

Physics, B.S.

B.S. in Physics

The Bachelor of Science degree in Physics allows students to choose courses in a wide variety of intermediate and advanced topics in physics but also a range of material in other science or engineering fields. The B.S. degree provides a solid foundation for students wishing to go on to graduate work in physics or any of a large number of fields in pure or applied science or engineering for which a sound grasp of physics and mathematics is essential. This program also provides excellent preparation for careers in teaching, for work in industrial or governmental research and development, or for other employment in business or industry with a significant scientific component.

Degree Requirements

Physics Core

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Most students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

	Units
33-121 Physics I for Science Students	12
or 33-151 Matter and Interactions I	
33-142 Physics II for Engineering and Physics Students	12
or 33-152 Matter and Interactions II	
33-104 Experimental Physics	9
33-201 Physics Sophomore Colloquium I	2
33-211 Physics III: Modern Essentials	10
33-231 Physical Analysis	10
33-202 Physics Sophomore Colloquium II	2
33-228 Electronics I	10
33-232 Mathematical Methods of Physics	10
33-234 Quantum Physics	10
33-301 Physics Upperclass Colloquium I	1
33-331 Physical Mechanics I	10
33-338 Intermediate Electricity and Magnetism I	10
33-341 Thermal & Statistical Physics	10
33-302 Physics Upperclass Colloquium II	1
33-340 Modern Physics Laboratory	10
Total Physics Core Units	129

Mathematics CORE

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

	Units
21-120 Differential and Integral Calculus	10
21-122 Integration and Approximation	10
21-259 Calculus in Three Dimensions	10
Total Mathematics Core Units	30

Technical CORE

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. The following three courses are required for physics majors to give them the technical breadth they need while also satisfying the college-level requirements.

	Units
03-121 Modern Biology ¹	9
09-105 Introduction to Modern Chemistry I ²	10
15-110 Principles of Computing ³	10-12
or 15-112 Fundamentals of Programming and Computer Science	
or 02-120 Programming for Scientists	
Total Technical Core Units	29-31

- ¹ If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.
- ² If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.
- ³ If 15-110 or 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives

Physics majors can choose to increase the breadth or depth of their studies through their choices of Technical Electives, including Physics Electives (p.). Students may choose these electives individually or may take a pre-set selection of technical electives known as a "track" to focus on a specific subfield of physics. **Details about the six available tracks are available here.**

	Units
33-xxx Physics Breadth Elective	9-12
33-xxx Three Qualifying Physics Electives	27-36
21-2xx Mathematics Elective ⁴	9-10
xx-xxx Three STEM Electives ⁴	27-36
Total Technical Electives Units	72-94

- ⁴ STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Director of Undergraduate Affairs.

Non-Technical Electives

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large.

	Units
99-101 Core@CMU	3
76-101 Interpretation and Argument	9
38-101 EUREKA!: Discovery and Its Impact	6
38-110 ENGAGE in Service	1
38-220 ENGAGE in the Arts	2
38-230 ENGAGE in Wellness: Looking Inward	1
38-330 ENGAGE in Wellness: Looking Outward	1
38-430 ENGAGE in Wellness: Looking Forward	1
38-304 Reading and Writing Science ⁵	6
xx-xxx Cultural/Global Understanding Elective ⁶	9
xx-xxx Four Non-Technical Breadth Electives ⁷	36
Total Non-Technical Units	75

- ⁵ Refer to the Mellon College of Science's Science and Society list for alternate courses that will fulfill this requirement. Placement credit may not be used.
- ⁶ Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.
- ⁷ Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical breadth electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required.

	Units
xx-xxx Free Electives ⁸	1-26
Total Free Elective Units	1-26

⁸ A maximum of 9 units of physical education and/or military science and/or STUCO courses counted towards degree requirements as free electives.

