PHYSICS

Students may complete a major or minor in Physics. Within the major, students may complete a minor in educational studies or complete the requirements for secondary education certification. Students may complete an M.A. in the combined A.B./M.A. program. The courses in Physics emphasize the concepts and techniques that have led to our present way of modeling the physical world. They are designed both to relate the individual parts of physics to the whole and to treat the various subjects in depth.

Opportunities exist for interdisciplinary work and for participation by qualified majors in research with members of the faculty and their graduate students. In addition, qualified majors may take graduate courses.

Required Introductory Courses for the Major and Minor

The introductory courses required for the physics major and minor are PHYS B121 and PHYS B122 and MATH B101 and MATH B102. Students are encouraged to place out of MATH B101 and MATH B102 if that is appropriate. Although College credit is given for a score of 4 or 5 on the AP tests and for a score of 5 or above on the IB examination, the AP and IB courses are not equivalent to PHYS B121 and PHYS B122 and advanced placement will not, in general, be given. However, students with a particularly strong background in physics are encouraged to take the departmental placement examination between the summer before entering Bryn Mawr and the end of the first week of classes in the fall semester. Based on the results, the department will place students in the appropriate course.

Academic Opportunities

Research

Participation in research with faculty is highly encouraged, though not required aspect to the major. Students can participate in research as early as the summer after their first year through the Summer Science Research program or by enrolling in PHYS 403 for either a half or full unit credit during a semester. Students who engage in research can learn a wide variety of experimental, theoretical, or computational skills in physics, as well as learn how to communicate their work through written reports, oral presentations given at departmental symposia held every semester, or through attendance at physics conferences. Though also not required for the major, research started earlier in one's college career can lead to the eventual completion and submission of a senior thesis, an honors senior thesis (see Honors), or an MA thesis (see A.B./M.A.). A tour of all physics research programs is provided during PHYS 121, but students are encouraged to reach out to physics faculty to learn more about their research programs.

Study Abroad

Many physics majors participate in the College's junior year study abroad program (https://www.brynmawr.edu/inside/offices-services/global-engagement/study-abroad/). Undergraduate physics courses are surprisingly standardized throughout the world. The Majors Adviser will work with you to design an appropriate set of courses to take wherever you go. If you are considering a physics major as well as studying abroad, you are encouraged to consult with the Physics Majors Advisor as early as possible.

Preparation for Graduate School

he department has been very successful in preparing students for graduate school in physics, physical chemistry, materials science, engineering, and related fields. To be well prepared for graduate school, students should take, at a minimum, these upper-level courses which span the basis of a traditional physics education: PHYS B302, PHYS B303, PHYS B308, and PHYS B309. Students should also take any additional courses in physics and allied fields that reflect their interests, and should engage in research with a member of the faculty by taking PHYS B403. (Note that PHYS B403 does not count towards the 14.5 courses required for the major.) Majors can also take graduate courses to get a head start on graduate school. The department generally offers graduate courses in Electromagnetism, Statistical Mechanics, and Classical Mechanics.

Minor in Educational Studies or Secondary-School Teacher Certification

Students majoring in physics can pursue a minor in educational studies or state certification to teach at the secondary-school level. Students seeking the minor need to complete six education courses including a two-semester senior seminar, which requires five to eight hours per week of fieldwork. To earn secondary-school certification (grades 7-12) in physics, students must: complete the physics major plus two semesters of chemistry and one semester as a teaching assistant in a laboratory for introductory or intermediate physics courses; complete six education courses; and student teach full-time (for two course credits) second semester of their senior year. For additional information, see Education (http://www.brynmawr.edu/education/).

Pre-Health Professions

A major in physics can be excellent preparation for a career in the health professions. A (2010) study by the American Institute of Physics finds that "…as a group, physics bachelor's degree recipients achieve among the highest scores of any college major on the entrance exams for medical school…" In addition to one year of physics, most medical and dental schools require one year of English, one year of biology, one year of general chemistry, and one year of organic chemistry. Students wishing to pursue this path should consult the physics major's advisor early in their studies as well as the Health Professions Advising Office to develop an appropriate major plan. For additional information, see Health Professions Advising (http://www.brynmawr.edu/health-professions-advising/).

