Physics at Boston University Undergraduate Program

CERN Study Abroad Program
Hydrophobic nanoconfinement of supercooled water Strekalova
Considering a major in physics?

Excellent choice! Physics is one of the most fundamental sciences, concerned with the nature of elementary constituents of matter, the character of the universe and its evolution, and emergent complex behavior that arises from the interactions of a large number of elemental units. Throughout the course of your studies, you will acquire essential analytical, quantitative, and problem-solving skills that will be valuable in a wide range of careers.

The underlying principles of physics are an integral part of many other sciences, including: chemistry, astronomy, biology, earth sciences, meteorology, and engineering. Physics is also valuable in certain areas of medicine, business, computer science, and law. As such, physics majors and minors receive ideal basic training to pursue successful careers in other fields. At the same time, many students enjoy the process of search and discovery in physics research, and have made lifetime careers as educators, or as physicists in national or industrial research laboratories. Our department offers a variety of educational programs to fit the needs of students with career aspirations in all of these diverse areas.

The department prides itself on the quality of its teaching, while also maintaining a vigorous research program. The diverse faculty assures an opportunity for close interaction with teachers and mentors. Students are encouraged to participate in ongoing research projects, and many get involved as early as their sophomore year. In the spring of 2010, the department launched a study abroad program at CERN in Geneva for students in their junior year. Currently the only of its kind in the US, our program brings students directly to the cutting edge of modern physics.

There are many advantages to studying physics at Boston University. While located in a dynamic urban environment at a large university, physics students will feel a sense of community in a small department. Each entering freshman is assigned a faculty advisor to guide them throughout their four years and upper-level courses do not exceed 40 students. The undergraduate physics club Photon serves as a social organization for undergraduates involved in physics at BU. Club meetings provide a casual environment for classmates to bond, receive advice from upperclassmen, and form study groups.

We hope that you find this information useful in evaluating the opportunities and advantages of pursuing a physics major at Boston University. If you would like further information on the program please contact our Undergraduate Coordinator Courtney Clark at (617) 353-7286 or cclark86@bu.edu.
Degree Programs

BA | PHYSICS

This option provides students with a comprehensive and rigorous education in classical and modern physics. It is well suited for students intending to pursue graduate study in physics or a closely related field, or planning to enter a technical physics-related career upon graduation.

Prerequisites
- Calculus I and II (MA 123, 124) OR Enriched Calculus (MA 127) or Honors Calculus (MA 129)
- Principles of Physics (PY 251, 252) and Modern Physics I (PY 351) or General Physics (PY 211, 212) and Elementary Modern Physics (PY 313)
- Methods of Theoretical Physics (PY 355)

Principal Courses
- Electromagnetic Fields and Waves I and II (PY 405, 406)
- Intermediate Mechanics (PY 408)
- Statistical Thermodynamics (PY 410)
- Quantum Physics (PY 451, 452)
- Advanced Laboratory (PY 581)
- An additional physics course at the 300 level or higher (excluding PY 401, 402, 482, 491, and 492)

Required Related Courses
- Multivariate Calculus (MA225)
- An additional mathematics course at the 200 level or higher

Recommended Courses
- Modern Physics II (PY 351)
- Electronics for Scientists (PY 371)
- Senior Independent Work (PY 401, 402)
- Advanced Scientific Computing (PY 421)
- Undergraduate Physics Seminar (PY 482)
- Introduction to Solid State Physics (PY 543)
- Introduction to Particle Physics (PY 551)
- Linear Algebra (MA 242)
- Advanced Calculus (MA 411)
- Complex Variables (MA 412)
- Methods of Applied Mathematics (MA 561)

BA | PHYSICS (INTERDISCIPLINARY)

This option provides students with a strong physics preparation, but also allows them the flexibility to pursue an interdisciplinary academic program combining physics with training in a related science (Astronomy, Biology, Chemistry, Computer Science, Mathematics, Geography, Energy and Environmental Studies or Earth Sciences). It is well suited for students planning to pursue graduate studies in another discipline or entering a career in a related field upon graduation. Students pursuing this option consult closely with their physics advisor and file a formal plan of study with the department.

