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

Upon completing this program, students will know how to do the following:

- 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.
- Demonstrate a fundamental understanding of the main areas of physics
- Demonstrate communication skills, both written and oral, needed to explain the analysis of technical problems
- Demonstrate scientific literacy skills including searching, reading and critically reviewing scientific publications
- 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.)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>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>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Select 30 credits of general education courses in consultation with an adviser.</td>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

Major requirements

- Major core requirements

<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 &amp; PHYZ 320</td>
<td>Modern Physics and Modern Physics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 340</td>
<td>Statistical Mechanics and Thermodynamics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 376</td>
<td>Electromagnetism I</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 380</td>
<td>Quantum Physics I</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 450</td>
<td>Senior Physics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 490</td>
<td>Seminar in Conceptual Physics</td>
<td>1</td>
</tr>
</tbody>
</table>

- 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.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUMS 202 &amp; MATH 200</td>
<td>Choices in a Consumer Society &amp; Calculus with Analytic Geometry I (satisfies general education quantitative foundations)</td>
<td>1 &amp; 4</td>
</tr>
<tr>
<td>MATH 201 &amp; 301</td>
<td>Calculus with Analytic Geometry II &amp; Differential Equations</td>
<td>4 &amp; 3</td>
</tr>
<tr>
<td>MATH 307</td>
<td>Multivariate Calculus</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 207</td>
<td>University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)</td>
<td>5</td>
</tr>
</tbody>
</table>

Experiential fine arts | 1\-3 |
Foreign language through the 102 level (by course or placement) | 0\-6 |

Open electives

Select any course. | 35-43 |

Total Hours | 120 |

1

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 211</td>
<td>Physical Analysis</td>
<td></td>
</tr>
<tr>
<td>PHYS 302</td>
<td>Classical Mechanics II</td>
<td></td>
</tr>
<tr>
<td>PHYS 325</td>
<td>Visualization of Physics Using Mathematica</td>
<td></td>
</tr>
<tr>
<td>PHYS 335</td>
<td>Experimental Skills for Physicists</td>
<td></td>
</tr>
<tr>
<td>PHYS 351</td>
<td>Guided Inquiry for University Physics I</td>
<td></td>
</tr>
<tr>
<td>PHYS 352</td>
<td>Guided Inquiry for University Physics II</td>
<td></td>
</tr>
<tr>
<td>PHYS 377</td>
<td>Electromagnetism II</td>
<td></td>
</tr>
<tr>
<td>PHYS 397</td>
<td>Directed Study (maximum of 3 credits)</td>
<td></td>
</tr>
<tr>
<td>PHYS 417</td>
<td>Topics in Biophysics</td>
<td></td>
</tr>
<tr>
<td>PHYS 420</td>
<td>Quantum Physics II</td>
<td></td>
</tr>
<tr>
<td>PHYS 422</td>
<td>Optics</td>
<td></td>
</tr>
<tr>
<td>PHYS 425</td>
<td>Computational Physics and Data Analysis</td>
<td></td>
</tr>
<tr>
<td>PHYS 440</td>
<td>Introduction to Condensed Matter Physics</td>
<td></td>
</tr>
<tr>
<td>PHYS 470</td>
<td>Introduction to Nanoscience</td>
<td></td>
</tr>
<tr>
<td>PHYS 480</td>
<td>Particle Physics</td>
<td></td>
</tr>
<tr>
<td>PHYS 483</td>
<td>Introduction to Astrophysics</td>
<td></td>
</tr>
<tr>
<td>PHYS 491</td>
<td>Topics in Physics (maximum of 3 credits)</td>
<td></td>
</tr>
<tr>
<td>PHYS 492</td>
<td>Independent Study (maximum of 3 credits)</td>
<td></td>
</tr>
</tbody>
</table>
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  
EGRM 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**  

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

**Fall semester**  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 200</td>
<td>Calculus with Analytic Geometry I</td>
<td>4</td>
</tr>
<tr>
<td>(satisfies general education quantitative foundations)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIV 112</td>
<td>Focused Inquiry I (satisfies general education UNIV foundations)</td>
<td>3</td>
</tr>
<tr>
<td>Experiential fine arts</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>General education course (select AOI to complete breadth of knowledge requirement and AOI for creativity, innovation and aesthetic inquiry)</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Term Hours: 14-16  

**Spring semester**  

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUMS 202</td>
<td>Choices in a Consumer Society</td>
<td>1</td>
</tr>
<tr>
<td>MATH 201</td>
<td>Calculus with Analytic Geometry II</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 207</td>
<td>University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)</td>
<td>5</td>
</tr>
<tr>
<td>UNIV 112</td>
<td>Focused Inquiry II (satisfies general education UNIV foundations)</td>
<td>3</td>
</tr>
<tr>
<td>General education course (select BOK to complete breadth of knowledge requirement and AOI for creativity, innovation and aesthetic inquiry)</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Term Hours: 16  

**Sophomore year**  

...
Students holding these degrees will be more competitive when seeking research and development positions in industry and admission to physics Ph.D. programs. In addition, an M.S. degree is required for most undergraduate teaching positions. The master's program enables students to deepen their understanding of physics while gaining actual experience in research at the frontiers of physics.

