

# PHYSICS, BACHELOR OF SCIENCE (B.S.)

The Bachelor of Science in Physics requires a minimum of 120 credits, including 54 credits in physics and physics-related courses, as detailed in the course lists.

The curriculum in physics prepares students for technical careers in physics or an allied area, for careers in engineering and for the teaching of physics in secondary schools. The curriculum also prepares students for graduate studies in physics or a related area.

## Student learning outcomes

Students will learn to perform scientific reasoning and complex problem-solving. Physics majors will receive a fundamental understanding of the main areas of physics so that they are prepared for jobs that use physics-based technologies. They are expected to have mastered the analytical approach to solving technical problems by identifying simple subsystems that obey known physical laws and using these laws to approximate the behavior of the whole system.

Students will demonstrate a fundamental understanding of the main areas of physics.

Students will demonstrate communication skills, both written and oral, needed to explain the analysis of technical problems.

Students will demonstrate scientific literacy skills including searching, reading and critically reviewing scientific publications.

Students will demonstrate proficiency in information processing by generating and interpreting data presented in tables, graphs, drawings and models.

## Double major in engineering and physics

A detailed description of this program (<http://bulletin.vcu.edu/undergraduate/engineering/double-major-physics/>) can be found in the "College of Engineering" section of this bulletin.

## Degree requirements for Physics, Bachelor of Science (B.S.)

Course	Title	Hours
General education ( <a href="http://bulletin.vcu.edu/undergraduate/undergraduate-study/general-education-curriculum/">http://bulletin.vcu.edu/undergraduate/undergraduate-study/general-education-curriculum/</a> )		
Select 12-13 credits from general education foundations and 17-18 credits from areas of inquiry.		30
<b>Major requirements</b>		
• Major core requirements		
PHYS 208	University Physics II	5
PHYS 301	Classical Mechanics I	3
PHYS 320 & PHYS 320	Modern Physics and Modern Physics Laboratory	4
PHYS 340	Statistical Mechanics and Thermodynamics	3
PHYS 376	Electromagnetism I	3
PHYS 380	Quantum Physics I	3
PHYS 450	Senior Physics Laboratory	3

PHYS 490	Seminar in Conceptual Physics	1
• Major electives		
Select a total of nine credits from the list of elective physics and physics-related courses provided below. Those students who have their primary major in physics are required to fulfill at least three of these credits using upper-level physics courses		9
<b>Ancillary requirements</b>		
HUMS 202	Choices in a Consumer Society	1
MATH 200	Calculus with Analytic Geometry I (satisfies general education quantitative foundations)	4
MATH 201	Calculus with Analytic Geometry II	4
MATH 301	Differential Equations	3
MATH 307	Multivariate Calculus	4
PHYS 207	University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)	5
Experiential fine arts <sup>1</sup>		1-3
Foreign language through the 102 level (by course or placement)		0-6
<b>Open electives</b>		
Select any course.		35-43
Total Hours		120

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Course offered by the School of the Arts

The minimum number of credit hours required for this degree is 120.

## Physics and physics-related electives

Course	Title	Hours
Any of the following upper-level physics courses:		
PHYS 302	Classical Mechanics II	
PHYS 325	Visualization of Physics Using Mathematica	
PHYS 335	Experimental Skills for Physicists	
PHYS 351	Guided Inquiry for University Physics I	
PHYS 352	Guided Inquiry for University Physics II	
PHYS 377	Electromagnetism II	
PHYS 397	Directed Study (maximum of 3 credits)	
PHYS 420	Quantum Physics II	
PHYS 422	Optics	
PHYS 440	Introduction to Condensed Matter Physics	
PHYS 480	Particle Physics	
PHYS 483	Introduction to Astrophysics	
PHYS 491	Topics in Physics (maximum of 3 credits)	
PHYS 492	Independent Study (maximum of 3 credits)	
PHYS 514	Modeling Biocomplexity	
PHYS 522	Optics and Laser Physics	
PHYS 571	Theoretical Mechanics	
PHYS 573	Analytical Methods in Physics	

PHYS 576	Electromagnetic Theory
PHYS 580	Quantum Mechanics
PHYS 583	Geometrical Methods of Physics and Gravitation

Any of the following math or statistics courses:

MATH 310	Linear Algebra
MATH 415	Numerical Methods
MATH 433	Partial Differential Equations
MATH 511	Applied Linear Algebra
STAT 441	Applied Statistics for Engineers and Scientists

Any of the following chemistry courses:

CHEM 409	Instrumental Analysis
CHEM 510	Atomic and Molecular Structure

Any of the following engineering courses:

CLSE 301	Transport Phenomena I
CLSE 302	Transport Phenomena II
EGMN 301	Fluid Mechanics
EGMN 309	Material Science for Engineers
EGMN 351	Nuclear Engineering Fundamentals
EGMN 352	Nuclear Reactor Theory
EGRB 427	Biomaterials
EGRE 303	Electronic Devices
EGRE 306	Introduction to Microelectronics
EGRE 307	Integrated Circuits
EGRE 310	Electromagnetic Fields and Waves
EGRE 334	Introduction to Microfabrication
EGRE 521	Advanced Semiconductor Devices

Those students intending to pursue graduate studies in physics should choose electives from the following:

Course	Title	Hours
PHYS 302	Classical Mechanics II	
PHYS 325	Visualization of Physics Using Mathematica	
PHYS 420	Quantum Physics II	
PHYS 440	Introduction to Condensed Matter Physics	
PHYS 480	Particle Physics	
PHYS 483	Introduction to Astrophysics	
PHYS 514	Modeling Biocomplexity	
PHYS 522	Optics and Laser Physics	
PHYS 571	Theoretical Mechanics	
PHYS 573	Analytical Methods in Physics	
PHYS 576	Electromagnetic Theory	
PHYS 580	Quantum Mechanics	
PHYS 583	Geometrical Methods of Physics and Gravitation	

Those interested in experimental physics should also take one or more credits in PHYS 397 or PHYS 492.

## Courses not applicable toward the major

**Course Title Hours**

The following courses are not applicable toward the physics major requirements but may be used as general electives toward the bachelor's degree:

PHYS 101	Foundations of Physics	
PHYS 103	Elementary Astronomy	
PHYS 107	Wonders of Technology	
PHYS 201	General Physics I	
PHYS 202	General Physics II	
PHYS 215	Science, Technology and Society	
PHYS 291	Topics in Physical Science	
PHYS/MHIS 307	The Physics of Sound and Music	
PHYS/ENVS 315	Energy and the Environment	
PHYS 391	Topics in Physics	
PHYZ 101	Foundations of Physics Laboratory	
PHYZ 103	Elementary Astronomy Laboratory	

What follows is a sample plan that meets the prescribed requirements within a four-year course of study at VCU. Please contact your adviser before beginning course work toward a degree.

### Freshman year

Fall semester	Hours	
MATH 200	Calculus with Analytic Geometry I (satisfies general education quantitative foundations)	4
UNIV 111	Focused Inquiry I (satisfies general education UNIV foundations)	3
Play course video for Focused Inquiry I		
Experiential fine arts		1-3
General education course (select AOI for global perspectives)		3
General education course (select AOI for diversities in the human experience)		3
Term Hours:		14-16

### Spring semester

HUMS 202	Choices in a Consumer Society	1
MATH 201	Calculus with Analytic Geometry II	4
PHYS 207	University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)	5
UNIV 112	Focused Inquiry II (satisfies general education UNIV foundations)	3
Play course video for Focused Inquiry II		
General education course (select BOK to complete breadth of knowledge requirement and AOI for creativity, innovation and aesthetic inquiry)		3
Term Hours:		16

### Sophomore year

Fall semester	Hours	
MATH 307	Multivariate Calculus	4

PHYS 208	University Physics II	5
UNIV 200	Inquiry and the Craft of Argument (satisfies general education UNIV foundations)	3
Foreign language 101		3
Term Hours:		15
<b>Spring semester</b>		
MATH 301	Differential Equations	3
PHYS 301	Classical Mechanics I	3
PHYS 320 & PHYZ 320	Modern Physics and Modern Physics Laboratory	4
Foreign language 102		3
Open elective		1-3
Term Hours:		14-16
<b>Junior year</b>		
<b>Fall semester</b>		
General education course (select BOK to complete breadth of knowledge requirement)		3
Major electives		6
Open electives		6
Term Hours:		15
<b>Spring semester</b>		
PHYS 376	Electromagnetism I	3
PHYS 380	Quantum Physics I	3
Open electives		9
Term Hours:		15
<b>Senior year</b>		
<b>Fall semester</b>		
PHYS 340	Statistical Mechanics and Thermodynamics	3
Major elective		3
Open electives		9
Term Hours:		15
<b>Spring semester</b>		
PHYS 450	Senior Physics Laboratory	3
PHYS 490	Seminar in Conceptual Physics	1
Open electives (complete upper level if needed)		12
Term Hours:		16
Total Hours:		120-124

The minimum number of credit hours required for this degree is 120.

