# PHYSICS

Physicists study the properties and behavior of matter and energy in a wide variety of contexts, ranging from the sub-microscopic particles from which all ordinary matter is made (particle physics) to the behavior of the Universe as a whole (cosmology). Physics primarily is the science that deals with exploring the Rules of Nature. The fundamental understanding of nature that comes from the study of physics is central to all of the natural sciences, applied sciences and technology; and, thus, profoundly affects the life of every human along with their environment.

The Department of Physics of Saint Joseph's University offers students a comprehensive and flexible curriculum in the discipline of physics. The program offers several advisory tracks (Materials Science and Nanotechnology, Astrophysics, Biophysics, Engineering Physics, Computational Physics and Engineering, Medical Physics, Physics Education, Pre-Med and Pre-Dental) which will allow students to specialize in variety of areas and prepare for a range of careers. The program begins with a core grouping of three introductory physics courses (freshman and sophomore years) in the foundations of classical Newtonian mechanics and Maxwellian electricity and magnetism, geometrical optics, thermodynamics and fluids along with a one-semester program in nonclassical (modern) physics: this course, based on developments in physics that occurred in the first quarter of the twentieth century, introduce students to quantum theory and special relativity. Each of the introductory physics courses is accompanied by a laboratory , which not only complements the didactic material but also trains the student in the methodology of doing experimental physics. During this time, students master the language of physics, i.e., mathematics. Students take three semesters of calculus, Differential Equations and Introduction to Linear Algebra. In addition, they are exposed to modern computational techniques in Numerical Analysis. These physics and mathematics courses provide the foundation to explore a vast array of upper division courses, including physics electives in particular areas of interest. The upper-level courses include the study of classical mechanics, statistical mechanics , electricity and magnetism, quantum mechanics, and experimental methods of physics. Elective topics include solid state physics, biophysics, nuclear and particle physics, computational physics, astrophysics, physics of fluids, advanced quantum mechanics, complex systems and more.

The Department of Physics at Saint Joseph's University has developed a research-oriented culture for both its faculty and students. Most students will engage in research, alongside faculty mentors, at some point during their four years. The ability to put into practice what is learned in the classroom is paramount to the growth of the scientist and the professional. In the research laboratory, the student will learn to design and perform experiments, to analyze data using computational methods, and draw appropriate conclusions. Students will also be exposed to the interfaces of physics where physics meets biology, chemistry and engineering; to that end, the student of physics will witness how the methods of physics are central to addressing key problems in the disciplines of biology, chemistry and engineering. The various tracks will provide the students with an interdisciplinary education.

Undergraduates participate in research in three different ways. First, they may decide to take research for academic credit. Within the major, students take three physics electives and one or more of these may be used to perform scientific research under the guidance of our physics faculty. Second, students may opt to do research as a Summer Scholar. Saint Joseph's University is well known for its 10-week Summer Scholars Research Program. Historically, the Physics Department, through the generosity of its alumni, Dean and Provost, has been able to provide stipends for all physics students who have wanted to do summer research. Students selected to participate in the Summer Scholars Program not only receive a stipend but also are provided low-cost housing by the University. Lastly, students may opt to volunteer in a laboratory at SJU or elsewhere.

## Department Mission

At its core, the mission of the Department of Physics at Saint Joseph's University is to educate students who are broadly trained in the discipline of physics, critical thinking and complex problem solving. They will have the ability to attack problems and enter professional areas, not only in the field of physics, but also in the areas of biology, chemistry, the applied sciences and engineering. Graduates of the department will be able to succeed in a wide range of professional careers where the principles of physics and critical thinking skills associated with a degree in physics are used on a routine basis.

In the spirit of the mission of the university, we believe that our students, through the liberal arts training gleaned from the General Education Program, in particular the "ethical dimension in learning", and the concentration curriculum in physics, will become lifelong learners and will use their knowledge and education for the betterment of humanity.

## Five Year Combined B.S. in Physics/M.S. in Education Option

In addition to the Physics Education track which will allow students to complete an undergraduate double major in Physics and Education and earn a secondary-education (7-12) certification in four years, students can choose to pursue a five-year combined BS in Physics/MS in Education which will also lead to a secondary-education (7-12) certification. Students interested in the five-year program should speak to the Chair of the Department of Physics as early in their academic careers as possible.

# Faculty

The full-time faculty and staff in the Department of Physics at Saint Joseph's University have engaged in significant research and teaching with real-work knowledge and experience in a wide range of physics topics, including soft condensed matter, fluid dynamics, granular materials, patterns in solidification, crystallization, flame fronts, fluid flow, pattern formation and much more.

