HENRY A. ROWLAND
DEPARTMENT OF PHYSICS AND ASTRONOMY

http://physics-astronomy.jhu.edu/

Johns Hopkins is the nation’s first research university. That emphasis on research continues to this day and forms the backbone of the undergraduate and graduate programs in the Department of Physics and Astronomy. The department’s research program is focused into four areas of excellence: Astrophysics, Condensed Matter Physics, Elementary Particle Physics, and Plasma Physics. For graduate students interested in these fields, the department offers world-class research opportunities in a friendly and supportive setting. For undergraduates, JHU offers exposure to cutting-edge research combined with a level of personal attention that is typically found only in liberal arts colleges. Nearly all physics majors at JHU work on research projects and many begin as freshmen or sophomores.

All research builds upon an established body of knowledge. To be effective researchers, teachers, or professionals, both undergraduate and graduate students must acquire a core knowledge of physics. Our undergraduate and graduate courses are designed to cover the core subjects at the appropriate levels, leading to advanced courses on a variety of specialized topics. As a consequence, students having different backgrounds or different ultimate objectives can select those parts that are most appropriate for them. The selections are made under the guidance of a faculty advisor. The advisor aids the student in making the most efficient use of his or her time and ensures that his or her program contains a reasonable balance among classroom and laboratory, mathematics, seminars, and introduction to research.

http://physics-astronomy.jhu.edu/

Requirements for the B.A. and B.S. Degrees
(See also Requirements for a Bachelor’s Degree (http://e-catalog.jhu.edu/undergrad-students/academic-policies/requirements-for-a-bachelors-degree).)

The major program is structured so that nearly all students take the same classes during the first two years and must complete the same list of core upper-level courses during their second two years, but permits a variety of choices in upper-level electives. The total number of credits required for the B.A. degree is 120 and the B.S. is 126. By the end of the four years our students share an understanding of classical mechanics, electromagnetism, and quantum mechanics, and have acquired physics lab skills that will support them in graduate school or in a host of other pursuits.

Core Courses
Mathematics
The standard mathematics requirements for all physics majors consist of:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.109</td>
<td>Calculus II (For Physical Sciences and Engineering)</td>
<td>4</td>
</tr>
</tbody>
</table>

or AS.110.113 Honors Single Variable Calculus

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.110.202</td>
<td>Calculus III</td>
<td>4</td>
</tr>
<tr>
<td>or AS.110.211</td>
<td>Honors Multivariable Calculus</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.302</td>
<td>Differential Equations and Applications</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.201</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>or AS.110.212</td>
<td>Honors Linear Algebra</td>
<td>4</td>
</tr>
</tbody>
</table>

Total Credits 20

Physics and Astronomy
The standard physics and astronomy requirements for all physics majors consist of:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.171.105</td>
<td>Classical Mechanics I</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.115</td>
<td>Classical Mechanics Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>AS.171.106</td>
<td>Electricity and Magnetism I</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.116</td>
<td>Electricity and Magnetism Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>AS.171.201</td>
<td>Special Relativity/Waves</td>
<td>4</td>
</tr>
<tr>
<td>or AS.171.309 &amp; AS.171.207</td>
<td>Wave Phenomena with Biophysical Application &amp; Special Relativity</td>
<td>4</td>
</tr>
<tr>
<td>AS.172.203</td>
<td>Contemporary Physics Seminar</td>
<td>1</td>
</tr>
<tr>
<td>AS.171.202</td>
<td>Modern Physics</td>
<td>4</td>
</tr>
<tr>
<td>or AS.171.310</td>
<td>Biological Physics</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.204</td>
<td>Classical Mechanics II</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.301</td>
<td>Electromagnetic Theory II</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.303</td>
<td>Quantum Mechanics I</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.304</td>
<td>Quantum Mechanics II</td>
<td>4</td>
</tr>
<tr>
<td>or AS.171.312</td>
<td>Statistical Physics/Thermodynamics</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.308</td>
<td>Advanced Physics Laboratory</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Credits 38

*Note: AS.171.101-102, AS.171.103-104 or AS.171.107-108 with their labs is acceptable in place of AS.171.105-106, AS.173.115-116

Sample Program of Study
A typical B.S. in Physics program might include the following sequence of courses:

*Note: Because our students arrive with a wide range of mathematical preparation, we advise them to consult the Department of Mathematics to determine the best plan.

Freshman

<table>
<thead>
<tr>
<th>Course Code</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AS.171.105</td>
<td>Classical Mechanics I</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.106</td>
<td>Electricity and Magnetism I</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.115</td>
<td>Classical Mechanics Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>AS.171.309</td>
<td>Wave Phenomena with Biophysical Application</td>
<td>4</td>
</tr>
<tr>
<td>or AS.171.312</td>
<td>Statistical Physics/Thermodynamics</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>or AS.110.109</td>
<td>Calculus II (For Physical Sciences and Engineering)</td>
<td>4</td>
</tr>
</tbody>
</table>

Total Credits 9

9
Recommendations

An additional two semesters of mathematics are recommended, either AS.110.405 Real Analysis I or AS.110.311 Methods of Complex Analysis and one other. It is recommended that Physics majors become proficient in a computer programming language, either independently or through course work. Students are encouraged to broaden their background by taking introductory courses in other natural science or engineering disciplines, such as AS.030.101 Introductory Chemistry I.

