

PHYSICS

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Undergraduate Information

Physics, as the most fundamental of the sciences, is the foundation upon which many other disciplines are built. Therefore, other programs often require knowledge of the fundamentals of physics, and a physics degree is an outstanding platform for employment and advanced study in many technical disciplines. The department offers both a course of study fulfilling the bachelor of science degree and a wide range of service courses for students majoring in disciplines other than physics. Students intending to major in physics should have a high school background that includes trigonometry, algebra, and physics, as well as a good preparation in the arts and humanities. Students have an option during their first year to build their mathematics skills before taking their first physics course.

The Department of Physics offers a track in Pure and Applied Physics which is intended for students preparing for graduate school, teaching careers, or careers in industry or government labs. Students preparing for employment in an interdisciplinary area (such as environmental, geophysical or, energy study) can choose to add an appropriate minor or arrange a specific major program on an individual basis. The department also offers a 4+1 accelerated Master's program in Physics and Integrated Sciences is an expedited program of study that allows students to complete a Bachelor's degree in Physics (B.S.) and a Master's degree in Integrated Sciences (<https://clas.ucdenver.edu/mis/>) in as little as five years. Students can also pursue our Quantum Information Technology Certificate at the undergraduate (<https://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/quantum-information-technology-certificate/>) or graduate (<https://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-liberal-arts-sciences/physics/quantum-information-technology-certificate/>) levels. Offered in collaboration with the Department of Electrical Engineering this certificate is to better prepare students and working professionals to enter into the quantum information technology workforce and for those wanting to learn more about quantum computing and quantum technologies.

Students majoring in other disciplines have the option of choosing a minor in physics, in astrophysics, or in biophysics.

To enhance the employment and postgraduate study options of physics majors, the department is committed to providing students with opportunities for experimental, computational, and theoretical research. On-campus opportunities are available through the faculty research programs. Questions regarding physics courses or the physics curriculum should be directed to a departmental advisor. Appointments should be made through the physics office.

Departmental Honors

Qualified students are encouraged to participate in the physics honors program. For these students, a physics capstone thesis is required. This work will be conducted under the supervision of a faculty advisor. The topic and scope of this work will be chosen by the student in consultation

with the thesis advisor. The student has the option of registering for up to 3 semester hours of directed research or independent study for the thesis project; regardless of registered semester hours, the student must commit the effort of a minimum of 135 hours toward completion of the thesis, which is equivalent to a 3-semester-hour course. The levels of passing scores are satisfactory, meritorious, and excellent.

Within this framework, three levels of honors are awarded by CU Denver in conjunction with the physics major:

1. *Cum laude*: The student must have a cumulative GPA of 3.25 both in physics and overall at the University of Colorado. The student's physics capstone thesis and presentation must be judged to be meritorious.
2. *Magna cum laude*: The student must have a cumulative GPA of 3.50 both in physics and overall at the University of Colorado. The student's physics capstone thesis and presentation must be judged to be meritorious.
3. *Summa cum laude*: The student must have a cumulative GPA of 3.75 both in physics and overall at the University of Colorado. The student's physics capstone thesis and presentation must be judged to be excellent.

Physics Major

Click here (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/physics-pure-applied-physics-option-bs/>) to learn about the requirements for the Physics - Pure and Applied Physics BS.

Click here (<http://catalog.ucdenver.edu/cu-denver/graduate/schools-colleges-departments/college-liberal-arts-sciences/integrated-sciences/integrated-sciences-mis/>) to learn about the requirements for the Physics 4+1 BS to Integrated Sciences MS.

Physics Minors

Click here (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/physics-minor/>) to learn about the requirements for the Minor in Physics.

Click here (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/astrophysics-minor/>) to learn about the requirements for the Minor in Astrophysics.

Click here (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/biophysics-minor/>) to learn about the requirements for the Minor in Biophysics.

Programs Offered

- Physics, BS (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/physics-bs/>)
- Astrophysics Minor (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/astrophysics-minor/>)
- Biophysics Minor (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/biophysics-minor/>)

- Physics Minor (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/physics-minor/>)
- Quantum Information Technology Undergraduate Certificate (<http://catalog.ucdenver.edu/cu-denver/undergraduate/schools-colleges-departments/college-liberal-arts-sciences/physics/quantum-information-technology-certificate/>)

Faculty

Professors:

Martin E. Huber, PhD, Stanford University
Michael “Bodhi” Rogers, PhD, RPA, Oregon State University
Alberto C. Sadun, PhD, Massachusetts Institute of Technology

Associate Professor:

Randall P. Tagg, PhD, Massachusetts Institute of Technology

Assistant Professors:

Amy L. Roberts, PhD, University of Notre Dame
Anthony N. Villano, PhD, Rensselaer Polytechnic Institute
Kathryn Hamilton, PhD, Queen’s University Belfast

Teaching Professor:

Masoud Asadi-Zeydabadi, PhD, University of Colorado Boulder

Assistant Teaching Professor:

Ramesh Dhungana, PhD, University of North Dakota, Grand Forks
Julian Gifford, PhD, University of Colorado Boulder

