PHYSICS & ASTRONOMY (PHYS)

PHYS 1011 21st-Century Physics and Astronomy I (4 Credits)
First class in a three-quarter sequence that explores the meaning of discoveries in our physical world in terms of astronomy and astrophysics, and how they shape modern research into our knowledge of the nature of the universe. In this course sequence, students (1) survey the fundamentals of the cutting-edge astronomy and astrophysics and (2) learn how physics works in explaining varieties of observed astronomical phenomena that encompass the origin and evolution of the universe and its contents--from galaxies to stars and planets. In this way students become familiar with the essential concepts of modern physics in terms of astronomy and astrophysics. Lab fee associated with these courses. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement.

PHYS 1012 21st-Century Physics and Astronomy II (4 Credits)
Second class in a three-quarter sequence that explores the meaning of discoveries in our physical world in terms of astronomy and astrophysics, and how they shape modern research into our knowledge of the nature of the universe. In this course sequence, students (1) survey the fundamentals of the cutting-edge astronomy and astrophysics and (2) learn how physics works in explaining varieties of observed astronomical phenomena that encompass the origin and evolution of the universe and its contents--from galaxies to stars and planets. In this way students become familiar with the essential concepts of modern physics in terms of astronomy and astrophysics. Lab fee associated with these courses. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement.

PHYS 1013 21st-Century Physics and Astronomy III (4 Credits)
Third class in a three-quarter sequence that explores the meaning of discoveries in our physical world in terms of astronomy and astrophysics, and how they shape modern research into our knowledge of the nature of the universe. In this course sequence, students (1) survey the fundamentals of the cutting-edge astronomy and astrophysics and (2) learn how physics works in explaining varieties of observed astronomical phenomena that encompass the origin and evolution of the universe and its contents--from galaxies to stars and planets. In this way students become familiar with the essential concepts of modern physics in terms of astronomy and astrophysics. Lab fee associated with these courses. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement.

PHYS 1050 Descriptive Astronomy (4 Credits)
Introduction to the cosmos, including stars, galaxies, and origin and fate of universe; constellations and observing techniques. Includes laboratory and observing sessions at Chamberlin Observatory's 20-inch refractor telescope.

PHYS 1070 Solar System Astronomy (4 Credits)
Introduction to advances in knowledge of atmospheres, surfaces and interiors of other planets in our solar system and elsewhere; emphasis on interpretation and significance of discoveries for the nonspecialist. Includes observing at Chamberlin Observatory. Recommended Prerequisite: PHYS 1050.

PHYS 1090 The Observable Universe (4 Credits)
In astronomy, the Universe is our laboratory! By actively studying the dynamic cosmos, we can understand where we came from, where we are going, and how physics works under conditions that are impossible to recreate on Earth. In this course, we will explore the origin and fate of the Universe: how it all began, how it might end, and how we can use astronomical observations to peer back into ancient time and predict the far future. We will also enjoy exclusive access to DU's historic Chamberlin Observatory for actual use of the telescope. By actively engaging with the night sky, we learn by hands-on observation and kinetic learning modalities. For some, astronomy provides a sense of wonder and awe, while others see it as a way to uncover the secrets of the cosmos. No matter what your motivation, whether it comes from artistic wonder or a wish to understand humanity better, astronomy has the power to change your perspective on everyday life. Recommended prerequisite: PHYS 1050.

PHYS 1111 General Physics I (5 Credits)
This is the first of a three-quarter sequence for students in any Natural Science and Mathematics field of study. The course stresses physics concepts rather than equation derivation as in the calculus-based course (PHYS 1211/PHYS 1212/PHYS 1213 or PHYS 1214). Algebra and trigonometry are used regularly to solve problems and make predictions. Includes topics in mechanics (kinematics, dynamics) including forces, one and two dimensional motion, work, energy and momentum. The course includes a rigorous algebra-based laboratory that exposes students to a broad range of the real physical phenomena investigated using equipment as well as computerized instrumentation and data acquisition techniques. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Prerequisites: high school algebra, trigonometry. Students majoring in physics or engineering are required to take PHYS 1211/PHYS 1212/PHYS 1213 or PHYS 1214. Lab fee associated with this course.