Physics Electives

Physics Breadth Electives

Students pursuing a B.S. in Physics must take at least one course from the Physics Breadth Elective list to gain experience in a subfield of physics. Some tracks have this course prescribed, while others allow free choice from this list. All of these courses may also be taken as Qualifying Physics Electives, but they may not fulfill both requirements simultaneously.

	Units
33-224 Stars, Galaxies and the Universe	9
33-226 Physics of Energy	9
33-353 Intermediate Optics	12
33-355 Nanoscience and Nanotechnology	9
33-431 Stars and Black Holes	9
33-432 Galaxies	9
33-433 Cosmology	9
33-441 Introduction to Biophysics	10
33-444 Introduction to Nuclear and Particle Physics	9
33-448 Introduction to Solid State Physics	9
33-650 General Relativity	9

Total Physics Breadth Elective Units 9-12

Qualifying Physics Electives

Students pursuing a B.S. in Physics must take at least three courses totaling at least 27 units from the Qualifying Physics Elective list, not including the 100-level courses. Some tracks have these courses prescribed, while others allow free choice from this list, enabling students to choose between broad and in-depth study.

Students pursuing a B.A. in Physics must take at least two courses totaling at least 18 units from this list and may take **only one** of the 100-level courses.

Students pursuing a Minor in Physics must take at least three courses totaling at least 27 units from this list or non-prescribed courses from the Physics Core list.

While all courses on the Physics Breadth Elective list are also on the Qualifying Physics Elective list, a course may not fulfill both requirements simultaneously. Certain courses are offered only in alternate years, as indicated.

33-114 Physics of Musical Sound (B.A. and Minor only) ^a	9
33-115 Physics for Future Presidents (B.A. and Minor only) ^a	9
33-120 Science and Science Fiction (B.A. and Minor only) ^a	9
33-224 Stars, Galaxies and the Universe	9
33-226 Physics of Energy	9
33-241 Introduction to Computational Physics	9
33-332 Physical Mechanics II	10
33-339 Intermediate Electricity and Magnetism II	10
33-342 Advanced Thermal & Statistical Physics	10
33-350 Undergraduate Research ^b	Var.
33-353 Intermediate Optics	12
33-355 Nanoscience and Nanotechnology	9
33-431 Stars and Black Holes	9
33-432 Galaxies	9
33-433 Cosmology	9
33-441 Introduction to Biophysics	10
33-444 Introduction to Nuclear and Particle Physics	9
33-445 Advanced Quantum Physics I	9
33-446 Advanced Quantum Physics II	9
33-448 Introduction to Solid State Physics	9
33-451 Senior Research ^b	Var.

33-456 Advanced Computational Physics	9
33-499 Supervised Reading ^b	Var.
33-650 General Relativity	9
33-658 Quantum Computation and Quantum Information Theory	10
33-659 Modern Topics in Condensed Matter Physics	12
33-7xx Physics Graduate Level Courses (see list below)	

Total Qualifying Physics Electives Units 27-37

a Only one of these three courses (33-114, 33-115, and 33-120) may be used for the B.A. These classes may not be used as Qualifying Physics Electives for the B.S.

b Only one of these three courses (33-350, 33-451, and 33-499) of 9 units may be used as a Qualifying Physics Elective. To be counted as a Qualifying Physics Elective, all 9 units must be taken in a single semester. Any exceptions must be approved by the Director of Undergraduate Affairs.

Qualifying Physics Electives Recommended for Physics Graduate School

Students planning to undertake graduate studies in physics are strongly advised to take the following courses, which may count as Qualifying Physics Electives and STEM Electives.

	Units
33-332 Physical Mechanics II	10
33-339 Intermediate Electricity and Magnetism II	10
33-445 Advanced Quantum Physics I	9
33-446 Advanced Quantum Physics II	9

Physics Graduate Courses

These courses are intended for graduate students in physics, but may be taken by advanced undergraduates as Qualifying Physics or STEM Electives.

Undergraduate students require special permission of both the course instructor and the Director of Undergraduate Affairs to register for these classes.

