

# DEPARTMENT OF PHYSICS AND ASTRONOMY

## Contact Information

### Department of Physics and Astronomy

Visit Program Website (<http://physics.unc.edu>)

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## Introduction

The goal of physics and astronomy is a unified description of the properties of matter and energy. The study of matter and energy encompasses a range of phenomena, from the subnuclear to the cosmological. Physics seeks to understand the way the universe “works,” from the very small scale (quarks and neutrinos) to the human scale (materials encountered in daily life) to the very large (the structure of the cosmos). Different approaches and technologies are used in these different regimes.

The areas of active research at UNC–Chapel Hill can be divided into nuclear physics and nuclear astrophysics, condensed matter and materials physics, field and particle physics, astronomy and astrophysics, and biophysics. Often the separation between subfields is not as distinct as it appears. For example, nuclear and particle physics are used to address questions in astrophysics. As scientists have learned more about the universe, they have realized that even the boundaries between the sciences have blurred. Today, physics shares interests with biology, chemistry, and computer science. Physicists are also responsible for the invention of much of our modern technology, including computers, lasers, medical imaging devices such as MRI and ultrasound, nuclear reactors, and the World Wide Web.

Physics has played a significant role in shaping modern society and culture, and some knowledge of physics is essential to fully appreciate the world. As the frontiers of physics and astronomy have advanced, old questions have been answered or refined, new questions have been asked, and major surprises have been encountered. The joy of doing

physics is “to see a world in a grain of sand and a heaven in a wild flower, hold infinity in the palm of your hand and eternity in an hour” (William Blake).

## Advising

All majors and minors have a primary academic advisor in Steele Building. 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 Web site 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 and 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 provides useful information about the careers of physics bachelor’s degree recipients, including who is hiring them in North Carolina.

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 are considering marine sciences as a graduate specialty should consult the material under the Department of Marine Sciences. 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. Those interested in science teaching can take the educational coursework required for a high school science teaching license through the UNC Baccalaureate Education in Science and Teaching (UNC–BEST (<http://unc.edu/uncbest>)) program.

### Majors

- Physics Major, B.A. (<http://catalog.unc.edu/undergraduate/programs-study/physics-major-ba>)
- Physics Major, B.S. (<http://catalog.unc.edu/undergraduate/programs-study/physics-major-bs>)

### Minors

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

### Graduate Programs

- M.S. in Physics (<http://catalog.unc.edu/graduate/schools-departments/physics-astronomy>)

- Ph.D. in Physics (<http://catalog.unc.edu/graduate/schools-departments/physics-astronomy>)

## Professors

Gerald N. Cecil, Arthur E. Champagne, James Christopher Clemens, Louise A. Dolan, Jonathan H. Engel, Charles R. Evans, Reyco Henning, Christian G. Iliadis, Robert Victor Janssens, Dmitri V. Khveshchenko, Rene Lopez, Jianping Lu, Laurie E. McNeil, Yee Jack Ng, Lu-Chang Qin, Dan Reichart, Frank Tsui, Sean Washburn, John Wilkerson, Yue Wu, Otto Zhou.

## Associate Professors

Fabian Heitsch, Sheila Kannappan, Laura Mersini-Houghton, Amy Lynn Oldenburg.

## Assistant Professors

Rosa Tamara Branca, Joaquin Emiliano Drut, Adrienne Lynn Erickcek, Nicholas M. Law, Amy Nicole Nicholson.

## Research Professors

Michael Falvo, Alfred Kleinhammes.

## Research Associate Professors

David B. Hill, Edward Timothy O'Brien III.

## Teaching Associate Professors

Alice D. Churukian, Duane L. Deardorff.

## Teaching Assistant Professors

Stefan Jeglinski, Colin Wallace, Jennifer R. Weinberg-Wolf, Daniel Edward Young.

## Lecturer

Ted Gwyn Oakley.

## Adjunct Professors

Steven Mark Christensen, Brand Fortner, Richard T. Hammond, David Clarke Radford, Ryan M. Rohm, Gregory Clayton Sloan, Rachel Lofsky Smith, Jie Tang.