PHYS 1112 General Physics II (5 Credits)
This is the second of a three-quarter sequence for students in any Natural Science and Mathematics field of study. The course stresses physics concepts rather than equation derivation as in the calculus-based course (PHYS 1211/PHYS 1212/PHYS 1213 or PHYS 1214). Algebra and trigonometry are used regularly to solve problems and make predictions. Includes topics in rotational motion, torque, vibrations, fluids, heat and thermodynamics, kinetic theory, and particles and matter waves. The course includes a rigorous algebra-based laboratory that exposes students to a broad range of the real physical phenomena investigated using equipment as well as computerized instrumentation and data acquisition techniques. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Prerequisites: high school algebra, trigonometry, PHYS 1111. Students majoring in physics or engineering are required to take PHYS 1211/PHYS 1212/PHYS 1213 or PHYS 1214. Lab fee associated with this course.

PHYS 1113 General Physics III (5 Credits)
This is the third of a three-quarter sequence for students in any Natural Science and Mathematics field of study. The course stresses physics concepts rather than equation derivation as in the calculus-based course (PHYS 1211/PHYS 1212/PHYS 1213 or PHYS 1214). Algebra and trigonometry are used regularly to solve problems and make predictions. Includes topics in rotational motion, torque, vibrations, fluids, heat and thermodynamics, kinetic theory, and particles and matter waves. The course includes a rigorous algebra-based laboratory that exposes students to a broad range of the real physical phenomena investigated using equipment as well as computerized instrumentation and data acquisition techniques. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Prerequisites: high school algebra, trigonometry, PHYS 1112. Students majoring in physics or engineering are required to take PHYS 1211/PHYS 1212/PHYS 1213 or PHYS 1214. Lab fee associated with this course.

PHYS 1200 Physics Preparatory (2 Credits)
This course is strongly recommended to everyone considering a major in physics and astronomy. It introduces students to problems, techniques, and tools used in physics and astronomy and offers an overview of the research carried out in the Department of Physics and Astronomy. High-school physics knowledge is not required.

PHYS 1211 University Physics I (5 Credits)
First of a three-quarter sequence. Kinematics, vectors, force, energy and work, linear momentum, rotation of rigid bodies. Required for all physics and engineering majors and recommended for all science majors who are also required to take calculus. The course includes a rigorous calculus-based laboratory that exposes students to a broad range of the real physical phenomena studied in the lecture course. Through the use of experimental apparatus, computerized instrumentation and data acquisition, data analysis and graphical representation, students use the observed phenomena to exemplify the laws of physics. Physics theory and other relevant background information are explored individually by students in weekly prelab exercises. Students learn to write introductory-level laboratory reports and become familiar with good laboratory technique. Emphasis for this lab is on mechanics. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Corequisite: MATH 1951.

PHYS 1212 University Physics II (5 Credits)
Second of a three-quarter sequence. Gravitation, fluids; oscillatory motion; waves; thermal physics. Required for all physics and engineering majors and recommended for all science majors who are also required to take calculus. The lab portion of this course is a continuation of the PHYS 1211 lab portion and builds on laboratory skills and knowledge from that course. Emphasis for this lab is on waves, oscillations, sound, fluids and thermodynamics. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Prerequisite: PHYS 1211. Corequisite: MATH 1952.

PHYS 1213 University Physics III (5 Credits)
Third of a three-quarter sequence. Electrostatics, electric circuits, magnetism and electromagnetism; electromagnetic waves. Required for all physics and engineering majors and recommended for all science majors who are also required to take calculus. The lab portion of this course is a continuation of the PHYS 1221 and 1222 lab portions and builds on the students' laboratory skills and knowledge from those labs. Emphasis for this lab is on electricity, magnetism and circuits. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Cross listed with PHYS 1214. Prerequisite: PHYS 1212. Corequisite: MATH 1953.

PHYS 1214 University Physics III for Engineers (4 Credits)
This is the third course of a three-quarter sequence and is for engineers only; this is equivalent to PHYS 1213, but does not include lab component. Electrostatics, electric circuits, magnetism and electromagnetism; electromagnetic waves. Required for all engineering majors. This course counts toward the Scientific Inquiry: The Natural and Physical World requirement. Cross listed with PHYS 1213. Prerequisite: PHYS 1212. Corequisite: MATH 1953.

PHYS 1991 Independent Study (1-10 Credits)

PHYS 1995 Independent Research (1-10 Credits)

PHYS 2011 Circuits I (3 Credits)
Cross-listed with ENEE 2012. An introduction to electrical circuits analysis and design. Emphasis is on definitions of basic variables, passive circuit components and the ideal operational amplifier. DC analysis of circuits and circuit theorems are stressed. AC signals are introduced. Computer analysis software is integrated throughout the course. Cross listed with ENEE 2011. Co-requisites: PHYS 1213 or 1214, MATH 1953, PHYS 2015 or instructor's permission.