	Units
33-731 Stars and Black Holes	12
33-732 Galaxies	12
33-733 Cosmology	12
33-755 Quantum Mechanics I	12
33-756 Quantum Mechanics II	12
33-757 Classical Mechanics	12
33-761 Classical Electrodynamics I	12
33-762 Classical Electrodynamics II	12
33-765 Statistical Mechanics	12
33-767 Biophysics: From Basic Concepts to Current Research	12
33-769 Quantum Mechanics III: Many Body and Relativistic Systems	12
33-770 Field Theory I	12
33-771 Field Theory II	12
33-779 Introduction to Nuclear and Particle Physics	12
33-780 Nuclear and Particle Physics II	12
33-783 Solid State Physics	12

Tracks for the B.S. in Physics

Students seeking a B.S. in Physics may choose from 6 optional Physics tracks, or may opt to pursue no track. Tracks are not possible as part of the B.A. in Physics, although they are possible as part of an Additional Major in Physics. Each of our tracks fulfills the Technical Electives of the B.S. in Physics. The available options are:

- No Track
- Applied Physics
- Astrophysics
- Biological Physics
- Chemical Physics

- Computational Physics
- Quantum Physics

The track descriptions and requirements are listed below.

No Track

Physics students who seek maximum flexibility in selecting their Technical Electives can choose not to pursue a track.

	Units
33-xxx Physics Breadth Elective	9-12
33-xxx Three Qualifying Physics Electives	27-36
21-2xx Mathematics Elective	9-10
xx-xxx Three STEM Electives ^c	27-36
Total Technical Elective Units	72-94

^c STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Director of Undergraduate Affairs.

Applied Physics Track

The B.S. in Physics/Applied Physics Track is designed primarily for students who want to prepare for a career path that takes advantage of the diverse and expanding opportunities for employment in industrial and government laboratories with a B.S. degree. The program provides a solid foundation in the concepts of physics, as well as giving the student the experience and understanding of the application of these concepts. The track is intended to enhance computing and laboratory skills, and to introduce the application of physics to those subjects of particular interest to the student. Since the possible subject areas for study are so varied, the track will be tailored to each student's needs within the framework described below.

	Units
33-448 Introduction to Solid State Physics	9
xx-xxx Computational Science Course ^d	9-12
xx-xxx Four Applied Physics/Laboratory Electives ^d	36-48
33-350 Undergraduate Research ^d	9
or 33-451 Senior Research	
21-2xx Mathematics Elective	9-10
Total Applied Track Elective Units	72-88

^d The elective courses and research topic are decided after consultation with, and approval by, the Director of Undergraduate Affairs. No more than 2 of these requirements may be at the introductory course level. Research must be completed in a single 9-unit block.

Astrophysics Track

The B.S. in Physics/Astrophysics Track provides an option for those Physics majors who either want to specialize in this subfield or plan careers in astronomy or astrophysics. Career paths may include postgraduate training in astronomy or astrophysics or proceeding directly to jobs in these fields. The program provides a thorough foundation in the core physics program with electives concentrating in astrophysics.

	Units
33-224 Stars, Galaxies and the Universe	9
33-350 Undergraduate Research ^e	9
or 33-451 Senior Research	
xx-xxx Three STEM Electives	27-36
21-2xx Mathematics Elective	9-10
Two (2) of the following Advanced Astrophysics Electives:	18
33-431 Stars and Black Holes	
or 33-43 Galaxies	
or 33-43 Cosmology	
Total Astrophysics Track Elective Units	72-82

^e The research topic must be approved by the Director of Undergraduate Affairs and must be completed in a single 9-unit block.

Biological Physics Track

The B.S. in Physics/Biological Physics Track combines a rigorous foundation in undergraduate physics with courses in Biological Physics and Chemistry. It is particularly suitable for students preparing for post-baccalaureate careers in the expanding areas of biological and medical physics or for graduate study in biophysics. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Director of Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

The Biological Physics Track is excellent preparation for Medical School.