## Adjunct Assistant Professor

Thomas Osburn.

## Professors Emeriti

Charles V. Briscoe, Bruce Carney, Sang-Il Choi, Wayne Christiansen, Thomas Clegg, Kian S. Dy, John P. Hernandez, William M. Hooke, Paul S. Hubbard, Hugon J. Karwowski, Horst Kessemeier, Edward J. Ludwig, J. Ross Macdonald, Nalin Parikh, James A. Rose, Lawrence G. Rowan, Dietrich Schroerer, Lawrence M. Slifkin, William J. Thompson, James W. York Jr.

## ASTR–Astronomy

### Undergraduate-level Courses

**ASTR 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.

**Gen Ed:** PL, NA, WB.

**Grading status:** Letter grade

**Same as:** PHYS 61.

**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.

**Gen Ed:** PL, QI.

**Grading status:** Letter grade

**Same as:** PHYS 63.

**ASTR 63H. 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.

**Gen Ed:** PL, QI.

**Grading status:** Letter grade

**Same as:** PHYS 63H.

**ASTR 89. First-Year Seminar: Special Topics. 3 Credits.**

Special topics course content will vary each semester.

**Repeat rules:** May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 2 total completions.

**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).

**Gen Ed:** PX.

**Grading status:** Letter grade.

**ASTR 101L. Introduction to Astronomy Laboratory: Our Place in Space. 1 Credit.**

Observing with robotic telescopes in Chile, Australia, and around the world: planets, dwarf planets, moons, asteroids, binary and variable stars, supernovae, star-forming regions, star clusters, and galaxies; the seasons, the Galilean revolution; the cosmic distance ladder; the Great Debate; dark matter; Hubble's Law; dark energy.

**Requisites:** Pre- or corequisite, ASTR 101.

**Grading status:** Letter grade.

**ASTR 101H. 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, the moon; terrestrial and gas planets and their moons; dwarf planets; asteroids; comets; planetary system formation; extrasolar planets; the search for extraterrestrial intelligence (SETI).

**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.

**Requisites:** Prerequisite, ASTR 101, or pre- or co-requisite, PHYS 117 or 119; Permission of the instructor for students lacking the pre- or co-requisites.

**Gen Ed:** PL.

**Grading status:** Letter grade.

**ASTR 102H. 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.

**Requisites:** Prerequisite, ASTR 101, or pre- or co-requisite, PHYS 117 or 119; Permission of the instructor for students lacking the pre- or co-requisites.

**Gen Ed:** PL.

**Grading status:** Letter grade.

**ASTR 105H. 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?

**Gen Ed:** PL, WB.

**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?

**Gen Ed:** PL, WB.

**Grading status:** Letter grade.

**ASTR 111L. Educational Research in Radio Astronomy. 1 Credit.**

Permission of the instructor. One-week field experience at the National Radio Astronomy Observatory in Green Bank, WV, for experiential education (EE) credit. Observing with radio telescopes and antennae: supernova remnants, star-forming regions, normal and active galaxies, quasars, solar system objects (sun, moon, Jupiter), radio spectroscopy.

**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.

**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.

**Gen Ed:** PL, WB.

**Grading status:** Letter grade.

**ASTR 301. Stars, Galaxies, and Cosmology. 1 Credit.**

Pre- or Permission of the instructor for students lacking the prerequisites. 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.

**Requisites:** co-requisites, ASTR 102, and PHYS 117 or 119;

**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.

**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. Astrophysics I (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.

**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. Astrophysics II (Modern Research in Astrophysics). 3 Credits.**

An introduction to modern research in astrophysics based on scientific journal articles addressing a current topic of interest in galactic or extragalactic astrophysics, including training in computer modeling and statistical analysis, culminating in the completion of a research project.

