Physics (PHYS)

Courses

PHYS 1000. Physics at Northeastern. (1 Hour)
Intended for freshmen in the College of Science. Introduces freshmen to the liberal arts in general; familiarizes them with their major; helps them develop the academic skills necessary to succeed (analytical ability and critical thinking); provides grounding in the culture and values of the University community; and helps them develop interpersonal skills—in short, familiarizes students with all skills needed to become a successful university student.

PHYS 1111. Introduction to Astronomy. (4 Hours)
Introduces modern astronomical ideas. Topics include an introduction to the cosmos, Earth and its relation to the universe, our solar system (planets, moons, asteroids, and comets), the sun and how it works, stars and their classification, and the life and death of stars. Introduces various tools of the astronomer (the nature of light and radiation, telescopes, the types of spectra, and what they tell us).

Attribute(s): NUpath Natural/Designed World

PHYS 1115. Life in the Universe. (4 Hours)
Explores the possibility of life in the universe from the astronomy, geology, biology, and chemistry point of view, emphasizing the recent astronomical discoveries of planets outside the solar system. Invites students to consider how planetary evolution affects life or the potential habitability of exoplanets. Analyzes environmental limits or "extremes" under which life can survive and what life might look like on another world. Guides the student on a quest to identify habitable—or even inhabited—worlds through the data of the most recent discoveries and observations.

Attribute(s): NUpath Natural/Designed World

PHYS 1122. Modern Science: A Voyage into Matter, Life, and Mind. (4 Hours)
Offers an intellectual voyage into matter, life, and mind—the three pillars of modern science. It is a mosaic of different themes that offer a concise overview of science's greatest minds, ideas, questions, discoveries, theories, and methods while placing all of them within their historical contexts. Emphasizes the profound scientific revolutions of the 20th century—quantum mechanics, biogenetics, and artificial intelligence—that unlocked the secrets of the atom, unraveled the molecule of life, and created the electronic computer. Recognizes significant trends across a wide range of subjects, including medicine, biotechnology, computing and communicating, artificial intelligence and artificial life, and robotics. Discusses the synergism of science, technology, and business on future scientific development.

Attribute(s): NUpath Natural/Designed World

PHYS 1125. Introduction to Network Science: From the Human Cell to Facebook. (4 Hours)
Introduces network science as a way to understand complex patterns of connections and relationships in increasingly complex social, infrastructure, transportation, information, and biological networks, as well as business and consumer networks. Describes basic conceptual and computational tools to model networks and discusses applications of those tools through a wide range of examples from the World Wide Web to protein and gene networks to massive social networks such as Twitter and Facebook. Discusses both network structures and dynamical phenomena on networks, such as spreading of information, rumors, gossip, and epidemics.

Attribute(s): NUpath Natural/Designed World, NUpath Societies/Institutions

PHYS 1130. Computing, Data, and Science. (4 Hours)
Introduces how to deal with data and computation problems through the use of computer languages commonly used in the sciences. Focuses on manipulating data, but symbolic calculations are also covered. Intended for science majors during the first summer, when such a course can act as a foundation for later work.

Attribute(s): NUpath Analyzing/Using Data

PHYS 1132. Energy, Environment, and Society. (4 Hours)
Seeks to provide nonscience students with a practical knowledge of our present use of the Earth's energy resources and the environmental consequences. Topics include fossil fuels for transportation and electrical power, global warming, nuclear energy, solar energy, wind power, biomass, electric and hybrid vehicles, and air pollution. No previous knowledge of physics is assumed; nevertheless, because of the nature of the subject, a significant part of the course includes simple quantitative reasoning.

Attribute(s): NUpath Natural/Designed World, NUpath Societies/Institutions

PHYS 1141. General Physics. (4 Hours)
Covers mechanics, fluids, and vibrations and waves. Emphasizes the application of physics to a variety of problems in structural engineering. Mechanics topics include one-dimensional motion, forces, vectors, Newton's laws, equilibrium, work, energy, and power. Fluids topics include density, pressure, buoyancy, and fluids in motion. Vibrations and waves topics include mechanical vibrations and sound. Requires knowledge of algebra.

Attribute(s): NUpath Natural/Designed World

PHYS 1145. Physics for Life Sciences 1. (4 Hours)
Covers mechanics, fluids, and temperature and kinetic theory. The application of physics to a variety of problems in the life and health sciences is emphasized. Mechanics topics include one-dimensional motion, forces, vectors, Newton's laws, equilibrium, work, energy, and power. Fluids topics include density, pressure, buoyancy, fluids in motion, viscosity, and surface tension. Temperature and kinetic theory topics include temperature, thermal equilibrium, gas laws, ideal gas law, kinetic theory, vapor pressure, and diffusion. A laboratory is included.

Corequisite(s): PHYS 1146
Attribute(s): NUpath Natural/Designed World

PHYS 1146. Lab for PHYS 1145. (1 Hour)
Accompanies PHYS 1145. Covers topics from the course through various experiments.

Corequisite(s): PHYS 1145
Attribute(s): NUpath Analyzing/Using Data

PHYS 1147. Physics for Life Sciences 2. (4 Hours)
Continues PHYS 1145. Covers heat, electricity, vibrations and waves, sound, geometrical optics, and nuclear physics and radioactivity. The application of physics to a variety of problems in the life and health sciences is emphasized. Electricity topics include electrostatics, capacitance, resistivity, direct-current circuits, and RC circuits. Vibrations and waves topics include simple harmonic motion and wave motion. Sound topics include wave characteristics, the ear, Doppler effect, shock waves, and ultrasound. Optics topics include reflection, mirrors, refraction, total internal reflection, fiber optics, lenses, the eye, telescopes, and microscopes. Nuclear physics and radioactivity topics include atomic nucleus, radioactivity, half-life, radioactive dating, detectors, nuclear reaction, fission, fusion, radiation damage, radiation therapy, PET, and MRI. A laboratory is included.

