

PHYSICS, BS

Degree: Bachelor of Science (BS)

Major: Physics

Program Overview

The mission of the Bachelor of Science in physics degree program is to develop professional physicists by providing majors a comprehensive undergraduate education in classical mechanics, electromagnetism, quantum mechanics, thermal physics/statistical mechanics, and laboratory, data analysis and computational skills. Majors learn how to communicate professionally and reason quantitatively and ethically. They are prepared for employment or graduate study in physics and aligned technical disciplines and have a solid foundation for other professional career paths.

This degree is traditionally pursued by students interested in a career in physics research in government or industry, or in college- and university-level teaching and research. Approximately three-quarters of our graduates continue their studies in physics, engineering or another professional area. Others choose immediate employment in a variety of technical fields in industry and government. CWRU physics majors have been remarkably successful at winning prestigious national and international fellowships and earning admission to top graduate programs and professional schools.

An important component of the program is the senior capstone. BS in physics students who choose to do their capstone project through the Department of Physics have a year-long research experience with a research mentor, devoted to a project chosen by the student.

Majors in the standard BS in physics program have the option to pursue one of two concentrations: mathematical physics or biophysics.

The mission of the mathematical physics concentration is to develop professional physicists whose interests are focused on theoretical physics. This undergraduate program provides an enhanced, graduate-level education in electromagnetism and quantum mechanics as well as experience in mathematical methods used in theoretical physics. This program is based on the BS in physics, with mathematical methods courses replacing two upper-level physics laboratory courses and some undergraduate lecture courses replaced by graduate-level courses on the same topics. This program is distinct from the BS in mathematics and physics, which is a parallel education in both mathematics and physics administered jointly by both departments.

The biophysics concentration offers an ideal preparation for biological research in graduate-level physics programs and in industry. It also provides an appropriate foundation for careers in biology, biophysics, and biomedical engineering, as well as for medical school. Select courses in the regular BS degree program are replaced by a "biogroup" of five courses (generally chosen from available biology, biophysics, biochemistry, and biomedical engineering courses) and a technical elective. The biogroup and technical elective courses are chosen by the student in consultation with the biophysics academic advisor.

Learning Outcomes

- Students will be able to master classical mechanics, electromagnetism, quantum mechanics, thermal physics/ statistical

mechanics and other topics expected for a professional physicist and needed for admission to a graduate program in physics and other professional programs.

- Students will be able to carry out experiments, take measurements and analyze data to support or refute a scientific hypothesis.
- Students will be able to demonstrate proficiency in the methods of scientific inquiry, including critical thinking and problem-solving, and be able to formulate and solve quantitative problems using computational and analytical methods.
- Students will be able to research and demonstrate they can contribute to an experimental, theoretical or computational research effort.
- Students will be able to demonstrate proficiency in communicating scientific concepts and results orally and in writing in styles appropriate to proposals, reports and formal publications.
- Students will be well-versed in professional ethics.
- Students will be prepared for employment or graduate study in physics and aligned technical disciplines, as well as other professional career paths.

Undergraduate Policies

For undergraduate policies and procedures, please review the Undergraduate Academics section of the General Bulletin.

Accelerated Master's Programs

Undergraduate students may participate in accelerated programs toward graduate or professional degrees. For more information and details of the policies and procedures related to accelerated studies, please visit the Undergraduate Academics section of the General Bulletin.

Program Requirements

Students seeking to complete this major and degree program must meet the general requirements for bachelor's degrees and the Unified General Education Requirements. Students completing this program as a secondary major while completing another undergraduate degree program do not need to satisfy the school-specific requirements associated with this major.

The Bachelor of Science in Physics requires completion of the courses listed in the table below (99 credit hours) as well as completion of the Unified General Education Requirements (21 credit hours). Current students should always consult their advisers and their individual graduation requirement plans. Many courses may be taken at times other than those shown in the Sample Plan of Study.