Department of Physics Faculty & Staff (https://www.sju.edu/departments/physics/faculty-staff/)

# Physics in the GEP

The GEP requires that all students take EITHER one semester of a lab-based natural science course (6 contact hours) OR two semesters of lecture-only natural science courses. Students who entered SJU in the fall of 2010 or later, or transfer students who entered SJU on the GEP curriculum and who wish to satisfy the natural science GEP by completing courses in Physics may do so by taking the first semester of the science majors, lab-based course sequence, PHY 101 (https://academiccatalog.sju.edu/search/?P=PHY%20101)/PHY 101L (https://academiccatalog.sju.edu/search/?P=PHY%20101L) or PHY 105 (https://academiccatalog.sju.edu/search/?P=PHY%20105)/PHY 105L (https://academiccatalog.sju.edu/search/?P=PHY%20105L), or one of the lab-based, one-semester courses for non-science majors, as they become available. Alternatively, students may fulfill one or both semesters of

the natural science GEP by completing one or two of the special one-semester lecture-only Physics courses designed for non-science majors listed below.

Non-science majors Physics GEP lecture-only courses:

| Code | Title | Hours |
|---|---|---|
| PHY 110 | Understanding Natural World | 3 |
| PHY 111 | The Astronomical Universe | 3 |
| PHY 112 | Energy: Problems & Promises | 3 |
| PHY 114 | Tech Breakthroughs of 20th Cen | 3 |

Non-science majors Physics GEP lab-based courses:

| Code | Title | Hours |
|---|---|---|
| PHY 115 | Investigations in Astronomy | 4 |

# Programs

## Undergraduate Major

- Physics (https://academiccatalog.sju.edu/arts-sciences/physics/bs-physics/)

## Undergraduate Minor

- Physics (https://academiccatalog.sju.edu/arts-sciences/physics/minor-physics/)

# Courses

**PHY 100 Physics Orientation (1 credit)**
In this orientation course students are presented with an overview of all aspects of physics, including current topics, career opportunities in the field, academic standards, and integrity, as well as general information about the University and services that help students achieve academic success.
*Attributes:* Undergraduate

**PHY 101 General Physics I (3 credits)**
This two-semester sequence is an algebra-based physics course intended primarily for students majoring in biological and health sciences. Emphasis is on understanding fundamental principles and applying them to the analysis of physical phenomena, with several applications that arise in biology. Topics include classical kinematics and dynamics, fluids, waves, optics, electricity and magnetism and optics.
*Attributes:* GEP Natural Science, Science Course w/Lab (Sci Maj), Undergraduate

**PHY 101L General Physics Laboratory I (1 credit)**
A two-semester laboratory sequence to accompany PHY 101-102.
*Attributes:* GEP Natural Science, Undergraduate

**PHY 102 General Physics II (3 credits)**
This two-semester sequence is an algebra-based physics course intended primarily for students majoring in biological and health sciences. Emphasis is on understanding fundamental principles and applying them to the analysis of physical phenomena, with several applications that arise in biology. Topics include classical kinematics and dynamics, fluids, waves, optics, electricity and magnetism and optics.
*Prerequisites:* PHY 101
*Attributes:* GEP Natural Science, Science Course w/Lab (Sci Maj), Undergraduate

**PHY 102L General Physics Laboratory II (1 credit)**
A two-semester laboratory sequence to accompany PHY 101-102.
*Attributes:* Undergraduate

**PHY 105 University Physics I (3 credits)**
This two-semester sequence is a calculus-based physics course intended primarily for students majoring in physics, chemistry, mathematics, or computer science. Emphasis is on developing both qualitative and quantitative understanding of fundamental physical principles, and the ability to apply those principles to analyze physical phenomena. Topics include classical kinematics and dynamics, electricity and magnetism, waves, and optics.
*Prerequisites:* MAT 161 (may be taken concurrently)
*Restrictions:* Enrollment is limited to students with a major in Actuarial Science, Chemistry, Computer Science, Mathematics, Mathematics - Secondary Educat or Physics.
*Attributes:* GEP Natural Science, Science Course w/Lab (Sci Maj), Undergraduate

**PHY 105L University Physics Lab I (1 credit)**
A two-semester laboratory sequence to accompany PHY 105-106.
*Attributes:* GEP Natural Science, Undergraduate

**PHY 106 University Physics II (3 credits)**
This two-semester sequence is a calculus-based physics course intended primarily for students majoring in physics, chemistry, mathematics, or computer science. Emphasis is on developing both qualitative and quantitative understanding of fundamental physical principles, and the ability to apply those principles to analyze physical phenomena. Topics include classical kinematics and dynamics, electricity and magnetism, waves, and optics.
*Prerequisites:* PHY 105
*Attributes:* GEP Natural Science, Science Course w/Lab (Sci Maj), Undergraduate

**PHY 106L University Physics Lab II (1 credit)**
A two-semester laboratory sequence to accompany PHY 105-106.
*Attributes:* Undergraduate

**PHY 110 Understanding Natural World (3 credits)**
This course offers the non-science major an opportunity to explore how physics impacts everyday life. Topics will vary depending upon the interests of the class, but may include: the physics of sports, why musical instruments sound different from each other, rainbows and other optical phenomena, the physics of toys, Einstein's theory of relativity, and how a laser works. Although mathematics will not be the focus of the course, a working knowledge of algebra, geometry, and simple trigonometry is necessary. Emphasis is placed on developing critical thinking and scientific observation skills.
*Restrictions:* Students cannot enroll who have a major in Biology, Chemistry, Chemical Biology, Environmental Science or Physics.
*Attributes:* GEP Natural Science, Undergraduate