Research Professor:

Glen S. Mattioli, PhD, Northwestern University

Research Associate Professor:

Michael J. Friedel, PhD, University of Minnesota

Senior Instructors:

John Carlson, PhD, University of Michigan, Ann Arbor

Emeritus Professors:

Bill Chappell, PhD, University of Colorado Boulder
Martin M. Maltempo, PhD, Columbia University
Clyde S. Zaidins, PhD, California Institute of Technology

Physics (PHYS)

PHYS 1052 - General Astronomy I (4 Credits)

The history of astronomy is studied from early civilizations to the present. The basic motions of the earth, moon, sun, and planets are discussed both qualitatively and quantitatively, using elementary principles of physics. Properties of our solar system are discussed in detail, including results from unmanned space probes. Note: An additional 30 hours of laboratory work (at times to be arranged), plus appropriate report preparation time, are required to complete laboratory component of the course. Note: High school algebra or equivalent are strongly recommended preparation for this course. Term offered: spring, fall. Max hours: 4 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-SC1
 Grading Basis: Letter Grade
 Additional Information: Denver Core Requirement, Biol Phys Sci - Lec/Lab; GT courses GT Pathways, GT-SC1, Nat Phy Sci:Course w/Req Lab.
 Typically Offered: Fall, Spring.

PHYS 1100 - Foundations of Physics (4 Credits)

One-semester non-lab survey course especially designed for non-science majors. Acquaints students with some of the major principles and methods of physics. Includes applications of physics to everyday life and some discussion of the historical development of physics. Note: this course assumes that students have a good working knowledge of elementary algebra. Term offered: spring, summer, fall. Max Hours: 4 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-SC2
 Grading Basis: Letter Grade
 Additional Information: Denver Core Requirement, Biol Phys Sci - No Lab; GT courses GT Pathways, GT-SC2, Nat Phy Sci:Lec w/o Req Lab.
 Typically Offered: Fall, Spring, Summer.

PHYS 1111 - First Year Seminar (3 Credits)

Restriction: Restricted to Freshman level students. Offered irregularly. Max Hours: 3 Credits.
 Grading Basis: Letter Grade
 Restriction: Restricted to Freshman level students

PHYS 1300 - Contemporary Topics in Physics. (2 Credits)

Covers various current topics in physics at a qualitative level. Designed primarily for students intending to major in physics, engineering, and chemistry. Max hours: 2 Credits.
 Grading Basis: Letter Grade

PHYS 1450 - Professional Development I (1 Credit)

Introduction to the physics program for all beginning physics majors or those considering the major. Discussions about career opportunities, the various physics undergraduate and graduate degree paths, research being conducted within the physics department, and strategies for being a successful and engaged physics major. Term offered: fall. Max hours: 1 Credit.
 Grading Basis: Letter Grade
 Typically Offered: Fall.

PHYS 1840 - Independent Study: PHYS (1-3 Credits)

Students must check with a faculty member before taking this course. Repeatable. Term offered: spring, summer, fall. Max Hours: 3 Credits.
 Grading Basis: Letter Grade
 Repeatable. Max Credits: 3.
 Typically Offered: Fall, Spring, Summer.

PHYS 2010 - College Physics I (4 Credits)

This is an algebra based physics course covering mechanics, heat and sound. Note: College algebra and trigonometry are strongly recommended preparation for optimal student success. Term offered: spring, summer, fall. Max Hours: 4 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-SC2.

Grading Basis: Letter Grade

Additional Information: Denver Core Requirement, Biol Phys Sci - Lec; GT courses GT Pathways, GT-SC2, Nat Phy Sci:Lec w/o Req Lab.

Typically Offered: Fall, Spring, Summer.

PHYS 2020 - College Physics II (4 Credits)

This is an algebra based physics course covering electricity, magnetism, light and modern physics. Prereq: PHYS 2010 or PHYS 2311 with a C- or higher. Term offered: spring, summer, fall. Max hours: 4 Credits. GT: Course is approved by the Colorado Dept of Higher Education for statewide guaranteed transfer, GT-SC2.

Grading Basis: Letter Grade

Prerequisite: PHYS 2010 or PHYS 2311 with a C- or higher.

Additional Information: Denver Core Requirement, Biol Phys Sci - Lec; GT courses GT Pathways, GT-SC2, Nat Phy Sci:Lec w/o Req Lab.

Typically Offered: Fall, Spring, Summer.

PHYS 2311 - General Physics I: Calculus-Based (4 Credits)

This is a calculus based physics course covering vector displacement, uniform and accelerated motion, force, momentum, energy, rotating systems, oscillations, and an introduction to thermodynamics. Emphasis is on basic principles. Prereq: MATH 1401 with a C- or higher. Term offered: spring, summer, fall. Max hours: 4 Credits.

Grading Basis: Letter Grade

Prerequisite: MATH 1401 with a C- or higher.

Additional Information: Denver Core Requirement, Biol Phys Sci - Lec; GT courses GT Pathways, GT-SC2, Nat Phy Sci:Lec w/o Req Lab.

Typically Offered: Fall, Spring, Summer.

