

Bachelor of Science in Engineering Physics

Program Description

Physics provides the foundation for most applied science and engineering disciplines. It attracts those who wish to understand nature at its most fundamental level. The engineering physics program at Mines (<https://physics.mines.edu>) is interdisciplinary in nature, taking basic undergraduate physics subjects further with direct applications to engineering. ABET, the Accreditation Board for Engineering and Technology (<https://www.abet.org>), accredits the degree to provide graduates the first step toward professional licensure.

At Mines, the required engineering physics curriculum includes the requisite undergraduate physics courses that form rigorous study at any four-year university. In addition to these core courses, Mines requirements include pre-engineering and engineering classes that physics majors at other universities would not ordinarily take. These courses include immersions in engineering science, engineering design, systems, a summer field session practicum, and a capstone senior design sequence culminating in a senior thesis.

The unique blend of physics and engineering makes it possible for a Mines engineering physics graduate to work at the interface between science and technology where new discoveries are made and continually being put into practice. While engineering physicists are proficient applying existing technologies, they are also willing to explore novel approaches and capable of developing new technologies. The excitement and fulfillment of working on innovative challenges make a Mines engineering physics degree attractive to many students.

With the flexibility of our degree, our undergraduates find themselves following a variety of career paths. Many find employment in fields as diverse as aerospace engineering, biomedical science, computational modeling of physical systems, device manufacturing and semiconductor processing, geophysics, materials development, nanotechnology, nuclear science and engineering, renewable and conventional energy industries, semiconductor manufacturing and processing, energy, and even entertainment enterprises that place high demands on animation, audio, special effects, and visualization talents. More than half of our seniors pursue graduate studies in physics or a closely related field of engineering. Some take their undergraduate training into post-graduate professional studies in business, law, management, medicine, or quantum engineering.

Mines physics faculty and staff maintain modern, state-of-the-art laboratories for general physics, modern physics, electronics, and advanced investigations. There are research laboratories for the study of condensed matter, materials science, nuclear physics, optics, and quantum physics and computing. The department maintains well-equipped, professionally staffed, electronic labs and machine shops to help students and faculty accomplish their curriculum, project, and research goals. The department also nurtures strong ties with national laboratories and local engineering design firms that provide students with authentic collaboration opportunities.

Program Educational Objectives

In addition to contributing toward achieving the educational objectives described in the CSM Graduate Profile, the Physics department is dedicated to additional educational objectives.

The program prepares graduates who, based on factual knowledge and other skills necessary to construct an appropriate understanding of physical phenomena in applied contexts, will:

1. Obtain a range of positions in industry or positions in government facilities or pursue graduate education in engineering, science or related fields.
2. Communicate and perform effectively within the criteria of their chosen careers.
3. Engage in appropriate professional societies and continuing education activities.
4. Participate ethically as members of the global society.

Student Learning Outcomes

Each BS Engineering Physics graduate will have:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ABET Accreditation Status

The Bachelor of Science in Engineering Physics is accredited by the Engineering Accreditation Commission of ABET, <https://www.abet.org>, under the commission's General Criteria with no applicable program criteria.

Primary Contact

Dr. Fred Sarazin, Department Head
<https://physics.mines.edu/>

Degree Requirements (Engineering Physics)

First Year

	lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I		4.0
CHGN121	PRINCIPLES OF CHEMISTRY I		4.0

HASS100	NATURE AND HUMAN VALUES			3.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
S&W	SUCCESS AND WELLNESS			1.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1)			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				31.0
Sophomore				
Fall				
		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS			4.0
HASS215	FUTURES			3.0
EDNS251	CORNERSTONE DESIGN II			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
				15.0
Spring				
		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS or 235			3.0
MATH332	LINEAR ALGEBRA or 342			3.0
PHGN215	ANALOG ELECTRONICS			4.0
PHGN310	HONORS PHYSICS III- MODERN PHYSICS or 300**			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective [^]			3.0
				16.0
Summer				
		lec	lab	sem.hrs
PHGN384	FIELD SESSION TECHNIQUES IN PHYSICS			6.0
				6.0
Junior				
Fall				
		lec	lab	sem.hrs
PHGN311	INTRODUCTION TO MATHEMATICAL PHYSICS			3.0
PHGN315	ADVANCED PHYSICS LAB I			2.0
PHGN317	SEMICONDUCTOR CIRCUITS- DIGITAL			3.0
PHGN350	INTERMEDIATE MECHANICS			4.0