**PHY 111 The Astronomical Universe (3 credits)**
In this course designed for the non-science major, the student is introduced to modern astronomical knowledge and theories. The planets, stars, and galaxies are investigated. Space exploration is discussed. Minimal mathematics is used and no previous science is required.
*Restrictions:* Students cannot enroll who have a major in Biology, Chemistry, Chemical Biology, Environmental Science or Physics.
*Attributes:* GEP Natural Science

**PHY 112 Energy: Problems & Promises (3 credits)**
The goal of this course is to teach the student how to read, analyze, and intelligently comment on news articles about energy and the environment. The physics is straightforward and requires no more than basic business mathematics. Topics include: fossil fuels, large scale renewables, small scale renewables, nuclear power, megawatt accounting for conservation, transportation, and emissions control. The course emphasizes how real data shapes economics and policy, so the exact content will vary with current events.
*Restrictions:* Students cannot enroll who have a major in Biology, Chemistry, Chemical Biology, Environmental Science or Physics.
*Attributes:* GEP Natural Science, Undergraduate

**PHY 113 Physics by Experiment (4 credits)**
In this course, students build up the basic principles of geometrical optics, electricity, thermodynamics, and/or classical mechanics by carrying out guided experiments and interpreting their results. Mathematics, at the level of geometry and simple algebra, is introduced when and as it is needed. This course is a Laboratory /Lecture combination.
*Attributes:* GEP Natural Science, Science Course w/Lab (Sci Maj), Undergraduate

**PHY 114 Tech Breakthroughs of 20th Cen (3 credits)**
This course will explore a smorgasbord of major technological advances that occurred during the 20th century. Many of these developments occurred as a result of the historical, political, and economic factors that shaped much of the landscape of the previous century. The scientific achievements will be discussed in the historical context upon which they occurred paying particular emphasis on the interesting personalities that were responsible for many of the discoveries.
*Attributes:* GEP Natural Science

**PHY 115 Investigations in Astronomy (4 credits)**
This course, designed for the non-science major, provides an introduction to the science of astronomy. Topics include the roles of observation, theory, philosophy, and technology in the development of the modern conception of the Universe. The Copernican Revolution, the birth and death of stars, our Milky Way galaxy, time, and our ancestral heritage in the cosmos will be discussed and explored. No previous science, nor mathematics beyond the level of high school algebra, is required.
*Restrictions:* Students cannot enroll who have a major in Biology, Chemistry, Chemical Biology, Environmental Science or Physics.
*Attributes:* GEP Natural Science, Science Course w/Lab (Sci Maj), Undergraduate

**PHY 115L Investigations in Astro Lab (0 credits)**

**PHY 150 First Year Seminar (3 credits)**
First year seminar course in Physics.
*Attributes:* First-Year Seminar, Undergraduate

**PHY 170 Special Topics in Physics (3 credits)**
Topics will vary according to the semester in which the class is offered.
*Attributes:* Undergraduate

**PHY 200 Survey of Physics (3 credits)**
Covers the basic concepts in physics, including biological and medical applications of pressures and fluids, bioelectricity, biodynamics, and kinesiology.
*Prerequisites:* (MAT 120 (may be taken concurrently) or MA 107) or (MAT 155 (may be taken concurrently) or MA 110) or (MAT 161 (may be taken concurrently) or MA 122)

**PHY 200L Survey of Physics Laboratory (1 credit)**
A laboratory course to accompany PHY 200.
*Attributes:* Undergraduate

**PHY 201 Introductory Physics I (3 credits)**
Algebra- and trigonometry-based general physics course covering principles of mechanics and heat with applications to the health sciences. First course in a two-semester course sequence. This course is not interchangeable with one-semester physics courses such as PHY 200.
*Prerequisites:* (MAT 120 (may be taken concurrently) or MA 107) or (MAT 155 (may be taken concurrently) or MA 110) or (MAT 161 (may be taken concurrently) or MA 122)
*Attributes:* Undergraduate

**PHY 201L Intro. Physics I Laboratory (1 credit)**
A laboratory course to accompany PHY 201.
*Attributes:* Undergraduate

**PHY 202 Introductory Physics II (3 credits)**
Algebra- and trigonometry-based general physics course covering principles of wave motion, electricity and magnetism, optics, and modern physics with applications to the health sciences. Second course in a two-semester course sequence. This course is not interchangeable with one-semester physics courses such as PHY 200.
*Prerequisites:* PHY 201 or PHY 101
*Attributes:* Undergraduate

**PHY 202L Intro. Physics II Laboratory (1 credit)**
A laboratory course to accompany PHY 202.
*Attributes:* Undergraduate