PHYS 2015 Engineering Applications I (1 Credit)
Cross-listed with ENEE 2015. Laboratory program introduces electronic test equipment, verifies circuit theorems and practices elementary interface circuit design. Cross listed with ENGR 2015. Co-requisite: PHYS 2011 or instructor's permission.

PHYS 2021 Circuits II (3 Credits)
Cross-listed with ENEE 2021. AC analysis of linear circuits to include circuit theorems via classical and transform techniques. Emphasis is on Laplace transform, including use of pole-zero and Bode diagrams to analyze and design circuits, including multiple filters (single-pole cascade, Butterwork, Chebyshev), and step response circuits. Phasors applications to sinusoidal steady state analysis and AC power. Computer analysis software is used as an aid to circuit design. Cross listed with ENEE 2021. Prerequisites: PHYS 2011, PHYS 2015. Corequisites: PHYS 2025, MATH 2070.

PHYS 2025 Engineering Applications II (1 Credit)
Cross-listed with ENEE 2025. Laboratory program practicing time and frequency domain analysis and design techniques on step response and filter problems. Applications to instrumentation and circuits. Cross listed with ENEE 2025. Prerequisite: PHYS 2011. Corequisite: PHYS 2021 or instructor's permission.

PHYS 2050 Ways of Seeing and Sensing: Astrophysics (4 Credits)
Ways of Seeing and Sensing represents a new collaboration between the departments of Media, Film & Journalism Studies, Biological Sciences, and Physics & Astronomy. The class is a place-based exercise revolving around the idea that what we know about our surroundings depends on how we “see” or “sense.” We will examine various aspects of nature specific to the Kennedy Mountain Campus (KMC) using both micro and macro approaches to “seeing” through a variety of technologies, including microscopes, trail cameras, photo and video cameras, night vision glasses, and telescopes. To develop the concept of “sensing,” we will explore the soundscapes of the KMC as well as the ways plants and animals endemic to this ecosystem sense their surroundings. We will also explore using human senses other than sight to navigate the nighttime environment. The course will focus on science communication, storytelling, and the creation of professional-quality photo and video content for dissemination on the Internet, at environmental film festivals, in galleries, at campus events, and potentially via broadcast outlets. Students will work in teams of 3–4 to develop and produce documentary stories unique to the ecology and astronomy of the KMC. Students choosing the astrophysics focus will also complete assignments on optics and telescope design, coordinates and motions of the night sky, and the use of non-optical wavelengths and multimessenger techniques as ways of "sensing" in modern observational astronomy. This course will meet together with BIOL 2050 and MFJS 2050 courses, which have different prerequisites and discipline-specific assignments. Prerequisites: PHYS 1013 or PHYS 1113 or PHYS 1212.

PHYS 2051 Astrobiology (4 Credits)
The nature of our solar system, and those of recently discovered solar systems around other stars, will be examined using the tools of modern physics and astronomy, with a focus on biogenic opportunities in these diverse environments. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1113, PHYS 1213, PHYS 1214, or instructor’s permission.

PHYS 2052 Stellar Physics (4 Credits)
The physics of stars will be examined using the tools of modern physics and astronomy, with the focus on their structure, interiors, origin and evolution, including single and multiple star systems, white dwarf, neutron stars and black holes. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1113, PHYS 1213, PHYS 1214, or instructor’s permission.

PHYS 2053 Galaxies and Cosmology (4 Credits)
Modern discoveries involving galaxies in our universe and cosmological theories based on these and particle physics findings will be examined using the tools of modern physics and astronomy. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1113, PHYS 1213, PHYS 1214, or instructor’s permission.

PHYS 2061 Telescopes and Instrumentation (4 Credits)
The student will develop and refine facility and experience with telescopes, software, methods, catalogs, libraries, astronomical instrumentation and assorted contents of the universe, including ground-based and space-based telescopes and detector systems. Observing projects included; use of the Student Astronomy Lab and/or internet telescope(s) for observing projects and variable star monitoring, plus occasional use of the 20 inch Clark/Saegmuller refractor or Mt. Evans reflectors for observing, measuring and practicing public instruction. Math tools include algebra, statistics, Excel, Mathcad, IDL, C++, etc. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1050 or PHYS 1070 or PHYS 1090 or PHYS 1112 or PHYS 1212 or instructor’s permission.