EBGN321	ENGINEERING ECONOMICS (*For the 2023 Catalog EBG321 replaced EBG201 as a Core requirement. EBG321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBG201 the sophomore year may need to wait to take EBG321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/)	3.0
---------	---	-----

Spring **lec lab sem.hrs**

PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS			4.0
PHGN326	ADVANCED PHYSICS LAB II			2.0
PHGN341	THERMAL PHYSICS			3.0
PHGN361	INTERMEDIATE ELECTROMAGNETISM			3.0

12.0

Senior

Fall **lec lab sem.hrs**

PHGN471	SENIOR DESIGN PRINCIPLES I			1.0
PHGN481	SENIOR DESIGN PRACTICE [#]			3.0
PHGN462	ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective [^]			3.0
FREE	Free Elective I			3.0
FREE	Free Elective II			3.0

16.0

Spring **lec lab sem.hrs**

PHGN472	SENIOR DESIGN PRINCIPLES II			1.0
PHGN482	SENIOR DESIGN PRACTICE [#]			3.0
ENG SCI	Engineering Science Elective			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective [^]			3.0
FREE	Free Elective III			3.0
FREE	Free Elective IV			3.0

16.0

Total Semester Hrs: 127.0

Note: HNRS105 & HNRS115 replaces HASS100 & EDNS151

** The Physics department recommends that you take PHGN310

[^] Culture & Society includes HASS & EBG321 courses (see <https://www.mines.edu/registrar/core-curriculum/>)

[#] Honors courses PHGN491/PHGN492 may be substituted with instructor's consent.

Major GPA

During the 2016-2017 academic year, the Undergraduate Council considered the policy concerning required major GPAs and which courses are included in each degree's GPA. While the GPA policy has not been officially updated, in order to provide transparency, council members agreed that publishing the courses included in each degree's GPA is beneficial to students.

The following list details the courses that are included in the GPA for this degree:

PHGN100 through PHGN599 inclusive

Combined Baccalaureate/Master's and Baccalaureate/Doctoral Degree Programs

The Physics Department offers combined BS/MS degree programs in which students obtain an undergraduate degree in Engineering Physics, in as few as four years, as well as a master's degree in Applied Physics, in an Engineering discipline, in Technology Management, in Materials Science, or in Mathematics after an additional year of study. There are engineering tracks, physics tracks, a management track, a materials science track, and a mathematics track. These programs emphasize a strong background in fundamentals of science in addition to practical experience within an applied science, engineering, or mathematics discipline. Many of the undergraduate electives of students involved in each track are specified. For this reason, students are expected to apply to the program during the first semester of their sophomore year (in special cases late entry can be approved by the program mentors). A 3.0 grade-point average must be maintained to guarantee admission into the physics, engineering, and materials science graduate programs. A 3.3 grade-point average must be maintained to guarantee admission into the mathematics graduate program.

Students in the engineering tracks must complete a report or case study during the last year. Students in the physics, materials science, and mathematics tracks must complete a master's thesis. Students in the nuclear engineering program can choose between thesis and non-thesis options. The case study or thesis should begin during the senior year as part of the Senior Design experience. Participants must identify an engineering or physics advisor as appropriate prior to their senior year who will assist in choosing an appropriate project and help coordinate the senior design project with the case study or thesis completed in the last year.

It is also possible for undergraduate students to begin work on a doctoral degree in Applied Physics while completing the requirements for their bachelor's degree. Students in this combined baccalaureate/doctoral program may fulfill part of the requirements of their doctoral degree by including up to 6 hours of specified course credits that are also used to fulfill the requirements of their undergraduate degree. These courses may only be applied toward fulfilling doctoral degree requirements. Courses must meet all requirements for graduate credit, but their grades are not included in calculating the graduate GPA.

Interested students can obtain additional information and detailed curricula from the Physics Department or from the participating engineering departments.

