

# Physics

## Program Description - Engineering Physics

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 (<http://www.abet.org>), accredits the degree to provide graduates the first step towards professional licensure.

At Mines, the required engineering physics curriculum includes the requisite undergraduate physics courses that form rigorous study at any 4-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 & 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 (Bachelor of Science in Engineering Physics)

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.

## Degree Requirements (Engineering Physics)

### Freshman

Fall		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
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
S&W	SUCCESS AND WELLNESS			1.0
				<b>16.0</b>

Spring		lec	lab	sem.hrs
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
CHGN122	PRINCIPLES OF CHEMISTRY II (SC1) or 125			4.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
				<b>15.0</b>

### Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III			4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS			4.0
EDNS251	CORNERSTONE DESIGN II			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS200	GLOBAL STUDIES			3.0
				<b>15.0</b>

<b>Spring</b>		<b>lec</b>	<b>lab</b>	<b>sem.hrs</b>
CSCI250	PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM			3.0
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH332	LINEAR ALGEBRA			3.0
PHGN310	HONORS PHYSICS III-MODERN PHYSICS or 300			3.0
PHGN215	ANALOG ELECTRONICS			4.0
				<b>16.0</b>
<b>Summer</b>		<b>lec</b>	<b>lab</b>	<b>sem.hrs</b>
PHGN384	FIELD SESSION TECHNIQUES IN PHYSICS			6.0
				<b>6.0</b>

**Junior**

<b>Fall</b>		<b>lec</b>	<b>lab</b>	<b>sem.hrs</b>
PHGN315	ADVANCED PHYSICS LAB I			2.0
PHGN311	INTRODUCTION TO MATHEMATICAL PHYSICS			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) Mid-Level Restricted Elective			3.0
PHGN317	SEMICONDUCTOR CIRCUITS-DIGITAL			3.0
PHGN350	INTERMEDIATE MECHANICS			4.0
				<b>15.0</b>

<b>Spring</b>		<b>lec</b>	<b>lab</b>	<b>sem.hrs</b>
PHGN361	INTERMEDIATE ELECTROMAGNETISM			3.0
PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS			4.0
PHGN326	ADVANCED PHYSICS LAB II			2.0
PHGN341	THERMAL PHYSICS			3.0
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: <a href="https://www.mines.edu/registrar/core-curriculum/">https://www.mines.edu/registrar/core-curriculum/</a>			3.0
				<b>15.0</b>

**Senior**

<b>Fall</b>		<b>lec</b>	<b>lab</b>	<b>sem.hrs</b>
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
		<b>16.0</b>

<b>Spring</b>		<b>lec</b>	<b>lab</b>	<b>sem.hrs</b>
PHGN472	SENIOR DESIGN PRINCIPLES II			1.0
PHGN482	SENIOR DESIGN PRACTICE			3.0
ELECTIVE	CULTURE AND SOCIETY (CAS) 400-Level Restricted Elective			3.0
ENG SCI	Engineering Science Elective			3.0
FREE	Free Elective III			3.0
FREE	Free Elective IV			3.0
				<b>16.0</b>

**Total Semester Hrs: 130.0****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/Masters 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 masters 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 six 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.

The Mines guidelines for Minor/ASI can be found in the Undergraduate Information section of the Mines Catalog.

## Minor in Engineering Physics

### Required Courses - 7.0 credits

PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
or PHGN310	HONORS PHYSICS III-MODERN PHYSICS	

### Elective Courses (select at least 11 credits from the following)

PHGN215	ANALOG ELECTRONICS	4.0
PHGN315	ADVANCED PHYSICS LAB I	2.0
PHGN317	SEMICONDUCTOR CIRCUITS- DIGITAL	3.0
PHGN324	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	3.0
PHGN326	ADVANCED PHYSICS LAB II	2.0
PHGN384	FIELD SESSION TECHNIQUES IN PHYSICS	1-6
PHGN399	INDEPENDENT STUDY	1-6
PHGN417	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
PHGN419	PRINCIPLES OF SOLAR ENERGY SYSTEMS	3.0
PHGN422	NUCLEAR PHYSICS	3.0
PHGN424	ASTROPHYSICS	3.0
PHGN433	BIOPHYSICS	3.0
PHGN435	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
PHGN466	MODERN OPTICAL ENGINEERING	3.0

## Minor in Physics

### Required Courses (16.5 credits)

PHGN200	PHYSICS II-ELECTROMAGNETISM AND OPTICS	4.0
PHGN300	PHYSICS III-MODERN PHYSICS I	3.0
or PHGN310	HONORS PHYSICS III-MODERN PHYSICS	
MATH332	LINEAR ALGEBRA	3.0
CSCI250	PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM	3.0
PHGN311	INTRODUCTION TO MATHEMATICAL PHYSICS	3.0