PHYS 2321 - Intro Experimental Phys Lab I (1 Credit)

This introductory experimental physics laboratory introduces students to the methods of science through a series of experiments and exercises focused on how objects move. Students working in teams use mathematical and computational approaches to acquire data, examine data, and make conclusions about how well these data support hypotheses and models. Students will use different types of scientific communication, including graphs and other forms of data visualization and cogent written and oral evaluation of experimental findings. Term offered: spring, summer, fall. Max hours: 1 Credit.

Grading Basis: Letter Grade

Additional Information: Denver Core Requirement, Biol Phys Sci - Lab.

Typically Offered: Fall, Spring, Summer.

PHYS 2331 - General Physics II: Calculus-Based (4 Credits)

This is a calculus based physics course covering electrostatics, magnetic fields, electromagnetic waves (including light), and optics. Prereq: PHYS 2311 and MATH 2411 with a C- or higher. Term offered: spring, summer, fall. Max hours: 4 Credits.

Grading Basis: Letter Grade

Prerequisite: PHYS 2311 and MATH 2411 with a C- or higher.

Additional Information: Denver Core Requirement, Biol Phys Sci - Lec; GT courses GT Pathways, GT-SC2, Nat Phy Sci:Lec w/o Req Lab.

Typically Offered: Fall, Spring, Summer.

PHYS 2341 - Intro Experimental Phys Lab II (1 Credit)

This introductory experimental physics laboratory introduces students to the methods of science through a series of experiments and exercises focused on electricity and magnetism. Students working in teams use mathematical and computational approaches to acquire data, examine data, and make conclusions about how well these data support hypotheses and models. Students will use different types of scientific communication, including graphs and other forms of data visualization and cogent written and oral evaluation of experimental findings. Prereq: PHYS 2321 or PHYS 2030 with a C- or higher. Term offered: spring, summer, fall. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: PHYS 2321 or PHYS 2030 with a C- or higher.

Additional Information: Denver Core Requirement, Biol Phys Sci - Lab.

Typically Offered: Fall, Spring, Summer.

PHYS 2351 - Applied Physics Lab I (1 Credit)

Introduces physics majors to several ways that fundamental concepts in mechanics intersect with useful technologies, resulting in documented technical competencies useful in research and industry. Term offered: fall, spring. Max hours: 1 Credit.

Grading Basis: Letter Grade

Additional Information: Denver Core Requirement, Biol Phys Sci - Lab.

Typically Offered: Fall, Spring.

PHYS 2361 - Applied Physics Lab II (1 Credit)

Introduces physics majors to several ways that fundamental concepts in electrodynamics and optics intersect with useful technologies, resulting in documented technical competencies useful in research and industry. Prereq: PHYS 2351 with a C- or higher. Term offered: spring. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: PHYS 2351 with a C- or higher.

Additional Information: Denver Core Requirement, Biol Phys Sci - Lab.

Typically Offered: Spring.

PHYS 2711 - Vibrations and Waves (3 Credits)

Introduces vibrations and waves associated with physical phenomena. Analytic and numerical methods in physical contexts. Topics include harmonic oscillators, resonance, coupled oscillators, nonlinear oscillators, waves in elastic media, sound waves, pulses and dispersion. Prereq: PHYS 2331 and MATH 2411 with a C- or higher. Term offered: typically offered spring only. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prerequisite: PHYS 2331 and MATH 2411 with a C- or higher.

Typically Offered: Spring.

PHYS 2811 - Modern Physics I (3 Credits)

Presents a study of the events and discoveries that occurred during the latter part of the 19th and the first part of the 20th centuries which led to the discovery of quantum mechanics; namely, special relativity, particle nature of radiation, wave properties of particles, models of the atom, and the introduction of quantum mechanics. Prereq: PHYS 2331 and MATH 2411 with a C- or higher. Term offered: typically offered in spring only. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prerequisite: PHYS 2331 and MATH 2411 with a C- or higher.

Typically Offered: Spring.

PHYS 2840 - Independent Study: PHYS (1-3 Credits)

Students must check with a faculty member before taking this course.
Repeatable. Term offered: spring, summer, fall infrequently. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

Typically Offered: Fall, Spring, Summer.

PHYS 2880 - Directed Research (1-3 Credits)

Students will engage in original research projects supervised and mentored by faculty. Students must work with faculty prior to registration to develop a proposal for their project and receive permission to take this course. Note: Students must submit a special processing form completely filled out and signed by the student and faculty member, describing the course expectations, assignments and outcomes, to the CLAS undergraduate advising office for approval. Repeatable. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

PHYS 2939 - Internship (1-3 Credits)

Experiences involving application of specific, relevant concepts and skills in supervised employment situations. Note: students must work with the Experiential Learning Center advising to complete a course contract and gain approval. Prereq: 15 hours of 2.75 GPA. Repeatable. Term offered: spring, summer, fall infrequently. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Typically Offered: Fall, Spring, Summer.