- Physics (PHYS) (p. 3)
- Physics labs (PHYZ) (p. 5)

## Physics

### PHYS 101. Foundations of Physics. 3 Hours.

Semester course; 3 lecture hours. 3 credits. For non-science majors. Introduction to the fundamental ideas of physics. The course covers selected topics in mechanics, heat, optics, electricity and magnetism, and modern physics. Not applicable toward the physics major. An optional laboratory may be taken with this course; see PHYZ 101.

### PHYS 103. Elementary Astronomy. 3 Hours.

Semester course; 3 lecture hours. 3 credits. A descriptive approach to astronomy dealing with basic features of our solar system, our galaxy and the universe. Not applicable toward physics major. An optional laboratory may be taken with this course; see PHYZ 103.

### PHYS 107. Wonders of Technology. 4 Hours.

Semester course; 5 lecture/laboratory/recitation hours. 4 credits. Introduction to physics concepts involved in everyday technological applications. The course covers selected topics in mechanics, heat, optics, electricity and magnetism, and modern physics by depicting their role in common devices. The laboratory focuses on applications of physics principles to everyday real-life situations. Not applicable toward the physics major.

### PHYS 201. General Physics I. 4 Hours.

Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisite: MATH 151. Designed primarily for life-science majors. Basic concepts of motion, waves and heat. Not applicable toward the physics major.

### PHYS 202. General Physics II. 4 Hours.

Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisite: PHYS 201 or PHYS 207. Designed primarily for life-science majors. Basic concepts of electricity, magnetism, light and modern physics. Not applicable toward the physics major.

### PHYS 207. University Physics I. 5 Hours.

Semester course; 3 lecture, 1 recitation and 3 laboratory hours. 5 credits. Prerequisite: MATH 200 or permission of instructor. A vector- and calculus-based introduction to the fundamental concepts of mechanics, heat and wave motion.

### PHYS 208. University Physics II. 5 Hours.

Semester course; 3 lecture, 1 recitation and 3 laboratory hours. 5 credits. Prerequisite: PHYS 207. Corequisite: MATH 201. A vector- and calculus-based introduction to the fundamentals of electricity, magnetism and optics.

### PHYS 211. Physical Analysis. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 201 and PHYS 208. Corequisite: MATH 307. Extends the discussion of physical phenomena introduced in prerequisite courses to introduce topics and skills needed for more advanced physics courses. Topics include applying complex analysis to wave motion and oscillations, methods to solve problems in mechanics and an introduction to classical thermodynamics using multivariate analysis.

### PHYS 215. Science, Technology and Society. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Examination of scientific breakthroughs that have led to transformational technologies that are continuing to impact society today. Topics include a historical perspective, an understanding of scientific principles and technologies and an examination of how such discoveries have changed society. Not applicable toward physics major.

### PHYS 291. Topics in Physical Science. 1-3 Hours.

Semester course; 1-3 lecture or laboratory hours. 1-3 credits per semester. A study of a selected topic in physics, astronomy, geology, meteorology or oceanography. Not applicable toward physics major. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

### PHYS 301. Classical Mechanics I. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 208 and MATH 307. Corequisite: MATH 301. Review of vector calculus. Newtonian mechanics: single particle, oscillations, motion under central forces and dynamics of a systems of particles.

**PHYS 302. Classical Mechanics II. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 301 and MATH 301. Motion in noninertial frames, dynamics of rigid bodies, coupled oscillators, continuous systems and wave equations in one dimension.

**PHYS 307. The Physics of Sound and Music. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: A 100- or 200-level physics course or equivalent and the ability to read music or sing or play a musical instrument, or permission of instructor. Basics of the physics of waves and sound. Fourier synthesis, tone quality, human ear and voice, musical temperament and pitch, physics of musical instruments, electronic synthesizers, sound recording and reproduction, room and auditorium acoustics. Not applicable toward the physics major. Crosslisted as: MHIS 307.