Code	Title	Credit Hours
Required Courses:		
PHYS 121 or PHYS 123	General Physics I - Mechanics Physics and Frontiers I - Mechanics	4
PHYS 122 or PHYS 124	General Physics II - Electricity and Magnetism Physics and Frontiers II - Electricity and Magnetism	4
PHYS 203	Analog and Digital Electronics	4
PHYS 204	Advanced Instrumentation Laboratory	4
PHYS 221	Introduction to Modern Physics	3
PHYS 250	Computational Methods in Physics	3
PHYS 301	Advanced Laboratory Physics I	3
PHYS 302	Advanced Laboratory Physics II	4

PHYS 303	Advanced Laboratory Physics Seminar	1
PHYS 310	Classical Mechanics	3
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 324	Electricity and Magnetism I	3
PHYS 325	Electricity and Magnetism II	3
PHYS 331	Introduction to Quantum Mechanics I	3
PHYS 332	Introduction to Quantum Mechanics II	3
Condensed Matter Physics Elective		3
<i>Choose one of the following:</i>		
PHYS 315	Introduction to Solid State Physics	
PHYS 320	Introduction to Biological Physics	
PHYS 326	Physical Optics	
PHYS 327	Laser Physics	
Particle/Astrophysics Elective		3
<i>Choose one of the following:</i>		
PHYS 316	Introduction to Nuclear and Particle Physics	
PHYS 328	Cosmology and the Structure of the Universe	
PHYS 336	Modern Cosmology	
PHYS 365	General Relativity	
PHYS 351	Senior Physics Project ^a	4
PHYS 352	Senior Physics Project Seminar ^a	2
CHEM 105	Principles of Chemistry I	3-4
or CHEM 111	Principles of Chemistry for Engineers	
CHEM 106	Principles of Chemistry II	3-4
or ENGR 145	Chemistry of Materials	
ENGR 131	Elementary Computer Programming	3
or CSDS 132	Programming in Java	
MATH 121	Calculus for Science and Engineering I	4
MATH 122	Calculus for Science and Engineering II	4
or MATH 124	Calculus II	
MATH 223	Calculus for Science and Engineering III	3
or MATH 227	Calculus III	
MATH 224	Elementary Differential Equations	3
Open Electives ^b		16-14
Total Credit Hours		99

a The capstone courses, PHYS 351 Senior Physics Project and PHYS 352 Senior Physics Project Seminar, are two-semester long courses taken in the fall and spring of the students senior year.

b The number of credit hours for the open electives may vary depending on course choices made by the student but the degree requires that the total number of credits be at least 120.

Concentration Requirements

Bachelor of Science in Physics: Mathematical Physics Concentration

Students who are interested in theoretical physics and who have a strong background in mathematics may consider this concentration. The program is based on the Bachelor of Science in Physics degree, but with certain substitutions in the course requirements. Several of the laboratory courses are replaced by advanced mathematics courses, and some of the undergraduate physics courses are replaced by graduate courses.

The Bachelor of Science in Physics with mathematical physics concentration requires completion of the courses listed below. Current students should always consult their advisers and their individual graduation requirement plans. Many courses may be taken at times other than those shown in the **Sample Study Plan**.

Note: This program is not the same as the BS program in Mathematics and Physics, which provides a coherent and parallel education in both mathematics and physics.

Code	Title	Credit Hours
Required Courses:		
PHYS 121	General Physics I - Mechanics	4
or PHYS 123	Physics and Frontiers I - Mechanics	
PHYS 122	General Physics II - Electricity and Magnetism	4
or PHYS 124	Physics and Frontiers II - Electricity and Magnetism	
PHYS 203	Analog and Digital Electronics	4
PHYS 221	Introduction to Modern Physics	3
PHYS 250	Computational Methods in Physics	3
PHYS 301	Advanced Laboratory Physics I	3
PHYS 303	Advanced Laboratory Physics Seminar	1
PHYS 310	Classical Mechanics	3
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 349	Methods of Mathematical Physics I	3
PHYS 350		3
PHYS 481	Quantum Mechanics I	3
PHYS 482	Quantum Mechanics II	3
<i>Choose one of the following:</i>		
PHYS 423	Classical Electromagnetism	
PHYS 324	Electricity and Magnetism I	
& PHYS 325	and Electricity and Magnetism II	
Advanced Mathematics Electives: M-Group 1, 2 & 3 ^a		9
Condensed Matter Physics Elective		3
<i>Choose one of the following:</i>		
PHYS 315	Introduction to Solid State Physics	
PHYS 320	Introduction to Biological Physics	
PHYS 326	Physical Optics	
PHYS 327	Laser Physics	
Particle/Astrophysics Elective		3
<i>Choose one of the following:</i>		
PHYS 316	Introduction to Nuclear and Particle Physics	
PHYS 328	Cosmology and the Structure of the Universe	
PHYS 336	Modern Cosmology	
PHYS 365	General Relativity	
PHYS 351	Senior Physics Project	4
PHYS 352	Senior Physics Project Seminar	2
CHEM 105	Principles of Chemistry I	3-4
or CHEM 111	Principles of Chemistry for Engineers	
CHEM 106	Principles of Chemistry II	3-4
or ENGR 145	Chemistry of Materials	
ENGR 131	Elementary Computer Programming	3
or CSDS 132	Programming in Java	
MATH 121	Calculus for Science and Engineering I	4