PHYS 3010 - Physics for Applied Scientists (4 Credits)

Physics for Applied Scientists covers standard topics including the nature and practice of science, scientific modeling, and the application of physics to real-world problems and daily life. Specific physics content (e.g. Light and Color, Atmospheric Physics, Energy Production, Astronomy) will be decided each semester based on student choice.

Prereq: Requires prerequisite course of MATH 1010 or equivalent (minimum grade C-). Recommended MATH 1100 or equivalent (minimum grade C-). Term offered: Fall. Max hours: 3 Credits.

Grading Basis: Letter Grade

Requires prerequisite course of MATH 1010 or equivalent (minimum grade C-). Recommended MATH 1100 or equivalent (minimum grade C-).

Typically Offered: Fall.

PHYS 3050 - General Astronomy II (3 Credits)

Evolution of our sun and other stars is studied, as well as the methods used to gain the information. Discussion includes objects such as neutron stars, novae and supernovae, and black holes. Large-scale structures, including clusters and galaxies, are studied. Prereq: PHYS 1052 or PHYS 2010 or PHYS 2311. Term offered: fall. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 1052 or PHYS 2010 or PHYS 2311

Typically Offered: Fall.

PHYS 3070 - Physical Cosmology (3 Credits)

Designed for science and engineering maj. stud. in quantitative fields/ w req math skills interested in physical universe. Covers large-scale structure of universe & its evolution from birth well into future. Gravitational concepts, neutron stars, black holes, big bang univ, cosmological tests, dark matter & energy. Problem solving emphasized. Prereq: PHYS 1052 or PHYS 2010 or PHYS 2311 or permission. Note: This course assumes that students have completed PHYS 2010 or PHYS 2311 prior to taking this course. Note: Routine knowledge of algebra, geometry and trigonometry is assumed. Knowledge of trig and calculus also useful. Term offered: spring. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 1052 or PHYS 2010 or PHYS 2311

Typically Offered: Spring.

PHYS 3082 - Energy and the Environment (3 Credits)

For students of various backgrounds who wish to increase their understanding of the environmental and technical issues of supplying the energy demands of our society. Alternative energy sources and conservation are explored as solutions to promote sustainable society. Note: One college-level science course and MATH 1110 or equivalent are strongly recommended as preparation for optimal student success. Cross-listed with ENVS 3082. Term offered: fall. Max hours: 3 Credits.

Grading Basis: Letter Grade

Typically Offered: Fall.

PHYS 3120 - Methods of Mathematical Physics (3 Credits)

Typically covers calculus of variations, special functions, partial differential equations, integral transforms, linear vector spaces, and tensor analysis. Prereq: MATH 2421 and either MATH 3195 or MATH 3191 and MATH 3200 with a C- or higher. Term offered: fall. Max hours: 3 Credits.

Grading Basis: Letter Grade

Pre: MATH 2421 and either MATH 3195 or MATH 3191 and MATH 3200 with a C- or higher.

Typically Offered: Fall.

PHYS 3151 - Biophysics Outlook I (1 Credit)

Designed as a companion to General Biology I (but can take stand-alone), this course explores how biophysics concepts and experimental methods add to the knowledge of life's processes at the molecular and cellular level. Note: PHYS 2010 and 2020 strongly recommended for optimal student success. Term offered: fall. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Typically Offered: Fall.

PHYS 3161 - Biophysics Outlook II (1 Credit)

Designed as a companion to General Biology I (but can take stand-alone), this course explores how biophysics concepts and experimental methods contribute to the understanding of the structure and function of plants, animals & ecological systems. Note: PHYS 2010 and PHYS 2020 strongly recommended for optimal student success. Term offered: spring. Max Hours: 1 Credit.

Grading Basis: Letter Grade

Typically Offered: Spring.

PHYS 3211 - Analytical Mechanics (4 Credits)

Topics include the Lagrange and Hamiltonian formulations, the two-body problem, rigid body motion, and small oscillations. Prereq: PHYS 2711, MATH 2421 and either MATH 3195 or MATH 3191 and MATH 3200 with a C- or higher. Coreq: PHYS 3120. Term offered: fall. Max hours: 4 Credits.

Grading Basis: Letter Grade

Pre-req: PHYS 2711, MATH 2421 and either MATH 3195 or MATH 3191 and MATH 3200 with a C- or higher. Co-req PHYS 3120.

Typically Offered: Fall.

PHYS 3251 - Biophysics of the Body (4 Credits)

Fundamental ideas of anatomy, physiology, and biomechanics from the viewpoint of physics. Biological topics covered include: skeletal systems, muscular systems, circulatory systems, and human motion. Analytical mechanics topics include: Newtonian mechanics, harmonic motion, energy conservation, and introductory fluid dynamics. Prereq: PHYS 2711, 3161, MATH 2421 and 3195 or equivalent or permission of instructor.