PHYS 2062 Astronomy with Digital Cameras (4 Credits)
The revolution brought about with digital recording systems has revolutionized astronomy by providing access to faint source imaging and in-depth astronomical spectroscopy not possible during the photographic era. This course will train students to apply this technology to problems associated with light and spectrum measurement that facilitate tests of modern astrophysical theories. Each student will select an observing project to develop during the term, pursue data collection and analysis at the Student Astronomy Lab or other telescope(s), and report results on a personal website and/or in poster format. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1050 or PHYS 1070 or PHYS 1090 or PHYS 1113 or PHYS 1213 or instructor’s permission.

PHYS 2063 Observing & Data Analysis (4 Credits)
Students will learn fundamentals of astronomical research with hands-on data analysis opportunities. After going over the basics of astronomical observations and the standard FITS data file format, students will practice both imaging and spectroscopic data reduction processes using actual astronomical data. Proficiency in computer programing/scripting is strongly desired (strong preference is given to Python, IDL, C, and any other for which FITS I/O routines are available). Students are required to bring their own laptop to class. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1113, or PHYS 1213, or PHYS 1214; or instructor’s permission.

PHYS 2251 Modern Physics I (4 Credits)
First of a two-quarter sequence. Topics covered: Introduction to special relativity; photons, de Broglie wavelength, Heisenberg uncertainty principles, quantum numbers and invariance principles; introduction to quantum physics of atoms, molecules, solids and nuclei; radioactive decay; elementary particles. Prerequisites: PHYS 1113, PHYS 1213 or PHYS 1214 and MATH 1953. Corequisite: MATH 2070.

PHYS 2252 Modern Physics II (4 Credits)
Second of a two-quarter sequence. Topics covered: Advanced topics in quantum mechanics: particle in a box, tunneling, variational principle, symmetry; introduction to statistical physics and thermodynamics: ensembles, Bose-Einstein condensation, super-fluidity, superconductivity, nano-science; introduction to chaos: maps, stability analysis, bifurcations; introduction to computational physics. Prerequisite: PHYS 2251. Corequisite: PHYS 2260.

PHYS 2259 Uncertainty and Error Analysis (2 Credits)
In this course, students will build on the laboratory experience gained in University Physics Lab. Students will learn why uncertainty analysis is crucial to reducing and correcting errors in science. Additionally, students will develop the theory behind, and learn how to carry out, uncertainty and data analysis calculations. Uncertainty analysis topics include statistical analysis of data, propagation of error, the normal distribution, rejection of data, weighted averages, least-squares fitting, covariance and correlation, the binomial and Poisson distributions, and the chi-squared test. Strong emphasis for this course is placed on having students develop independence with their laboratory skills, as well as preparing students for Modern Physics Lab (PHYS 2260). Prerequisites: PHYS 1213 or PHYS 1214 and MATH 1953 or MATH 1963.

PHYS 2260 Modern Physics Lab (1 Credit)
Laboratory to accompany PHYS 2252. Students will perform laboratories that demonstrate special relativity, the wave/particle duality of light, the quantization of charge, and the discrete nature of energy levels in bound systems. Laboratories include the Michelson-Morley experiment, spectroscopy, blackbody radiation, laser diffraction and the double slit experiment, the photoelectric effect, the Millikan oil drop experiment, the charge-to-mass ratio of the electron, and the Franck-Hertz experiment. Students will apply uncertainty and error analysis to real experimental data. Strong emphasis for this lab is placed on having students develop independence with their laboratory skills. A Windows-based laptop computer is required for this lab. Lab fee associated with this course. Prerequisites: PHYS 2259 and MATH 2070. Corequisite: PHYS 2252.

PHYS 2300 Physics of the Body (3 Credits)
This is the first course required for a medical physics minor. Muscles and forces; physics of the skeleton; energy, heat, work and power of the body; osmosis and kidneys; lungs and breathing; cardiovascular system; electrical and magnetic signals in the body. Prerequisite: PHYS 1113, PHYS 1213, or PHYS 1214.

PHYS 2311 Intermediate Lab I (2 Credits)
In this lab, students learn to develop laboratory instrumentation to make physical measurements using electronic circuitry and the personal computer. Laboratory exercises include a review of DC circuits including transistors, LabVIEW programming, the PC parallel port, AC circuits and the oscilloscope, operational amplifiers and the RS-232C serial port. Strong emphasis for this lab is placed on having students develop independence with their laboratory skills. Prerequisites: PHYS 2260 and MATH 2070.