All courses suggested for medical school applicants can be completed within this track. Students interested in both the Biological Physics Track and the pre-medical program should consult with both the Director of Undergraduate Affairs in the Physics Department and the Director of the Health Professions Program for help in planning their programs.

	Units
33-441 Introduction to Biophysics	10
or 03-439 Introduction to Biophysics	
33-xxx One Qualifying Physics Elective	9-12
21-2xx Mathematics Elective	9-10
03-231 Honors Biochemistry	9
09-217 Organic Chemistry I	9
09-218 Organic Chemistry II	9
03-xxx Two Biological Sciences Electives ^f	18
Total Biological Physics Track Elective Units	73-77

^f The elective courses in Biological Sciences are decided after consultation with, and approval by, the Director of Undergraduate Affairs.

Chemical Physics Track

The B.S. in Physics/Chemical Physics Track is designed for students wishing to have a strong grounding in physics along with a specialization in physical chemistry and/or chemical physics. It is particularly suitable for those students planning on graduate studies in physics with an emphasis on chemical physics or chemistry. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Director of Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

	Units
33-xxx One Physics Breadth Elective	9-12
21-2xx Mathematics Elective	9-10
09-106 Modern Chemistry II	10
09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-xxx Three Chemistry Electives ^g	27
Total Chemical Physics Track Elective Units	73-77

^g The elective courses in Chemistry are decided after consultation with, and approval by, the Director of Undergraduate Affairs.

Computational Physics Track

The B.S. in Physics/Computational Physics Track is intended to fill the increasing demand for physics graduates who are skilled in computational and numerical techniques that are used in the analysis of physical problems in areas ranging from academia to Silicon Valley. This degree provides the student with a rigorous grounding in physics as well as in the foundations and practice of computational skills to address theoretical and applied problems in society. Flexibility in the degree requirements allows students to choose technical electives that prepare them for future careers in a range of emerging computational science fields including data science, artificial intelligence, and software development. Students who complete this track will also gain experience in the application of high-performance computing resources to a wide variety of problems.

	Units
33-241 Introduction to Computational Physics	9

33-456	Advanced Computational Physics	9
33-xxx	One Physics Breadth Elective	9-12
33-xxx	One Qualifying Physics Elective or xx-xxx Computational Science Elective ^h	9-12
21-127	Concepts of Mathematics	12
21-369	Numerical Methods	9-12
or 21-325	Probability	
or 36-225	Introduction to Probability Theory	
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
Total Computational Physics Track Elective Units		81-90

^h Selected in consultation with, and requires approval of, the Director of Undergraduate Affairs. Common choices outside qualifying physics electives include 10-301, 11-485, and 15-388, but other options may be approved.

Quantum Physics Track

In the early 20th century, the first quantum revolution led to a disruption of accepted physics paradigms and resulted in rapid innovation in science and technology. The development of the transistor, the laser, and the atomic clock, for example, allowed for innovations in computing, communications, and medical imaging that we now take for granted. The second quantum revolution, defined by the development and application of quantum materials and quantum computing, is poised to unleash another era of innovation in science and technology. The B.S. in Physics/Quantum Physics Track is designed for students who want to prepare for a career at the cutting-edge of this exciting field.

		Units
33-445	Advanced Quantum Physics I	9
33-446	Advanced Quantum Physics II	9
33-658	Quantum Computation and Quantum Information Theory	10
33-448	Introduction to Solid State Physics	9
or 33-444	Introduction to Nuclear and Particle Physics	
or 33-355	Nanoscience and Nanotechnology	
33-350	Undergraduate Research ^j	9
or 33-451	Senior Research	
21-2xx	Mathematics Elective	9-10
xx-xxx	Two STEM Electives	18-24
Total Quantum Track Elective Units		73-80

^j The elective courses and research topic are decided after consultation with, and approval by, the Director of Undergraduate Affairs. Research must be completed in a single 9-unit block.