Prerequisite(s): PHYS 1145 with a minimum grade of D- or PHYS 1149 with a minimum grade of D- or PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- or PHYS 1171 with a minimum grade of D-
Corequisite(s): PHYS 1148
Attribute(s): NUpath Natural/Designed World

PHYS 1148. Lab for PHYS 1147. (1 Hour)
Accompanies PHYS 1147. Covers topics from the course through various experiments.

Corequisite(s): PHYS 1147
Attribute(s): NUpath Analyzing/Using Data

PHYS 1149. Physics for Pharmacy. (4 Hours)
Offers an integrated lecture and laboratory course for pharmacy students.

Corequisite(s): PHYS 1150
Attribute(s): NUpath Natural/Designed World

PHYS 1150. Lab for PHYS 1149. (1 Hour)
Accompanies PHYS 1149. Covers topics from the course through various experiments.

Corequisite(s): PHYS 1149
Attribute(s): NUpath Analyzing/Using Data

PHYS 1151. Physics for Engineering 1. (3 Hours)
Covers calculus-based physics. Offers the first semester of a two-semester integrated lecture and laboratory sequence intended primarily for engineering students. Covers Newtonian mechanics and fluids. Stresses the balance between understanding the basic concepts and solving specific problems. Includes topics such as one-dimensional and three-dimensional motion, Newton's laws, dynamics friction, drag, work, energy and power, momentum and collisions, rotational dynamics, forces, torque and static equilibrium, pressure, fluids, and gravity.

Prerequisite(s): MATH 1241 with a minimum grade of D- or MATH 1251 with a minimum grade of D- or MATH 1340 (may be taken concurrently) with a minimum grade of D- or MATH 1341 (may be taken concurrently) with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-
Attribute(s): NUpath Natural/Designed World

PHYS 1152. Lab for PHYS 1151. (1 Hour)
Accompanies PHYS 1151. Covers topics from the course through various experiments. Requires concurrent registration in PHYS 1151 and PHYS 1153.

Attribute(s): NUpath Analyzing/Using Data

PHYS 1153. Interactive Learning Seminar for PHYS 1151. (1 Hour)
Offers interactive problem solving for PHYS 1151. Emphasizes organized approaches and use of mathematical techniques, including calculus, to solve a wide range of problems in mechanics. Topics include static equilibrium, applications of Newton's laws and conservation principles, rotational dynamics, and fluids. Requires concurrent registration in PHYS 1151 and PHYS 1152.

PHYS 1155. Physics for Engineering 2. (3 Hours)
Continues PHYS 1151. Offers integrated lecture and laboratory. Covers electrostatics; capacitors; resistors and direct-current circuits; magnetism and magnetic induction; RC, LR, and LRC circuits; waves; electromagnetic waves; and radiation.

Prerequisite(s): (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- or PHYS 1171 with a minimum grade of D-); (MATH 1242 (may be taken concurrently) with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-)
Corequisite(s): PHYS 1157
Attribute(s): NUpath Natural/Designed World

PHYS 1156. Lab for PHYS 1155. (1 Hour)
Accompanies PHYS 1155. Covers topics from the course through various experiments. Requires concurrent registration in PHYS 1155 and PHYS 1157.

Attribute(s): NUpath Analyzing/Using Data

PHYS 1157. Interactive Learning Seminar for PHYS 1155. (1 Hour)
Offers interactive problem solving for PHYS 1155. Emphasizes organized approaches and use of mathematical techniques, including calculus, to solve a wide range of problems in electricity, magnetism, and waves. Requires concurrent registration in PHYS 1155 and PHYS 1156.

Corequisite(s): PHYS 1155

PHYS 1161. Physics 1. (4 Hours)
Covers calculus-based physics. Offers the first semester of a two-semester integrated lecture and laboratory sequence intended primarily for science students. Covers Newtonian mechanics and fluids. Emphasizes the underlying concepts and principles. Takes applications from a wide variety of fields, such as life sciences and medicine, astro- and planetary physics, and so on. Includes topics such as forces, torque and static equilibrium, one-dimensional and three-dimensional motion, Newton's laws, dynamics friction, drag, work, energy and power, momentum and collisions, rotational dynamics, oscillations, pressure, fluids, and gravity.

Prerequisite(s): MATH 1241 with a minimum grade of D- or MATH 1251 with a minimum grade of D- or MATH 1341 (may be taken concurrently) with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-
Corequisite(s): PHYS 1162, PHYS 1163
Attribute(s): NUpath Natural/Designed World

PHYS 1162. Lab for PHYS 1161. (1 Hour)
Accompanies PHYS 1161. Covers topics from the course through various experiments.

Corequisite(s): PHYS 1161, PHYS 1163
Attribute(s): NUpath Analyzing/Using Data

PHYS 1163. Recitation for PHYS 1161. (0 Hours)
Accompanies PHYS 1161. Offers an opportunity for interactive problem solving.

Corequisite(s): PHYS 1161, PHYS 1162

PHYS 1165. Physics 2. (4 Hours)
Continues PHYS 1161. Offers the second semester of a two-semester integrated lecture and laboratory sequence intended primarily for science students. Includes topics such as electrostatics; capacitors; resistors and direct-current circuits; magnetism and magnetic induction; RC, LR, and LRC circuits; waves; electromagnetic waves; and fluids.