**PHY 211 Physics I (3 credits)**
First semester of a three-semester, calculus-based general physics course sequence. It covers principles of mechanics and heat with applications to the health sciences. The course may involve the use of physics web resources, computer-controlled laboratory experiments, and spreadsheets for data analysis.
*Prerequisites:* (MAT 161 (may be taken concurrently) or MA 122 (may be taken concurrently))
*Attributes:* Undergraduate

**PHY 211L Physics I Laboratory (1 credit)**
A laboratory course to accompany PHY 211.
*Attributes:* Undergraduate

**PHY 212 Physics II (3 credits)**
Second semester of a three-semester, calculus-based general physics course sequence. It covers principles of waves, electricity, magnetism, optics, and modern physics with applications. The course may involve the use of physics web resources, computer-controlled laboratory experiments, and spreadsheets for data analysis. This course meets the PHY 202 prerequisite for all physics elective courses where applicable.
*Prerequisites:* PHY 211 or PHY 105
*Attributes:* Undergraduate

**PHY 212L Physics II Laboratory (1 credit)**
A laboratory course to accompany PHY 212.
*Attributes:* Undergraduate

**PHY 213 Physics III (3 credits)**
Third semester of a three-semester, calculus-based general physics course sequence. It is an introduction to the physics of waves, geometrical optics, fluids, and classical thermodynamics. The course may involve the use of physics web resources.
*Prerequisites:* (PHY 212 or PHY 106) and (PHY 202 or PHY 102) and (MAT 162 or MA 221)
*Attributes:* Undergraduate

**PHY 213L Intro. Physics III Laboratory (1 credit)**
A laboratory course to accompany PHY 213.
*Prerequisites:* PHY 212 and PHY 212L
*Attributes:* Undergraduate

**PHY 235 Views of the Cosmos (3 credits)**
An introduction to the study of the universe from scientific, religious, and philosophical standpoints. Surveys mankind's efforts to understand the nature of the cosmos, including its origins, evolution, and eventual demise. Viewpoints of many religious groups, cultures, and scientific thinkers will be discussed and compared. Contemporary debates in cosmology will be fully explored without mathematics.
*Attributes:* GEP Natural Science, Undergraduate

**PHY 235L Views of the Cosmos Laboratory (1 credit)**

**PHY 251 Modern Physics I (3 credits)**
An analytical survey of the experiments, theories, and principles that led to the modern view of physical reality. Topics include: an introduction to special relativity theory, the dual nature of waves and particles, uncertainty relations, Bohr theory of hydrogen, fundamental aspects of quantum mechanics, the quantum theory of the hydrogen atom, and, if time permits, many-electron atoms.
*Prerequisites:* PHY 106
*Attributes:* Undergraduate

**PHY 252 Modern Physics II (4 credits)**
An extension of PHY 251 to include specific applications of the quantum theory. Topics include: structure and spectra of many-electron atoms and molecules, classical and quantum statistics, theory of solids, nuclear structure and dynamics, and an introduction to elementary particles.
*Prerequisites:* PHY 251
*Attributes:* Undergraduate

**PHY 253 Survey of Nanotechnology (3 credits)**
Nanotechnology embraces the disciplines of applied physics, materials science, supramolecular chemistry, and biological engineering to name a few. An overview of this highly interdisciplinary field will be given with a focus on the role of physics principles that guides this technology and on the new and exotic materials used.
*Prerequisites:* PHY 106
*Attributes:* Undergraduate

**PHY 257 Math Methods in Physics (3 credits)**
Advanced mathematical methods for physics: includes linear vector spaces, orthogonal functions, partial differential equations, complex variables, and transform techniques. Emphasis is on application of these mathematical techniques in solving problems in physics.
*Prerequisites:* PHY 106 or PY 212
*Attributes:* Undergraduate

**PHY 270 Special Topics in Physics (3 credits)**
Topics will vary according to the semester in which the class is offered.
*Attributes:* Undergraduate

**PHY 301 Classical Mechanics (3 credits)**
Newtonian particle dynamics is presented with special emphasis on damped and forced simple harmonic motion and central-force motion. Generalized coordinates are introduced, and both Lagrange's formulation and Hamilton's formulation of classical mechanics are developed.
*Prerequisites:* PHY 106
*Attributes:* Undergraduate

**PHY 303 Thermal Physics (3 credits)**
The laws of thermodynamics are introduced and studied in the classical manner and the statistical mechanical foundations of thermodynamics are developed, including quantum statistics.
*Prerequisites:* PHY 251
*Attributes:* Undergraduate

**PHY 307 Electricity and Magnetism (3 credits)**
The classical (non-quantum) theory of electric and magnetic fields and charge interactions is presented. The appropriate tools of vector analysis are developed as they are needed. The Maxwell equations in both differential and integral form are introduced.
*Prerequisites:* PHY 106 and PHY 257
*Attributes:* Undergraduate

