CREATE, RESEARCH.
Making Connections Gen Ed: EE- Mentored Research.
Requisites: Prerequisite, ASTR 202.
Grading Status: Letter grade.

ASTR 503. Structure and Evolution of Galaxies. 3 Credits.
Overview of the structure and evolution of galaxies, with emphasis on learning and applying modern research methods such as scientific literature review and computational astrostatistics. Includes galaxy morphology and dynamics, star formation, active galactic nuclei, galaxy interactions, large-scale clustering, environment-dependent physical processes, and the evolution of the galaxy population over cosmic time.

Rules & Requirements
Requisites: Prerequisites, ASTR 202 or ASTR 301, MATH 383, and PHYS 331.
Grading Status: Letter grade.

ASTR 504. Cosmology. 3 Credits.
An introduction to modern cosmology: the study of the contents and evolution of the universe. Covers expanding spacetime, the thermal history of the early universe, including nucleosynthesis and the cosmic microwave background, the inflationary model for the origins of cosmic structure, and the growth of that structure through time.

Rules & Requirements
Requisites: Prerequisites, ASTR 202 or ASTR 301, and PHYS 401; pre- or corequisite, PHYS 421.
Grading Status: Letter grade.

ASTR 505. Physics of Interstellar Gas. 3 Credits.
Surveys the physical processes governing the interstellar medium (ISM), which takes up the "refuse" of old stars while providing fuel for young stars forming. Covers the processes regulating the galactic gas budget and the corresponding observational diagnostics. Topics: radiative transfer, line formation mechanisms, continuum radiation, gas dynamics, star formation.

Rules & Requirements
Requisites: Prerequisites, ASTR 202 or ASTR 301, and PHYS 331.
Grading Status: Letter grade.

ASTR 511. Atomic and Radiative Processes in Astrophysics. 3 Credits.
This course covers key topics in electromagnetism, radiative transport, and thermal and statistical mechanics in the context of astrophysics, such as stellar and planetary interiors and atmospheres, stellar evolution (including star formation and death), stellar populations, and the early universe.

Rules & Requirements
Requisites: Prerequisite, ASTR 202; Pre- or corequisite, PHYS 412.
Grading Status: Letter grade.

ASTR 512. Astrophysical Dynamics. 3 Credits.
This course provides a broad overview of astrophysical principles underlying stellar and planetary dynamics; N-body dynamics of star clusters, galaxies, and dark matter; fluid dynamics of astrophysical plasmas; and dynamics of the Universe and spacetime.

Rules & Requirements
Requisites: Prerequisites, ASTR 202 and PHYS 201 or PHYS 401.
Grading Status: Letter grade.

ASTR 519. Observational Astronomy. 4 Credits.
An introduction to modern techniques in observational astronomy with an emphasis on optical and near-infrared wavelengths. Topics covered include practical python for astronomy, telescopes and CCDs, spectroscopy, astrostatistics, and mining large astronomical surveys. Three lecture and three laboratory hours a week.

Rules & Requirements
IDEAs in Action Gen Ed: RESEARCH.
Requisites: Prerequisite, ASTR 102 or 202; Pre- or corequisite, PHYS 331; permission of the instructor for students lacking the prerequisite.
Grading Status: Letter grade.

PHYS–Physics

Undergraduate-level Courses

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 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 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 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 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 PHYS 117 or 119; Pre- or corequisite, MATH 383.
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 290. Special Topics in Physics. 1-3 Credits.
Elective topics in the field of Physics. This course has variable content and may be taken multiple times for credit.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 6 total completions.
Grading Status: Letter grade.

PHYS 293. Internship In Physics and Astronomy. 3 Credits.
The sponsored, off-campus work must involve at least 140 hours. Does not fulfill any requirement in the physics major or minor. Physics majors only. Permission of instructor/department.

Rules & Requirements
IDEAs in Action Gen Ed: HI-INTERN.
Requisites: Pre- or corequisite, PHYS 331.
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. Mentored research courses (PHYS 295 or PHYS 395) may be used to satisfy degree requirements only for a maximum of 3 credit hours.

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 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 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 381. 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. Course previously offered as PHYS 581.

Rules & Requirements
Requisites: Prerequisites, PHYS 119 or PHYS 115 and MATH 233.
Grading Status: Letter grade.

PHYS 390. Special Topics in Physics and Astronomy. 1-3 Credits.
Elective topics in the field of Physics and Astronomy. This course has variable content and may be taken multiple times for credit.

Rules & Requirements
Repeat Rules: May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 6 total completions.
Grading Status: Letter grade.

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. Mentored research courses (295 or 395) may be used to satisfy degree requirements only for a maximum of 3 credit hours.

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.

Advanced Undergraduate and Graduate-level Courses

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 451. Electronics I. 4 Credits.
DC and AC circuit analysis and design, construction, test, and measurements. Semiconductors physics and semiconductor devices (diodes and transistors). Signal conditioning and introduction to digital electronics and automated data acquisition and analysis. Previously offered as PHYS 351.

Rules & Requirements
Requisites: Prerequisite, PHYS 115 or 119; Pre- or corequisites, MATH 383 and PHYS 331; permission of the instructor for students lacking the prerequisites.
Grading Status: Letter grade.

PHYS 452. 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. Course previously offered as PHYS 352.

Rules & Requirements
Requisites: Prerequisites, PHYS 451 or BMME 207 and BMME 365; permission of the instructor for students lacking the prerequisites.
Grading Status: Letter grade.

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: Prerequisites, PHYS 119 or PHYS 115 and MATH 233.
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.
A survey of materials processing and characterization used in fabricating microelectronic devices. Crystal growth, thin film deposition and etching, and microlithography. Previously offered as APPL 472. Permission of the instructor.

Rules & Requirements
Requisites: Prerequisite, CHEM 482 or PHYS 117 or 119.
Grading Status: Letter grade.
Same as: 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. Previously offered as APPL 491L.

Rules & Requirements
Requisites: Prerequisites, APPL 470 and PHYS 351.
Grading Status: Letter grade.

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. Previously offered as APPL 492L.

Rules & Requirements
Requisites: Prerequisite, APPL 491L or PHYS 491L.
Grading Status: Letter grade.

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
IDEAs in Action Gen Ed: HI-LEARNTA.
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
IDEAs in Action Gen Ed: HI-LEARNTA.
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: Prerequisite, PHYS 211 or PHYS 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. Previously offered as APPL 573.

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

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