COURSES

PHGN1XX. Engineering Physics Elective. 0-6 Semester Hr.

PHGN100. PHYSICS I - MECHANICS. 4.0 Semester Hrs.

A first course in physics covering the basic principles of mechanics using vectors and calculus. The course consists of a fundamental treatment of the concepts and applications of kinematics and dynamics of particles and systems of particles, including Newton's laws, energy and momentum, rotation, oscillations, and waves. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1. Prerequisite: MATH111. Co-requisite: MATH112 or MATH122.

Course Learning Outcomes

- No change

PHGN198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Course Learning Outcomes

- No change

PHGN200. PHYSICS II-ELECTROMAGNETISM AND OPTICS. 4.0 Semester Hrs.

Continuation of PHGN100. Introduction to the fundamental laws and concepts of electricity and magnetism, electromagnetic devices, electromagnetic behavior of materials, applications to simple circuits, electromagnetic radiation, and an introduction to optical phenomena. Prerequisite: Grade of C- or higher in PHGN100. Co-requisite: MATH213 or MATH223.

PHGN215. ANALOG ELECTRONICS. 0-4 Semester Hr.

Introduction to analog devices used in modern electronics and basic topics in electrical engineering. Introduction to methods of electronics measurements, particularly the application of oscilloscopes and computer based data acquisition. Topics covered include circuit analysis, electrical power, diodes, transistors (FET and BJT), operational amplifiers, filters, transducers, and integrated circuits. Laboratory experiments in the use of basic electronics for physical measurements. Emphasis is on practical knowledge gained in the laboratory, including prototyping, troubleshooting, and laboratory notebook style. 3 hours lecture, 3 hours lab; 4 semester hours. Prerequisite: PHGN200.

PHGN298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN298. SPECIAL TOPICS. 1-6 Semester Hr.

PHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Course Learning Outcomes

- No change

PHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN300. PHYSICS III-MODERN PHYSICS I. 3.0 Semester Hrs.

Equivalent with PHGN310,

Our technical world is filled with countless examples of modern physics. This course will discuss some historic experiments that led to the key discoveries, and the basic concepts, theories, and models behind some of our present day technologies. Topics may include special relativity, quantum physics, atomic and molecular physics, solid-state physics, semiconductor theory and devices, nuclear physics, particle physics and cosmology. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200; Concurrent enrollment in MATH225.

PHGN310. HONORS PHYSICS III-MODERN PHYSICS. 3.0 Semester Hrs.

Equivalent with PHGN300,

The third course in introductory physics with in depth discussion on special relativity, wave-particle duality, the Schroedinger equation, electrons in solids, quantum tunneling, nuclear structure and transmutations. Registration is strongly recommended for declared physics majors and those considering majoring or minoring in physics. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200; Concurrent enrollment in MATH225.

PHGN311. INTRODUCTION TO MATHEMATICAL PHYSICS. 3.0 Semester Hrs.

Demonstration of the unity of diverse topics such as mechanics, quantum mechanics, optics, and electricity and magnetism via the techniques of linear algebra, complex variables, Fourier transforms, and vector calculus. 3 hours lecture; 3 semester hours. Prerequisite: PHGN300 or PHGN310, MATH225, MATH332.

Course Learning Outcomes

- Given some data, immediately have a set of analysis tools you can use to understand the physics behind it.
- Given a modeling problem, be able to reach into your mathematical toolbox and solve it at least three ways, developing different lines of evidence.
- Given a mathematical technique or idea, be able to understand the deep concepts underlying it and provide a clear physical example.

PHGN315. ADVANCED PHYSICS LAB I. 2.0 Semester Hrs.

(WI) Introduction to laboratory measurement techniques as applied to modern physics experiments. Experiments from optics and atomic physics. A writing-intensive course with laboratory and computer design projects based on applications of modern physics. 1 hour lecture, 3 hours lab; 2 semester hours. Prerequisite: PHGN300/310, PHGN384.

PHGN317. SEMICONDUCTOR CIRCUITS- DIGITAL. 3.0 Semester Hrs.