**PHY 308 Waves and Optics (3 credits)**
The study of electromagnetic waves and their associated boundary-value problems. Other topics include a brief analysis of geometrical optics, and detailed study of interference, diffraction, and polarization phenomena associated with electromagnetic waves.
*Prerequisites:* PHY 106 and PHY 257
*Attributes:* Undergraduate

**PHY 311 Experimental Methods of Phy I (3 credits)**
Laboratory intensive with some lecture. Provides the theory of operation and laboratory experiences for both analog and digital circuitry. Emphasis placed on written and oral communication skills and team work.
*Prerequisites:* (PHY 106 or PY 212) and (PHY 106L or PY 212L)
*Attributes:* Undergraduate

**PHY 312 Experimental Methods in Phy II (3 credits)**
Laboratory intensive. Focus on modern physics experiments.
*Prerequisites:* PHY 106 and PHY 106L
*Attributes:* Undergraduate

**PHY 315 Einstein, Bohr, & Modern Phys (3 credits)**
An examination of the lives and achievements of the great physicists of the first half of the twentieth century, including Albert Einstein, Niels Bohr, Werner Heisenberg, Wolfgang Pauli, and others, as they developed the basis of special relativity, general relativity, quantum physics, and nuclear physics. Considers the personal and philosophical dilemmas they faced, through an analysis of historical source materials such as letters, papers, and interview transcripts, and delves into the cultural impact of their work.
*Prerequisites:* PHY 200 or PHY 202 or PHY 212 or PHY 102 or PHY 106
*Attributes:* Undergraduate

**PHY 321 Quantum Mechanics I (3 credits)**
The Schrodinger formulation of quantum theory is developed with its constructs of wave packets, differential operators, and eigenvalue equations. Special emphasis is given to the quantum theory of measurement. Applications include various one-dimensional problems, central potentials and angular momenta. The transition to the matrix formulation of quantum theory is developed.
*Prerequisites:* PHY 251 and (MAT 213 or MA 222)
*Attributes:* Undergraduate

**PHY 330 Descriptive Astronomy (3 credits)**
Covers basic concepts of astronomy, its historical development, and theories of the origin of the universe. The search for life in the universe, the colonization of outer space, and the social and moral issues of the space program are also covered.
*Attributes:* Undergraduate

**PHY 331 Nonlinear Dynamics and Chaos (3 credits)**
This course introduces the theoretical foundations of nonlinear dynamics and chaos. Phase space analysis, bifurcations, routes to chaos, renormalization and universality, fractals and strange attractors are presented for a variety of nonlinear systems including maps and flows. Several examples are used to illustrate the theory, from physics, chemistry, biology , neuroscience, economics and social science. Simulations are used throughout the course either by numerical computations with Matlab, Mathematica, or specific software packages.
*Prerequisites:* MAT 161 or MAT 155
*Attributes:* GEP Natural Science, Undergraduate

**PHY 332 Intro. to Network Science (3 credits)**
Basics of networks theory is introduced. Different network architectures are studied and analyzed . These include random and scale-free networks. Their properties and evolution are presented. In each component of the course a variety of examples of how these networks can model real processes and systems in various fields (data science, social science, mathematics, physics, environmental science, epidemiology, computer science, biology and chemistry , business analytics) will be analyzed. In particular the application of network science in Physics will be included for example for topics such as aggregation phenomena, lattices, neuro physics, critical phenomena, percolation to name few. Also the application of these physics topics to other fields will be presented. This course can be taken only by students in their third year or above.
*Prerequisites:* (MAT 161 or MA 122 or MA 110)
*Attributes:* GEP Natural Science, Undergraduate

**PHY 357 Mathematical Methods (3 credits)**
This course is an introduction to mathematical methods used in physics, chemistry, and related sciences: vector calculus, functions of complex variable, Fourier series, Fourier transform, series solutions of ordinary differential equations, and introduction to group theory. These topics are introduced in the context of specific problems in various areas of physics and physical science such as fluid dynamics, electricity and magnetism, quantum mechanics, thermodynamics, biophysics, and mechanics.
*Prerequisites:* (PHY 212 or PHY 106) and MAT 123
*Attributes:* Undergraduate

**PHY 370 Special Topics in Physics (3 credits)**
Topics will vary according to the semester in which the class is offered.
*Attributes:* Undergraduate

**PHY 390 Physics Seminar (0 credits)**
Topics and agenda may include outside speakers, local speakers, and discussion of special topics in physics and related areas. Physics majors are required to attend each semester. Physics minors are also encouraged to attend. Graded on a P/NP basis.
*Attributes:* Undergraduate

**PHY 401 Advanced Mechanics (3 credits)**
This course will further develop the Lagrangian and Hamiltonian formulations of classical mechanics. Additional emphasis will be given to such topics as: collision theory, noninertial reference frames, nonlinear mechanics and chaos, continuum mechanics, and topics in special relativity.
*Prerequisites:* PHY 301
*Attributes:* Undergraduate