Prerequisite(s): (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- or PHYS 1171 with a minimum grade of D- or PHYS 1191 with a minimum grade of D-); (MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-)
Corequisite(s): PHYS 1166, PHYS 1167
Attribute(s): NUpath Natural/Designed World

PHYS 1166. Lab for PHYS 1165. (1 Hour)
Accompanies PHYS 1165. Covers topics from the course through various experiments.

Corequisite(s): PHYS 1165, PHYS 1167
Attribute(s): NUpath Analyzing/Using Data

PHYS 1167. Recitation for PHYS 1165. (0 Hours)
Accompanies PHYS 1165. Offers an opportunity for interactive problem solving.

Corequisite(s): PHYS 1165, PHYS 1166

PHYS 1171. Physics 1 for Bioscience and Bioengineering. (3 Hours)
Designed for students in engineering and science majors with a biologically related curriculum. Studies the fundamentals of calculus-based physics through a relationship with living systems. Includes topics such as kinematics of living systems, stress/strain/strength of biomaterials, fluid flow and boundary layers, aspiration and circulatory models, diffusion and random motion, and thermodynamics with examples from living systems.

Prerequisite(s): MATH 1241 (may be taken concurrently) with a minimum grade of D- or MATH 1251 (may be taken concurrently) with a minimum grade of D- or MATH 1340 (may be taken concurrently) with a minimum grade of D- or MATH 1341 (may be taken concurrently) with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-
Attribute(s): NUpath Natural/Designed World

PHYS 1172. Lab for PHYS 1171. (1 Hour)
Accompanies PHYS 1171. Experiments include measurement and error, forces in one dimension, work and energy on an air track, fluid flow, Brownian diffusion, uniform circular motion, and ideal gas laws. Requires concurrent registration in PHYS 1171 and PHYS 1173.

Attribute(s): NUpath Analyzing/Using Data

PHYS 1173. Interactive Learning Seminar for PHYS 1171. (1 Hour)
Offers interactive problem solving for PHYS 1171. Emphasizes organized approaches to solve a wide range of problems in the course. Requires concurrent registration in PHYS 1171 and PHYS 1172.

PHYS 1175. Physics 2 for Bioscience and Bioengineering. (3 Hours)
Continues PHYS 1171. Includes topics such as wave motion and hearing; electric fields (including application to biological membranes); direct current electrical circuits (including biological circuits); RC circuit models of ion channels; bioelectricity in marine organisms; electromagnetic waves and optics; modern physics (including radioactive decay, applications of radioactivity in nuclear medicine, and carbon 14 dating).

Prerequisite(s): (PHYS 1151 with a minimum grade of D- or PHYS 1161 with a minimum grade of D- or PHYS 1171 with a minimum grade of D-); (MATH 1242 (may be taken concurrently) with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-)
Attribute(s): NUpath Natural/Designed World

PHYS 1176. Lab for PHYS 1175. (1 Hour)
Accompanies PHYS 1175. Experiments include standing waves, electric charge/field, DC circuits, gel electrophoresis, geometric optics, light spectroscopy, and radioactive decay. Requires concurrent registration in PHYS 1175 and PHYS 1177.

Attribute(s): NUpath Analyzing/Using Data

PHYS 1177. Interactive Learning Seminar for PHYS 1175. (1 Hour)
Offers interactive problem solving for PHYS 1175. Emphasizes organized approaches to solve a wide range of problems in the course. Requires concurrent registration in PHYS 1175 and PHYS 1176.

PHYS 1191. Foundations of Theoretical Physics. (4 Hours)
Presents a comprehensive, self-contained introduction to the conceptual and mathematical foundations of theoretical physics. Commences with an integrated, first-principles approach to its five main areas: analytical dynamics, fields, statistical physics, relativity, and quantum theory. Focuses mostly on classical mechanics. Constitutes the first half of a two-semester calculus-based introductory physics sequence for science majors. Designed for students with preparation in Newtonian mechanics or those with advanced math preparation.

Prerequisite(s): (MATH 1241 with a minimum grade of D- or MATH 1242 (may be taken concurrently) with a minimum grade of D- or MATH 1341 with a minimum grade of D- or MATH 1342 (may be taken concurrently) with a minimum grade of D- or MATH 2321 (may be taken concurrently) with a minimum grade of D-)
Corequisite(s): PHYS 1192, PHYS 1193
Attribute(s): NUpath Formal/Quant Reasoning, NUpath Natural/Designed World

PHYS 1192. Lab for PHYS 1191. (1 Hour)
Accompanies PHYS 1191. Covers topics from the course through various experiments.

Corequisite(s): PHYS 1191, PHYS 1193
Attribute(s): NUpath Analyzing/Using Data

PHYS 1193. Recitation for PHYS 1191. (0 Hours)
Accompanies PHYS 1191. Offers an opportunity for interactive problem solving.

Corequisite(s): PHYS 1191, PHYS 1192

PHYS 1211. Computational Problem Solving in Physics. (4 Hours)
Introduces students to computational problem-solving techniques with common computer languages used in the physical sciences. Begins with programming basics of data handling, visualization tools, random number generators, functions, and control statements and expands to more advanced topics of interpolation, numeric integration, numeric derivatives, ordinary differential equations, and some Monte Carlo techniques. Explores topics contextually using physical models and problems.

Prerequisite(s): (PHYS 1155 (may be taken concurrently) with a minimum grade of D or PHYS 1165 (may be taken concurrently) with a minimum grade of D or PHYS 1175 (may be taken concurrently) with a minimum grade of D); (MATH 1342 (may be taken concurrently) with a minimum grade of D or MATH 2321 (may be taken concurrently) with a minimum grade of D)
Attribute(s): NUpath Analyzing/Using Data, NUpath Natural/Designed World

PHYS 1990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

PHYS 2303. Modern Physics. (4 Hours)
Reviews experiments demonstrating the atomic nature of matter, the properties of the electron, the nuclear atom, the wave-particle duality, spin, and the properties of elementary particles. Discusses, mostly on a phenomenological level, such subjects as atomic and nuclear structure, properties of the solid state, and elementary particles. Introduces the special theory of relativity.