**PHYS 315. Energy and the Environment. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Enrollment restricted to non-physics majors with junior or senior standing; not applicable to the physics major. A study of society's demands for energy, how it is currently being met, the environmental consequences thereof and some discussion of alternatives. Crosslisted as: ENVS 315.

**PHYS 317. Preparing for the MCAT and Medical Sciences. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 152, CHEM 102, PHYS 202 or PHYS 208. This course introduces physics majors to areas of medical practice where physical sciences play a key role. These include but are not limited to radiology and radiation oncology, orthopedics, pulmonology, and electrophysiology. Students will also review key topics in physics and life sciences that are tested on the Medical College Admissions Test. Broadly, these include chemical and physical foundations of biological systems as well as biological and biochemical foundations of living systems.

**PHYS 320. Modern Physics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 208 and MATH 307. Corequisite: MATH 301. Foundations of modern physics including special relativity, thermal radiation and quantization, wave-particle duality of radiation and matter, Schrodinger equation, atomic, nuclear and particle physics, and molecular structure and spectra. A continuation of PHYS 208.

**PHYS 325. Visualization of Physics Using Mathematica. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 208 and MATH 307. Corequisite: PHYS 301 or PHYS 320. Visualization of various areas of physics using the Mathematica language for performing numerical calculations and producing graphics and animations. Examples will be taken from classical mechanics, classical electromagnetism, modern physics, statistical mechanics and condensed matter physics.

**PHYS 335. Experimental Skills for Physicists. 3 Hours.**

Semester course; 2 lecture and 2 laboratory hours. 3 credits. Prerequisites: PHYS 320 and PHYS 320. Practical skills in experimental physics, including use of micro controllers, sensor modules, high-precision positions and opto-electronics. Skills will be used to address engaging and current real-world challenges.

**PHYS 340. Statistical Mechanics and Thermodynamics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 301 and MATH 301. Microscopic theory of temperature, heat and entropy, kinetic theory, multicomponent systems, and quantum statistics. Mathematical relationships of thermodynamics.

**PHYS 351. Guided Inquiry for University Physics I. 1.5 Hour.**

Semester course; 1 lecture and 1 recitation hour. 1.5 credits. Prerequisites: PHYS 207 and permission of instructor. Student learning assistants aid in recitation sections of PHYS 207 University Physics I using guided inquiry and group-based activities. Further develops the core skills of PHYS 207. Introduces students to the principles of active and collaborative learning in physics through practical, hands-on problem-solving, class discussions and demonstrations.

**PHYS 352. Guided Inquiry for University Physics II. 1.5 Hour.**

Semester course; 1 lecture and 1 recitation hour. 1.5 credits. Prerequisites: PHYS 208 and permission of instructor. Student learning assistants aid in recitation sections of PHYS 208 University Physics II using guided inquiry and group-based activities. Further develops the core skills of PHYS 208. Introduces students to the principles of active and collaborative learning in physics through practical, hands-on problem-solving, class discussions and demonstrations.

**PHYS 376. Electromagnetism. 3 Hours.**

I Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 301 and MATH 301. Electrostatics, magnetism and electromagnetic properties of matter, Maxwell's equations, electromagnetic waves, boundary conditions, and polarization.

**PHYS 377. Electromagnetism II. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: PHYS 376. Advanced topics in electromagnetism, such as the microscopic theory of magnetism, slowly varying currents, physics of plasmas, electromagnetic properties of superconductors, Maxwell's equations and propagation of electromagnetic waves in bounded media, dispersive media, electromagnetic radiation, electrodynamics of moving charges, and the relativistic formulation of electrodynamics.

**PHYS 380. Quantum Physics I. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 301, PHYS 320 and MATH 301, or permission of instructor. Brief introduction to the correspondence between classical and quantum mechanics, Schrodinger wave equation, operator methods in quantum mechanics, angular momentum and conservation laws, solution to harmonic oscillator and the hydrogen atom, magnetic dipole momentum and spin.

