PHYSICS (PHYS)

PHYS 101 - Concepts of Science I with Lab
A descriptive and conceptual course in physics designed for the non-science major. Topics are selected from light, sound, motion, and astronomy to develop a necessary scientific attitude and background for today's society. There are two lectures and one-two hour laboratory per week.

Credits: 3
Term(s) Typically Offered: Offered Every Term

PHYS 102 - Concepts of Science II
A descriptive and conceptual course in physics designed for the non-science major to study energy systems. Topics are selected from heat, electricity, magnetism, and the structure of matter and modern areas of physics, such as lasers, X-rays, and nuclear energy. The purpose of the course is to develop a positive scientific attitude and background for today's society. No laboratory.

Credits: 3

PHYS 103 - Investigating Matter and Energy/ Lab
This is an activity-based and discussion-oriented course designed for the non-science major. The topics of light, matter, heat, and electricity have been selected to help students develop meaningful understanding of some powerful ideas that they can apply to a wide variety of interesting phenomena. Laboratory credit is given for taking this liberal studies enrichment course.

Credits: 3

PHYS 139 - Foundations of Academic Discovery
Foundations of Academic Discovery serves as the entry point to the Rock Integrated Studies Program. With its strong faculty-student interaction, the course promotes intellectual inquiry, critical and creative thinking, and academic excellence. Through varied content, the course introduces students to academic discourse and information literacy while exploring topics such as diversity and inclusion and global awareness. This course will set students along the path to becoming engaged with issues and scholarship important to a 21st century education while they learn about themselves and their place in the world.

Credits: 3
Term(s) Typically Offered: Offered as Needed
Enrollment limited to students with a semester level of Freshman 1 or Freshman 2.
Enrollment limited to students with the ROCK STUDIES 2 STUDENT or ROCK STUDIES STUDENT attributes.

PHYS 140 - Engineering Graphics I
A beginning laboratory course in technological design and drawing. Topics: lettering, scales, geometric construction, orthographic sketching, and auxiliary views.

Credits: 2
Term(s) Typically Offered: Offered Fall Terms Odd

PHYS 141 - Engineering Graphics II
An advanced laboratory course in technological drawing and implementation. Topics: Vectors, graphing, nomography, isometric pictorials, technical illustration, computer graphics, and working drawings.

Prerequisite: PHYS 140[D]
[D] Requires minimum grade of D.
Credits: 1
Term(s) Typically Offered: Offered Spring Terms

PHYS 190 - Experimental
A unique and specifically focused course within the general purview of a department which intends to offer it on a "one time only" basis and not as a permanent part of the department's curriculum.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed

PHYS 195 - Workshop
A workshop is a program which is usually of short duration, narrow in scope, often non-traditional in content and format, and on a timely topic.

Credits: 1-6
Term(s) Typically Offered: Offered as Needed

PHYS 198 - Selected Topics
A Selected Topics course is a normal, departmental offering which is directly related to the discipline, but because of its specialized nature, may not be able to be offered on a yearly basis by the department.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed

PHYS 201 - Elements of Physics I with Lab
Introduction to physics at the algebra/trigonometry mathematical level. Topics include: mechanics, fluids, oscillations, waves, and sound. Course is especially designed for students enrolled in health science majors. This course must be taken with Elements of Physics Lab PHYS021.

Credits: 4
Term(s) Typically Offered: Offered Fall, Spring, & Summer

PHYS 202 - Elements of Physics II/ Lab
Introduction to physics at the algebra/trigonometry mathematical level. Topics include: thermal physics, optics, electricity and magnetism, and nuclear physics. Course is especially designed for health science majors.This course must be taken with Elements of Physics II Lab PHYS022.

Prerequisite: PHYS 201[D]
[D] Requires minimum grade of D.
Credits: 4
Term(s) Typically Offered: Offered Spring & Summer Terms

PHYS 204 - Environmental Biophysics
An introductory course covering the energy problem and alternative solutions; radiation and its effects on man; the eye and vision; the ear, hearing and noise pollution; electrical power production alternatives and the environmental costs; some instruments used in biophysics and medicine.