Prerequisites
- Calculus I and II (MA 123, 124) or Enriched Calculus (MA 127)
- Principles of Physics (PY 251, 252) and Modern Physics I (PY 351) or General Physics (PY 211, 212) and Elementary Modern Physics (PY 313)
- Methods of Theoretical Physics (PY 355)

Principal Courses
- Electromagnetic Fields and Waves I (PY 405)
- Intermediate Mechanics (PY 408)
- Statistical Thermodynamics (PY 410)
- Quantum Physics (PY 451, 452)
- Advanced Laboratory (PY 581)
- An additional physics course at the 300 level or higher (excluding PY 401, 402, 482, 491, 492, 581)
- Three coordinated courses from a participating science or engineering department

Required Related Courses
- Multivariate Calculus (MA 225)
- An additional mathematics course at the 200 level or higher

Recommended Courses
- Modern Physics II (PY 351)
- Electronics for Scientists (PY 371)
- Electromagnetic Fields and Waves II (PY 406)
- Advanced Scientific Computing in Physics (PY 421)
- Statistical Thermodynamics (PY 410)
- Quantum Physics (PY 452)
- Undergraduate Physics Seminar (PY 482)
BA | ASTRONOMY & PHYSICS

Physics when paired with Astronomy helps students understand how physical concepts are applied in our universe. Whether students are interested in solar flares or the Big Bang, this joint-degree program arms them with the knowledge and skills to observe physics in our solar system and beyond. Students who choose this concentration will be prepared to enter graduate school to study astronomy or astrophysics.

Prerequisites
- Principles of Astronomy I and II (AS 202, 203)
- Principles of Physics (PY 251, 252) or General Physics (PY 211, 212)

Principal Physics Courses
- Modern Physics (PY 351, 352) or Elementary Modern Physics (PY 313)
- Methods of Theoretical Physics (PY 355)
- Electromagnetic Fields and Waves I and II (PY 405, 406)
- Intermediate Mechanics (PY 408)
- Statistical Thermodynamics (PY 410)
- Quantum Physics (PY 451)

Principal Astronomy Courses
- Planetary Physics (AS 311)
- Stellar and Galactic Astrophysics (AS 312)
- Observational Astronomy (AS 441) or Advanced Laboratory (PY 581)
- Two courses from the following list: Extragalactic Astrophysics and Cosmology (AS 413), Solar and Space Physics (AS 414), Quantum Physics (PY 452)

Required Related Courses
- Calculus I and II (MA 123, 124) or Enriched Calculus (MA 127)
- Multivariate Calculus (MA 225)

BA | PHILOSOPHY & PHYSICS

With this degree option, the Physics and Philosophy departments enable students to study the fundamental, philosophical questions underlying modern physics, the study of matter and energy, and how they interact. This joint-degree program provides a framework within which students can better understand some of the more theoretical aspects of the field of Physics.

Prerequisites
- One course in philosophy at the 100 level
- Principles of Physics (PY 251, 252) or General Physics (PY 211, 212)
- Calculus I and II (CAS MA 123, 124)

Principal Physics Courses
- Modern Physics (PY 351, 352)
- Methods of Theoretical Physics (PY 355)
- Electromagnetic Fields and Waves I and II (PY 405, 406)
- Intermediate Mechanics (PY 408)
- Quantum Physics I and II (PY 451, 452)

Principal Philosophy Courses
- Philosophy of Science (PH 270)
- History of Ancient Philosophy (PH 300)
- History of Modern Philosophy (PH 310)
- Symbolic Logic (PH 360) or Philosophical Problems of Logic and Mathematics (PH 468)
- Philosophy of Physics (PH 470) or a directed study in philosophy.

Required Related Courses
- Multivariate Calculus (MA 225)
Degree Programs

BA | PHYSICS & ANOTHER FIELD

Many of our students decide to pair their Physics major with another CAS field, such as Mathematics or English Literature. All requirements of both majors must be met, and any overlapping courses may be credited toward both majors, within a specified limit. Students should plan carefully with a faculty advisor in each department before they declare two majors.