**Requisites:** Prerequisites, ASTR 202 or ASTR 301, and MATH 383; pre- or corequisite, PHYS 331.

**Gen Ed:** EE- Mentored Research.

**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.

**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.

**Requisites:** Prerequisites, ASTR 202 or ASTR 301, and PHYS 401; pre- or corequisite, PHYS 321.

**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.

**Requisites:** Prerequisites, ASTR 202 or ASTR 301, MATH 383, and PHYS 331.

**Grading status:** Letter grade.

**ASTR 519. Observational Astronomy. 4 Credits.**

A course designed to familiarize the student with observational techniques in optical and radio astronomy, including application of photography, spectroscopy, photometry, and radio methods. Three lecture and three laboratory hours a week.

**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.

**Gen Ed:** HS.

**Grading status:** Letter grade

**Same as:** HIST 50.

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

Acoustics and music from a practical standpoint.

**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.

**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.

**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.

**Gen Ed:** PL.

**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.

**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.

**Gen Ed:** PL, QI.

**Grading status:** Letter grade

**Same as:** ASTR 63.

**PHYS 63H. 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.

**Gen Ed:** PL, QI.

**Grading status:** Letter grade

**Same as:** ASTR 63H.

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

Special Topics course. Content will vary each semester.

**Repeat rules:** May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 2 total completions.

**Grading status:** Letter grade.

**PHYS 100. How Things Work. 3 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.

**Gen Ed:** PL.

**Grading status:** Letter grade.

**PHYS 101. Basic Concepts of Physics. 4 Credits.**

Basic principles of physics with introduction to quantum physics, atoms, nuclei, and relativity. Not to be taken for credit after PHYS 104-105 or 114-115 or 116-117 or 118-119. Three lecture and two laboratory hours a week.

**Gen Ed:** PX.

**Grading status:** Letter grade.



**PHYS 102. General Physics Lecture I. 3 Credits.**

Lecture portion of 104, awarded as AP credit.

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 103. General Physics Lecture II. 3 Credits.**

Lecture portion of 105, awarded as AP credit.

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 104. General Physics I. 4 Credits.**

permission of the instructor for students lacking the requisite. Three lecture hours and two laboratory hours a week. Students may not receive credit for both PHYS 104 and PHYS 114, 116, or 118.

**Requisites:** Pre- or corequisite, MATH 130;

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 105. General Physics II. 4 Credits.**

permission of the instructor for students lacking the requisite. Three lecture hours and two laboratory hours a week. Students may not receive credit for both PHYS 105 and PHYS 115, 117, or 119.

**Requisites:** Pre- or corequisite, PHYS 104;

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

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

A hands-on/minds-on approach to learning the basic concepts of physical science. Emphasis will be placed on examining the nature of science, your own learning, and the way scientists learn science.

**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.

**Gen Ed:** PX, GL.

**Grading status:** Letter grade

**Same as:** MASC 108, GEOL 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.

**Requisites:** Prerequisite, MATH 231.

**Gen Ed:** PX, QI.

**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.

**Requisites:** Prerequisite, PHYS 114.

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 116. Mechanics. 4 Credits.**

Mechanics of particles and rigid bodies. Newton's laws; conservation principles. Oscillatory and wave motion. Sound. Lecture, recitation, and laboratory. Students may not receive credit for both PHYS 116 and PHYS 104, 114, or 118.

**Requisites:** Prerequisite, MATH 231; pre- or corequisite, MATH 232; permission of the instructor for students lacking the requisites.

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 116H. Mechanics. 4 Credits.**

Mechanics of particles and rigid bodies. Newton's laws; conservation principles. Oscillatory and wave motion. Sound. Lecture, recitation, and laboratory. Students may not receive credit for both PHYS 116 and PHYS 104, 114, or 118.

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

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 117. Electromagnetism and Optics. 4 Credits.**

Electricity and magnetism; laws of Coulomb, Ampere, and Faraday. Electromagnetic oscillations and waves. Light; diffraction and interference. Lecture, recitation, and laboratory. Students may not receive credit for both PHYS 117 and PHYS 105, 115, or 119.