Credits: 3

PHYS 211 - General Physics I with Lab
Introduction to physics using calculus and including extensive problem solving. Topics include mechanics statics, kinematics, kinetics, work-energy, rotational motion, and impulse-momentum. This course must be taken with General Physics Lab PHYS011.

Prerequisite: MATH 225 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 4
Term(s) Typically Offered: Offered Fall & Spring Terms

PHYS 212 - General Physics II with Lab
This is a calculus based course, which follows PHYS 211. It develops the concepts of electric and magnetic fields. Topics covered are Gauss' Law, Ampere's Law, Biot's Law, Faraday's Law, electric charges and their dynamics, capacitance, resistance inductance, etc. Offered fall semester only. Includes a lab.

Prerequisites: MATH 225[D] and PHYS 211[D] and MATH 230 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms

PHYS 213 - General Physics III/ Lab
Covers fluids, hydrostatics and hydro-dynamics, heat transfer and measurements, laws of thermodynamics, vibrating bodies, wave motion, light lenses and optical instruments, interference and diffraction, polarization.This course must be taken with General Physics III Lab PHYS023. Offered spring term only.

Prerequisite: PHYS 211[D]
[D] Requires minimum grade of D.
Credits: 4
Term(s) Typically Offered: Offered Spring Terms

PHYS 216 - University Physics 1 with Lab
First of a two semester calculus based introduction to physics sequence for science, engineering, and mathematics students. Students will acquire knowledge of fundamental physics principles and their applications as well as problem solving skills and laboratory and data acquisition experience. Topics covered: kinematics, dynamics, momentum of particles and rigid bodies, work and energy, gravitation, simple harmonic motion, and waves. This course must be taken with University Physics 1 Lab.

Prerequisite: MATH 225 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 4

PHYS 217 - University Physics 2 with Lab
Second of a two semester calculus based introduction to physics sequence for science, engineering, and mathematics students. Students will acquire knowledge of fundamental physics principles and their applications as well as problem solving skills and laboratory and data acquisition experience. Topics Covered: Fluids, Thermodynamics, Electricity and Magnesium, Circuits, and Optics. This course must be taken with University Physics 2 Lab.

Prerequisites: PHYS 216[D] and MATH 230 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 4

PHYS 271 - Astronomy
This course is designed for the general student. Recent findings in astronomy are discussed, i.e., black holes, quasars, etc. Other topics of interest are the evolution of stars, galaxies, and the universe since the big bang. No math required.

Credits: 3
Term(s) Typically Offered: Offered Spring Terms
Thematic Thread(s): Institutions & Human Innovations, Transfer Thread Completion Course

PHYS 290 - Experimental
A unique and specifically focused course within the general purview of a department which intends to offer it on a "one time only" basis and not as a permanent part of the department's curriculum.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed

PHYS 295 - Workshop
A workshop is a program which is usually of short duration, narrow in scope, often non-traditional in content and format, and on a timely topic.

Credits: 1-6
Term(s) Typically Offered: Offered as Needed

PHYS 298 - Selected Topics
A Selected Topics course is a normal, departmental offering which is directly related to the discipline, but because of its specialized nature, may not be able to be offered on a yearly basis by the department.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed

PHYS 301 - Physical Chemistry I
Thermodynamics and chemical kinetics. Cross listed as CHEM301.

Prerequisites: CHEM 108[D] and CHEM 112[D] and (PHYS 212[D] or PHYS 213[D]) and MATH 230[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 312 - Modern Physics 1
An introductory course that focuses on the transition from classical physics covered in the calculus based introductory physics sequence to contemporary physics. Topics include: Grief overview of special relativity, experimental and theoretical developments that led to the discovery of the atomic structure, early quantum mechanics, Schrodinger's equation and its application and a brief introduction to solid state physics.