A Physics Major With an Engineering Focus

Students interested in enriching their physics education by incorporating engineering coursework can do so through coursework in engineering at Swarthmore College or the University of Pennsylvania. Bryn Mawr students also have the opportunity to transition to an engineering program through a combined degree program. See below for a short description of the programs available through the physics major. In addition, while departmental research programs are focused on physics, participation in experimental physics research laboratories can expose students to many engineering concepts, design cycles, and construction, and can adequately prepare students for careers in industry or continuing engineering-focused education.

Master's Programs

University of Pennsylvania 4+1 Program

Qualified students can earn a master's degree in engineering following the completion of four years at Bryn Mawr and at least one year at UPenn. A GPA of 3.0 in all courses and of 3.0 in science and math courses is required to apply. Contact Dr. Evan Arena (https://www.brynmawr.edu/inside/people/evan-j-arena/) for more information regarding the program and learn more here (https://www.brynmawr.edu/

inside/academic-information/departments-programs/physics/ mmatlin@brynmawr.edu).

University of Rochester 4+2 Master's in Optics
Earn a master's degree in optics following completion of four years at Bryn Mawr and two years at The University of Rochester's Institute of Optics. Contact Dr. Mike Noel (https://www.brynmawr.edu/inside/people/michael-noel/) for more information.

Villanova University 4+1 Program in Mechanical or Aerospace Engineering
Qualified students can earn a Masters degree from Villanova University in Mechanical Engineering or Aerospace Engineering through the Villanova bridge program. Students must be accepted to the program no later than Spring of junior year. The program includes a bridge course during the summer between junior and senior year, two graduate courses taken at Villanova during the senior year, and seven additional courses taken at Villanova in the summer before and during the fifth year. A GPA of 3.0 at Bryn Mawr is required to apply. Contact Dr. Evan Arena (https://www.brynmawr.edu/inside/people/evan-j-arena/) for more information regarding the program.

Dual Degree Programs
Caltech or Columbia 3+2 AB/BS Program
Students interested in earning a BS degree in engineering in addition to an AB degree can apply for either the Caltech or Columbia 3+2 program. A student in this program would complete three years of coursework at Bryn Mawr College and then attend Caltech or Columbia for the remaining two years, receiving both an AB and a BS at the end of five years total. Both programs require that a student take specific prerequisite courses and submit an application. Contact Dr. Xuemei Cheng (https://www.brynmawr.edu/inside/people/xuemei-may-cheng/) for more information.

A.B./M.A. Program
Students with a physics major GPA of 3.60 or above are encouraged to explore the combined A.B./M.A. program in physics, which provides the opportunity to work towards their bachelor's and master's degrees concurrently in four to five years. Students normally apply to this program during their sophomore or junior year.

To earn an M.A. degree in physics in the College's A.B./M.A. program, a student must complete the requirements for an undergraduate physics major and must complete six units of graduate level work in physics. Of these six units, as many as two units may be undergraduate courses at the 300 level taken for graduate credit (these same two courses may be used to fulfill the major requirements for the A.B. degree), at least two units must be graduate course at the 500 level (or equivalent courses taken at the University of Pennsylvania), and two units must be graduate research at the 700 level leading to the submission and oral defense of an acceptable M.A. thesis. Students interested in the A.B./M.A. program should contact the Physics Majors Advisor to develop a feasible curricular workplan and start supervised research as early as possible.

Courses at Haverford College

Many upper-level physics courses are taught at Haverford and Bryn Mawr in alternate years as indicated in the listings of the specific courses below. These courses (numbered 302, 303, 308, 309, and 322) may be taken at either institution to satisfy major requirements. Haverford 335 and Bryn Mawr 325 are both topics in advanced theoretical physics and they also tend to alternate. In addition, 100- and 200-level courses at Haverford can be used to replace 100- and 200-level courses at Bryn Mawr but these courses are not identical and careful planning is required.