BA/MA | PHYSICS

This five-year program is intended for students who want to continue their education in Physics at a graduate level, as well as for students who want to extend their knowledge of Physics beyond the undergraduate level before entering the job market. Students should enroll in this program no later than the end of their sophomore year.

Prerequisites
• Calculus I and II (MA 123, 124) or Enriched Calculus (MA 127)
• Principles of Physics (PY 251, 252)
• Modern Physics (PY 351, 352)
• Methods of Theoretical Physics (PY 355)

Principal Courses
• Electromagnetic Fields and Waves I and II (PY 405, 406)
• Intermediate Mechanics (PY 408)
• Statistical Thermodynamics (PY 410)
• Quantum Physics I and II (PY 451, 452)
• Mathematical Physics (PY 501)
• Quantum Mechanics I and II (PY 511, 512)
• Electromagnetic Theory I (PY 521)
• Statistical Mechanics I (PY 541)
• Advanced Laboratory (PY 581)
• Introduction to Solid State Physics (PY 543) or Introduction to Particle Physics (PY 551).

In addition, students are required to enroll for two semesters of Directed Research (GRS PY 901, 902) in their final year, in connection with their work on a master’s thesis, or to achieve a “low pass” on the graduate comprehensive examination. In the latter case, the student must also take one additional Physics course at the 500 level or above.

Required Related Courses
• Multivariate Calculus (MA 225)
• An additional mathematics course at the 200 level or higher

Recommended Courses
• Computational Physics (PY 502)
• Introduction to Solid State Physics (PY 543)
• Introduction to Particle Physics (PY 551)
• Introduction to Nuclear Physics (PY 561)
• Linear Algebra (MA 242)
• Advanced Calculus (MA 411)
• Complex Variables (MA 412)
• Mathematical Logic (MA 531)
• Methods of Applied Mathematics II (MA 561)

BA/MA | ASTROPHYSICS & SPACE PHYSICS

The BA/MA program in Astrophysics and Space Physics is designed for those well-prepared students who wish to obtain a master’s degree by adding a fifth year of intensive study in Astrophysics and Space Physics. Application to the Department of Astronomy’s Director of Graduate Studies must be completed by March of the junior year.

The requirements of the BA/MA program consist of those for the BA in Astronomy and Physics plus those of the MA in Astronomy. There are two tracks in the program, one comprising 38 courses plus a master’s thesis, and one comprising 40 courses without a thesis. Further details may be obtained at the Department of Astronomy office or from the Director of Graduate Studies.

MINOR | PHYSICS

A minor in Physics is a great way to supplement any science major or simply support a student who would like a well-rounded background. Many math and engineering students decide to enhance their majors with a minor in Physics.
PHYSICS & EDUCATION

Perhaps you were inspired to become a physics major by one of your teachers in high school. You can go on to inspire new generations of students to study science or engineering at the university level by becoming an inspiring teacher yourself. There has always been a need for qualified physics teachers in this country. Recently, that need has increased significantly because many school districts (including the Boston Public Schools) have adopted a Physics First curriculum, with many students taking a conceptual physics course in the 9th grade.

To be able to teach effectively, a teacher needs a solid background in their subject area. As a physics major, you will learn many different things about how the world works. Deciding to share your knowledge with others by becoming a physics teacher could be the best decision you ever make.

Possible routes include a BA in physics, followed by a one-year Master of Arts in Teaching (MAT) program through the School of Education; an interdisciplinary BA in Physics and Education, which combines a degree in Physics with several education courses; and a double major in Physics and Education through the Boston University Collaborative Degree Program (BUCOP).

If you’re interested in becoming a physics teacher and would like more information, contact Andrew Duffy in the Physics Department (duffy@bu.edu).