**Requisites:** Prerequisites, MATH 232 and PHYS 116; pre- or corequisite, MATH 233; permission of the instructor for students lacking the requisites.

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

**PHYS 117H. Electromagnetism and Optics. 4 Credits.**

Electricity and magnetism; laws of Coulomb, Ampere, and Faraday. Electromagnetic oscillations and waves. Light; diffraction and interference. Lecture, recitation, and laboratory. Students may not receive credit for both PHYS 117 and PHYS 105, 115, and 119.

**Requisites:** Prerequisites, MATH 232 and PHYS 116; pre- or corequisite, MATH 233; permission of the instructor for students lacking the requisites.

**Gen Ed:** PX, QI.

**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. Lecture and studio. Students may not receive credit for PHYS 118 in addition to PHYS 104, 114, or 116.

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

**Gen Ed:** PX, QI.

**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. Lecture and studio. Students may not receive credit for PHYS 119 in addition to PHYS 105, 115, or 117.

**Requisites:** Prerequisites, MATH 232 and PHYS 118; pre- or corequisite, MATH 233; permission of the instructor for students lacking the prerequisites.

**Gen Ed:** PX, QI.

**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.

**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 Credit.**

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

**Requisites:** co-requisite, 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.

**Requisites:** Corequisite, PHYS 131L.

**Gen Ed:** PX, QI.

**Grading status:** Letter grade.

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

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

**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.

**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.

**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.

**Requisites:** Prerequisites, MATH 233 and one of PHYS 105, 115, 117, 119; permission of the instructor for students lacking the prerequisites.

**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.

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

**Grading status:** Letter grade.

**PHYS 231. Physical Computing. 3 Credits.**

permission of the instructor for students lacking the requisite. Combines sensors and actuators to sense, interact with, and control the nearby physical environment. Students are introduced to analog and digital electronics, lab equipment, Python and C-like programming, the Arduino microcontroller, 3-D design tools, and Makerspace prototyping. Students collaborate, then propose and complete individual final projects.

**Requisites:** Pre- or corequisite, PHYS 114 or 118;

**Grading status:** Letter grade.

**PHYS 281L. Experimental Techniques in Physics. 2 Credits.**

Exploration of modern physics experiments, techniques, and data analysis to prepare students for research and advanced laboratory work. Written and oral reports with peer review. Meets four hours per week.

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

**Gen Ed:** CI.

**Grading status:** Letter grade.

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

Research with a faculty mentor. Approved learning contract required.

**Gen Ed:** EE- Mentored Research.

**Repeat rules:** May be repeated for credit. 12 total credits. 4 total completions.

**Grading status:** Letter grade.

**PHYS 311. Electromagnetism I. 3 Credits.**

Pre- or permission of the instructor for students lacking the requisite. Brief treatment of DC and AC circuit theory. Electrostatics: dielectrics, the magnetic field, magnetic materials. Maxwell's equations and their application to electromagnetic waves.

**Requisites:** co-requisite, PHYS 358;

**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.

**Grading status:** Letter grade.

**PHYS 321. Introduction to Quantum Mechanics. 3 Credits.**

Origins of quantum theory. Uncertainty principle. Schroedinger equation for simple systems, including hydrogen atom. Perturbation theory. Spin. Identical particles.

**Requisites:** Prerequisites, MATH 383; MATH 547 or PHYS 331; pre- or co-requisite, PHYS 401; permission of the instructor for students lacking the requisites.

**Grading status:** Letter grade.

**PHYS 331. Introduction to Numerical Techniques in Physics. 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.

**Requisites:** Prerequisite, one of PHYS 104, 114, 116, 118; pre- or co-requisite, MATH 383.

**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.

**Requisites:** Prerequisites, MATH 233 and one of PHYS 105, 115, 117, 119; permission of the instructor for students lacking the prerequisites.