Introductory Physics Sequences

Students on a pre-health professions track wanting to take one year of physics should take PHYS B101 and PHYS B102. Some students on a physical sciences major track could take PHYS B121 and PHYS B122 and others might take PHYS B122 and PHYS B201. See your major adviser and carefully note the math pre- and co-requisites for these courses. PHYS B121/PHYS B122/PHYS B201/PHYS B214 is a coordinated, four-semester sequence in physics. Students are encouraged to place out of MATH B101 and MATH B102 if that is appropriate.

Major Requirements

The physics major provides depth in the discipline through a series of required courses, as well as the flexibility to choose from a range of electives in physics and related fields. This allows students to follow various paths through the major and thus tailor their program of study to best meet their career goals and scientific interests.

Beyond the two introductory physics courses (PHYS B121 and PHYS B122) and the two introductory mathematics courses (MATH B101 and MATH B102), twelve additional courses are required for the major with 14 units in total.

Code	Title	Units
Eight courses (7 units) must be:		
PHYS B201	Electromagnetism	1
PHYS B206	Computational Methods for the Sciences	0.5
PHYS B214	Introduction to Quantum Mechanics	1
PHYS B306	Mathematical Methods in the Physical Sciences	1
PHYS B398	Senior Seminar	0.5
MATH B201	Multivariable Calculus	1
MATH B203	Linear Algebra	1
PHYS B331	Advanced Experimental Physics	1
or PHYS B305	Advanced Electronics Lab	
Total Units		**7**

PHYS B206, a half credit computational lab course, must also be taken; PHYS B398, offered each fall, is a half-credit Senior Seminar. PHYS B331 and PHYS B305 are Writing Intensive courses and by completing at least one of them, students can meet the Writing Requirement in the major. Haverford courses may be substituted for Bryn Mawr courses where appropriate. The remaining three courses must be chosen from among the other 300-level physics courses, one of which may be substituted with one course from among ASTR 342, 343, and 344, or a 300-level math course, with the approval of the major advisor. 500-level graduate courses may also fulfil this requirement with advisor's approval. Other substitutions from related disciplines such as chemistry, geology, and engineering may be possible. Please consult with the major advisor to discuss such options.

Four-Year Plan Meeting the Minimum Requirements for the Major

Course	Title	Units
First Year		
PHYS B121	Modern Physics	1
PHYS B122	Classical Mechanics	1
MATH B101	Calculus I	1

MATH B102	Calculus II	1
	Units	**4**
Second Year		
PHYS B201	Electromagnetism	1
PHYS B214	Introduction to Quantum Mechanics	1
PHYS B206	Computational Methods for the Sciences	0.5
MATH B201	Multivariable Calculus	1
MATH B203	Linear Algebra	1
	Units	**4.5**
Third Year		
PHYS B306	Mathematical Methods in the Physical Sciences	1
PHYS B331 or PHYS B305	Advanced Experimental Physics or Advanced Electronics Lab	1
Select one other 300-level physics course		1
	Units	**3**
Fourth Year		
Select two 300-level physics courses		2
PHYS B398	Senior Seminar	0.5
	Units	**2.5**
	Total Units	**14**

The physics program at Bryn Mawr allows for a student to major in physics even if the introductory courses are not completed until the end of the sophomore year.

Three-Year Plan Meeting the Minimum Requirements for the Major

Course	Title	Units
First Year		
MATH B101	Calculus I	1
MATH B102	Calculus II	1
	Units	**2**
Second Year		
PHYS B121	Modern Physics	1
PHYS B122	Classical Mechanics	1
PHYS B206	Computational Methods for the Sciences	0.5
MATH B201	Multivariable Calculus	1
MATH B203	Linear Algebra	1
	Units	**4.5**
Third Year		
PHYS B201	Electromagnetism	1
PHYS B214	Introduction to Quantum Mechanics	1
PHYS B306	Mathematical Methods in the Physical Sciences	1
PHYS B331 or PHYS B305	Advanced Experimental Physics or Advanced Electronics Lab	1
	Units	**4**
Fourth Year		
Select three 300-level physics courses		3
PHYS B398	Senior Seminar	0.5
	Units	**3.5**
	Total Units	**14**

Honors

The degree of Bachelor of Arts is awarded with honors in physics in recognition of excellence as demonstrated by both academic work and research. The award is made upon the recommendation of the department based on the following criteria:

- distinction in undergraduate research and quality of a written senior thesis;
- achievement of a major GPA of at least 3.6 and an overall GPA of at least 3.0.