### Elective Courses (select at least 2.0 credits from the following)

PHGN320	MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS	4.0
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PHGN341	THERMAL PHYSICS	3.0
PHGN350	INTERMEDIATE MECHANICS	4.0
PHGN361	INTERMEDIATE ELECTROMAGNETISM	3.0
PHGN418	GENERAL RELATIVITY	3.0
PHGN423	PARTICLE PHYSICS	3.0
PHGN440	SOLID STATE PHYSICS	3.0
PHGN450	COMPUTATIONAL PHYSICS	3.0

## Courses

### PHGN100. PHYSICS I - MECHANICS. 4.0 Semester Hrs.

(I,II,S) 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. Prerequisite: MATH111. Co-requisites: MATH112 or MATH113 or MATH122. 2 hours lecture; 4 hours studio; 4.5 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

### 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.

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

(I, II, S) 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, concurrent enrollment in MATH213 or MATH214 or MATH223. 2 hours lecture; 4 hours studio; 4.5 semester hours.

### PHGN215. ANALOG ELECTRONICS. 4.0 Semester Hrs.

(II) 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. Prerequisite: PHGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

### 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.

### 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.

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

Equivalent with PHGN310,

(I) 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. Prerequisite: PHGN200; Concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

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

Equivalent with PHGN300,

(II) 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. Prerequisite: PHGN200; Concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

**PHGN311. INTRODUCTION TO MATHEMATICAL PHYSICS. 3.0 Semester Hrs.**

(I) 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. Prerequisites: PHGN300 or PHGN310, MATH225, MATH332, and CSCI250. 3 hours lecture; 3 semester hours.

**PHGN315. ADVANCED PHYSICS LAB I. 2.0 Semester Hrs.**

(I) (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. Prerequisite: PHGN300/310, PHGN384. 1 hour lecture, 3 hours lab; 2 semester hours.

**PHGN317. SEMICONDUCTOR CIRCUITS- DIGITAL. 3.0 Semester Hrs.**

(I) 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. Prerequisite: PHGN215 and CSCI250. 2 hours lecture; 3 hours lab; 3 semester hours.

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

(II) 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: MATH332, MATH342.

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

(I) 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.

**PHGN326. ADVANCED PHYSICS LAB II. 2.0 Semester Hrs.**

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

**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.**

(II) 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. Prerequisite: CHGN122 or CHGN125 and PHGN311. 3 hours lecture; 3 semester hours.

**PHGN350. INTERMEDIATE MECHANICS. 4.0 Semester Hrs.**

(I) 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. Prerequisite: PHGN200. Corequisite: PHGN311. 4 hours lecture; 4 semester hours.

**PHGN361. INTERMEDIATE ELECTROMAGNETISM. 3.0 Semester Hrs.**

(II) 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. Prerequisite: PHGN200 and PHGN311. 3 hours lecture; 3 semester hours.

**PHGN384. FIELD SESSION TECHNIQUES IN PHYSICS. 1-6 Semester Hr.**

(S) 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. Prerequisites: PHGN300 or PHGN310, PHGN215, CSCI250. 6 semester hours.

**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.

**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.

**PHGN418. GENERAL RELATIVITY. 3.0 Semester Hrs.**

(II) 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.

**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.**

(II) 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.**

(II) 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,

(II) 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.

**PHGN435. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.**

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 MATH214 or MATH223 or MATH224.

**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. (Graduate students in physics may register only for PHGN440.) Prerequisite: PHGN320. 3 hours lecture; 3 semester hours.

**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.

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

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

**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. 0.5 Semester Hrs.**

(I) (WI) 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. Prerequisites: PHGN384 and PHGN326. Co-requisites: PHGN481 or PHGN491. 1 hour lecture in 7 class sessions; 0.5 semester hours.

**PHGN472. SENIOR DESIGN PRINCIPLES II. 0.5 Semester Hrs.**

(II) (WI) Continuation of PHGN471. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN482 or PHGN492. 1 hour lecture in 7 class sessions; 0.5 semester hours.

**PHGN480. LASER PHYSICS. 3.0 Semester Hrs.**

(I) 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.

**PHGN481. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.**

(I) (WI) 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. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN471. 6 hour lab; 2.5 semester hours.

**PHGN482. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.**

(II) (WI) Continuation of PHGN481. The course culminates in a formal written report and poster. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN472. 6 hour lab; 2.5 semester hours.

**PHGN491. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.**

(I) (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. 2.5 Semester Hrs.**

(II) (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.

**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.

**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.

## Professors Emeriti

F. Edward Cecil

Reuben T. Collins

Thomas E. Furtak

Frank V. Kowalski

John Scales

P. Craig Taylor

John Trefny, President Emeritus

Don L. Williamson

## Associate Professors Emeriti

David M. Wood

## Professors

Lincoln D. Carr

Patrice Genevet

Charles G. Durfee III

Uwe Greife

Mark T. Lusk

Frederic Sarazin, Department Head

Jeff A. Squier

Eric. S. Toberer, Director of the Materials Science Program

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### **Research Professor**

Wendy Adams Spencer

### **Research Associate Professor**

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### **Research Assistant Professors**

Serena M. Eley

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