Term offered: infrequent. Max Hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2711, 3161, MATH 2421 and 3195

PHYS 3252 - Biophysics of the Body NM (4 Credits)

Fundamental ideas of anatomy, physiology, and biomechanics from the viewpoint of physics. Biological topics covered include: skeletal systems, muscular systems, circulatory systems, and human motion. Analytical mechanics topics include: newtonian mechanics, harmonic motion, energy conservation, and introductory fluid dynamics. Prereq: PHYS 2010 and PHYS 2020. Term offered: infrequently. Max Hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2010 and PHYS 2020

PHYS 3411 - Thermal Physics (3 Credits)

Covers the basic concepts of the three related disciplines of thermodynamics, statistical mechanics, and kinetic theory. Prereq: PHYS 2331, PHYS 2811 and MATH 2421 with a C- or higher; Prereq or Coreq: MATH 3195 or MATH 3191 and MATH 3200 with a C- or higher if completed prior to PHYS 3411. Term offered: spring. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: Prereq: PHYS 2331, 2811 and MATH 2421 with a C- or higher; Pre or Coreq: MATH 3195 or (MATH 3191 and MATH 3200) with a C- or higher. Typically Offered: Spring.

PHYS 3450 - Professional Development II (1 Credit)

Continuation of professional preparation for careers and graduate school. Students will conduct career-related research and engage in classroom discussions. Students will also examine their resume and transcript to create individualize action plans to bridge the gap between their current skills and those desired by employers and graduate schools. Term offered: fall. Max hours: 1 Credit.

Grading Basis: Letter Grade

Typically Offered: Fall.

PHYS 3451 - Biophysics of the Cell (4 Credits)

Fundamentals of cellular biology from the viewpoint of physics. Biological topics covered include: the central dogma of molecular biology, cellular signaling, genetic regulation, molecular crowding, and ion channels. Statistical and thermal physics topics include: statistics, probability, thermodynamics, heat, and entropy. Prereq: PHYS 2811, 3151 and MATH 2421 or permission of instructor. Coreq: MATH 3195. Term offered: on demand. Max Hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2811, 3151 and MATH 2421 Coreq: MATH 3195

PHYS 3452 - Biophysics of the Cell NM (4 Credits)

Fundamentals of cellular biology from the viewpoint of physics. Biological topics covered include: the central dogma of molecular biology, cellular signaling, genetic regulation, molecular crowding, and ion channels. Statistical and thermal physics topics include: statistics, probability, thermodynamics, heat, and entropy. Prereq: PHYS 2020, 2040 and 3151 or permission of instructor. Term offered: infrequent. Max Hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2020, 2040 and 3151

PHYS 3513 - Optical Systems Design (1 Credit)

Lenses, mirrors, prisms, polarizers, optical fibers, and other optical elements are placed in appropriately designed mechanical mounts to develop useful optical instruments. Light sources of many types are selected for particular applications. Repeatable. Max hours: 3 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

PHYS 3514 - Optoelectronics (1 Credit)

Solid state sources, lasers, modulators, and detectors are combined into optoelectronic systems for scientific apparatus and technological devices. Repeatable. Max hours: 3 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

PHYS 3515 - Imaging Systems. (1 Credit)

Photographic, analog electronic, and digital imaging systems are applied to the acquisition of data in conventional and in unusual image formats to aid in scientific experiments. Repeatable. Max hours: 3 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

PHYS 3620 - Sound and Music (3 Credits)

Considers the basic nature of sound waves, the ear and hearing, and musical instruments. Although this course is mainly descriptive, some high school algebra will be used. Term offered: typically offered fall only. Max hours: 3 Credits.

Grading Basis: Letter Grade

Typically Offered: Fall.

PHYS 3711 - Advanced Experimental Physics Laboratory (2 Credits)

An advanced lab in which students select and explore the ideas and laboratory methods of major professional areas of physics: classical mechanics & nonlinear dynamics, electrodynamics, thermal physics, fundamental quantum behavior, nuclear and elementary particle physics, atomic and molecular physics, optics and photonics, condensed matter physics, fluid dynamics, acoustics, plasma physics, and astrophysics as well as interdisciplinary topics. Note: Must be taken twice by students majoring in physics. Prereq: PHYS 2711 or 2811 with a C- or higher or permission of instructor. Term offered: fall, spring. Max hours: 4 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 4.

Prereq: PHYS 2711 or PHYS 2811 with a grade of C- or better.

Typically Offered: Fall, Spring.

PHYS 3751 - Physics Capstone Proposal (1 Credit)

Provides opportunity for physics majors to prepare a written proposal in preparation for senior thesis research or a senior project. Emphasis placed on describing the problem, methodology, equipment, and data analysis needed to successfully complete the research or project.

Completed proposals are submitted to each student's potential research or project advisor for review and approval. Note: Required for all students majoring in physics. Prereq: PHYS 2711 or PHYS 2811 with a grade of C- or better. Term offered: spring. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: PHYS 2711 or PHYS 2811 with a grade of C- or better.

Typically Offered: Fall, Spring.

PHYS 3840 - Independent Study: PHYS (1-3 Credits)

Note: Students must check with a faculty member before taking this course. Repeatable. Term offered: spring, summer, fall infrequently. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 6.

Typically Offered: Fall, Spring, Summer.