For purposes of honors, the major GPA is computed from the following courses:

- Physics courses at the 200-level and above at Bryn Mawr and Haverford Colleges, excluding PHYS B380, B390, B398, and B403 at Bryn Mawr College and their analogs at Haverford College; 200-level courses in mathematics required for the physics major (MATH B201 and B203); 300-level courses in mathematics, astronomy (or in some cases another field) only if substituted for a 300-level course in physics with the approval of the major advisor.

Minor Requirements

The requirements for the minor, beyond the introductory sequence:

Code	Title	Units
PHYS B201	Electromagnetism	1
PHYS B214	Introduction to Quantum Mechanics	1
PHYS B306	Mathematical Methods in the Physical Sciences	1
PHYS B331 or PHYS B305	Advanced Experimental Physics Advanced Electronics Lab	1
MATH B201	Multivariable Calculus	1
MATH B203	Linear Algebra	1
Select one additional 300-level physics course		1
Total Units		**7**

The astronomy and mathematics courses described under "Major Requirements" may not be substituted for the one additional 300-level physics course.

PHYS B101 Introductory Physics I (1 Unit)
PHYS B101/B102 is an algebra-based introductory sequence intended primarily for students on the pre-health professions track. Emphasis is on developing an understanding of how we study the universe, the ideas that have arisen from that study, and on problem solving. Topics are taken from among Newtonian kinematics and dynamics, relativity, gravitation, fluid mechanics, waves and sound, electricity and magnetism, electrical circuits, light and optics, quantum mechanics, and atomic and nuclear physics. An effective and usable understanding of algebra and trigonometry is assumed. First year students who will take or place out of MATH B101 should take PHYS B121. PHYS B101 and B102 are considered two sequential semesters in a full-year course and as such cannot be taken out of order. Corequisites: MATH B100 or H105. Lecture three hours, laboratory two hours.

PHYS B102 Introductory Physics II (1 Unit)
PHYS B101/B102 is an algebra-based introductory sequence intended primarily for students on the pre-health professions track. Emphasis is on developing an understanding of how we study the universe, the ideas that have arisen from that study, and on problem solving. Topics are taken from among Newtonian kinematics and dynamics, relativity, gravitation, fluid mechanics, waves and sound, electricity and magnetism, electrical circuits, light and optics, quantum mechanics, and atomic and nuclear physics. An effective and usable understanding of algebra and trigonometry is assumed. PHYS B101 and B102 are considered two sequential semesters in a full-year course and as such cannot be taken out of order. Prerequisites: PHYS B101. Lecture three hours, laboratory two hours.

PHYS B110 Physics of Computers: Early Computing to Quantum Computing (1 Unit)
Modern computers and computing hardware are the direct result of the successful development of the physics of both quantum mechanics and complex materials over the past 120 years and continued innovation has lead to the invention of the Quantum Computer. Computing has become ubiquitous in our society as the performance of computers have improved. Computers and computing have many applications which influence our lives such as social media, large language models, cryptocurrency, and scientific research. The complexity of these topics leads to many natural questions. How do classical and quantum computers function? What key physics principles allow modern computers to operate? How powerful can computers be and what are their current limitations? What are the implications, such as scientific innovation or environmental impact, of large scale computing? How will quantum computers revolutionize computing? This conceptual course will explore these types of questions and provide opportunities to work with such technologies.

PHYS B114 Machine learning and quantum computing (1 Unit)
This is a 1.0-credit course that introduces a variety of computational methods and techniques, which include but are not limited to quantum computing, machine learning, and deep learning. Students will learn the foundational concepts for these various computational methods to gain an understanding of how modern world uses them to solve big problems.