Prerequisites: PHYS 212[D] and PHYS 213[D] and MATH 230[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 314 - Statics
Includes the application of equilibrium conditions to structures, trusses, frames and machines, and beams with concentrated and distributed loads.

Prerequisites: PHYS 211[D] and MATH 230 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 315 - Dynamics
Integrates the subject content of kinematics and kinetics that deal respectively with the description of motion of bodies and the causes for their motion.

Prerequisites: PHYS 314[D] and ENGR 210[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Spring Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 317 - Space Science
Introductory course in space exploration. It emphasizes the evolution of the earth with respect to its neighbors in the solar system. Other topics covered are the earth's ionosphere, magnetosphere, hazards of satellite communication, and orbital dynamics.

Credits: 3
Term(s) Typically Offered: Offered Fall Terms
Thematic Thread(s): Conservation, Technology & Imagination, Transfer Thread Completion Course
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 325 - Analog & Digital Electronics
An introductory analog and digital electronics course designed primarily for science students. The course will start with an analysis of AC and DC circuits using Kirchhoff's laws and complex numbers. The analog part will include a study of discrete components including diodes, transistors, and SCRs as well as linear integrated circuits. The digital part will include basic gates as well as MSI and LSI circuits and will be center around interfacing computers to experiments.

Prerequisite: PHYS 212[D]
[D] Requires minimum grade of D.
Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 331 - Mathematical Methods of Physics
Applications in physical science and engineering of the following: vector analysis, complex variables, Fourier and Laplace transforms, linear algebra, and some boundary value problems. Cross-linked as MATH 331. This course may be counted as a physics course or as a mathematics course, but not both.

Prerequisites: MATH 240[D] and PHYS 211[D] and MATH 231 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 371 - Physical Optics
This is a physical optics course dealing with the nature and transmission of light. Topics covered will include the propagation of light, coherence, interference, diffraction, Maxwell's Equations, optics of solids, thermal radiation, optical spectra and lasers.

Prerequisites: PHYS 212[D] and PHYS 213[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms Odd
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 375 - Thermal Physics
This is an introductory course in thermodynamics and statistical mechanics, with appication to both physics and engineering.

Prerequisites: PHYS 213[D] and MATH 231[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Spring Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 381 - Advanced Physics Laboratory
Selected experiments in all branches of physics that are of a more advanced grade than those given at the general or intermediate level. Each experiment will be an extended piece of careful, thorough work, culminating in a detailed report.

Prerequisites: PHYS 211[D] and PHYS 212[D] and PHYS 213[D]
[D] Requires minimum grade of D.
Credits: 2
Term(s) Typically Offered: Offered Spring Terms Even
Students with a semester level of Freshman 1, Freshman 2, Sophomore 1 or Sophomore 2 may **not** enroll.

PHYS 382 - Optics Laboratory
This course will provide in depth experience in laboratory techniques, data acquisition and analysis in the field of Optical Physics. Experiments are of a more advanced grade than those given at the general or intermediate level. Each experiment will be an extended piece of careful, thorough work, culminating in a detailed report. Appropriate for students majoring in the Biological, Earth, Environmental, Health, Mathematics and Physical sciences.

Prerequisites: PHYS 211[D] and PHYS 212[D] and (PHYS 213[D] or PHYS 201[D]) and PHYS 202[D] and (MATH 225[D] or MATH 230[D] or MATH 231[D])
[D] Requires minimum grade of D.
Credits: 2
Term(s) Typically Offered: Offered Spring Terms Odd
Students with a semester level of Freshman 1, Freshman 2, Sophomore 1 or Sophomore 2 may **not** enroll.

PHYS 385 - Computational Physics
An introduction to scientific computational methods and their application in physics. A range of numerical and symbolic computing techniques will be explored, including numerical integration, matrix methods, differential equations, random walks, and Monte Carlo simulations. These techniques together with visualization methods will be used to solve problems taken from different physics topics, such as classical mechanics, electricity and magnetism, thermodynamics, quantum mechanics, and biophysics.