Introduction to digital devices used in modern electronics. Topics covered include logic gates, flip-flops, timers, counters, multiplexing, analog-to-digital and digital-to-analog devices. Emphasis is on practical circuit design and assembly. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: PHGN215.

Course Learning Outcomes

- 1. To understand the basics of digital electronics commonly used as part of instrumentation used in physical measurements.
- 2. To be able to construct and recognize combinational and sequential circuits, understand and implement simple state machine design principles in circuit design.

- 3. To be familiar with common techniques, interfaces and tools used in data acquisition.
- 4. Combine these topics to produce a viable microcontroller system capable of making physical measurements.

PHGN320. MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS. 4.0 Semester Hrs.

Introduction to the Schroedinger theory of quantum mechanics. Topics include Schroedinger's equation, quantum theory of measurement, the uncertainty principle, eigenfunctions and energy spectra, angular momentum, perturbation theory, and the treatment of identical particles. Example applications taken from atomic, molecular, solid state or nuclear systems. 4 hours lecture; 4 semester hours. Prerequisite: PHGN300, PHGN310, and MATH332, MATH342.

PHGN324. INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS. 3.0 Semester Hrs.

Celestial mechanics; Kepler's laws and gravitation; solar system and its contents; electromagnetic radiation and matter; stars: distances, magnitudes, spectral classification, structure, and evolution. Variable and unusual stars, pulsars and neutron stars, supernovae, black holes, and models of the origin and evolution of the universe. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200.

Course Learning Outcomes

- No change

PHGN326. ADVANCED PHYSICS LAB II. 2.0 Semester Hrs.

(WI) Continuation of PHGN315. A writing-intensive course which expands laboratory experiments to include nuclear and solid state physics. 1 hour lecture, 3 hours lab; 2 semester hours. Prerequisite: PHGN315.

PHGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.

(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Repeatable up to 3 credit hours.

PHGN341. THERMAL PHYSICS. 3.0 Semester Hrs.

An introduction to statistical physics from the quantum mechanical point of view. The microcanonical and canonical ensembles. Heat, work and the laws of thermodynamics. Thermodynamic potentials; Maxwell relations; phase transformations. Elementary kinetic theory. An introduction to quantum statistics. 3 hours lecture; 3 semester hours. Prerequisite: CHGN122 or CHGN125 and PHGN311.

Course Learning Outcomes

- Demonstrate an understanding of the microscopic statistical framework for the thermodynamic properties of systems with a large number of particles
- Demonstrate an understanding of the laws of thermodynamics, their applications, and their justification through statistical physics
- Construct an appropriate understanding of thermodynamic phenomena in an applied context
- Develop communication, teamwork, and leadership skills through group activities

PHGN350. INTERMEDIATE MECHANICS. 4.0 Semester Hrs.

Begins with an intermediate treatment of Newtonian mechanics and continues through an introduction to Hamilton's principle and Hamiltonian and Lagrangian dynamics. Includes systems of particles, linear and driven oscillators, motion under a central force, two-particle collisions and

scattering, motion in non-inertial reference frames and dynamics of rigid bodies. 4 hours lecture; 4 semester hours. Prerequisite: PHGN200. Co-requisite: PHGN311.

Course Learning Outcomes

- No change

PHGN361. INTERMEDIATE ELECTROMAGNETISM. 3.0 Semester Hrs.

Theory and application of the following: static electric and magnetic fields in free space, dielectric materials, and magnetic materials; steady currents; scalar and vector potentials; Gauss' law and Laplace's equation applied to boundary value problems; Ampere's and Faraday's laws. 3 hours lecture; 3 semester hours. Prerequisite: PHGN200 and PHGN311.

Course Learning Outcomes

- No change

PHGN384. FIELD SESSION TECHNIQUES IN PHYSICS. 6.0 Semester Hrs.

Introduction to the design and fabrication of engineering physics apparatus. Intensive individual participation in the design of machined system components, vacuum systems, electronics, optics, and application of computer interfacing systems and computational tools. Supplementary lectures on safety, laboratory techniques and professional development. Visits to regional research facilities and industrial plants. 6 semester hours. Prerequisites: PHGN300 or PHGN310, PHGN215.