Prerequisite(s): (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D- or PHYS 1175 with a minimum grade of D-); MATH 2321 (may be taken concurrently) with a minimum grade of D-
Attribute(s): NUpath Natural/Designed World

PHYS 2371. Electronics. (3 Hours)
Covers the physics underlying computers and our modern electronic world. Focuses on principles of semiconductor devices (diodes, transistors, integrated circuits, LEDs, photovoltaics); analog techniques (amplification, AC circuits, resonance); digital techniques (binary numbers, NANDs, logic gates, and circuits); electronic subsystems (operational amplifiers, magnetoelectronics, optoelectronics); and understanding commercial electronic equipment. Lab experiments are designed to investigate the properties of discrete and integrated devices and use them to design and build circuits.

Prerequisite(s): PHYS 1165 with a minimum grade of D- or PHYS 1155 with a minimum grade of D- or PHYS 1175 with a minimum grade of D-
Corequisite(s): PHYS 2372
Attribute(s): NUpath Natural/Designed World

PHYS 2372. Lab for PHYS 2371. (1 Hour)
Accompanies PHYS 2371. Illustrates topics from the lecture course through various hands-on experimental projects. Covers the process of electronics design from a goal-oriented perspective. Students are expected to consider their own electronics design project and build a prototype device that accomplishes a specific purpose.

Corequisite(s): PHYS 2371
Attribute(s): NUpath Creative Express/Innov

PHYS 2990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

PHYS 2991. Research in Physics. (1-4 Hours)
Offers an opportunity to conduct introductory-level research or creative endeavors under faculty supervision. May be repeated seven times.

PHYS 3111. Astrophysical Processes: Decoding the Universe. (4 Hours)
Introduces the important astrophysical processes happening in the universe, including interactions between astrophysical matter and radiation (scattering, absorption, refraction); interaction between astrophysical matter and space (Doppler effect and gravitational lensing); and emission of radiation from astrophysical sources (continuous and line). By the end of the course, successful students should be able to recognize the nature of an astrophysical source from the signal as detected on Earth or in space.

Prerequisite(s): (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D-); PHYS 2303 (may be taken concurrently) with a minimum grade of D-

PHYS 3211. Advanced Computational Problem Solving in Physics. (4 Hours)
Explores the application of scientific computing languages, such as Python, in modeling the physical world and advancing physics. Topics include linear and non-linear systems, eigensystems, ordinary differential equations, boundary value problems, Monte Carlo techniques, and machine learning. Contextualizes topics within natural phenomena, physics models, and physics problems. Emphasizes developing proficiency in computational methods for modeling nature and solving complex physical phenomena.

Prerequisite(s): (MATH 2331 with a minimum grade of C- or MATH 2341 with a minimum grade of C-); PHYS 2303 with a minimum grade of C-
Attribute(s): NUpath Analyzing/Using Data

PHYS 3600. Advanced Physics Laboratory. (4 Hours)
Introduces research through experiments that go beyond the simple demonstration of basic physical principles found in introductory physics courses. Data are taken to higher precision and the analysis is more in-depth. Experiments focus on lasers, fiber-optic communication, spectroscopy, Faraday rotation, speed of light, semiconductor physics, Hall effect, fuel cells, and Fourier analysis of music and sound. Lab reports are assessed on organization, format, grammar, and style. Offers students an opportunity to significantly improve their abilities in written scientific communication.

Prerequisite(s): PHYS 2303 with a minimum grade of D- ; (ENGL 1102 with a minimum grade of C or ENGL 1111 with a minimum grade of C or ENGW 1102 with a minimum grade of C or ENGW 1111 with a minimum grade of C or ENGW 1113 with a minimum grade of C or ENGW 1114 with a minimum grade of C)
Attribute(s): NUpath Analyzing/Using Data, NUpath Natural/Designed World, NUpath Writing Intensive

PHYS 3601. Classical Dynamics. (4 Hours)
Covers advanced topics in classical mechanics including vector kinematics, harmonic oscillator and resonance, generalized coordinates, Lagrange's equations, central forces and the Kepler problem, rigid body motion, and mathematical methods in physics.

Prerequisite(s): (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D- or PHYS 1175 with a minimum grade of D-); (MATH 2341 (may be taken concurrently) with a minimum grade of D- or MATH 2351 (may be taken concurrently) with a minimum grade of D-)
Attribute(s): NUpath Natural/Designed World

PHYS 3602. Electricity and Magnetism 1. (4 Hours)
First course of a two-course sequence in electricity, magnetism, and electromagnetic theory. Covers electrostatics and dielectric materials, magnetostatics and magnetic materials, currents in conductors, induction, displacement currents, computer solutions of EM problems, and Maxwell's equations.

Prerequisite(s): (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D- or PHYS 1175 with a minimum grade of D-); MATH 2321 with a minimum grade of D- ; (MATH 2341 (may be taken concurrently) with a minimum grade of D- or MATH 2351 (may be taken concurrently) with a minimum grade of D-)
Attribute(s): NUpath Natural/Designed World

PHYS 3603. Electricity and Magnetism 2. (4 Hours)
Continues PHYS 3602. Focuses on electromagnetic waves in vacua and matter, electrodynamics and radiation, and computer visualization of electromagnetic fields. Also considers special relativity.

