PHYSICS, BACHELOR OF SCIENCE (B.S.) WITH A CONCENTRATION IN NANOSCIENCE

The Bachelor of Science in Physics with a concentration in nanoscience requires a minimum of 120 credits. The curriculum prepares students for careers in industry, academia, applied health or nanoscience-related areas. The curriculum also prepares students for graduate studies in nanoscience and related areas.

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.

Students must complete 40-42 credits in physics and physics-related electives and 14-22 credits in ancillary requirements.

Degree requirements for Physics, Bachelor of Science (B.S.) with a concentration in nanoscience

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 208</td>
<td>University Physics II</td>
<td>5</td>
</tr>
<tr>
<td>PHYS 301</td>
<td>Classical Mechanics I</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 320</td>
<td>Modern Physics</td>
<td>4</td>
</tr>
<tr>
<td>&amp; PHYZ 320</td>
<td>and Modern Physics Laboratory</td>
<td></td>
</tr>
</tbody>
</table>

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

Courses not applicable toward the major

Course offered by the School of the Arts

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 101</td>
<td>Foundations of Physics</td>
</tr>
</tbody>
</table>
Physics, Bachelor of Science (B.S.) with a concentration in nanoscience

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Semester Hours</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 103</td>
<td>Elementary Astronomy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 107</td>
<td>Wonders of Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 201</td>
<td>General Physics I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 202</td>
<td>General Physics II</td>
<td></td>
<td></td>
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<tr>
<td>PHYS 215</td>
<td>Science, Technology and Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 291</td>
<td>Topics in Physical Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS/MHIS 307</td>
<td>The Physics of Sound and Music</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS/ENVS 315</td>
<td>Energy and the Environment</td>
<td></td>
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<tr>
<td>PHYS 391</td>
<td>Topics in Physics</td>
<td></td>
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<tr>
<td>PHYZ 101</td>
<td>Foundations of Physics Laboratory</td>
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<td></td>
</tr>
<tr>
<td>PHYZ 103</td>
<td>Elementary Astronomy Laboratory</td>
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</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Fall semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 101</td>
<td>3</td>
</tr>
<tr>
<td>CHEZ 101</td>
<td></td>
</tr>
<tr>
<td>MATH 200</td>
<td>4</td>
</tr>
<tr>
<td>UNIV 111</td>
<td>3</td>
</tr>
<tr>
<td>General Chemistry I (satisfies general education AOI for scientific and logical reasoning)</td>
<td></td>
</tr>
<tr>
<td>Play course video for Focused Inquiry I</td>
<td></td>
</tr>
<tr>
<td>Experiential fine arts</td>
<td>1-3</td>
</tr>
<tr>
<td>General education course (select AOI for global perspectives)</td>
<td>3</td>
</tr>
<tr>
<td>Term Hours:</td>
<td>15-17</td>
</tr>
</tbody>
</table>

**Spring semester**

<table>
<thead>
<tr>
<th>Semester Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUMS 202</td>
</tr>
<tr>
<td>MATH 201</td>
</tr>
<tr>
<td>PHYS 207</td>
</tr>
<tr>
<td>UNIV 112</td>
</tr>
<tr>
<td>University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)</td>
</tr>
<tr>
<td>Play course video for Focused Inquiry II</td>
</tr>
<tr>
<td>General education course (select BOK to complete breadth of knowledge requirement and AOI for diversities in the human experience)</td>
</tr>
<tr>
<td>Term Hours:</td>
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</tbody>
</table>

**Sophomore year**

<table>
<thead>
<tr>
<th>Fall semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 307</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 208</td>
<td>5</td>
</tr>
<tr>
<td>UNIV 200</td>
<td>3</td>
</tr>
<tr>
<td>Multivariate Calculus</td>
<td></td>
</tr>
<tr>
<td>University Physics II</td>
<td></td>
</tr>
<tr>
<td>Inquiry and the Craft of Argument (satisfies general education UNIV foundations)</td>
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</table>

**Junior year**

**Fall semester**

<table>
<thead>
<tr>
<th>Hours</th>
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<tbody>
<tr>
<td>PHYS 376</td>
</tr>
<tr>
<td>PHYS 380</td>
</tr>
<tr>
<td>General education course (select BOK to complete breadth of knowledge requirement AOI for creativity, innovation and aesthetic inquiry)</td>
</tr>
<tr>
<td>Open electives</td>
</tr>
<tr>
<td>Term Hours:</td>
</tr>
</tbody>
</table>

**Spring semester**

<table>
<thead>
<tr>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 335</td>
</tr>
<tr>
<td>PHYS 340</td>
</tr>
<tr>
<td>Open electives</td>
</tr>
<tr>
<td>Term Hours:</td>
</tr>
</tbody>
</table>

**Senior year**

**Fall semester**

<table>
<thead>
<tr>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 397</td>
</tr>
<tr>
<td>PHYS 440</td>
</tr>
<tr>
<td>PHYS 450</td>
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<tr>
<td>PHYS 491</td>
</tr>
<tr>
<td>Concentration elective</td>
</tr>
<tr>
<td>Term Hours:</td>
</tr>
</tbody>
</table>

**Spring semester**

<table>
<thead>
<tr>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>PHYS 490</td>
</tr>
<tr>
<td>PHYS 492</td>
</tr>
<tr>
<td>Concentration elective</td>
</tr>
<tr>
<td>Open elective (complete upper-level if needed)</td>
</tr>
<tr>
<td>Term Hours:</td>
</tr>
<tr>
<td>Total Hours:</td>
</tr>
</tbody>
</table>

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

- Physics (PHYS) (p. 2)
- 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
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, Schroedinger 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 PHYZ 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, Schroedinger wave equation, operator methods in quantum mechanics, angular momentum and conservation laws, solution to harmonic oscillator and the hydrogen atom, magnetic dipole moment 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.