PHYS 3880 - Directed Research (1-3 Credits)

Students will engage in original research projects supervised and mentored by faculty. Students must work with faculty prior to registration to develop a proposal for their project and receive permission to take this course. Note: Students must submit a special processing form completely filled out and signed by the student and faculty member, describing the course expectations, assignments and outcomes, to the CLAS undergraduate advising office for approval. Repeatable. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

PHYS 3939 - Internship (1-3 Credits)

Designed experiences involving application of specific, relevant concepts and skills in supervised employment situations. Note: students must work with the Experiential Learning Center advising to complete a course contract and gain approval. Prereq: Junior standing or higher and at least a 2.75 cumulative GPA. Repeatable. Term offered: spring, summer, fall infrequently. Max Hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Prereq: Junior standing or higher and at least a 2.75 cumulative GPA

Typically Offered: Fall, Spring, Summer.

PHYS 4211 - Quantum Mechanics (3 Credits)

A course in which both wave and matrix mechanics are developed and applied to selected problems in atomic physics. Prereq: PHYS 2811 and 3211 with a C- or higher. Co-req: PHYS 4212. Term Typically Offered: Fall. Cross-listed with PHYS 5211. Max hours: 3 credits

Grading Basis: Letter Grade

Prereq: PHYS 2811 and 3211 with a C- or higher. Coreq: PHYS 4212.

Typically Offered: Fall.

PHYS 4212 - Quantum Mechanics Seminar (1 Credit)

This course involves supplemental discussion and guided extension of course content presented in PHYS4211 Quantum Mechanics through the use of one or more of the following: Interactive Tutorials, Collaborative Problem Solving, Computation, and Hands-on Activities. Co-req: PHYS 4211. Term Typically Offered: Fall. Max hours: 3 credits

Grading Basis: Letter Grade

Co-req: PHYS 4211

Typically Offered: Fall.

PHYS 4251 - Physical Fluid Dynamics (3 Credits)

Fundamental concepts and methods in fluid dynamics are developed through basic laws, the Navier-Stokes equation, viscous fluid flow, dimensional analysis, vorticity, boundary layers, linear stability and turbulent flow. Cross-listed with PHYS 5251. Prereq: Restricted to students who have completed PHYS 2311, PHYS 2331 and PHYS 3120 with a C- or higher or with instructor permission. Max hours: 3 Credits.

Grading Basis: Letter Grade

Restricted to students who have completed PHYS 2311, PHYS 2331 and PHYS 3120 with a C- or higher or with instructor permission.

PHYS 4311 - Electricity & Magnetism (3 Credits)

Elements of mathematical theory of electricity and magnetism, including electrostatics, magnetostatics, polarized media, direct and alternating current theory, and introduction to electromagnetic fields and waves. Prereq: PHYS 2331 and PHYS 3120 with a C- or higher. Co-req: PHYS 4312. Term Typically Offered: Spring. Cross-listed with PHYS 5311. Max hours: 3 credits.

Grading Basis: Letter Grade

Pre-req: PHYS 2331 and PHYS 3120 with a C- or higher. Co-req:

PHYS 4312.

Typically Offered: Spring.

PHYS 4312 - Electricity & Magnetism Seminar (1 Credit)

This course involves supplemental discussion and guided extension of course content presented in PHYS 4311 Electricity & Magnetism through the use of one or more of the following: Interactive Tutorials, Collaborative Problem Solving, Computation, and Hands-on Activities. Co-req: PHYS 4311. Term Typically Offered: Spring. Max hours: 1 credit

Grading Basis: Letter Grade

Co-req of PHYS 4311

Typically Offered: Spring.

PHYS 4351 - Bioelectromagnetism (4 Credits)

The fundamental theory of electric and magnetic fields is developed and applied to problems of biology and medicine. Examples in medical diagnostics and treatment are built upon rigorous application of Maxwell's equations and constitutive models of electromagnetic properties of biomaterials. Prereq: PHYS 2331 and 3120 or permission of instructor. Cross-listed with PHYS 5351. Term offered: spring infrequently. Max Hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2331 and 3120

Typically Offered: Spring.

PHYS 4352 - Bioelectromagnetism NM (4 Credits)

This course is the non-majors' companion to PHYS 4351/5351 (taught simultaneously) using modeling approaches accessible to the general science student. Prereq: PHYS 2010, 2020 and MATH 1401 or permission of instructor. Cross-listed with PHYS 5352. Term offered: spring. Max Hours: 4 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2010, 2020 and MATH 1401

Typically Offered: Spring.

PHYS 4400 - Scientific Instrumentation (3 Credits)

Conceptual and practical knowledge needed to design scientific instruments, develop technical products, and use special laboratory procedures to research. Topics include materials, mechanisms, electronics, and optics. Note: Two semesters of 2000-level introductory physics strongly recommended for optimal student success. Cross-listed with PHYS 5400. Repeatable. Term offered: infrequent. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 6.

PHYS 4401 - Special Topics (1-3 Credits)

Repeatable. Infrequently Offered. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 3.

PHYS 4450 - Professional Development III (1 Credit)

Continuation of professional preparation for careers and graduate school. This seminar provides opportunities for students to reflect upon connections between the physics major, the core curriculum, and other learning experiences while a student. Students will develop a written reflection on their undergraduate experiences. Students will also learn how to locate and apply to open job positions and graduate school programs. Prereq: PHYS 3450 with a C- or higher. Term offered: fall. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: PHYS 3450 with a C- or higher.