Student Spotlight

Julie Hammond, Class of 2015

What made you choose physics as your major?
I chose physics because its main purpose is to explain how the world works. To do physics is to recognize patterns in the world around us, and represent those patterns mathematically so that calculations may be made to predict future events. We know that all things fall down, but it was Newton who explained gravity using three amazing equations, and physicists today are revolutionizing our knowledge of gravity with the discovery of the Higgs boson.

Describe your experiences living on the Women in Science and Engineering floor in Warren Towers and being a Learning Assistant.
The WISE floor is an amazing experience. It’s a supportive community full of young women who are passionate about science. I never felt “geeky” or “nerdy” there; in fact, it’s common to hear people discussing calculus in the common room on Friday nights! And when I had difficulty with my class work, there was always someone there to help me. This year I’m a Peer Leader on the WISE floor, I have tutoring hours to help students with their coursework, and I mentor freshmen informally.

As a Learning Assistant I’m helping students learn in the same physics discussions I took when I was in the class. It’s a different way to review the same material, and helps reinforce the physics concepts I learned last year. In addition, I’m taking a class that helps me to understand how students learn, which makes me a better teacher and a better learner. It has helped me realize that I definitely want to go into physics.

What are your plans after graduation?
I want to be a high school physics teacher!
Undergraduate Program

Boston University's Geneva Physics Program, in cooperation with the University of Geneva, brings students directly to the cutting edge of modern physics. With classes at the University of Geneva and directed research at CERN, students work with the world's leading physicists to explore the universe on the level of its most basic constituent particles.

The semester starts with a six-week orientation. During that time, students attend a lecture (Computational Methods for Statistical Analysis in Experimental Physics) at CERN, in addition to intensive French classes. Both courses are accompanied by weekly follow-ups. During the internship, the students are mentored by BU physicists and others at CERN and the University of Geneva.

The lectures at the University of Geneva (Electrodynamics and Quantum Mechanics) are taught in French, with a separate discussion section in English held weekly. Students are considered full-time University of Geneva students, and enjoy all student privileges. Boston University's residence hall is located in the center of Geneva.

For more information visit physics.bu.edu/sites/geneva-program/
INTRODUCTORY COURSES

**PY 195 FRESHMAN SEMINAR FOR PHYSICISTS**
Seminar for freshman physics majors. Learn successful strategies for studying physics and become familiar with BU’s policies, procedures, resources, and extracurricular activities. Explore research and career opportunities through invited speakers, book discussions, and laboratory tours.

**PY 211, 212 GENERAL PHYSICS**
For premedical students who want a more analytical course than CAS PY 105, 106, and for science concentrators and engineers. Basic principles of physics emphasizing Newtonian mechanics, conservation laws, thermal physics, electricity and magnetism, geometrical optics.

**PY 251, 252 PRINCIPLES OF PHYSICS**
Introduction to mechanics, conservation laws, heat and thermodynamics, electrostatics, magnetism, alternating currents, electromagnetic radiation, geometrical optics. Primarily for physics, mathematics, and astronomy concentrators, but open to other students with a strong background in mathematics. Lectures, discussions, and laboratory.

**PY 313 ELEMENTARY MODERN PHYSICS**
Waves and physical optics, relativistic mechanics, experimental foundations of quantum mechanics, atomic structure, physics of molecules and solids, atomic nuclei and elementary particles. Along with CAS PY 211, 212, PY 313 completes a three-semester introductory sequence primarily intended for students of engineering.

**PY 351 MODERN PHYSICS I**
Introduction to special relativity, foundations of quantum theory, and introduction to wave mechanics, topics in atomic and molecular structure, solid state, and nuclear physics. Lectures, discussions, and laboratory.

**PY 352 MODERN PHYSICS II**
An introduction to modern physics including quantum mechanics of atoms and molecules, condensed matter physics, nuclear physics, and elementary particle physics. Labs are a required course component.

**PY 355 METHODS OF THEORETICAL PHYSICS**

**PY 371 ELECTRONICS FOR SCIENTISTS**
A survey of practical electronics for all College of Arts & Sciences science students wishing to gain a working knowledge of electronic instrumentation, and in particular, its construction.