PHYS 2312 Intermediate Lab II (2 Credits)
This lab is a continuation of PHYS 2311 and builds heavily on the concepts learned during that first quarter. Laboratory exercises include using the personal computer, LabVIEW programming, and electronic circuitry for single point and waveform data acquisition including the Fast Fourier Transform, GPIB and serial devices, transducers, controls and feedback systems, counting, and timing. Strong emphasis for this lab is placed on having students develop independence with their laboratory skills. Prerequisite: PHYS 2311.

PHYS 2313 Intermediate Lab III (2 Credits)
This lab is the final lab in the Intermediate Lab sequence. Students leverage the knowledge gained in the first two quarters to perform physics experiments using electronic circuitry and the personal computer. It is expected that students will be independent in their ability to perform in the laboratory. Prerequisite: PHYS 2312.

PHYS 2340 Medical Imaging Physics (3 Credits)
This is the second course required for a medical physics minor, following Physics of the Body (PHYS 2300). X-rays; nuclear medicine instrumentation; radiography and fluoroscopy; computed tomography; ultrasound; magnetic resonance imaging; radiobiology. Prerequisites: PHYS 1112, PHYS 1212.

PHYS 2350 Radiology and Nuclear Medicine (3 Credits)
This course will give students an understanding of the physical underpinnings of diagnostic radiological techniques (including x-ray imaging, CT, ultrasound, and MRI), and nuclear medicine (including radiation safety, dosimetry, PET and SPECT imaging, and radiation therapy). Pre-requisites: PHYS 1113 or PHYS 1213 or PHYS 1214.

PHYS 2400 Introduction to Quantum Computing (4 Credits)
This physics course will introduce students to the theory and applications of quantum computing. Students will gain a foundational understanding of quantum computing concepts, principles, and applications, and will gain experience simulating and programming quantum gates – culminating in students designing a quantum computation and running it on a real quantum computer. This experience will prepare students to engage with quantum science and engineering. Prerequisite: MATH 1953.

PHYS 2510 Applied Mechanics I (3 Credits)
First of a three-quarter sequence. Co-listed with ENME 2510. Statics of particles, equivalent systems of forces, centroids and center of gravity, frames and machines, friction, moments of inertia, method of virtual work. Kinematics of particles, Newton's second law, energy and momentum, central force motion, impulsive motion, kinematics and motion of rigid bodies in two and three dimensions; accelerated frames of reference; mechanical vibrations. Cross listed with ENME 2510. Prerequisite: PHYS 1211.

PHYS 2520 Applied Mechanics II (3 Credits)
Second of a three-quarter sequence. Statics of particles, equivalent systems of forces, centroids and center of gravity, frames and machines, friction, moments of inertia, method of virtual work. Kinematics of particles, Newton's second law, energy and momentum methods for particles and systems of particles, angular momentum, central force motion, impulsive motion, kinematics and motion of rigid bodies in two and three dimensions; accelerated frames of reference; mechanical vibrations. Cross listed with ENME 2520. Prerequisites: PHYS 2510, ENGR 3610.

PHYS 2530 Applied Mechanics III (3 Credits)
Third of a three-quarter sequence. Statics of particles, equivalent systems of forces, centroids and center of gravity, frames and machines, friction, moments of inertia, method of virtual work. Kinematics of particles, Newton's second law, energy and momentum methods from particles and systems of particles, angular momentum, central force motion, impulsive motion, kinematics and motion of rigid bodies in two and three dimensions; accelerated frames of reference; mechanical vibrations. Cross listed with ENME 2530. Prerequisites: PHYS 2520, ENGR 3610.

PHYS 2610 Physics of Climate (4 Credits)
The course will examine energy from the sun and how it flows into the land, atmosphere, and oceans and then out to space, and how that regulates the average temperature of Earth (and other planets). Emphasis will be placed on the carbon cycle of the Earth and related topics: atmospheric chemistry of greenhouse gases, forests and phytoplankton, weathering, glaciers, paleontological climate, and the formation of ancient hydrocarbons. Algebra will be used in the class. A 1000-level NSM course or permission of the instructor is required.