MATH 122	Calculus for Science and Engineering II	4
or MATH 124	Calculus II	
MATH 223	Calculus for Science and Engineering III	3
or MATH 227	Calculus III	
MATH 224	Elementary Differential Equations	3
Open Electives		7-12
Total Credit Hours		91-98

a Advanced Mathematics Electives: M-group 1, 2 and 3 are to be chosen, in consultation with the advisor, from among approved advanced mathematics or statistics courses.

Bachelor of Science in Physics: Biophysics Concentration

This concentration is directed towards students interested in the combined study of biology and physics. The degree is a track within the standard BS in physics, in which four physics courses and certain open electives are replaced by a "biogroup" of five courses and a technical elective.

The Bachelor of Science in Physics with biophysics concentration requires completion of the courses listed below. Current students should always consult their advisers and their individual graduation requirement plans. Many courses may be taken at times other than those shown in the **Sample Study Plan**.

Code	Title	Credit Hours
Required Courses:		
PHYS 121	General Physics I - Mechanics	4
or PHYS 123	Physics and Frontiers I - Mechanics	
PHYS 122	General Physics II - Electricity and Magnetism	4
or PHYS 124	Physics and Frontiers II - Electricity and Magnetism	
PHYS 203	Analog and Digital Electronics	4
PHYS 204	Advanced Instrumentation Laboratory	4
PHYS 221	Introduction to Modern Physics	3
PHYS 250	Computational Methods in Physics	3
PHYS 301	Advanced Laboratory Physics I	3
PHYS 303	Advanced Laboratory Physics Seminar	1
PHYS 310	Classical Mechanics	3
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 324	Electricity and Magnetism I	3
PHYS 325	Electricity and Magnetism II	3
PHYS 331	Introduction to Quantum Mechanics I	3
PHYS 351	Senior Physics Project	4
PHYS 352	Senior Physics Project Seminar	2
CHEM 105	Principles of Chemistry I	3-4
or CHEM 111	Principles of Chemistry for Engineers	
CHEM 106	Principles of Chemistry II	3-4
or ENGR 145	Chemistry of Materials	
CHEM 113	Principles of Chemistry Laboratory	2
ENGR 131	Elementary Computer Programming	3
or CSDS 132	Programming in Java	
MATH 121	Calculus for Science and Engineering I	4
MATH 122	Calculus for Science and Engineering II	4

or MATH 124	Calculus II	
MATH 223	Calculus for Science and Engineering III	3
or MATH 227	Calculus III	
MATH 224	Elementary Differential Equations	3
Physics Elective ^a		3
Biogroup Elective: B-Group 1 ^b		3-4
Biogroup Elective: B-Group 2 ^b		3-4
Biogroup Elective: B-Group 3 ^b		3
Biogroup Elective: B-Group 4 ^b		3
Biogroup Elective: B-Group 5 ^b		3-4
Open Electives ^c		9-4
Total Credit Hours		99

a Suggested courses for the Physics Elective include PHYS 315, PHYS 316, PHYS 320, PHYS 326, PHYS 327, PHYS 328, PHYS 336, and PHYS 365.

b Biogroup Electives (B-group 1-5) are to be chosen in consultation with the biophysics academic advisor from among approved biology, biophysics, biochemistry, and biomedical engineering courses, including certain prerequisites as needed (e.g., chemistry). BIOL 214 and BIOL 215 are suggested for B-group 1 and 2. PHYS 320 may be used as a B-group option if it is not selected as a PHYS technical elective. The listing of credits includes numbers for the most likely choices of courses and, in parentheses, possible alternatives.

c The number of open electives may vary, depending on course choices made by the student, but the degree requires that the total number of credits be at least 120.