**PY 401, 402 SENIOR INDEPENDENT WORK**
By approval of CAS Honors Committee.

PRINCIPAL COURSES

**PY 405 ELECTROMAGNETIC FIELDS AND WAVES I**
Vector analysis; Gauss’s law; electric field intensity; energy and potential; conductors, dielectrics, and capacitance; Poisson’s and Laplace’s equations; steady magnetic fields.

**PY 406 ELECTROMAGNETIC FIELDS AND WAVES II**
Maxwell’s equations; electro-magnetic waves in vacuum and matter; reflection and refraction; diffraction and interference; coherence; special theory of relativity.

**PY 408 INTERMEDIATE MECHANICS**

**PY 410 STATISTICAL THERMODYNAMICS**
The laws of thermodynamics, statistical basis of thermodynamics, ensemble theory, equilibrium statistical mechanics and its application to physical systems of interest, irreversibility, transport, and the approach to equilibrium.

**PY 421 INTRODUCTION TO COMPUTATIONAL PHYSICS**
Undergraduate-level introduction to computer programming and methods used to formulate and solve physics problems on the computer. Also touches on more advanced topics such as parallel computing and graphical visualization.
**Course Descriptions**

**PY 451, 452 QUANTUM PHYSICS**
Uncertainty principle; Schrödinger wave equation and applications; operators; hermitian operators and unitary transformations; harmonic oscillator; angular momentum and spin; time dependence; magnetic resonance; parity and identity; helium atom and hydrogen molecule; exclusion principle; Fermi-Dirac statistics; Zeeman Effect.

**ADVANCED COURSES**

**PY 501 MATHEMATICAL PHYSICS**
Introduction to complex variables and residue calculus, asymptotic methods, and conformal mapping; integral transforms; ordinary and partial differential equations; nonlinear equations; integral equations.

**PY 502 COMPUTATIONAL PHYSICS**
Fundamental methods of computational physics and applications; numerical algorithms; linear algebra, differential equations; computer simulation; vectorization, parallelism, and optimization. Examples and projects on scientific applications.

**PY 511 QUANTUM MECHANICS I**

**PY 512 QUANTUM MECHANICS II**
Degenerate and nondegenerate perturbation theory. Second quantization of nonrelativistic systems with applications to scattering, lifetime of excited atomic states, many-body problems. Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation.

**PY 521 ELECTROMAGNETIC THEORY I**

**PY 522 ELECTROMAGNETIC THEORY II**
Course Descriptions

PY 541 STATISTICAL MECHANICS I

PY 542 STATISTICAL MECHANICS II

PY 543 INTRODUCTION TO SOLID STATE PHYSICS
An introduction to crystal structure; lattice vibrations; electronic energy bands and Fermi surfaces; semiconductors, conductors, and insulators; superconductivity and magnetism.

PY 551 INTRODUCTION TO PARTICLE PHYSICS

PY 561 INTRODUCTION TO NUCLEAR PHYSICS
A general introduction to nuclear physics. Topics covered include an introduction to the nucleus, nuclear forces, theories of nuclear structure, decay and reaction processes, and special topics of interest (nuclear energy, origin of nuclei, and the like).

PY 581 ADVANCED LABORATORY
Classical experiments in atomic and nuclear physics, development of new experiments, basic research projects. Experiments include magnetic resonance, nuclear-decay studies, Zeeman effect, holography, black-body radiation, X-ray diffraction, Mössbauer studies, and flux quantization, positron annihilation.
Research Opportunities

A large goal of the BU Physics Department is to ensure that all undergraduate students have an opportunity to conduct research. Research provides students the hands-on experience they need to supplement the lessons learned in the classroom. Projects are often also published or form part of a larger project. We encourage our undergraduates to become involved in research by the end of their sophomore year, and to continue through graduation. It’s a great way to enhance an education and prepare for both graduate school and beyond.