PHYS 2710 The Nanoscale Physics of Energy, Information, and Environment (4 Credits)
This course, intended for physics majors with interests in nanoscale science and applications in condensed matter physics, sustainability, complex systems, and similar topics but open to other science or engineering majors on request, is formed from a series of quantitative explorations of the physics underpinning critical challenges for science and society in the 21st century. The level goes beyond introductory material, and students will exercise a basic understanding of quantum mechanics, chemical bonding, and thermodynamics. The goal is provide the bedrock understanding of the grand challenges that enables scientifically "literate" citizenship and action. Planned topics include the molecular and chemical physics that influences climate, the fundamentals of energy consumption in organisms, the nanoscale physics of information technology and energy generation. We will naturally explore connections between these areas. Enforced Prerequisites and Restrictions: (PHYS 1213 OR PHYS 1214) AND MATH 1953.

PHYS 2830 Natural Optics (3 Credits)
An investigation of naturally occurring optical phenomena with an emphasis on observational characteristics and causes. The winter 2020 planned offering will be hybrid, with in-class and online meetings. Credit can apply toward physics or astrophysics minor. Prerequisite: PHYS 1113, PHYS 1213 or PHYS 1214 or instructor's permission.

PHYS 2991 Independent Study (1-10 Credits)

PHYS 2995 Independent Research (1-10 Credits)

PHYS 3100 Senior Seminar (2 Credits)
This course offers primers on literature research, practices of a good scientific writing, putting together a good presentation or report, carrying out and documenting research, preparing for graduate program and/or job. Required for all Physics majors. Prerequisite: PHYS 2252.

PHYS 3111 Quantum Physics I (4 Credits)
First of a two-quarter sequence. The Schrödinger equation: interpretation of wave functions; the uncertainty principle; stationary states; the free particle and wave packets; the harmonic oscillator; square well potentials. Hilbert space: observables, commutator algebra, eigenfunctions of a Hermitian operator; the hydrogen atom and hydrogenic atoms. Prerequisites: PHYS 2252, PHYS 2260, PHYS 2556, PHYS 3612 and MATH 2070.

PHYS 3112 Quantum Physics II (4 Credits)
Second of a two-quarter sequence. Angular momentum and spin; identical particles; the Pauli exclusion principle; atoms and solids: band theory; perturbation theory; the fine structure of hydrogen; the Zeeman effect; hyperfine splitting; the variational principle; the WKB approximation; tunneling; time dependent perturbation theory; emission and absorption of radiation. Scattering: partial wave analysis; the Born approximation. Prerequisite: PHYS 3111.

PHYS 3251 Astrophysics: Radiative Processes (4 Credits)
Because light is the primary means by which astronomers learn about the Universe, understanding the production and subsequent behavior of light is key to interpreting astronomical observations. This course introduces students to the physics of astrophysical radiation and its interaction with matter as it travels from its source to our detectors. Topics may include radiative transfer, emission and absorption processes, Compton processes, synchrotron radiation, thermodynamic equilibrium, radiative and collisional excitation, and spectroscopy of atoms and molecules. The course is aimed at advanced undergraduates, as well as graduate students focusing on astrophysics research. Credit can apply toward physics or astrophysics minor. Prerequisites: PHYS 2252 and MATH 1953, or instructor's permission.

PHYS 3252 Astrophysics: Observations (4 Credits)
Astronomy is fundamentally an observational science and as such it is important for practitioners to understand how their data are collected and analyzed. This course is therefore a comprehensive review of current observational techniques and instruments, aimed at advanced undergraduates, as well as graduate students focusing on astrophysics research. This class introduces students to the capabilities and limitations of different types of instruments while exploring the sources and types of noise and providing statistical tools necessary for interpreting observational data. Credit can apply toward physics or astrophysics minor. Prerequisites: PHYS 2252 and MATH 1953, or instructor's permission.

PHYS 3254 Astrophysics: Stars (4 Credits)
Stars are the fundamental building blocks of the Universe. Hence, understanding the nature of stars is the first step toward understanding the Universe. This course is therefore intended to introduce students to the rigorous physical and mathematical treatise of stellar structure and evolution. Topics may include the theoretical origins and applications fundamental equations of stellar structure and other supporting equations, and theoretical and observational applications of stellar evolution. The course is aimed at advanced undergraduates, as well as graduate students focusing on astrophysics research. Credit can apply toward Physics major or Astrophysics minor. Prerequisites: PHYS 2252 and MATH 1953, or instructor's permission.