Prerequisite(s): PHYS 3602 with a minimum grade of D-
Attribute(s): NUpath Natural/Designed World

PHYS 3990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

PHYS 4111. Multimessenger Astrophysics. (4 Hours)
Investigates the variety of astrophysical signals produced by galactic and extragalactic sources, in connection with and independently from the electromagnetic wave (EM) signals. Introduces the basic theory behind the production, transmission, and detection of astrophysical neutrinos, cosmic rays, dark matter, and gravitational waves. Topical in nature, the course offers a solid introduction to the newest discoveries in astrophysics.

Prerequisite(s): PHYS 2303 with a minimum grade of D-

PHYS 4115. Quantum Mechanics. (4 Hours)
Focuses on observations of macroscopic and microscopic bodies. Covers the uncertainty principle and wave-particle duality; probability amplitudes; Schrödinger wave theory and one-dimensional problems, Schrödinger equation in three dimensions; and angular momentum and the hydrogen atom.

Prerequisite(s): PHYS 2303 with a minimum grade of D-
Attribute(s): NUpath Formal/Quant Reasoning, NUpath Natural/Designed World

PHYS 4305. Thermodynamics and Statistical Mechanics. (4 Hours)
Focuses on first and second laws of thermodynamics, entropy and equilibrium, thermodynamic potentials, elementary kinetic theory, statistical mechanics, and the statistical interpretation of entropy. Utilizes the principles of quantum mechanics to describe the behavior of thermodynamic/statistically-large systems such as quantum gases.

Prerequisite(s): (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D- or PHYS 1175 with a minimum grade of D-); MATH 2321 (may be taken concurrently) with a minimum grade of D- ; PHYS 2303 with a minimum grade of D-
Attribute(s): NUpath Natural/Designed World

PHYS 4606. Mathematical and Computational Methods for Physics. (4 Hours)
Covers advanced mathematical methods topics that are commonly used in the physical sciences, such as complex calculus, Fourier transforms, special functions, and the principles of variational calculus. Applies these methods to computational simulation and modeling exercises. Introduces basic computational techniques and numerical analysis, such as Newton's method, Monte Carlo integration, gradient descent, and least squares regression. Uses a simple programming language, such as MATLAB, for the exercises.

Prerequisite(s): PHYS 2303 with a minimum grade of D- ; MATH 2321 with a minimum grade of D- ; (MATH 2341 with a minimum grade of D- or MATH 2351 with a minimum grade of D-)
Attribute(s): NUpath Formal/Quant Reasoning

PHYS 4621. Biological Physics 1. (4 Hours)
Offers an introduction to biophysics focusing on development and implementation of physical models for various biophysical processes that occur in living organisms and in living cells. Topics covered, some of which are explored through computational examples, include thermodynamics of solutions and cells, randomness, diffusion, entropy, membranes, electrostatics, and electricity in cells.

Prerequisite(s): PHYS 2303 with a minimum grade of D-
Attribute(s): NUpath Natural/Designed World

PHYS 4623. Medical Physics. (4 Hours)
Introduces the physical principles and basic mathematical methods underlying the various modalities of medical imaging. These include computed tomography (CT), magnetic resonance (MRI), positron emission tomography (PET), single-photon emission tomography (SPECT), and ultrasound. Covers nuclear physics and the interaction of radiation with biological matter with application to radiation therapy.

Prerequisite(s): MATH 2321 with a minimum grade of D-

PHYS 4651. Medical Physics Seminar 1. (4 Hours)
Offers the first part of a seminar series conducted by expert practitioners from Boston-area hospitals. Examines the clinical applications of medical imaging methods (CT, MRI, and PET), the clinical applications of radiation therapy, and the clinical applications of lasers and optical techniques. Includes site visits to local hospitals and medical instrumentation companies.

Prerequisite(s): PHYS 4623 with a minimum grade of D-

PHYS 4652. Medical Physics Seminar 2. (4 Hours)
Continues PHYS 4651. Further examines the clinical applications of medical imaging methods (CT, MRI, and PET), the clinical applications of radiation therapy, and the clinical applications of lasers and optical techniques.

Prerequisite(s): PHYS 4623 with a minimum grade of D-

PHYS 4970. Junior/Senior Honors Project 1. (4 Hours)
Focuses on in-depth project in which a student conducts research or produces a product related to the student's major field. Combined with Junior/Senior Project 2 or college-defined equivalent for 8-credit honors project. May be repeated without limit.

PHYS 4971. Junior/Senior Honors Project 2. (4 Hours)
Focuses on second semester of in-depth project in which a student conducts research or produces a product related to the student's major field. May be repeated without limit.

Prerequisite(s): PHYS 4970 with a minimum grade of D-

PHYS 4990. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

PHYS 4991. Research. (4 Hours)
Offers an opportunity to conduct research under faculty supervision.

Attribute(s): NUpath Integration Experience

PHYS 4992. Directed Study. (1-4 Hours)
Offers independent work under the direction of a member of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

PHYS 4996. Experiential Education Directed Study. (4 Hours)
Draws upon the student's approved experiential activity and integrates it with study in the academic major. Restricted to those students who are using it to fulfill their experiential education requirement. May be repeated without limit.

Attribute(s): NUpath Integration Experience

PHYS 5113. Particle Physics. (4 Hours)
Introduces the physics of elementary particles and the fundamental interactions among them. Topics include classification of particles, electromagnetic interactions, strong and weak nuclear forces, mesons and nucleons, quarks and gluons, and unified theories of elementary particle interactions.