Typically Offered: Fall.

PHYS 4510 - Optics (3 Credits)

Presents a contemporary treatment of selected topics in optics, such as matrix methods in geometrical optics, the Fourier analysis approach to physical optics, and interaction of light with matter. Prereq: PHYS 2331, 2811 and 3120 with a C- or higher. Infrequently Offered. Term offered: spring. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2331, 2811 and 3120 with a C- or higher.

Typically Offered: Spring.

PHYS 4550 - Astrophysics (3 Credits)

Covers stellar astrophysics, solar physics, star formations, stellar evolution, processes in the interstellar medium, galactic dynamics and evolution, formation of galaxies and cosmology. Note: MATH 3195; PHYS 2821 and 3050 are strongly recommended preparation for optimal student success. Infrequently Offered. Max Hours: 3 Credits.

Grading Basis: Letter Grade

PHYS 4611 - Computational Physics (3 Credits)

Designed to provide an understanding of the role of the computer in modern theoretical physics by studying the simulation of physical phenomena in various fields of physics. Prereq: PHYS 3120. Note: Students will not earn credit for PHYS 4611, if they have already earned credit for PHYS 4610. Infrequently Offered. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prerequisite: PHYS 3120

PHYS 4620 - Computational Physics II (2 Credits)

Assigns the student to an individual, advanced-level project modeling a physical phenomenon on the computer. Prereq: PHYS 4611 with a C- or higher. Infrequently Offered. Max hours: 2 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 4611 with a C- or higher.

PHYS 4650 - Solid State Physics (3 Credits)

Covers the basic thermal and electrical properties of solids which are explained in terms of the Brillouin zone structures of phonons and electrons. Infrequently Offered. Prereq: PHYS 3411, PHYS 3811, and PHYS 4211 with a C- or higher. Cross-listed with PHYS 5650. Max Hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 3411, PHYS 3811, and PHYS 4211 with a C- or higher.

PHYS 4678 - Quantum Computing (3 Credits)

The course teaches students the principles, the algorithms and the programming methods of quantum computing, and also discusses the associated physics and mathematics background required. Other related topics such as quantum communication and quantum entanglement will also be discussed. Prereq: PHYS 2811 with a C- or higher or Permission of Instructor. Cross-listed with PHYS 5678, ELEC 4678, and ELEC 5678. Term offered: spring. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 2811 with a C- or higher.

Typically Offered: Spring.

PHYS 4679 - Quantum Computing Algorithms (3 Credits)

The course discusses several seminal quantum algorithms, including the quantum Fourier transforms, Grover's and Shor's algorithms, followed by explaining several advanced quantum computing algorithms, including quantum error correction, sparse linear systems, and variational eigensolver. Google Cirq quantum programming library will be used for actual quantum programming implementations of the algorithms discussed. Prereq: PHYS 3120 or PHYS 3211 or PHYS 3411 with a C- or higher or Permission of Instructor. Cross-listed with PHYS 5679, ELEC 4679, and ELEC 5679. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 3120 or PHYS 3211 or PHYS 3411 with a C- or higher.

Typically Offered: Fall.

PHYS 4680 - Quantum Computing Technology (3 Credits)

Students will explore some of the concepts and experimental practices for realizing quantum computers. They will engage in laboratory practice of relevant skills including high-performance analog electronics; optics-based quantum encryption and eraser implementations; RF electronics; and vacuum and cryogenic techniques. Prereq: PHYS 3711 with a C- or higher or Permission of Instructor. Cross-listed with PHYS 5680, ELEC 4680, and ELEC 5680. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 3711 with a C- or higher.

PHYS 4681 - Quantum Technology Systems (3 Credits)

Students will explore a systems approach toward experimental practices for realizing quantum information science and engineering (QISE), with a focus on vacuum and cryogenic techniques and integration of electronics subsystems into a "dry" cryostat. They will engage in laboratory practice of relevant skills including creation and measurement of high vacuum, methods for reaching ultra-low temperatures, concerns in the design and construction of cryogenic apparatuses, and operation of a "dry" cryogenic system at 4 K, including measurements on superconducting quantum interference devices. Prereq: PHYS 4680 OR PHYS 5680 OR ELEC 4680 OR ELEC 5680 with a C- or higher. Cross-listed with PHYS 5681, ELEC 4681 and ELEC 5681. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 4680 OR PHYS 5680 OR ELEC 4680 OR ELEC 5680 with a C- or higher.

PHYS 4711 - Physics Capstone Project (2 Credits)

A one-semester intensive physics capstone project in experimental or computational physics. Projects may include (A) development of a new or enhanced experiment for PHYS 3711, (B) further independent investigation in one of the fundamental areas of physics, or (C) development of a technical innovation for society and industry. Prereq: PHYS 3751 with a C- or higher or permission of instructor. Term offered: spring, fall. Max hours: 2 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 3751 with a C- or higher.

Typically Offered: Fall, Spring.