Course Learning Outcomes

- 1. to give students a working knowledge of the practical aspects of materials, instrumentation and phenomena associated with laboratory practice
- 2. to train students in the use of important experimental and data analysis devices and tools
- 3. to show students how working physicists operate and to help them achieve professional standards in work practice and communication

PHGN398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Course Learning Outcomes

- No change

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN401. PHYSICS SEMINAR. 1.0 Semester Hr.

Students will attend the weekly physics seminar. Students will be responsible for presentation and discussion. Co-requisite: PHGN300 or PHGN310.

PHGN417. FUNDAMENTALS OF QUANTUM INFORMATION. 3.0 Semester Hrs.

This course serves as a broad introduction to quantum information science, open to students from many backgrounds. The basic structure of quantum mechanics (Hilbert spaces, operators, wavefunctions, entanglement, superposition, time evolution) is presented, as well as a number of important topics relevant to current quantum hardware (including oscillating fields, quantum noise, and more). Finally, we will survey the gate model of quantum computing, and study the critical subroutines which provide the promise of a quantum speedup in future quantum computers. Prerequisite: MATH332 or MATH342.

Course Learning Outcomes

1. Construct Hilbert spaces, operators, wavefunctions and predict the outcome of measurements
2. Identify the key ways in which quantum mechanics differs from classical mechanics: entanglement and superposition
3. Simulate time evolution in quantum systems
4. Diagonalize simple quantum Hamiltonians and predict their spectra
5. Simulate oscillating fields in quantum systems
6. Implement simple calculations using the gate model of quantum computing. They will also learn how to use ancilla qubits, and how to construct arbitrary operations from one- and two-qubit gates
7. Identify mechanisms for a quantum speedup in quantum algorithms, learned through a survey of some of the most famous ones

PHGN418. GENERAL RELATIVITY. 3.0 Semester Hrs.

Introduction to Einstein's theory of gravitation. Requisite mathematics introduced and developed including tensor calculus and differential geometry. Formulation of Einstein field and geodesic equations. Development and analysis of solutions including stellar, black hole and cosmological geometries. Prerequisite: PHGN350. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- No change

PHGN419. PRINCIPLES OF SOLAR ENERGY SYSTEMS. 3.0 Semester Hrs.

Review of the solar resource and components of solar irradiance; principles of photovoltaic devices and photovoltaic system design; photovoltaic electrical energy production and cost analysis of photovoltaic systems relative to fossil fuel alternatives; introduction to concentrated photovoltaic systems and manufacturing methods for wafer-based and thin film photovoltaic panels. Prerequisite: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

PHGN422. NUCLEAR PHYSICS. 3.0 Semester Hrs.

Introduction to subatomic (particle and nuclear) phenomena. Characterization and systematics of particle and nuclear states; symmetries; introduction and systematics of the electromagnetic, weak, and strong interactions; systematics of radioactivity; liquid drop and shell models; nuclear technology. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN423. PARTICLE PHYSICS. 3.0 Semester Hrs.

Introduction to the Standard Model of particle physics including: experimental methods, motivation and evaluation of amplitudes from Feynman diagrams with applications to scattering cross-sections and decay rates, organization of interactions based on underlying gauge-symmetry principles, Dirac equation and relativistic spinors, C, P and T symmetries, renormalization, spontaneous symmetry breaking and the

Higgs mechanism for mass generation. Prerequisites: PHGN350. Co-requisites: PHGN320. 3 hour lecture.

PHGN424. ASTROPHYSICS. 3.0 Semester Hrs.

A survey of fundamental aspects of astrophysical phenomena, concentrating on measurements of basic stellar properties such as distance, luminosity, spectral classification, mass, and radii. Simple models of stellar structure evolution and the associated nuclear processes as sources of energy and nucleosynthesis. Introduction to cosmology and physics of standard big-bang models. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN433. BIOPHYSICS. 3.0 Semester Hrs.

Equivalent with PHGN333,

This course is designed to show the application of physics to biology. It will assess the relationships between sequence structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics.

Prerequisites: CBEN110. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. To simulate and analyze random biological processes.
- 2. Ability to apply the principles learned in the course to contemporary research topic.
- 3. To understand the concepts of free energy and how it relates to the speed and spontaneity of chemical reactions.
- 4. Ability to work and communicate with others.
- 5. To analyze and solve problems independently.