Prerequisite(s): (PHYS 2303 with a minimum grade of D- ; PHYS 4115 with a minimum grade of D-) or graduate program admission
Attribute(s): NUpath Natural/Designed World

PHYS 5114. Physics and Applications of Quantum Materials. (4 Hours)
Introduces students to the quantum materials, the nature and origins of their unique behaviors, and how these systems can be used to enable new quantum technologies. Beginning with a description of the electronic structure of solids, describes how interactions between electrons and spins can manifest electrical and magnetic properties that cannot be explained with a classical description and how isolated defects in solids can be utilized for quantum technologies.

Prerequisite(s): (PHYS 2303 with a minimum grade of D- ; PHYS 3602 with a minimum grade of D- ; (PHYS 2305 with a minimum grade of D- or PHYS 4305 with a minimum grade of D-); PHYS 4115 (may be taken concurrently) with a minimum grade of D-) or graduate program admission
Attribute(s): NUpath Natural/Designed World

PHYS 5116. Network Science 1. (4 Hours)
Introduces network science and the set of analytical, numerical, and modeling tools used to understand complex networks emerging in nature and technology. Focuses on the empirical study of real networks, with examples coming from biology (metabolic, protein interaction networks), computer science (World Wide Web, Internet), or social systems (e-mail, friendship networks). Shows the organizing principles that govern the emergence of networks and the set of tools necessary to characterize and model them. Covers elements of graph theory, statistical physics, biology, and social science as they pertain to the understanding of complex systems.

Prerequisite(s): PHYS 2303 with a minimum grade of D- or graduate program admission
Attribute(s): NUpath Natural/Designed World

PHYS 5117. Advanced Astrophysics Topics. (4 Hours)
Seeks to provide an understanding of our universe through the connection between cosmology and particle physics. Covers basic concepts of the modern universe, stellar structure and evolution, and dark matter theory while introducing recent astrophysical observations and experiments.

Prerequisite(s): (PHYS 2303 with a minimum grade of D- ; (PHYS 2305 with a minimum grade of D- or PHYS 4305 with a minimum grade of D-)) or graduate program admission

PHYS 5118. General Relativity and Cosmology. (4 Hours)
Introduces basic concepts in the general theory of relativity, including Riemannian geometry and Einstein's field equations. These concepts are applied in studying the standard model of cosmology. Topics include thermodynamics in an expanding universe, dark matter and dark energy, and modern theories of cosmology.

Prerequisite(s): (PHYS 2303 with a minimum grade of D- ; (PHYS 2305 with a minimum grade of D- or PHYS 4305 with a minimum grade of D-)) or graduate program admission

PHYS 5125. Advanced Quantum Mechanics. (4 Hours)
Introduces time-independent and time-dependent perturbation theory. Covers hydrogen fine structure, Zeeman effect, helium splitting, variational principle, adiabatic approximation, scattering theory, second quantization, and modern topics such as theory of quantum entanglement, quantum computing, and quantum biology.

Prerequisite(s): PHYS 4115 with a minimum grade of D- or graduate program admission

PHYS 5260. Introduction to Nanoscience and Nanotechnology. (4 Hours)
Focuses on reviewing the basic scientific concepts relevant to this field and also gives a broad overview of the current state-of-the-art in research and technology. Nanotechnology promises to transform twenty-first century technology by exploiting phenomena exhibited by nanoscaled materials. This technology is expected to have significant impact in diverse areas such as computers, electronics, health, etc. Successful technological advancement of this field requires that we have a fundamental understanding of the "science" of these materials. This course comprises a series of lectures on various topics: development of nanofabrication methods, advanced microscopy techniques, fabrication of novel nanomaterials, investigation of their fundamental properties and device applications. Provides a strong introduction for students interested in nanoscience and technology.

Prerequisite(s): PHYS 2303 with a minimum grade of D- or graduate program admission
Attribute(s): NUpath Natural/Designed World

PHYS 5318. Principles of Experimental Physics. (4 Hours)
Designed to introduce students to the techniques of modern experimental physics. Topics include communication and information physics, signal processing and noise physics, applied relativity physics, detector techniques, semiconductor and superconductor physics, nanoscale microscopy and manipulation, and lasers and quantum optics.

Prerequisite(s): PHYS 2303 with a minimum grade of D- or graduate program admission
Attribute(s): NUpath Analyzing/Using Data, NUpath Capstone Experience, NUpath Natural/Designed World, NUpath Writing Intensive

PHYS 5352. Quantum Computation and Information. (4 Hours)
Introduces the foundations of quantum computation and information, including finite dimensional quantum mechanics, gates and circuits, quantum algorithms, quantum noise, and error-correcting codes. Assumes a working knowledge of linear algebra and matrix analysis, but no prior experience with quantum theory or algorithms is required.

PHYS 5608. Magnetic Materials for Next-Generation Electronics. (4 Hours)
Covers the fundamentals of magnetic materials. Focuses on the frontiers of research activities on magnetic materials for next-generation sensors and electronics. Topics include magnetic units, magnetic materials classification, origin of ferromagnetism and ferrimagnetism, magnetic anisotropies, magnetostriction, magnetic domain theory, ferromagnetic/ferrimagnetic resonance, magnetodynamics, and magnetic material characterization techniques. Explores soft and hard magnetic materials and their applications, which include magnetic sensors, antennas, hard disk drives, magnetic materials for power supplies on chips, RF and microwave magnetic materials and devices, and spintronics. Also covers magnetic characterization techniques such as vibrating sample magnetometry, B-H looper, ferromagnetic resonance spectrometry, magneto-optic Kerr effect imaging, and magnetic sensing.

Prerequisite(s): (MATH 2321 with a minimum grade of D- ; (PHYS 1155 with a minimum grade of D- or PHYS 1165 with a minimum grade of D-)) or graduate program admission

PHYS 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

PHYS 7200. Methods of Advanced Problem Solving. (4 Hours)
Designed to improve the ability of students to solve physics problems, which are of the same degree of difficulty as problems that often appear on the qualifying exam.