PHYS B121 Modern Physics (1 Unit)
This course presents current conceptual understandings and mathematical formulations of fundamental ideas used in physics. Students will develop physical intuition and problem-solving skills by exploring key concepts in physics such as conservation laws, symmetries and relativistic space-time, as well as topics in modern physics including but not limited to: fundamental forces, quantum physics, quantum information science and engineering, nuclear physics, particle physics, cosmology, nanomaterials, and statistical mechanics. This course can serve as a stand-alone survey of physics or as the first of a four-semester sequence designed for those majoring in the physical sciences. Corequisite: MATH B101. Lecture three hours.

PHYS B122 Classical Mechanics (1 Unit)
This course covers Newtonian Mechanics of single particles, systems of particles, rigid bodies, and continuous media with applications, one-dimensional systems including forced oscillators, scattering and orbit problems. Prerequisites: PHYS B121 (or permission of the instructor) and MATH B101. Corequisite: MATH B102. Lecture three hours, laboratory two hours.

PHYS B125 A Journey through Our Universe (1 Unit)
What can we discover about the Universe, and our place in it, from observations of the night sky? What is the James Webb Space Telescope looking for? What is dark matter and dark energy? Are we alone in the Universe? This course is a survey of topics in astronomy, astrophysics, and cosmology. We embark on a cosmic journey through space and time, where we examine our solar system, our galaxy, the Universe, and the concepts in physics that allow us to describe the cosmos.

PHYS B201 Electromagnetism (1 Unit)
This course covers electrostatics, magnetostatics, electric and magnetic fields, induction, Maxwell's equations, electromagnetic radiation, and the relationship between electromagnetism and special relativity. Scalar and vector fields and vector calculus are developed as needed. The laboratory involves passive and active circuits and projects in analog and digital electronics. Prerequisite: PHYS B122 (or permission of the instructor). Corequisite: MATH B201. Lecture three hours, laboratory three hours.

PHYS B205 Mathematical Methods in the Sciences I (0.5 Unit)
This course is the first of two half-semester sessions which presents topics in applied mathematics useful to students in physics, engineering, physical chemistry, geology, and computer science. This first session will cover infinite series, complex variables, Fourier series, integral transforms, special functions, and ordinary differential equations. Lecture three hours and additional recitation sessions as needed. Prerequisite: MATH B102.

PHYS B206 Computational Methods for the Sciences (0.5 Unit)
This is a half-unit laboratory course that introduces computational methods and techniques useful to students in the physical sciences. Topics covered may include but are not limited to basic programming using Python, functions and array handling, iterative methods, numerical integration and differentiation, and computational differential equations. Corequisite: MATH B102. Laboratory three hours.

PHYS B207 Mathematical Methods in the Sciences II (0.5 Unit)
This course is the second of two half-semester sessions which presents topics in applied mathematics useful to students in physics, engineering, physical chemistry, geology, and computer science. This second session covers advanced ordinary differential equations, partial differential equations, special functions, series solutions, and boundary-value problems. Lecture three hours and additional recitation sessions as needed. Prerequisite: PHYS B205, MATH B201 and MATH B203

PHYS B208 Computational methods for Biophysics (0.5 Unit)
This is a 0.5-credit quarter course that will introduce a variety of computational methods and techniques useful to students interested in biophysics. Topics covered include but are not limited to probability distributions of discrete and continuous distributions, Brownian motion, model selection and parameter estimation, and random walks in biological systems. Prerequisite: PHYS B205 and PHYS B206.

PHYS B214 Introduction to Quantum Mechanics (1 Unit)
This course presents an introduction to the principles governing systems at the atomic scale and below. Topics include the experimental basis of quantum mechanics, wave-particle duality, Schrödinger's equation and its solutions, and the time dependence of quantum states. Recent developments, such as paradoxes calling attention to the counter-intuitive aspects of quantum physics, will be discussed. Additional topics may be included at the discretion of the instructor. The laboratory involves quantum mechanics, solid state physics, and optics experiments. Prerequisite: PHYS B122 (or permission of the instructor). Corequisite: MATH B203. Lecture three hours, laboratory three hours.

PHYS B220 Introduction to Plasma Physics and Fusion (0.5 Unit)
This is a half-unit introduction to basic plasma physics including an overview of plasma systems, single particle motion, waves and instabilities, and applications of plasma particularly its connection to the development of fusion energy. Prerequisite: MATH B102.