Prerequisites: PHYS 213[D] and MATH 240[D] and CPSC 140[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 390 - Experimental
A unique and specifically focused course within the general purview of a department which intends to offer it on a "one time only" basis and not as a permanent part of the department's curriculum.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 395 - Workshop
A workshop is a program which is usually of short duration, narrow in scope, often non-traditional in content and format, and on a timely topic.

Credits: 1-6
Term(s) Typically Offered: Offered as Needed
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 398 - Selected Topics
A Selected Topics course is a normal, departmental offering which is directly related to the discipline, but because of its specialized nature, may not be able to be offered on a yearly basis by the department.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 410 - Electricity and Magnetism
Electric fields and potentials of charge distributions and polarized materials, magnetic fields and vector potentials of current distributions and magnetized materials; electric and magnetic energies and application of Maxwell's equations.

Prerequisites: PHYS 212[D] and PHYS 331[D]
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Fall Terms Even
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 412 - Modern Physics 2
This course explores the applications of Quantum mechanics and relativity. Topics covered will include atomic physics, quantum statistics, solid state physics, nuclear physics, astrophysics and cosmology.

Prerequisites: PHYS 312[D] and MATH 231[D] and PHYS 331 (may be taken concurrently)[D]
[D] Requires minimum grade of D.
Credits: 1
Term(s) Typically Offered: Offered Spring Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 421 - Materials Safety and Equipment Overview for Nanofabrication - NMT 311
This course provides an overview of basic nanofabrication processing equipment and materials handling procedures with a focus on safety, environment, and health issues. Topics covered include: cleanroom operation, environmental, safety, and health issues, vacuum pump systems operation, environmental safety and health issues (covering direct drive mechanical, roots blowers, turbomolecular, and dry mechanical systems); thermal- processing equipment operation, safety, environmental, and health issues (covering horizontal, vertical, rapid thermal annealing tools); chemical vapor deposition system operation, safety, environmental, and health issues (covering gas delivery, corrosive and flammable gas storage and plumbing, regulators, and mass flow controllers); and vacuum deposition/etching system operation, safety, environment, and health issues (covering microwave and RF power supplies and tuners, heating and cooling units, vacuum gauges, valves, and process controllers). Specific materials handling issues include those arising from using deionization water, solvents, cleansers, organic materials, ion implementation sources, diffusion sources, photoiesists, developers, metal dielectrics and toxic, flammable, corrosive and high purity gases as well as packaging materials.

Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 422 - Basic Nanofabrication Processes - NMT 312
The course provides an overview of basic processing steps used in all applications of nanofabrication. Both top-down and bottom-up nanofabrication are included. The majority of the course details a step-by-step description of the equipment and processes needed to fabricate devices and structures such as bio- chips, CMOS transistors, power devices, microelectromechanical (MEM) devices, and opto-electronic structures. Students learn the similarities and differences in both the equipment and process flows needed in fabricating all of these various structures.

Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 423 - Thin Films in Nanofabrication - NMT 313
This course covers thin film deposition and etching practices in nanofabrication. The deposition techniques addressed in the first part of the course include atmospheric, low pressure, and plasma enhanced chemical vapor deposition and sputtering, thermal evaporation, and beam evaporation physical vapor deposition. Also included are self-assembling molecule based techniques. Materials considered include organics, dielectrics (e.g., nitrides, oxides), polysilicon (doped and undoped), metals (e.g., aluminum, tungsten, copper), adhesion promoters and diffusion barriers. The second part of the course focuses on etching processes and emphasizes reactive ion etching (single wafer, batch), high-ion-density reactors, ion beam etching and wet chemical etching. Students receive hands-on experience in depositing and etching dielectric, semiconductor, and metal materials using state-of-the-art tools and experience practicing the steps critical to micro- and nanofabrication of structures used in a variety of fields from biotechnology and the biomedical fields to microelectronics.

Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 424 - Advanced Lithography and Dielectrics Nanofabrication - NMT 314
This course covers all aspects of lithography from design and mask fabrication to pattern transfer and inspection. The course is divided into three major sections. The first section describes the lithographic process from substrate preparation to exposure. The second section examines the processes from development through inspection (both before and after pattern transfer). This section introduces optical masks, aligners, steppers and scanners. In addition, critical dimension (CD) and profile control of photoresists are investigated. The last section discusses advances in optical lithographic techniques such as phase shifting masks and illumination schemes as well as molecular ruler, e-beam, x-ray, EUV, and ion beam lithography.

Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 425 - Materials Modification in Nanofabrication - NMT 315
This course covers in detail the processing steps used in modifying material properties in nanofabrication. Included are chemical reaction, growth and annealing processes. The impact of thermal processing and thermal processing on defects, gettering, and impurities and overall electrical, mechanical, optical, and chemical properties are studied. The student grows and measures gate and field oxides, implants and activates source and drain regions, and evaluates thermal budget requirements using state-of-the-art tools. Included also are other modification technologies such as ion implantation, diffusion and chemical surface preparation and treatment. Substrate preparation processing such as slicing, etching, polishing and epitaxial growth are also covered.

Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 426 - Characterization, Packaging and Testing of Nanofabrication Structures - NMT 316
This course examines a variety of measurements and techniques essential for controlling micro- and nanofabrication processes. Monitoring techniques such as residual gas analysis (RGA), optical emission spectroscopy (OES) and end point detection are discussed. Characterization techniques such as scanning electron microscopy x-ray photoelectron spectroscopy, atomic probe methods advanced optical microscopy, optical thin film measurements, ellipsometry, and resistivity/conductivity measurements are introduced and tied to process control. Basic measurements for yield analysis and process control are also stressed. These include breakdown measurements, junction testing, and capacitance-voltage and current voltage characterization. In addition, the characteristics of some simple bio-chip structures and MEMs devices are obtained and discussed. The student learns about the manufacturing issues involved in interconnects, materials compatibility and final device assembly. Aluminum, refractory metals and plastic fabrication techniques and characterization are discussed in detail along with topics such as diffusion barriers, contact resistance, electro migration, corrosion, and adhesion. The importance of planarization techniques such as deposition/etchback and chemical/mechanical polishing are emphasized. Lastly, procedures such as die separation, bonding, and sealing and final test for both conventional Cs and MEMs and biomedical devices are examined.

Credits: 3
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 450 - Internship
Supervised placement and research in selected public and private agencies.

Credits: 1-12
Term(s) Typically Offered: Offered as Needed

PHYS 480 - Quantum
In this introductory course in quantum mechanics, the foundations and origins will be covered. Other topics will include wave packets, the uncertainty principle, the Schroedinger equation, operator formalism, eigen functions, spherically symmetric systems, angular momentum, spin and scattering theory.

Prerequisites: PHYS 331[D] and PHYS 411[D] and MATH 240[D] and MATH 301[*D] (may be taken concurrently).
[D] Requires minimum grade of D.
Credits: 3
Term(s) Typically Offered: Offered Spring Terms
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 490 - Independent Study
Investigation of the theoretical or experimental area following a plan or proposal initiated by the student and approved by the major advisor. Independent Study courses give students the opportunity to pursue research and/or studies that are not part of the university's traditional course offerings. Students work one on one or in small groups with faculty guidance and are typically required to submit a final paper or project as determined by the supervising professor.

Credits: 1-3
Term(s) Typically Offered: Offerings Vary
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 495 - Workshop
A workshop is a program which is usually of short duration, narrow in scope, often non-traditional in content and format, and on a timely topic.

Credits: 1-6
Term(s) Typically Offered: Offered as Needed
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.

PHYS 498 - Selected Topics
A Selected Topics course is a normal, departmental offering which is directly related to the discipline, but because of its specialized nature, may not be able to be offered on a yearly basis by the department.

Credits: 1-3
Term(s) Typically Offered: Offered as Needed
Students with a semester level of Freshman 1, Freshman 2 or Sophomore 1 may **not** enroll.