PHYS 3255 Black Holes and Cosmology (4 Credits)
The very small, the very large, and the very gravitational provide extreme tests of physics. In this course, we will cover two of these: cosmology, i.e., the universe on large scales, or as a whole (the very large) and black holes (the very gravitational). We will cover some basics of special and general relativity and quantum mechanics relevant to these topics, and discuss recent research testing these frontiers of physics, emphasizing analogies that help to relate these exotica to more familiar physical systems. Prerequisites: PHYS 2252 and MATH 1953.

PHYS 3270 Workshop: Practical Astronomy (1-5 Credits)
Capstone coursework featuring studies in experimental, computational, and/or theoretical work in astronomy and astrophysics. Credit can apply toward physics or astrophysics minor.

PHYS 3310 Quantum Electronics & Topology (4 Credits)
This Physics course will introduce students to the basics of electrical and topological phenomena in quantum materials. The course will focus on phenomenology in two-dimensional (2D) materials, in which quantum electronic transport and topology play a major role. Starting from quantum mechanics and condensed matter basics, we will introduce the most widely used 2D systems, such as graphene, and explore their electronic properties. Students will learn about modern concepts in the field of 2D materials, such as topology, electronic correlations, moiré physics, and fractionalization. Students will also have hands-on experience with basic electrical measurements and 2D device fabrication, designed to supplement the lecture.

PHYS 3320 Introduction to Quantum Materials (4 Credits)
General: This physics course will introduce students to the recent experimental and theoretical developments in the field of quantum materials. Students will gain a basic understanding of how reducing the dimensions of materials to the nanoscale can produce extraordinary physical properties. The course will focus on fundamentals and recent advances in the fields of quantum transport, 2D materials, strongly correlated electronic systems, topological materials, and superconductivity. The goal of this course is to prepare students to engage with the modern condensed matter physics research and application engineering of novel quantum materials.

PHYS 3333 Magnetism and Spintronics: from Classical to Quantum (4 Credits)
This Physics course will introduce students the fundamentals of magnetism and spintronics as well as their applications in both classical world and quantum world. Besides understanding the principle of modern technologies such as motors, hard disk drives, MRI etc., the students will also have hands-on experience with microelectronics, microwave and laser techniques specially designed to supplement the lecture.

PHYS 3350 Physics and Information (4 Credits)
Students in Physical Sciences are often well versed in the art of model building but less so in the process of model-selection when multiple models can describe the same data. Students rarely learn tools beyond curve fitting and least square error minimization for model selection. Consequently, students are often unaware of the scope of different tools and fail to make judicious choice of algorithms/theories when faced with diverse problems. For example, building a model from data is very different from generating data (stochastic or deterministic) from a model. Next consider two contrasting challenges of model building i) when there is limited data vs ii) when there is too much data. For the first problem -- inferring models from limited data -- the solution can be traced back to Boltzmann's formulation of Statistical Physics describing motion of atoms. The connection between Information theory, Inference and Boltzmann's description, however, is often overlooked in introductory or even advanced classes in Physics, and Statistics. Studying these similarities can unlock novel solutions for problems well outside of thermodynamics, even as far as Image processing, Biology and Network science. Inference also requires us to appreciate fundamental topics in Probability -- difference between frequentist and non-frequentist approach, Bayesian formalism -- that are rarely taught to physical scientists, life scientists or engineers. At the other extreme, faced with data deluge, we routinely ask: how do we make sense of too much data ? We use clustering, PCA, Neural Networks. In this course we will discuss and connect all these seemingly disparate concepts and apply them -- at the appropriate context -- to diverse problems in Physics, Chemistry, Biology and beyond. In the process we will gain an in-depth knowledge about commonly heard but perhaps less understood topics such as: Entropy, Likelihood maximization, Bayesian statistics, PCA, Classification algorithms, and Neural Networks. We will also address another often overlooked but fundamental and fascinating topic, biology's inherent ability to encode and decode information. Currently there is no such course that address all these topics in Information and Data Science in an unified manner -- deeply connecting their formal basis, regime of applicability -- grounded on physical principles, with a forward looking approach towards application in many areas well outside of traditional sciences. A lot of learning in the course will happen `on the fly', where the tools and application problems are learnt as needed. Prerequisites: Calculus I, Calculus II, and at least two other courses focusing on application of mathematics to problems in physics/chemistry/biology or engineering. Example of this course can be University Physics, Modern Physics, Biostatistics, Differential Equation, Linear Algebra, Computational Physics, or other equivalent courses (upon Instructor approval).