**PHY 403 Quantum Mechanics II (3 credits)**
A continuation of the development of quantum theory started in PHY 321. Topics to include: identical particles including fundamental molecular quantum theory, time-independent and time dependent perturbation theory, the WKB and adiabatic approximations, scattering, and an introduction to field theory.
*Prerequisites:* PHY 321
*Attributes:* Undergraduate

**PHY 405 Solid State Physics (3 credits)**
A study of matter in its solid state. Topics include crystal structure, electrical conduction in metals and semiconductors, dielectrics, magnetic materials, and superconductivity. Includes applications to solid-state devices.
*Prerequisites:* PHY 251 and PHY 257
*Attributes:* Undergraduate

**PHY 407 Soft Condensed Matter Physics (3 credits)**
This course will study the physics of materials such as fluids, liquid crystal, polymers (including biological polymers such as proteins and DNA), colloids, emulsions, foams, gels, and granular materials.
*Prerequisites:* PHY 251 and PHY 252 and PHY 257
*Attributes:* Undergraduate

**PHY 408 Advanced Electromagnetism (3 credits)**
A selection of advanced topics in electromagnetism such as electrostatics, boundary-value problems, fields, and wave propagation in material media. Other topics include propagation in waveguides and transmission lines, gauge transformations, relativistic theory of electromagnetic fields, and numerical techniques in electromagnetism.
*Prerequisites:* PHY 307 and MAT 238
*Attributes:* Undergraduate

**PHY 409 Statistical Mechanics (3 credits)**
Topics include ensembles and distribution functions, quantum statistics, Bose-Einstein and Fermi-Dirac statistics, and partition functions.
*Prerequisites:* PHY 251 and PHY 257
*Attributes:* Undergraduate

**PHY 411 Nuclear Physics (3 credits)**
The phenomena of natural and artificial radioactivity are investigated. Various models of nuclear structure are introduced and examined. Nuclear reactions are studied with emphasis upon fission and fusion. Some of the apparatus of nuclear physics, such as particle accelerators and radiation detection devices, are analyzed.
*Prerequisites:* PHY 251 and MAT 213
*Attributes:* Undergraduate

**PHY 412 Physics of Radiation Therapy (3 credits)**
An introduction to the basics of radiation physics, radiation therapy, and dosimetry.
*Prerequisites:* PHY 102 or PHY 106 or PHY 202 or PHY 212
*Attributes:* Undergraduate

**PHY 413 Materials of Electronics (3 credits)**
This course will focus on the materials used to conduct electrical charge and spin and hence information from one region in space and time to another. Conduction processes in metals, traditional semiconductors, and in organic conducting and semi-conducting materials will be explored with a particular emphasis on the underlying physics principles employed.
*Prerequisites:* PHY 251 and PHY 252 and PHY 257
*Attributes:* Undergraduate

**PHY 415 Computational Physics (3 credits)**
Introduction to problem solving in physics using mathematical modeling, numerical methods, computer simulations and the fundamentals of programming. Topics may include: numerical solutions of Laplace and Poisson equations for electrostatic boundary-value problems, Monte Carlo simulation techniques, chaos theory.
*Prerequisites:* PHY 106 and MAT 213
*Attributes:* Undergraduate

**PHY 417 Astrophysics (3 credits)**
Application of the principles of classical and modern physics to astronomical phenomena. Topics include the acquisition and analysis of primary astronomical data; stellar energy production, structure, and evolution, including red giants, white dwarfs, neutron stars, and black holes; galactic structure and evolution; and cosmology.
*Prerequisites:* PHY 251 and PHY 257
*Attributes:* Undergraduate

**PHY 419 Biophysics (3 credits)**
Application of physics to biological systems. Topics include: molecular biomechanics, fluids, interaction of photons and charged particles with matter, transport phenomena, electrical properties of membranes and nerves, Fourier techniques and signal analysis, image reconstruction, fundamentals of radiology, and health physics issues.
*Prerequisites:* PHY 251 and PHY 257
*Attributes:* Undergraduate

**PHY 421 Physics of Fluids (3 credits)**
The mechanics of continuous media, including balance laws for mass and momentum. Hydrostatic equilibrium, compressible and incompressible flow, vorticity and circulation. Pressure and shear, viscosity, and an introduction to Newtonian and non-Newtonian fluids. Applications may include geophysical flows.
*Prerequisites:* PHY 106 and PHY 257
*Attributes:* Undergraduate

**PHY 423 Biomechanics (4 credits)**
The role played by physical forces in shaping our natural world can be seen in the morphology, behavior, material composition, and spatial distribution of every organism, whether aquatic or terrestrial, plant or animal. This course exposes students to the role of physics in biological systems at the organismic and super-organismic level. Each week the course will focus on a different sub-discipline of Biomechanics presenting the underlying physical principles and the biological ramifications of those principles. In addition, laboratory exercises will present techniques and experimental approaches available to measure forces relevant to biological systems, as well as the quantitative and analytical skills necessary to work in this field.
*Prerequisites:* PHY 101 or PHY 105
*Attributes:* Undergraduate