PHGN435. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 0-3 Semester Hr.

Equivalent with

CBEN435, CBEN535, CHEN435, CHEN535, MLGN535, PHGN535, Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisite: MATH213 or MATH223.

PHGN440. SOLID STATE PHYSICS. 3.0 Semester Hrs.

An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. 3 hours lecture; 3 semester hours. Prerequisite: PHGN320.

PHGN441. SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA. 3.0 Semester Hrs.

Continuation of PHGN440/ MLGN502 with an emphasis on applications of the principles of solid state physics to practical properties of materials including: optical properties, superconductivity, dielectric properties, magnetism, noncrystalline structure, and interfaces. (Graduate students in physics may register only for PHGN441.) Prerequisite: PHGN440 or MLGN502. 3 hours lecture; 3 semester hours.

PHGN450. COMPUTATIONAL PHYSICS. 3.0 Semester Hrs.

Introduction to numerical methods for analyzing advanced physics problems. Topics covered include finite element methods, analysis of scaling, efficiency, errors, and stability, as well as a survey of numerical algorithms and packages for analyzing algebraic, differential, and matrix systems. The numerical methods are introduced and developed in the analysis of advanced physics problems taken from classical physics, astrophysics, electromagnetism, solid state, and nuclear physics.

Prerequisites: Introductory-level knowledge of C, Fortran, or Basic; and PHGN311. 3 hours lecture; 3 semester hours.

PHGN461. ELEMENTS OF MODERN OPTICS. 3.0 Semester Hrs.

This course is designed to prepare students for a variety of goals including enrollment in advanced optics courses and research in both academia and industry. Topics covered in the course will provide foundational skills vital to all areas of optics and include the use of complex phasor notation, solutions to the wave equation, electromagnetic energy flow, the interaction of electromagnetic energy with matter, light propagation (through lenses, stops, mirrors, prisms, and fiber optics), as well as the effects of polarizers, birefringent materials, and retarders in optical system designs. Prerequisite: PHGN311.

Course Learning Outcomes

- 1. Use complex phasor notation, understand solutions to the Wave Equation, identify what phase is and its relationship with superposition.
- 2. Using basic laws of electricity and magnetism, calculate the direction and magnitude of electromagnetic energy flow including its interaction with matter.
- 3. Form a mathematical description of light propagation.
- 4. Use concepts from light propagation to analyze optical systems containing lenses, stops, mirrors, prisms, and fiber optics.
- 5. Explain the effects polarizers, birefringence, and retarders on light using Jones and Mueller matrix formalism.

PHGN462. ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS. 3.0 Semester Hrs.

Solutions to the electromagnetic wave equation, including plane waves, guided waves, refraction, interference, diffraction and polarization; applications in optics; imaging, lasers, resonators and wave guides. 3 hours lecture; 3 semester hours. Prerequisite: PHGN361.

PHGN466. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.

Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors and optical system examples.

PHGN471. SENIOR DESIGN PRINCIPLES I. 1.0 Semester Hr.

The first of a two semester sequence covering the principles of project design. Class sessions cover effective team organization, project planning, time management, literature research methods, record keeping, fundamentals of technical writing, professional ethics, project funding and intellectual property. 1 hour lecture in 7 class sessions; 1 semester hour. Prerequisites: PHGN384, PHGN326. Co-requisites: PHGN481 or PHGN491.

PHGN472. SENIOR DESIGN PRINCIPLES II. 1.0 Semester Hr.

Continuation of PHGN471. 1 hour lecture in 7 class sessions; 1 semester hour. Prerequisites: PHGN384, PHGN326. Co-requisites: PHGN482 or PHGN492.

PHGN480. LASER PHYSICS. 3.0 Semester Hrs.