**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.

**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.

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

**Gen Ed:** PH.

**Grading status:** Letter grade

**Same as:** PHIL 354.

**PHYS 358. Physical Modeling. 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.

**Requisites:** Prerequisite, PHYS 331.

**Grading status:** Letter grade.

**PHYS 391. Senior Seminar. 1-15 Credits.**

To be taken by seniors with permission of the department.

**Grading status:** Letter grade.

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

Research with a faculty mentor. Approved learning contract required. Additionally, students write and submit a proposal to an internal or external competition for funding intended for students. They also give a poster or oral presentation on the topic of their research at an appropriate symposium or meeting.

**Gen Ed:** CI, EE- Mentored Research.

**Repeat rules:** May be repeated for credit. 12 total credits. 4 total completions.

**Grading status:** Letter grade.

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

Research with a faculty mentor. Approved learning contract required. Additionally, students write and submit a proposal to an internal or external competition for funding intended for students. They also give a poster or oral presentation on the topic of their research at an appropriate symposium or meeting.

**Gen Ed:** EE- Mentored Research.

**Repeat rules:** May be repeated for credit. 12 total credits. 4 total completions.

**Grading status:** Letter grade.

**Advanced Undergraduate and Graduate-level Courses****PHYS 401. Mechanics I. 3 Credits.**

permission of the instructor for students lacking the requisites. 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.

**Requisites:** Pre- or corequisites, MATH 383 and PHYS 331;

**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.

**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 and college environments. Meets part of the licensure requirements for North Carolina public school teaching.

**Requisites:** Prerequisites, PHYS 116 and 117, or PHYS 118 and 119; permission of the instructor for students lacking the prerequisites.

**Gen Ed:** EE- Field Work.

**Grading status:** Letter grade.

**PHYS 412. Electromagnetism II. 3 Credits.**

Brief treatment of DC and AC circuit theory. Electrostatics: dielectrics; the magnetic field; magnetic materials. Maxwell's equations and their application to electromagnetic waves.

**Requisites:** Prerequisite, PHYS 311; permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade.

**PHYS 415. Optics. 3 Credits.**

Elements of geometrical optics; Huygens' principles, interference, diffraction, and polarization. Elements of the electromagnetic theory of light; Fresnel's equations, dispersion, absorption, and scattering. Photons. Lasers and quantum optics.

**Requisites:** Prerequisites, PHYS 311 and 412; 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.

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

**Grading status:** Letter grade

**Same as:** GEOL 422.

**PHYS 424. General Physics I. 4 Credits.**

This course is specifically for certification of high school teachers. Students may not receive credit for both PHYS 424 and PHYS 104 or 114.

**Grading status:** Letter grade.

**PHYS 425. General Physics II. 4 Credits.**

This course is specifically for certification of high school teachers. Students may not receive credit for both PHYS 425 and PHYS 105 or 115.

**Grading status:** Letter grade.

**PHYS 441. Thermal Physics. 3 Credits.**

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

**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 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.

**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.

**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 experiments illustrating modern techniques such as the use of laser technology to study the interaction of electromagnetic fields and matter. Six laboratory hours a week.

**Requisites:** Prerequisite, 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.

**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.

**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 Credit.**

How students learn and understand physics and astronomy. How to teach using current research-based methods.

**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.

**Requisites:** Prerequisite, PHYS 321.

**Grading status:** Letter grade.

**PHYS 543. Nuclear Physics. 3 Credits.**

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

**Requisites:** Prerequisite, PHYS 321; 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.

**Requisites:** Prerequisites, PHYS 321 and 412.

**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.

**Requisites:** Prerequisite, PHYS 321; 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.

**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?

**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.

**Requisites:** Prerequisites, MATH 233 and PHYS 118.

**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.

**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.

**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.

**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.

**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.

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

**Grading status:** Letter grade

**Same as:** MASC 560, ENVR 452, GEOL 560.

**PHYS 671L. Independent Laboratory I. 3 Credits.**

Six laboratory hours a week.

**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.

**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.

**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.

**Requisites:** Prerequisite, PHYS 691H.

**Gen Ed:** EE- Mentored Research.

**Grading status:** Letter grade.