PHYS B302 Advanced Quantum Mechanics and Applications (1 Unit)
This course presents nonrelativistic quantum mechanics, including Schrodinger's equation, the eigenvalue problem, the measurement process, the hydrogen atom, the harmonic oscillator, angular momentum, spin, the periodic table, perturbation theory, and the relationship between quantum and Newtonian mechanics. Prerequisites: (PHYS B214 or H214) and (PHYS B306 or B207 or H213). Lecture three hours and additional recitation sessions as needed.

PHYS B303 Statistical Mechanics and Thermodynamics (1 Unit)
This course presents the statistical description of the macroscopic states of classical and quantum systems, including conditions for equilibrium, the microcanonical, canonical, and grand canonical ensembles, and Bose-Einstein, Fermi-Dirac, and Maxwell Boltzmann statistics. The statistical basis of classical thermodynamics is investigated. Examples and applications are drawn from solid state physics, low temperature physics, atomic and molecular physics, electromagnetic waves, and cosmology. Prerequisite: PHYS B214 or H214. Corequisite: PHYS B306 or B207 or H213. Lecture three hours and additional recitation sessions as needed.

PHYS B305 Advanced Electronics Lab (1 Unit)
This laboratory course is a survey of electronic principles and circuits useful to experimental physicists and engineers. Topics include the design and analysis of circuits using transistors, operational amplifiers, feedback and analog-to-digital conversion. Also covered is the use of electronics for automated control and measurement in experiments, and the interfacing of computers and other data acquisition instruments to experiments. Prerequisite: PHYS B201. Laboratory eight hours.

PHYS B306 Mathematical Methods in the Physical Sciences (1 Unit)
This course presents topics in applied mathematics useful to students, including physicists, engineers, physical chemists, geologists, and computer scientists studying the natural sciences. Topics are taken from Fourier series, integral transforms, advanced ordinary and partial differential equations, special functions, boundary-value problems, functions of complex variables, and numerical methods. Corequisites: (PHYS B201 or H106) and MATH B201. Lecture three hours and additional recitation sessions as needed.

PHYS B308 Advanced Classical Mechanics (1 Unit)
This course presents kinematics and dynamics of particles and macroscopic systems using Newtonian, Lagrangian, and Hamiltonian mechanics. Topics include oscillations, normal mode analysis, inverse square laws, nonlinear dynamics, rotating rigid bodies, and motion in noninertial reference frames. Prerequisite: PHYS B306 or B207 or H213. Lecture three hours and additional recitation sessions as needed.

PHYS B309 Advanced Electromagnetic Theory (1 Unit)
This course presents electrostatics and magnetostatics, dielectrics, magnetic materials, electrodynamics, Maxwell's equations, electromagnetic waves, and special relativity. Some examples and applications may come from superconductivity, plasma physics, and radiation theory. Prerequisites: PHYS B201 and (B306 or B207 or H213). Lecture three hours and additional recitation sessions as needed.

PHYS B322 Condensed Matter Physics (1 Unit)
This course introduces the emergent properties and collective behaviors that arise when atoms and molecules come together in solids and liquids—systems known as condensed matter. We'll explore how these materials gain collective properties, such as specific heat, electrical conductivity, magnetism, and superconductivity from the interactions of their many particles. Frontier research topics in nanomaterials, quantum information science and biophysics will also be introduced if time permits. Prerequisite: PHYS B201 or H106. Corequisite: PHYS B306 or B207 or H213. Lecture three hours and additional recitation sessions as needed.

PHYS B324 Optics (1 Unit)
This course covers principles of geometrical and physical optics. Topics include electromagnetic waves and their propagation in both isotropic and anisotropic media; interference, diffraction, and Fourier optics; coherence theory; ray optics and image formation; and, as time permits, an introduction to the quantum nature of light. Prerequisite: PHYS B201 or H106. Corequisite: PHYS B306 or B207 or H213. Lecture three hours and additional recitation sessions as needed.