Most research is coordinated through the Undergraduate Research Opportunity Program (UROP), which is managed by BU. To choose a UROP opportunity, first choose an area of interest and then speak with professors and advisers about research possibilities. Once you have clarified your interests, check the UROP website and bulletin boards in the Undergraduate Resource Room for opportunities. If you find none that suit you, check professor profiles on the BU Physics website and contact professors who do research in your area of interest. Discussing research with professors is paramount, as most UROP application submissions require two letters of recommendation in addition to the application. Those conversations will educate you about professors’ research, as well as help them learn about you. More information is available at www.bu.edu/urop.

Student Spotlight

Daniel Arcaro, Class of 2013

What got you interested in physics?
As a kid, I always wanted to know how things worked. Back then it was easy because I could just break apart a toy to see its inner workings. I still want to learn how everything works together to create the systems around us, though the process has certainly become a bit more difficult. The field that I have always seen as the key to satisfying this need is physics.

Describe the research you’re working on?
I work in Professor Richard Averitt’s lab, where we do Terahertz spectroscopy on various correlated electron materials. The basic idea is that we use Terahertz radiation to determine the physical properties of interesting materials. The advantage to this technique is that it allows for non-contact measurements while varying the material’s environment as well as femto-second resolution of dynamics.

What are your plans after graduation?
Right now I’m in the middle of the decision process for graduate school. Whatever my choice though, I will continue to work in the condensed matter field, whether it be in spectroscopy or something else.
Photon is the Boston University chapter of the Society of Physics Students (SPS), and serves as a social organization for undergraduates involved in physics at BU. Every semester, Photon organizes social events for physics majors, sets up lectures by faculty on subjects of current interest, offers attendance at professional meetings, and participates in outreach programs in the Boston area.

In a recent outreach program, members presented educational and entertaining activities on kinematics to sixth graders in Belmont, MA with the aid of advisor Professor Robert Carey. Photon also participated in a program for high school girls called SET (science, engineering and technology) in the City, where members prepared a variety of demonstrations in astronomy and physics, such as the jumping rings, liquid oxygen, smoke ring shooter, and non-Newtonian fluid, and talked to the high school girls about pursuing physics.

Hands-on physics demonstrations are a major component of Photon. These range from light polarizers and Van de Graaff generators, to newer demonstrations such as musically induced laser light shows, cloud chambers and the invisible Pyrex glass. The latter three were demonstrations that members created themselves. Additional meetings have centered around specific student interests, such as the physics of ice skating (held at BU’s Walter Brown Arena), and the physics of Tae Kwon Do board splitting techniques.

Thanks to BU Physics Alum Zach Hartwig, Photon is able to tour MIT’s Fusion Lab. The tour includes an introduction to the basics of fusion and fusion power, and a walk through the reactor control room. Recently, Photon also toured the proton center at Boston MGH. Led by Dr. George Cheng, the tour exposed members to the field of medical physics, with an emphasis on radiation oncology.

Photon participates in department-wide events such as helping organize the annual physics Pumpkin Drop at Boston University. Members carve and decorate pumpkins and fill them with various ingredients such as paint, whipped cream, and non-Newtonian fluid. The pumpkins are then tossed from the roof of the Metcalf Science Center.

Photon also functions as a social gathering for physics undergraduates. Members get a chance to interact with other students from their classes without the stress of class or work. Students can learn more about the degree program from members who have already experienced it or create study groups, which are essential. Students will often gather for an hour or more after the meeting to socialize. It’s a great way for students to continue learning the material they love in a relaxing and fun manner.
Graduate Opportunities

Bachelor’s recipients from the Physics Department have been successful in being accepted to the most prestigious graduate programs in the United States. Graduates have also been successful in entering into a diverse range of disciplines, reflecting the broad value of an undergraduate degree in Physics.

The first chart (top) shows our majors’ post-graduation plans for the past 5 years.

Many students get involved in the department's annual Pumpkin Drop, which involves dropping pumpkins, filled with substances from whipped cream to neon paint, from the top of the Metcalf Science Center.
A flexible, multilayer metamaterial that is resonant at far-infrared wavelengths. Averitt