**PHYS 391. Topics in Physics. 1-3 Hours.**

Semester course; 1-3 lecture hours. 1-3 credits per semester. Maximum total of 6 credits. In-depth study of a selected topic in physics or physics-related technology, usually at a level requiring only elementary algebra. Not applicable toward physics major. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

**PHYS 397. Directed Study. 1-3 Hours.**

Semester course; variable hours. 1-3 credits per semester. Maximum of 3 credits applicable toward physics major requirement; maximum total of 4 credits. Open to nonmajors. Determination of amount of credit and permission of instructor must be obtained before registration of course. Intended to allow nonmajors and majors to examine in detail an area of physics or physics-related technology not otherwise available in upper-level courses. May involve either directed readings or directed laboratory work.

**PHYS 417. Topics in Biophysics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 208, CHEM 102 and BIOL 152. An introduction to biophysics examining many topics in life sciences. The course will introduce how to understand phenomena in life sciences from a quantitative perspective and use physical models for complex systems. Topics include Brownian motion, mechanical and chemical equilibrium, electrostatics, molecular machines, pattern formation and physical tools in biology.

**PHYS 420. Quantum Physics II. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: PHYS 380 or permission of instructor. Transition rates, addition of angular momentum, multi-electron atoms-ground state, X-ray and optical excitations, time independent perturbation theory, relativistic hydrogen atom and the structure of atoms, collision theory, nuclear structure, elementary particles and their symmetries.

**PHYS 422. Optics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: PHYS 376 or permission of instructor. Comprehensive study of propagation of light, including geometrical optics, polarization, interference, diffraction, Fourier optics and quantum optics.

**PHYS 440. Introduction to Condensed Matter Physics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 340 and 380. Corequisite: PHYS 376. Structure and bonding in solids, phonons, free electron Fermi gas, energy bands, semiconductors, Fermi surface, optical properties and magnetism.

**PHYS 450. Senior Physics Laboratory. 3 Hours.**

Semester course; 1 lecture and 4 laboratory hours. 3 credits. Prerequisites: PHYS 301 and 320, and PHYZ 320. Experiments in condensed matter physics with an introduction to the instrumentation and data analysis used in the research laboratory.

**PHYS 480. Particle Physics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 340, PHYS 376 and PHYS 420. Basic concepts of particle physics, including the Dirac equation, lowest-order quantum electrodynamics calculations, scattering amplitudes and cross sections, the weak interaction, processes involving quarks and their symmetries, and quantum chromodynamics.

**PHYS 483. Introduction to Astrophysics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: PHYS 320 and PHYS 340. Pre- or corequisites: PHYS 376 and PHYS 380. Basic concepts of star formation and evolution, galactic structures, and cosmology. Includes stellar atmospheres and interiors, the sun, the Milky Way and other galaxies, and black holes.

**PHYS 490. Seminar in Conceptual Physics. 1 Hour.**

Semester course; 1 lecture hour. 1 credit. Prerequisites: PHYS 340, PHYS 376, PHYS 380 and PHYZ 320. Restricted to seniors in physics with at least 85 credit hours taken toward the degree. A senior capstone course in physics designed to help students formulate physics-related questions in such a way that they can obtain quantitative answers. Students will describe their results in a senior paper and in an oral presentation.

**PHYS 491. Topics in Physics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Maximum of 3 credits applicable toward physics major requirement; maximum total of 6 credits. An in-depth study of a selected topic in physics. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

**PHYS 492. Independent Study. 1-3 Hours.**

Semester course; variable hours. 1-3 credits per semester. Maximum of 3 credits applicable toward physics major requirement; maximum total of 8 credits. Open generally to students of only junior or senior standing who have acquired at least 12 credits in the departmental discipline. Determination of the amount of credit and permission of instructor and department chair must be procured prior to registration of the course. Independent projects in experimental or theoretical physics.

## Physics labs

**PHYZ 101. Foundations of Physics Laboratory. 1 Hour.**

Semester course; 2 laboratory hours. 1 credit. Corequisite: PHYS 101. An optional laboratory consisting of experiments and activities correlated with PHYS 101.

**PHYZ 103. Elementary Astronomy Laboratory. 1 Hour.**

Semester course; 2 laboratory hours. 1 credit. Pre- or corequisite: PHYS 103. An optional laboratory course consisting of experiments and activities related to PHYS 103.

**PHYZ 320. Modern Physics Laboratory. 1 Hour.**

Semester course; 3 laboratory hours. 1 credit. Pre- or corequisite: PHYS 320. Experimental work correlated with PHYS 320.