Sample Plans of Study

Standard Plan of Study Without a Concentration

First Year

Fall	Credit Hours	
PHYS 121	General Physics I - Mechanics	4
or PHYS 123	or Physics and Frontiers I - Mechanics	
MATH 121	Calculus for Science and Engineering I	4
CHEM 105	Principles of Chemistry I	3-4
or CHEM 111	or Principles of Chemistry for Engineers	
PHYS 166	Physics Today and Tomorrow	1
Academic Inquiry Seminar, Breadth, or Elective course ^a		3
Credit Hours	15-16	

Spring

PHYS 122	General Physics II - Electricity and Magnetism	4
or PHYS 124	or Physics and Frontiers II - Electricity and Magnetism	
MATH 122	Calculus for Science and Engineering II	4
or MATH 124	or Calculus II	
CHEM 106	Principles of Chemistry II	3-4
or ENGR 145	or Chemistry of Materials	
ENGR 131	Elementary Computer Programming	3
or CSDS 132	or Programming in Java	
Academic Inquiry Seminar, Breadth, or Elective course		3
Credit Hours	17-18	

Second Year**Fall**

PHYS 203	Analog and Digital Electronics	4
PHYS 221	Introduction to Modern Physics	3
MATH 223 or MATH 227	Calculus for Science and Engineering III or Calculus III	3
Breadth, or Elective course ^a		3
Open Elective		3
Credit Hours		16

Spring

PHYS 204	Advanced Instrumentation Laboratory	4
PHYS 250	Computational Methods in Physics	3
PHYS 310	Classical Mechanics	3
MATH 224	Elementary Differential Equations	3
Breadth, or Elective course ^a		3
Credit Hours		16

Third Year**Fall**

PHYS 301	Advanced Laboratory Physics I	3
PHYS 303	Advanced Laboratory Physics Seminar	1
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 331	Introduction to Quantum Mechanics I	3
Breadth, or Elective course ^a		3
Open Elective		3
Credit Hours		16

Spring

PHYS 302	Advanced Laboratory Physics II	4
PHYS 324	Electricity and Magnetism I	3
PHYS 332	Introduction to Quantum Mechanics II	3
Breadth, or Elective course ^a		3
Open Elective		3
Credit Hours		16

Fourth Year**Fall**

PHYS 351	Senior Physics Project ^b	2
PHYS 352	Senior Physics Project Seminar ^b	1
PHYS 325	Electricity and Magnetism II	3
Breadth, or Elective course ^a		3
Condensed Matter Physics Elective		3
Open Elective		3
Credit Hours		15

Spring

PHYS 351	Senior Physics Project ^b	2
PHYS 352	Senior Physics Project Seminar ^b	1
Breadth, or Elective course ^a		3
Particle/Astrophysics Elective		3
Open Elective		3
Credit Hours		12

Total Credit Hours 123-125

courses taken in the fall and spring of the senior year.

Mathematical Physics Concentration**First Year****Fall**

PHYS 121 or PHYS 123	General Physics I - Mechanics or Physics and Frontiers I - Mechanics	4
MATH 121	Calculus for Science and Engineering I	4
CHEM 105 or CHEM 111	Principles of Chemistry I or Principles of Chemistry for Engineers	3-4
PHYS 166	Physics Today and Tomorrow	1
Academic Inquiry Seminar, Breadth, or Elective course ^a		3
Credit Hours		15-16

Spring

PHYS 122 or PHYS 124	General Physics II - Electricity and Magnetism or Physics and Frontiers II - Electricity and Magnetism	4
MATH 122	Calculus for Science and Engineering II	4
CHEM 106 or ENGR 145	Principles of Chemistry II or Chemistry of Materials	3-4
ENGR 131	Elementary Computer Programming	3
Academic Inquiry Seminar, Breadth, or Elective course ^a		3
Credit Hours		17-18

Second Year**Fall**

PHYS 203	Analog and Digital Electronics	4
PHYS 221	Introduction to Modern Physics	3
MATH 223	Calculus for Science and Engineering III	3
Breadth, or Elective course ^a		3
Open Elective		3
Credit Hours		16

Spring

PHYS 250	Computational Methods in Physics	3
PHYS 310	Classical Mechanics	3
MATH 224	Elementary Differential Equations	3
Breadth, or Elective course ^a		3
Open Elective		3
Credit Hours		15

Third Year**Fall**

PHYS 301	Advanced Laboratory Physics I	3
PHYS 303	Advanced Laboratory Physics Seminar	1
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 349	Methods of Mathematical Physics I	3
PHYS 481	Quantum Mechanics I	3
Breadth, or Elective course ^a		3
Credit Hours		16

Spring

PHYS 350		3
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^a Unified General Education Requirement.^b The capstone courses, PHYS 351 and PHYS 352, are two-semester long