PHYS B325 General Relativity (1 Unit)
An introductory course in general relativity with an emphasis on physical principles and geodesics in curved spacetime. Topics include special relativity, the calculus of variations, metrics, geodesics, the equivalence principle, gravitational redshift, the static weak field metric, the Schwarzschild metric describing spacetime outside of a black holes or star, the precession of planetary orbits and the bending of light by massive objects, the parametrized post-Newtonian formalism for probing deviations from general relativity, the Kruskal extension of the Schwarzschild spacetime, causal structure, gravitational collapse, tensors, covariant derivatives, parallel transport, geodesic deviation, curvature, and the Einstein equations. Additional topics may include applications to rotating black holes, gravitational waves, cosmology, or Hawking radiation Prerequisite: PHYS B306 or B207 or H213. Lecture three hours and additional recitation sessions as needed.

PHYS B328 Galactic Dynamics & Advanced Classical Mechanics (1 Unit)
This course is for the advanced undergraduate interested in the physics galactic dynamics and evolution, i.e. collisionless, gravitational N-body systems composed of stars and dark matter. Topics covered will include potential theory, orbit theory, collisionless Boltzmann equation, Jeans equations, disk stability, violent relaxation, phase mixing, dynamical friction and kinetic theory. To support the these theories, we will also cover advanced topics in classical mechanics including Lagrange & Hamilton methods, the central force problem, canonical transformations, action-angle variables, chaos and perturbation theory. This course is taught in a seminar format, in which students are responsible for presenting much of the course material in class meetings. Prerequisites: MATH B201, MATH B203, PHYS B201, B214, and PHYS B308 or permission from instructor.

PHYS B331 Advanced Experimental Physics (1 Unit)
This laboratory course consists of set-piece experiments as well as directed experimental projects to study a variety of phenomena in atomic, molecular, optical, nuclear, plasma, and condensed matter physics. The experiments and projects serve as an introduction to contemporary instrumentation and the experimental techniques used in physics research laboratories in industry and in universities. Students write papers in a format appropriate for research publications and make a presentation to the class. Corequisite: PHYS B214 or H214. Laboratory eight hours.

PHYS B390 Independent Study (1 Unit)
At the discretion of the department, juniors or seniors may supplement their work in physics with the study of topics not covered in regular course offerings.

PHYS B398 Senior Seminar (0.5 Unit)
This is a half-unit course required for physics majors. Students meet weekly with faculty to discuss recent research findings in physics as well as career paths open to students with a major in Physics, and practice in skills needed for future careers. Students are required to attend all colloquia and student research presentations hosted by the Bryn Mawr College Physics department. Prerequisite: Senior Standing. Seminar one and a half hours.

PHYS B403 Supervised Research (1 Unit)
At the discretion of the department, majors or prospective majors may supplement their work in physics with research in one of the faculty research groups. Students can enroll in either a half-unit or a full unit course which corresponds to about six or twelve hours per week of research engagement respectively. Students provide a written paper synopsis of work completed and give an oral presentation (for full unit only) at the end of the semester during the physics department research talks symposium. Students completing a senior thesis must enroll in B403. Students are encouraged to contact individual faculty members and the departmental website for further information.

PHYS B501 Quantum Mechanics I (1 Unit)
This course is the first semester of a year-long standard sequence on quantum mechanics. The year-long course will cover: the mathematical formulation of quantum mechanics, quantum dynamics, the theory of angular momentum, symmetry in quantum mechanics, approximation methods, identical particles, scattering theory, relativistic quantum mechanics. This course is taught in a seminar format, in which students are responsible for presenting much of the course material in class meetings.

PHYS B502 Quantum Mechanics II (1 Unit)
This course is the second semester of a year-long standard sequence on quantum mechanics. The year-long course will cover: the mathematical formulation of quantum mechanics, quantum dynamics, the theory of angular momentum, symmetry in quantum mechanics, approximation methods, identical particles, scattering theory, relativistic quantum mechanics. This course is taught in a seminar format, in which students are responsible for presenting much of the course material in class meetings.