**PHY 423L BioMechanics Lab (0 credits)**

**PHY 425 Biophysics of the Brain (3 credits)**
This course introduces biophysical models of the brain and the nervous system functioning. In particular the physics of the neocortex is presented through the analysis of EEG studies. Simulations with software packages are employed to illustrate with various examples the models and their results. Linear electrical analogs and some basics of neural network theory are part of the course content. Elements of Biophysics of consciousness are also presented and a set of case studies is analyzed and discussed.
*Prerequisites:* (PHY 102 or PY 202) or (PHY 106 or PY 212) or (MAT 161 or MA 122 or MA 110)
*Attributes:* Undergraduate

**PHY 435 General Relativity (3 credits)**
An introduction to the general theory of relativity. Topics include special relativity, tensor analysis, curved manifolds, the equivalence principle, Einstein's field equations, spherical static solutions, black holes, and cosmology.
*Prerequisites:* PHY 251 (may be taken concurrently)
*Attributes:* Undergraduate

**PHY 440 Introduction to Nanoscience (3 credits)**
Introduction to broad topics of nanoscience and technology, including micro- and nanofabrication methods, small scale surface modification and characterization, physical and chemical properties of nanomaterials, and quantum phenomena, and their application in natural and engineering sciences. Up-to-date novel experimental and theoretical methods via research-based studies.
*Prerequisites:* PHY 321
*Attributes:* Undergraduate

**PHY 463 Physics of Stars & Black Holes (3 credits)**
An introduction to the physics and astrophysics of stellar evolution, including stellar birth, nucleosynthesis, main sequence stars, binary systems, white dwarfs, neutron stars, and black holes.
*Prerequisites:* PHY 251 and PHY 301
*Attributes:* Undergraduate

**PHY 465 Introduction to Cosmology (3 credits)**
An introduction to the physical properties and evolution of the universe, including its age, content, dynamics, and fate.
*Prerequisites:* PHY 251 and PHY 301
*Attributes:* Undergraduate

**PHY 470 Adv Special Topics in Physics (3 credits)**
The topics to be discussed are decided upon by agreement between students and teacher. This sequence is designed for Honors and other qualified students.
*Attributes:* Undergraduate

**PHY 480 Intro to Materials Sci & Eng (3 credits)**
General introduction to different types of materials: metals, ceramics, polymers, and composite materials. The relationship between structure and properties of materials are studied, along with the illustration of their fundamental differences and their applications.
*Prerequisites:* (CHM 125 or CHM 126) and (PHY 303 or PHY 409)
*Attributes:* Undergraduate

**PHY 492 Internship in Physics (3 credits)**

**PHY 493 Research Project in Physics (1-4 credits)**
Students need to complete the application form for independent study (available in the Dean's Office) and have the approval of the department chair and Associate Dean in order to register. Honors Research Project (6 credits) Must be elected in junior year to allow adequate research time. Students need to complete the application form for independent study (available in the Dean's Office) and have the approval of the department chair, Associate Dean and the Honors Program Director in order to register.
*Attributes:* Undergraduate

**PHY 494 Research Project in Physics (1-4 credits)**
Students need to complete the application form for independent study (available in the Dean's Office) and have the approval of the department chair and Associate Dean in order to register. Honors Research Project (6 credits) Must be elected in junior year to allow adequate research time. Students need to complete the application form for independent study (available in the Dean's Office) and have the approval of the department chair, Associate Dean and the Honors Program Director in order to register.
*Attributes:* Undergraduate

**PHY 495 Undergrad Research in Physics (2 credits)**
Students will engage in a supervised research project related to physics or biophysics.
*Attributes:* Undergraduate

**PHY 496 Advanced Research in Physics (3 credits)**
Students will engage in an advanced research project related to physics or biophysics under the close supervision of a faculty member.
*Attributes:* Undergraduate

**PHY 498 Directed Research in Physics (3 credits)**
Students will engage in research of an experimental, computational, or theoretical nature in either physics or biophysics under the close supervision of a faculty member.
*Attributes:* Undergraduate