PHYS 7210. Introduction to Research in Physics. (0 Hours)
Offers a weekly seminar to introduce first- and second-year physics graduate students to research being done in the Physics department by advanced physics graduate students and faculty. May be repeated without limit.

PHYS 7220. Methods for Teaching in the Introductory Physics Laboratory 1. (0 Hours)
Introduces first-year physics graduate students to the role of teaching assistant (TA) in the laboratory. Designed to prepare TAs for the experiments they are required to teach undergraduate students. Focuses on improving their teaching and grading effectiveness.

PHYS 7230. Methods for Teaching Introductory Physics Laboratory 2. (0 Hours)
Continues PHYS 7220, offered to first-year graduate physics teaching assistants. Designed to prepare TAs for the experiments they teach to undergraduate students. Offers students an opportunity to improve their teaching and grading effectiveness.

Prerequisite(s): PHYS 7220 with a minimum grade of S

PHYS 7301. Classical Mechanics/Math Methods. (4 Hours)
Covers mathematical methods of physics and classical mechanics. Topics include differential equations, boundary value problems, functions of a complex variable, linear vector spaces, Green's functions, Lagrangian and Hamiltonian mechanics, linear oscillators, and scattering. May include additional topics as time permits.

PHYS 7302. Electromagnetic Theory. (4 Hours)
Analyzes Maxwell's equations in vacuum and special relativity. Topics include electric and magnetic fields due to known sources with boundary conditions, radiation fields, bremsstrahlung, synchrotron radiation, the energy-momentum tensor for the electromagnetic field, fields in material media, boundary conditions at the interface between two media, and scattering of radiation. May include additional topics as time permits.

PHYS 7305. Statistical Physics. (4 Hours)
Briefly reviews thermodynamics. Topics include the principles of statistical mechanics and statistical thermodynamics; density matrix; theory of ensembles; Fermi-Dirac and Bose-Einstein statistics, application to gases, liquids, and solids; theory of phase transitions; and thermodynamics of electric and magnetic systems, transport phenomena, random walks, and cooperative phenomena.

PHYS 7315. Quantum Theory 1. (4 Hours)
Explores the experimental basis of quantum theory, the Schr÷dinger equation, and probability interpretation of wave mechanics. Topics include the uncertainty principle, application to one-dimensional problems, the harmonic oscillator, orbital angular momentum, and the central force problem.

PHYS 7316. Quantum Theory 2. (4 Hours)
Continues PHYS 7315. Topics include quantum theory of scattering; Born approximation; phase-shift analysis; introduction to S-matrix theory; general formulation quantum mechanics in Hilbert space; spin; identical particles and symmetrization principle; time-independent and time-dependent perturbation theory; semiclassical theory of radiation and atomic spectra; addition of angular momentum; Wigner-Eckart theorem; quantum theory of radiation; and absorption, emission, and scattering of photons. Also introduces free particle Dirac equation.

Prerequisite(s): PHYS 7315 with a minimum grade of C-

PHYS 7321. Computational Physics. (4 Hours)
Covers basic numerical methods for differentiation, integration, and matrix operations used in linear algebra problems, discrete Fourier transforms, and standard and stochastic ordinary and partial differential equations. Specific applications of these methods may include classical chaos, computation of eigenstates of simple quantum systems, classical phase transitions, boundary value problems, pattern formation, and molecular dynamics and classical/quantum Monte Carlo methods to simulate the equilibrium and nonequilibrium properties of condensed phases.

PHYS 7322. Nonequilibrium Physics. (4 Hours)
Covers selected topics in nonequilibrium statistical mechanics and nonlinear physics to be selected by the instructor, with emphasis on classical theories of solids, fluids, and other more complex phases of matter. Topics may include Brownian motion, including Langevin and Fokker-Planck equations; linear response theory and transport phenomena; nonequilibrium phase transitions, including nucleation and phase-ordering kinetics; elasticity theory and fluid mechanics; and nonlinear dynamics and pattern formation.

Prerequisite(s): PHYS 7305 with a minimum grade of C

PHYS 7323. Elementary Particle Physics. (4 Hours)
Presents a survey of the present state of elementary particle physics, suitable for all graduate students. Topics include overview of strong interactions and their connection to nuclear physics; nonrelativistic quark structure of strongly interacting particles (hadrons); color and the SU(3) Yang-Mills theory of strong interactions; coupling constant renormalization and asymptotic freedom; and the parton model of scattering. Covers weak interactions including phenomenology of the Fermi V-A theory; universality; and neutrino scattering. Studies the Glashow-Weinberg-Salam theory including unification of weak and electromagnetic interaction, neutral currents, the Higgs mechanism, quark masses and mixing, neutrino masses, and neutrino oscillation. Offers experimental support for the standard model. Also examines supersymmetry including the hierarchy problem and broken supersymmetry; role of supersymmetry in cosmology.

PHYS 7324. Condensed Matter Physics. (4 Hours)
Explores condensed matter physics. Topics include Drude and Sommerfield models of electrons in metals, crystal structure, one-electron states in crystal lattices, Bloch's theorem, semiclassical theory of conduction, semiconductors and semiconducting devices, effects of electron-electron interactions, lattice vibrations and the classical and quantum theories of specific heat, optical properties of solids, investigation of crystal structure and excited states of crystals by x-ray and neutron scattering, simple transport theory based on the Boltzmann equation, and magnetic properties of solids.

PHYS 7325. Quantum Field Theory 1. (4 Hours)
Introduces the principles of quantum field theory. Topics include canonical quantization of scalar and spinor fields, functional integral methods, perturbation theory, regularization and renormalization, and symmetry breaking. Emphasizes applications to particle physics and condensed matter phenomena.

