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 (https://www.abet.org), accredits the degree to provide graduates the first step toward professional licensure.

The Engineering Physics program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Engineering Physics and Similarly Named Engineering Programs Program Criteria.

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 (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.

Student Learning Outcomes (Bachelor of Science in Engineering Physics)

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.

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.

**Student Learning Outcomes (Bachelor of Science in Engineering Physics)**

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.

**Degree Requirements (Engineering Physics)**

**Freshman**

<table>
<thead>
<tr>
<th>Fall</th>
<th>lec</th>
<th>lab</th>
<th>sem.hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH111</td>
<td>CALCULUS FOR SCIENTISTS AND ENGINEERS I</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>CHGN121</td>
<td>PRINCIPLES OF CHEMISTRY I</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>HASS100</td>
<td>NATURE AND HUMAN VALUES</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>CSM101</td>
<td>FRESHMAN SUCCESS SEMINAR</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>CSCI128</td>
<td>COMPUTER SCIENCE FOR STEM</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>S&amp;W</td>
<td>SUCCESS AND WELLNESS</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16.0</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Spring**

<table>
<thead>
<tr>
<th>lec</th>
<th>lab</th>
<th>sem.hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH112</td>
<td>CALCULUS FOR SCIENTISTS AND ENGINEERS II</td>
<td>4.0</td>
</tr>
<tr>
<td>CHGN122</td>
<td>PRINCIPLES OF CHEMISTRY II (SC1) or 125</td>
<td>4.0</td>
</tr>
<tr>
<td>PHGN100</td>
<td>PHYSICS I - MECHANICS</td>
<td>4.0</td>
</tr>
<tr>
<td>EDNS151</td>
<td>CORNERSTONE - DESIGN I</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Sophomore**

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

**Junior**

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

**Spring**

<table>
<thead>
<tr>
<th>lec</th>
<th>lab</th>
<th>sem.hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHGN361</td>
<td>INTERMEDIATE ELECTROMAGNETISM</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN320</td>
<td>MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS</td>
<td>4.0</td>
</tr>
<tr>
<td>PHGN326</td>
<td>ADVANCED PHYSICS LAB II</td>
<td>2.0</td>
</tr>
<tr>
<td>PHGN341</td>
<td>THERMAL PHYSICS</td>
<td>3.0</td>
</tr>
<tr>
<td>EBN321</td>
<td>ENGINEERING ECONOMICS</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

For the 2023 Catalog EBGN321 replaced EBGN201 as a Core requirement. EBGN321 was added to the core, but has a prerequisite of 60 credit hours. Students whose programs that required EBGN201 the sophomore year may need to wait to take EBGN321 until their junior year. For complete details, please visit: https://www.mines.edu/registrar/core-curriculum/
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,
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.

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHGN200</td>
<td>PHYSICS II-ELECTROMAGNETISM AND OPTICS</td>
<td>4.0</td>
</tr>
<tr>
<td>PHGN300</td>
<td>PHYSICS III-MODERN PHYSICS I</td>
<td>3.0</td>
</tr>
</tbody>
</table>
or | PHGN310      | HONORS PHYSICS III-MODERN PHYSICS              |         |

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHGN215</td>
<td>ANALOG ELECTRONICS</td>
<td>4.0</td>
</tr>
<tr>
<td>PHGN315</td>
<td>ADVANCED PHYSICS LAB I</td>
<td>2.0</td>
</tr>
<tr>
<td>PHGN317</td>
<td>SEMICONDUCTOR CIRCUITS-DIGITAL</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN324</td>
<td>INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN326</td>
<td>ADVANCED PHYSICS LAB II</td>
<td>2.0</td>
</tr>
<tr>
<td>PHGN384</td>
<td>FIELD SESSION TECHNIQUES IN PHYSICS</td>
<td>1-6</td>
</tr>
<tr>
<td>PHGN399</td>
<td>INDEPENDENT STUDY</td>
<td>1-6</td>
</tr>
<tr>
<td>PHGN417</td>
<td>FUNDAMENTALS OF QUANTUM INFORMATION</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN419</td>
<td>PRINCIPLES OF SOLAR ENERGY SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN422</td>
<td>NUCLEAR PHYSICS</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN424</td>
<td>ASTROPHYSICS</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN433</td>
<td>BIOPHYSICS</td>
<td>3.0</td>
</tr>
<tr>
<td>PHGN435</td>
<td>INTERDISCIPLINARY MICROELECTRONICS PROCESSING</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>LABORATORY</td>
<td></td>
</tr>
<tr>
<td>PHGN466</td>
<td>MODERN OPTICAL ENGINEERING</td>
<td>3.0</td>
</tr>
</tbody>
</table>
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: BASIC OF QUANTUM MECHANICS 4.0
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.
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.

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. 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 PHGN310,
(I) 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 hours lab; 3 semester hours.
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
depth concepts underlying it and provide a clear physical example.
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.

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.
(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.

Course Learning Outcomes

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

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.
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.

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.

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.
(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.

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.

PHGN424. ASTROPHYSICS. 3.0 Semester Hrs. (I) 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.

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. 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 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. 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. 

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. 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. 

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  
Lawrence R. Wiencke  

Associate Professors  
Eliot Kapit  
Kyle Leach  
Timothy R. Ohno  
Meenakshi Singh  
Jeramy D. Zimmerman
Assistant Professors
Daniel Adams
Zhexiong Gong
Eric Mayotte

Teaching Professors
Kristine E. Callan
Patrick B. Kohl
H. Vincent Kuo, Associate Department Head, Director of UG Studies
Todd G. Ruskell
Charles A. Stone

Teaching Associate Professor
Emily Smith

Teaching Assistant Professors
Laith Haddad
Alysa (Ly) Malespina

Research Professor
Wendy Adams Spencer

Research Associate Professor
K. Xerxes Steirer

Research Assistant Professors
Serena M. Eley
P. David Flammer
Susanta K. Sarkar