PHYS 482	Quantum Mechanics II	3
PHYS 324	Electricity and Magnetism I	3
Breadth, or Elective course ^a		3
Advanced Mathematics Elective		3

Credit Hours 15

Fourth Year

Fall

PHYS 351	Senior Physics Project ^b	2
PHYS 352	Senior Physics Project Seminar ^b	1
PHYS 325	Electricity and Magnetism II	3
Breadth, or Elective course ^a		3
Advanced Mathematics Elective		3
Condensed Matter Physics Elective		3

Credit Hours 15

Spring

PHYS 351	Senior Physics Project ^b	2
PHYS 352	Senior Physics Project Seminar ^b	1
Breadth, or Elective course ^a		3
Advanced Mathematics Elective		3
Particle/Astrophysics Elective		3
Open Elective		2

Credit Hours 14

Total Credit Hours 123-125

a Unified General Education Requirement.

b The capstone courses PHYS 351 and PHYS 352 are each two semester courses taken in the fall and spring of the students senior year.

Biophysics Concentration

First Year

Fall

PHYS 121 or PHYS 123	General Physics I - Mechanics or Physics and Frontiers I - Mechanics	4
MATH 121	Calculus for Science and Engineering I	4
CHEM 105 or CHEM 111	Principles of Chemistry I or Principles of Chemistry for Engineers	3-4
CHEM 113	Principles of Chemistry Laboratory	2
PHYS 166	Physics Today and Tomorrow	1
Academic Inquiry Seminar, Breadth, or Elective course ^a		3

Credit Hours 17-18

Spring

PHYS 122 or PHYS 124	General Physics II - Electricity and Magnetism or Physics and Frontiers II - Electricity and Magnetism	4
MATH 122	Calculus for Science and Engineering II	4
CHEM 106 or ENGR 145	Principles of Chemistry II or Chemistry of Materials	3-4
ENGR 131	Elementary Computer Programming	3
Academic Inquiry Seminar, Breadth, or Elective course ^a		3

Credit Hours 17-18

Second Year

Fall

PHYS 203	Analog and Digital Electronics	4
PHYS 221	Introduction to Modern Physics	3
MATH 223	Calculus for Science and Engineering III	3
Breadth, or Elective course ^a		3
Biogroup Elective ^b		3-4

Credit Hours 16-17

Spring

PHYS 204	Advanced Instrumentation Laboratory	4
PHYS 250	Computational Methods in Physics	3
PHYS 310	Classical Mechanics	3
MATH 224	Elementary Differential Equations	3
Breadth, or Elective course ^a		3

Credit Hours 16

Third Year

Fall

PHYS 301	Advanced Laboratory Physics I	3
PHYS 303	Advanced Laboratory Physics Seminar	1
PHYS 313	Thermodynamics and Statistical Mechanics	3
PHYS 331	Introduction to Quantum Mechanics I	3
Breadth, or Elective course ^a		3
Biogroup Elective ^b		4

Credit Hours 17

Spring

PHYS 324	Electricity and Magnetism I	3
Breadth, or Elective course ^a		3
Biogroup Elective ^b		3
Biogroup Elective ^b		3
Open Elective		3

Credit Hours 15

Fourth Year

Fall

PHYS 325	Electricity and Magnetism II	3
PHYS 351	Senior Physics Project ^c	2
PHYS 352	Senior Physics Project Seminar ^c	1
Breadth, or Elective course ^a		3
Physics Elective		3
Open Elective		3

Credit Hours 15

Spring

PHYS 351	Senior Physics Project ^c	2
PHYS 352	Senior Physics Project Seminar ^c	1
Breadth, or Elective course ^a		3
Biogroup Elective ^b		3-4
Open Elective		3

Credit Hours 12-13

Total Credit Hours 125-129

a Unified General Education Requirement.

b Biogroup Electives (B-group 1-5) are to be chosen in consultation with the biophysics academic advisor from among approved

biology, biophysics, biochemistry, and biomedical engineering courses, including certain prerequisites as needed (e.g., chemistry). BIOL 214 and BIOL 215 are suggested for B-group 1 and 2. PHYS 320 may be used as a B-group option if it is not selected as a PHYS technical elective. The listing of credits includes numbers for the most likely choices of courses and, in parentheses, possible alternatives.

- c The capstone courses PHYS 351 and PHYS 352 are each two semester courses taken in the fall and spring of the students senior year.