**PHY 700 Graduate Physics Seminar (1 credit)**
Reports and seminars on topics of current physics interest presented by students. Depending on the instructor, topic may be one of student's or instructor's choice.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 701 Medical Physics (3 credits)**
Biomedical applications of physics are covered with emphasis on diagnostic and treatment implications. Problem-solving opportunities and detailed literature review in the areas of physics pertinent to orthopedic and/or neurologic physical therapy practice are included.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 703 Entrepreneurship & Physics (2 credits)**
This course provides an overview of the tasks performed by physicists working in the private sector and industry. This includes an introduction of entrepreneurship basics. Students are also involved in projects which may include design, testing, cost feasibility and market analysis of simple products. Professional industrial physicists from the private, public, and government sectors are invited to give presentations and interact with the students.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 710 Advanced Mechanics (3 credits)**
Advanced methods for analyzing classical physical systems, making use of Lagrangian, Hamiltonian, and Newtonian techniques. Includes single and multiple particle systems, rigid bodies, symmetry and conservation principles, normal modes of oscillation, continuous systems, and modifications needed for special relativity.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 721 Quantum Mechanics (3 credits)**
The course covers the essential theoretical formulation of quantum mechanics and its formal structure. It analyzes kinematics and dynamics of a set of quantum systems in various representations. The course also introduces the path integral formulation of quantum mechanics and quantum mechanics in phase space. Several examples and applications will be used to illustrate the concepts. These include addition of angular momenta, and charged particle in a magnetic field.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 730 Advanced Nonlinear Dynamics (3 credits)**
The course covers advanced topics in chaos and nonlinear dynamics including center manifolds, homoclinic and heteroclinic tangles and chaotic transport, topology of chaos-branched manifolds, invariant sets, and universality. Also, the symmetry of chaos, chaos in Hamiltonian and conservative systems, KAM theorem, stochastic layers and diffusion, and chaos in quantum systems. Theory will be applied to various systems in physics, chemistry, biology, and other fields. Numerical and computational techniques will be presented and used in the applications.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 757 Mathematical Methods (3 credits)**
Advanced mathematical methods to model systems in physics, physical science and engineering. Integral transforms. Series solutions of ordinary differential equations. Special functions. Solution of partial differential equations, with boundary and initial conditions and their applications. Complex variables, complex integration and their applications. Calculus of variations.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 799 Graduate Research in Physics (3-5 credits)**
A research project in the student's chosen track under the direction of a faculty advisor.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 807 Advanced Electromagnetism (3 credits)**
Advanced methods to study boundary-value in electrostatics. Electrostatics of macroscopic media. Magnetostatics, Faraday's Law, and quasi-static fields. Maxwell Equations, macroscopic electromagnetism and conservation laws. Electromagnetic waves and wave propagation in different media. The course will cover some applications such as wave guides, resonant cavities, optical fibers, scattering and diffraction.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 809 Statistical Mechanics (3 credits)**
Foundations of classical statistical mechanics with applications. Phase transitions, critical phenomena, and renormalization group theory. Quantum statistics such as Bose-Einstein and Fermi-Dirac distributions and their applications. Advanced topics in non-equilibrium statistical mechanics such as classical and quantum theory of linear response, Langevin and Fokker-Planck equations and their applications.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 817 Quantum Information (3 credits)**
Provides a broad survey of the fundamentals and physical implementation of the rapidly-evolving field of quantum information and computation. It discusses the concept of qubits, quantum entanglement, quantum coherence, and quantum gates and algorithms, with a focus on superconductor-based approaches.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 832 Network Theory & Applications (3 credits)**
Different types of networks are analyzed. These include random and scale-free networks. Their properties and evolution are studied. Examples of how these networks can model real processes and systems are introduced.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 833 Pattern Formation (3 credits)**
This course covers different techniques to explore mechanisms of macroscopic pattern formation in a variety of physical systems such as fluids, materials, chemical and biophysical systems. The course introduces both time- and space-patterns. The concept of self-organization and formation of coherent structures is discussed in depth. The course also introduces basic techniques for digital pattern recognition.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 840 Biophysics Exptl Techniques (3 credits)**
Presentation of the available technologies for the research in biophysics, with emphasis on lab-on-a-chip and its interfaces with the atomic force microscopy (AFM) and mass spectrometry. It covers microfluidics techniques, including channel microfluidics and digital microfluidics. The concept of lab-on-a-chip technology is introduced, showing the possibilities for faster and accurate bio-analytical applications when compared to conventional methods.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 841 Physical Approach to Life Sci. (3 credits)**
The course applies physics and mathematics to obtain quantitative information that sheds light on biological processes, particularly at the cellular and molecular level. It includes microfluidics (with lab-on-chip technologies), random walks, diffusion with drift, statistical mechanics and rate equations, with applications to enzyme kinetics, molecular motors, biological electrcity, and protein folding. Throughout the course, the student is guided in up-to-date discussion on selected papers and presentations on current platforms in the discipline.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 850 Materials Sci Exptl Techniques (3 credits)**
Introduces students to the principles and applications of state-of-the-art experimental techniques for the measurement and analysis of the structure and properties of materials. The course will involve a mixture of lectures, demonstrations and hands-on laboratory exercises. Topics are selected from advanced microscopy, electronic, optical, and thermodynamic methods of probing materials.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 851 Quantum Materials (3 credits)**
Introduces students to quantum effects in materials. Topics include superconductivity, magnetism, graphene and nanomaterials, topological insulators, charge and spin density waves, classical and quantum phase transitions, and interfaces.
*Restrictions:* Enrollment is limited to Graduate level students.

**PHY 890 Graduate Special Topics (3 credits)**
This course is designed to allow in-depth exploration of one of a variety of topics of current interest in physics. The topic will be designated by the instructor.
*Restrictions:* Enrollment is limited to Graduate level students.