PHYS 4751 - Physics Capstone Thesis (1 Credit)

A two semester capstone experience in which students prepare, summarize, present their own research in physics in a formal written thesis. Must be taken twice by physics majors who choose this option. Students must also complete a minimum of 135 hours of research through completion of 3 credits of PHYS 4880 Directed Research or a research internship or other documented evidence of research efforts. Prereq: PHYS 3751 with a C- or higher or permission of instructor. Repeatable. Term offered: fall, spring. Max hours: 2 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 2.

Prereq: PHYS 3751 with a C- or higher.

Typically Offered: Fall, Spring.

PHYS 4810 - Atomic and Molecular Structure (3 Credits)

A course in which quantum mechanical methods are applied to problems in atomic and molecular physics, such as the one-electron atom, atomic and molecular spectra, and particle scattering. Infrequently Offered. Prereq: PHYS 3811 and PHYS 4211 with a C- or higher. Max hours: 3 Credits.

Grading Basis: Letter Grade

Prereq: PHYS 3811 and PHYS 4211 with a C- or higher.

PHYS 4820 - Subatomic Physics (3 Credits)

Introductory treatment of the various concepts and models used to describe nuclear and high energy particle phenomena. Prereq: PHYS 2811 with a C- or higher. Term offered: spring, infrequent. Max hours: 3 Credits. Grading Basis: Letter Grade
Prereq: PHYS 2811 with a C- or higher.
Typically Offered: Spring.

PHYS 4840 - Independent Study: PHYS (1-3 Credits)

Note: Students must check with a faculty member before taking this course. Repeatable. Term offered: spring, summer, fall infrequently. Max Hours: 12 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 12.

Typically Offered: Fall, Spring, Summer.

PHYS 4850 - Physics for Design and Innovation I (3 Credits)

A service-learning project using fundamental physical principles to design a prototype scientific instrument, technical device, or technical process for a real-world client. Includes instruction on project management, intellectual property, and market analysis. Cross-listed with PHYS 5850. Repeatable. Term offered: infrequent. Max hours: 6 Credits. Grading Basis: Letter Grade
Repeatable. Max Credits: 6.

PHYS 4852 - Physics for Design and Innovation II (3 Credits)

A capstone project using fundamental physical principles to prototype a scientific instrument, technical device or technical process. The focus is on the student's own product idea. Includes online guided readings on the wider context of product development. Students should consult with instructor on necessary physics and mathematics preparation for the project. Prereq: PHYS 4850 with a grade of C- or higher. Cross-listed with PHYS 5852. Repeatable. Term offered: infrequent. Max Hours: 6 Credits. Grading Basis: Letter Grade
Repeatable. Max Credits: 6.
Prereq: PHYS 4850 with a C- or higher.

PHYS 4880 - Directed Research (1-6 Credits)

Students will engage in original research projects supervised and mentored by faculty. Students must work with faculty prior to registration to develop a proposal for their project and receive permission to take this course. Repeatable. Term offered: spring, summer, fall. Max Hours: 6 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 6.

Typically Offered: Fall, Spring, Summer.

PHYS 4920 - Advanced Undergraduate Seminar (1 Credit)

Studies a focused topic such as: size and age of the universe, critical phenomena, non-linear optics, energy, fiber-optic communications, among others. Students research these topics and give a seminar outlining their findings. Prereq: PHYS 2811 with a C- or higher. Infrequently Offered. Max hours: 1 Credit.

Grading Basis: Letter Grade

Prereq: PHYS 2811 with a C- or higher.

PHYS 4921 - Senior Seminar (1 Credit)

Grading Basis: Letter Grade

PHYS 4939 - Internship (1-3 Credits)

Note: students must work with the Experiential Learning Center advising to complete a course contract and gain approval. Repeatable. Term offered: spring, summer, fall infrequently. Max hours: 9 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 9.

Typically Offered: Fall, Spring, Summer.

PHYS 4950 - General Relativity (3 Credits)

This course will introduce classical general relativity, a generalized theory of gravity that reduces to Newtonian gravity is the weak gravity limit. This course covers the basic principles of Einstein's general theory of relativity, differential geometry, experimental tests of general relativity, black holes, and cosmology. Since this course will emphasize both analytic calculation and physical understanding of classical gravity and is a 3 credit hour senior-level physics course, it can be very challenging, especially if taken with other physics courses. A good rule of thumb for a college course of this type is to expect to spend a minimum of 2 to 4 times the amount of time outside of class as you do in class. For this course, that means a minimum of 6 to 12 hours per week outside of class. Term offered: infrequent. Max Hours: 3 Credits.

Grading Basis: Letter Grade

PHYS 4980 - Advanced Physics Topics (1-3 Credits)

Covers a particular topic, as announced in the 'Schedule Planner.' Note: May be taken more than once for credit in different topics. Prereq: PHYS 2811 with a C- or higher. Repeatable. Term offered: spring, fall. Max Hours: 12 Credits.

Grading Basis: Letter Grade

Repeatable. Max Credits: 12.

Prereq: PHYS 2811 with a C- or higher.

Typically Offered: Fall, Spring.