PHYS B503 Electromagnetic Theory I (1 Unit)
This course is the first semester of a year-long standard sequence on electromagnetism. This semester begins with topics in electrostatics, including Coulomb's and Gauss's Laws, Green functions, the method of images, expansions in orthogonal functions, boundary-value problems, and dielectric materials. The focus then shifts to magnetic phenomena, including the magnetic fields of localized currents, boundary-value problems in magnetostatics, and the interactions of fields and magnetic materials. The last portion of the course treats Maxwell's equations, transformation properties of electromagnetic fields, electromagnetic waves and their propagation and, time permitting, the basics of waveguides. This course is taught in a seminar format, in which students are responsible for presenting much of the course material in class meetings.

PHYS B504 Electromagnetic Theory II (1 Unit)
This course is the second semester of a two-semester graduate level sequence on electromagnetic theory. Topics include electromagnetic radiation, multiple fields, scattering and diffraction theory, special relativity, Lagrangian and Hamiltonian descriptions, radiation from point particle motion, Lienard-Wiechert potentials, classical electron theory and radiation reaction. Additional topics may be included at the discretion of the instructor. This course is taught in a seminar format, in which students are responsible for presenting much of the course material in class meetings. Prerequisite: PHYS B503.

PHYS B505 Classical Mechanics I (1 Unit)
This course will cover mechanics topics familiar from the undergraduate curriculum, but from deeper theoretical and mathematical perspectives. Topics will include Lagrange & Hamilton methods, the central force problem, rigid body motion, oscillations, and canonical transformations. Time permitting, other topics that might be explored include chaos theory, special relativity, and the application of Lagrangian and Hamiltonian methods to continuous systems. This course is taught in a seminar format, in which students are responsible for presenting much of the course material in class meetings.

PHYS B506 Classical Mechanics II (1 Unit)

PHYS B507 Statistical Mechanics I (1 Unit)
Review of Thermodynamics; Equilibrium statistical mechanics -- microcanonical and canonical ensembles; Ideal gases, photons, electrons in metals; Phase transitions; Monte Carlo techniques; Classical fluids, Non-equilibrium statistical mechanics.

PHYS B522 Solid State Physics (1 Unit)
This graduate-level course explores the emergent properties and collective behaviors that arise when atoms and molecules come together in solids and liquids—systems known as condensed matter. Topics include crystal structure and diffraction, the reciprocal lattice and Brillouin zones, crystal binding, lattice vibrations and normal modes, phonon dispersion, Einstein and Debye models for the specific heat, the free electron model, the Fermi surface, electrons in periodic structures, the Bloch theorem, energy band structure, magnetism, superconductivity. Frontier research topics in nanomaterials, quantum information science, and biophysics will also be introduced if time permits. Prerequisites: PHYS B201 and B214 and (B306 or B207 or H213). Lecture three hours and additional recitation sessions as needed.

PHYS B701 Supervised Work (1 Unit)
Supervised Research

PHYS B800 Continuing Enrollment (0 Unit)
Continuing Enrollment

MATH B101 Calculus I (1 Unit)
This is the first in a sequence of two courses that covers single-variable calculus. Topics include functions, limits, continuity, derivatives, differentiation formulas, applications of derivatives, integrals, and the fundamental theorem of calculus. Prerequisite: proficiency in high-school mathematics (including algebra, geometry, and trigonometry).

MATH B102 Calculus II (1 Unit)
This is the second in a sequence of two courses that covers single-variable calculus. Topics include techniques of integration, applications of integration, infinite sequences and series, tests of convergence for series, and power series. Prerequisite: a merit grade in Math 101 (or an equivalent experience).

MATH B201 Multivariable Calculus (1 Unit)
This course extends calculus to functions of multiple variables. Topics include functions, limits, continuity, vectors, directional derivatives, optimization problems, multiple integrals, parametric curves, vector fields, line integrals, surface integrals, and the theorems of Gauss, Green and Stokes. Prerequisite: a merit grade in Math 102 (or an equivalent experience).

MATH B203 Linear Algebra (1 Unit)
This course considers systems of linear equations, matrix algebra, determinants, vector spaces, subspaces, linear independence, bases, dimension, linear transformations, eigenvalues, eigenvectors, orthogonality, and applications of linear algebra. Prerequisite (or corequisite): Math 102.