Theory and application of the following: Interaction of light with atoms: absorption, gain, rate equations and line broadening. Propagation, control and measurement of light waves: Gaussian beams, optical resonators and wave guides, interferometers. Laser design and operation: pumping, oscillation, and dynamics (Q-switching and mode-locking). Introduction to ultrafast optics. Laboratory: alignment and characterization of laser systems. Prerequisites: PHGN320. Co-requisites: PHGN462. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. understand the interaction of light with quantum transitions, including the origin of gain in different media
- 2. understand how to derive rate equations to describe the balance of stored energy in the gain medium and in the circulating light field in the resonator
- 3. understand how to use matrix methods to calculate the propagation of light as rays and as Gaussian beams and how to use these matrices to design optical resonators
- 4. understand how to build and apply a quantitative model of laser oscillation to a real laser system
- 5. be able to experimentally align and characterize simple lasers and interferometers
- 6. apply the principles of the course to a case study of a laser system

PHGN481. SENIOR DESIGN PRACTICE. 3.0 Semester Hrs.

The first of a two semester program covering the full spectrum of project design, drawing on all of the student's previous course work. At the beginning of the first semester, the student selects a research project in consultation with the Senior Design Oversight Committee (SDOC) and the Project Mentor. The objectives of the project are given to the student in broad outline form. The student then designs the entire project, including any or all of the following elements as appropriate: literature search, specialized apparatus or algorithms, block-diagram electronics, computer data acquisition and/or analysis, sample materials, and measurement and/or analysis sequences. The course culminates in a formal interim written report. 6 hour lab; 3 semester hours. Prerequisites: PHGN384, PHGN326. Corequisite: PHGN471.

PHGN482. SENIOR DESIGN PRACTICE. 3.0 Semester Hrs.

Continuation of PHGN481. The course culminates in a formal written report and poster. Prerequisites: PHGN384 and PHGN326. Corequisite: PHGN472. 6 hour lab; 3 semester hours.

PHGN491. HONORS SENIOR DESIGN PRACTICE. 3.0 Semester Hrs.

(WI) Individual work on an advanced research topic that involves more challenging demands than a regular senior design project. Honors students will devote more time to their project, and will produce an intermediate report in a more advanced format. Prerequisite: PHGN384 and PHGN326. Corequisite: PHGN471. 7.5 hour lab; 2.5 semester hours.

PHGN492. HONORS SENIOR DESIGN PRACTICE. 3.0 Semester Hrs.

(WI) Continuation of PHGN481 or PHGN491. The course culminates in a formal written report and poster. The report may be in the form of a manuscript suitable for submission to a professional journal. Prerequisite: PHGN481 or PHGN491. Corequisite: PHGN472. 7.5 hour lab; 2.5 semester hours.

PHGN497. SUMMER PROGRAMS. 0-6 Semester Hr.

PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.

This course is designed for anyone interested in teaching physics at either the college or high school level. Topics include teaching methods for class time, recitation, labs, and homework. Students will engage directly with these methods as well as read the literature supporting each. Additionally time will be spent on assessment, both formative and summative; how to probe student thinking, what they are learning each class period, and what they have learned by the end of the term.

PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

Course Learning Outcomes

- No change

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.

Professors

Lincoln Carr

Patrice Genevet

Uwe Greife

Frederic Sarazin, Department Head

Jeff Squier

Eric Toberer

Associate professors

Daniel Adams

Zhexuan Gong

Timothy Ohno

Meenakshi Singh

Jeremy Zimmerman, Director, Materials Science Program

Assistant professors

Eric Mayotte

Veronica Policht

Wouter Van de Pontseele

Teaching Professors

Kristine Callan

Patrick Kohl

H. Vincent Kuo, Associate Department Head, Director of UG Studies

Charles (Chuck) Stone

Teaching Associate Professor

Emily Smith

Teaching Assistant Professors

Victoria (Tori) Borish

Laith Haddad

Alysa (Ly) Malespina

Research Professor

Wendy Adams

Research Associate Professor

K. Xerxes Steirer

Research Assistant Professors

Kamil Ciesielski

Serena Eley

P. David Flammer

Emeriti Professors

F. Edward Cecil

Reuben Collins

Thomas Furtak

Frank Kowalski

Mark Lusk

P. Craig Taylor

John Trefny, President Emeritus

Lawrence Wiencke

Don Williamson

Emeritus Teaching Professor

Todd Ruskell

Emeritus Associate Professor

David Wood