PHYS 7326. Quantum Field Theory 2. (4 Hours)
Presents the quantum theory of gauge fields and their interactions, as well as advanced topics in quantum field theory. Additional topics covered may include Lie groups and Yang-Mills theory, asymptotic freedom, perturbation theory anomalies, and applications to phase transitions.

Prerequisite(s): PHYS 7325 with a minimum grade of C-

PHYS 7332. Network Science Data 2. (4 Hours)
Focuses on practical exercises in real network data. Offers students an opportunity to learn how to retrieve network data from the real world, analyze network structures and properties, study dynamical processes on top of the networks, and visualize networks. The main programming language used in this course is the current industry standard. This is an interdisciplinary course.

Prerequisite(s): PHYS 5116 with a minimum grade of C ; PHYS 7331 with a minimum grade of C

PHYS 7335. Dynamical Processes in Complex Networks. (4 Hours)
Immerses students in the modeling of dynamical processes (contagion, diffusion, routing, consensus formation, etc.) in complex networks. Includes guest lectures from local and national experts working in process modeling on networks. Dynamical processes in complex networks provide a rationale for understanding the emerging tipping points and nonlinear properties that often underpin the most interesting characteristics of sociotechnical systems. Reviews the recent progress in modeling dynamical processes that integrates the complex features and heterogeneities of real-world systems.

Prerequisite(s): NETS 5116 with a minimum grade of C- or PHYS 5116 with a minimum grade of C-

PHYS 7731. Biological Physics 1. (4 Hours)
Introduces the major classes of biological macromolecules and the physics underlying their structure, interaction, and biological function. Emphasis is on physical techniques for characterizing the structure and dynamics of proteins. Students are required to present a written and oral report on a focused research topic in molecular biophysics, based on a critical review of current scientific literature. Topics may include introduction to biomolecular structure, aqueous solution physics and hydrophobic interactions, chemical thermodynamics and reaction dynamics, spectroscopic techniques, molecular force measurements, and protein dynamics.

PHYS 7733. Topics: Elementary Particle Physics and Cosmology. (4 Hours)
Covers unified theories including evidence for supersymmetric SU(5) unification of couplings, and the grand unified scale and proton decay. Discusses particle physics and cosmology including a brief introduction to Einstein's theory of general relativity, candidates for dark matter, inflation and the primordial fluctuations, and the problem of the cosmological constant. Examines developments leading to string theory including normal mode expansion; open and closed strings; deduction of D-26 for bosonic and D-10 for superstrings; scattering amplitudes in strings; heterotic string; compactifications on the torus, orbifolds, and Calabi-Yau manifolds; 4-D strings; and superstring phenomenology. Explores physics with extra dimensions including gravity at small distances, branes, and new approaches to the hierarch problem. May be repeated without limit.

PHYS 7734. Topics: Condensed Matter Physics. (4 Hours)
Covers selected advanced topics in the theory of solids to be chosen each time by the interested students and instructor. Topics may include theory of normal metals, Hartree-Fock and random phase approximations, optical and transport properties, solid-state plasmas, Raman spectroscopy, quasiparticles and collective excitations, quantum solids, and amorphous solids. May be repeated without limit.

Prerequisite(s): PHYS 7324 with a minimum grade of C-

PHYS 7741. Biological Physics 2. (4 Hours)
Continues PHYS 7731. The first part of the course provides a foundation necessary to construct and implement models of neurons and networks of neurons. Topics include Hodgkin-Huxley form of the kinetical equations, single neuron models, dynamics of synapses, plasticity of synaptic strength, and neuromodulators. The second part covers nonlinear time series analysis and nonlinear dynamics in neuroscience. The goal is to provide a set of tools to analyze and model large multidimensional data sets encountered in many biological/neuroscience experiments. Topics include data testing of nonlinearity construction of linear and nonlinear models; spike sorting using independent component analysis and clustering algorithms; and analysis of continuous time series.

Prerequisite(s): PHYS 7731 with a minimum grade of C- ; PHYS 7321 with a minimum grade of C-

PHYS 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

PHYS 7976. Directed Study. (1-4 Hours)
Offers independent work under the direction of a member of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

PHYS 7990. Thesis. (1-4 Hours)
Undertakes a master's thesis in a selected topic in experimental or theoretical physics. Written thesis required. May be repeated without limit.

PHYS 9000. PhD Candidacy Achieved. (0 Hours)
Indicates successful completion of the doctoral comprehensive exam.

PHYS 9984. Advanced Research. (1-8 Hours)
Provides an opportunity for advanced students to work with an individual instructor on a topic related to current research. The instructor and student negotiate a written agreement as to what topic(s) are covered and what written or laboratory work forms the basis for the grade. Viewed as a lead-in to thesis research. May be repeated without limit.

PHYS 9986. Research. (0 Hours)
Offers an opportunity to conduct full-time research under faculty supervision. May be repeated without limit.

PHYS 9990. Dissertation Term 1. (0 Hours)
Offers experimental and theoretical work for PhD candidates. Requires written thesis and final oral exam.

Prerequisite(s): PHYS 9000 with a minimum grade of S

PHYS 9991. Dissertation Term 2. (0 Hours)
Offers dissertation supervision by members of the department.

Prerequisite(s): PHYS 9990 with a minimum grade of S

PHYS 9996. Dissertation Continuation. (0 Hours)
Offers experimental and theoretical work for PhD candidates. Requires written thesis and final oral exam.

Prerequisite(s): PHYS 9991 with a minimum grade of S or Dissertation Check with a score of REQ