PHYS 3510 Analytical Mechanics I (4 Credits)
Lagrangian and Hamiltonian mechanics. Prerequisites: PHYS 1113, PHYS 1213, or PHYS 1214 and MATH 2070 and consent of instructor.

PHYS 3520 Analytical Mechanics II (4 Credits)
Second of a two-quarter sequence: two-body central force problems, moving coordinate systems, rotational motion of rigid bodies, coupled oscillations and normal modes, and Hamiltonian mechanics. Prerequisite: PHYS 3510.

PHYS 3611 Electromagnetism I (4 Credits)
First of a two-quarter sequence. Vector algebra; differential vector calculus (gradient, divergence and curl); integral vector calculus (gradient, divergence and Stokes' Theorems); line, surface and volume integrals; Electrostatics: the electric field, electric potential, work and energy in electrostatics; method of images, boundary value problems and solutions to Laplace's equation in Cartesian, spherical and cylindrical coordinates; multipole expansion of the electric potential; electric fields in matter: polarization; the electric displacement vector; boundary conditions, linear dielectrics. Magnetostatics: magnetic fields and forces. Prerequisites: PHYS 1113, PHYS 1213, or PHYS 1214 and MATH 2070.

PHYS 3612 Electromagnetism II (4 Credits)
Second of a two-quarter sequence. Magnetic vector potential; magnetic fields in matter: magnetization; fields of magnetized objects; linear and nonlinear magnetic materials; electromotive force, Ohm's law; electromagnetic induction; Faraday's law; Maxwell's equations; the displacement current; boundary conditions; the Poynting theorem; momentum and energy density of the fields; the Maxwell stress tensor; the wave equation and electromagnetic waves in vacuum and matter; absorption and dispersion; wave guides; the potential formulation and gauge transformations; retarded potentials; dipole radiation. Prerequisite: PHYS 3611.

PHYS 3700 Advanced Topics: General (3 Credits)
Offered irregularly, depending on demand. May be taken more than once for credit. Prerequisite: instructor's permission.

PHYS 3711 Optics I (4 Credits)
First of a two-quarter sequence. Gaussian optics and ray tracing; matrix methods and application to optical design; elementary theory of aberrations; light as electromagnetic wave, diffraction and interference; interferometers and their applications. Elementary theory of coherence; selected topics. May include laboratory work as appropriate. Prerequisites: PHYS 1113, PHYS 1213 or PHYS 1214, and MATH 2070.

PHYS 3720 Light-Matter Interaction (4 Credits)
This course will introduce the theory and applications of light-matter interactions. Fundamental theory will be explored from both semi-classical and quantum perspectives, and photon-carrier interactions will be studied in a variety of physical systems, including atoms, glasses, semiconductors, and metals. Experimental techniques will also be discussed, such as absorption, photoluminescence, and coherent spectroscopies, in addition to ultrafast nonlinear optical interactions. Students will also build their own demonstration and teaching module for elementary-age children, and will use their module to teach children at a local school.

PHYS 3841 Thermal Physics I (4 Credits)
First of a two-quarter sequence. Laws of thermodynamics; thermal properties of gases and condensed matter; kinetic theory of gases, classical and quantum statistics. Prerequisites: PHYS 1113, PHYS 1213 or PHYS 1214 and MATH 2070.

PHYS 3850 Foundations of Biophysics (3 Credits)
The course highlights application of basic physics principles to the study of cells and macromolecules. Topics include random processes, thermodynamics, statistical mechanics, diffusion, to provide a quantitative description of different processes in biology at the molecular and cellular level.

PHYS 3860 Numerical and Computational Methods in Physics (4 Credits)
The main goal of this course is to gain a better understanding of physical problems by solving them numerically; in the process, students learn about several numerical methods and computational techniques that have a very broad range of applications in many other scientific fields. Depending on the problem, students work with a software package (Mathematica), and also acquire coding experience in different programming languages.

PHYS 3870 Special and General Relativity (4 Credits)
This course will start with the techniques in Special Relativity and build familiarity with tensors. In the second part of the quarter, we will generalize to curved spaces and the Schwarzschild solution. And, finally, we will set up and solve the Einstein equations using the Cartan equations of structure to study the Robertson Walker metric spacetime used to construct the energy budget of the universe. Prerequisites: MATH 1953 and either PHYS 1213 or PHYS 1214.

PHYS 3991 Independent Study (1-10 Credits)

PHYS 3995 Independent Research (1-10 Credits)