Entrance to the accelerated program

Interested undergraduate students should consult with their adviser as early as possible to receive specific information about the accelerated program, determine academic eligibility and submit (no later than two semesters prior to graduating with a baccalaureate degree, that is, before the end of the spring semester of their junior year) an Accelerated Program Declaration Form to be approved by the graduate program director. Limited spaces may be available in the accelerated program. Academically qualified students may not receive approval if capacity has been reached.

Minimum qualifications for entrance to this accelerated program include completion of 85 undergraduate credit hours, including PHYS 376 and PHYS 380; an overall GPA of 3.25; and a GPA of 3.25 in physics course work.

Once enrolled in the accelerated program, students must meet the standards of performance applicable to graduate students as described in the “Satisfactory academic progress” section of Bulletin, including maintaining a 3.0 GPA. Guidance to students in an accelerated program is provided by both the undergraduate physics adviser and the graduate adviser specified in the student's agreed-upon plan of study.

Admission to the graduate program

Entrance to the accelerated program enables the student to take the approved shared courses that will apply to the undergraduate and graduate degrees. However, entry into an accelerated program via an approved Accelerated Program Declaration Form does not constitute application or admission into the graduate program. Admission to the graduate program requires a separate step that occurs through a formal application. In order to continue pursuing the master's degree after the baccalaureate degree is conferred, accelerated students must follow the admission to graduate study requirements outlined in the VCU Bulletin.

Degree requirements

The Bachelor of Science in Physics degree will be awarded upon completion of a minimum of 120 credits and the satisfactory completion of all undergraduate degree requirements as stated in the Undergraduate Bulletin.

A maximum of 12 graduate credits may be taken prior to completion of the baccalaureate degree. These graduate credits substitute for required major electives or open elective credits for the undergraduate degree. These courses are shared credits with the graduate program, meaning that they will be applied to both undergraduate and graduate degree requirements.

The graduate physics courses that may be taken as an undergraduate, once a student is admitted to the program, are:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>NANO 570</td>
<td>Nanoscale Physics</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 560</td>
<td>Fundamentals of Semiconductor Nanostructures</td>
<td>3</td>
</tr>
</tbody>
</table>
PHYS 571  Theoretical Mechanics  3
PHYS 580  Quantum Mechanics  3

**Recommended course sequence/plan of study**

What follows is the recommended plan of study for students interested in the accelerated program beginning in the fall of the junior year prior to admission to the accelerated program in the senior year. The thesis option for the M.S. is shown.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Junior year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General education course (select BOK to complete breadth of knowledge requirement)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major electives</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Open electives</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Spring semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 340  Statistical Mechanics and Thermodynamics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 376  Electromagnetism I</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 380  Quantum Physics I</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Open electives</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td><strong>Senior year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NANO 570  Nanoscale Physics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 450  Senior Physics Laboratory</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 571  Theoretical Mechanics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Electives</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Spring semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 490  Seminar in Conceptual Physics</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PHYS 492  Independent Study (begin research)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 560  Fundamentals of Semiconductor Nanostructures</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 580  Quantum Mechanics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Open electives</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>Fifth year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NANO 571  Nanoscale Chemistry</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYS 697  Directed Research</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>600-level PHYS elective 1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Spring semester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 697  Directed Research</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>600-level PHYS elective 1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

It is recommended, but not required, that one hour of PHYS 690 be taken as part of the elective credits.

- Physics (PHYS) (p. 4)
- Physics labs (PHYZ) (p. 6)

**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 (delivered online, face-to-face or hybrid). 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
tbreakthroughs 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
with a minimum grade of B or PHYS 211 with a minimum grade of C; and
mechanics: single particle, oscillations, motion under central forces and
dynamics of 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, multicompontent 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 375. Electromagnetism I. 3 Hours.
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 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 425. Computational Physics and Data Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: PHYS 340. Introduces students to topics in computational physics and computational tools used for data analysis. This course teaches basic skills in programming in the context of applying them to biophysics-related problems. It is assumed that students have no computer programming experience, but have a modest understanding of physical systems.

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 PHYS 320. Experiments in condensed matter physics with an introduction to the instrumentation and data analysis used in the research laboratory.

PHYS 470. Introduction to Nanoscience. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: PHYS 320. An overview and introduction to a wide range of topics in nanoscience and nanotechnology from the point of view of physics, chemistry, engineering and biology. Takes a systems-based approach to demonstrate how different nano-concepts come together to create systems with unique functions and characteristics.

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.

PHYS 499. Directed Study. 1-3 Hours.
Semester course; 1-3 credits per semester. Maximum 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.