Other Departmental Requirements:

A grade of C- or higher is required for a course to be counted towards major requirements. This includes required math courses. An exception for a single course taken in the year before graduation may be granted by the Director of Undergraduate Studies when there are extenuating circumstances.

Honors in the Major:

To receive Honors in Physics, you must have a GPA in your major requirements of a 3.5 or higher.

Senior Thesis

Any student majoring in the department may write a senior thesis, based on original research conducted under the supervision of a member of the faculty. Arrangements for this research will be made on an individual basis. The department views the writing of a senior thesis as an excellent capstone experience to an undergraduate education in physics, and encourages all students to consider it.

Minor in Physics

To earn a minor in Physics, a student must complete four (4) courses (at least 3 credits each) at the 200-level or above, plus AS.172.203 Contemporary Physics Seminar

Donald E. Kerr Memorial Prize

In recognition of Dr. Kerr’s work in microwave physics, the department awards the Donald E. Kerr Memorial Prize each year to the most outstanding undergraduate major graduating in physics.

Graduate Programs

Graduate study in physics and astronomy at Hopkins is intended primarily to prepare Ph.D. graduates for careers in teaching and research in physics and astronomy, or in applications such as biophysics, space physics, and industrial research. Entering students may elect to work toward a Ph.D. in physics or a Ph.D. in astronomy and astrophysics. The two programs are similar in structure but have somewhat different course requirements (see below). A wide range of research projects—both theoretical and experimental—are available for graduate students in Astrophysics, Condensed Matter Physics, Particle Physics, and Plasma Spectroscopy.

Admission

To obtain admission, a student is expected to submit evidence that he or she has a good chance to succeed. Such evidence will ordinarily consist of transcripts of previous academic work, Graduate Record Examination scores (including advanced physics), letters of recommendation, and, for
international students, a Test of English as a Foreign Language (TOEFL) score.

Requirements for the Ph.D. Degree

The Ph.D. program has strong emphasis on early and active involvement in graduate research. Thus, students are required to have a research advisor and file a research summary every semester they are enrolled in the program, starting with the first one. Furthermore, students must complete the required courses with a grade of B- or better; the coursework is typically done over the first two years. In the beginning of the second year, students complete the research examination, and in the beginning of the third year – the University’s Graduate Board Oral examination, both of which are based on completed or proposed research. During the first two years, students are typically involved in introductory research projects, which may or may not be related to their thesis work, and sometimes work with several different advisors, but they must identify (and have an agreement with) a thesis advisor no later than the beginning of their third year in the program, after which point students focus on their thesis research. The thesis is to be completed by no later than the end of the 6th year, ending with an oral presentation of the thesis to a faculty committee.

Course Requirements

Ph.D. in Physics

Students must complete the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.171.603</td>
<td>Electromagnetic Theory</td>
</tr>
<tr>
<td>AS.171.605</td>
<td>Quantum Mechanics</td>
</tr>
<tr>
<td>AS.171.606</td>
<td>and Quantum Mechanics</td>
</tr>
<tr>
<td>AS.171.703</td>
<td>Advanced Statistical Mechanics</td>
</tr>
<tr>
<td>AS.172.632</td>
<td>Physics Seminar</td>
</tr>
</tbody>
</table>

Ph.D. in Astronomy and Astrophysics

Students must complete the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.171.611</td>
<td>Stellar Structure and Evolution</td>
</tr>
<tr>
<td>AS.171.612</td>
<td>Interstellar Medium and Astrophysical Fluid Dynamics</td>
</tr>
<tr>
<td>AS.171.613</td>
<td>Radiative Astrophysics</td>
</tr>
<tr>
<td>AS.171.627</td>
<td>Astrophysical Dynamics</td>
</tr>
<tr>
<td>AS.172.633</td>
<td>Language Of Astrophysics</td>
</tr>
</tbody>
</table>

The department offers a wide range of graduate physics, astrophysics, mathematical methods and statistics classes, and while only five are required, the students are encouraged to use the flexibility of the graduate program and the available classes to design programs of study that best prepare them for their chosen area of research. In addition to the required courses listed above, below is the list of the graduate courses that have been taught in recent years:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>AS.171.610</td>
<td>Numerical Methods-Physics</td>
</tr>
<tr>
<td>AS.171.618</td>
<td>Observational Astronomy</td>
</tr>
<tr>
<td>AS.171.619</td>
<td>Molecular Astrophysics</td>
</tr>
<tr>
<td>AS.171.621</td>
<td>Condensed Matter Physics</td>
</tr>
<tr>
<td>AS.171.622</td>
<td>and Condensed Matter Physics</td>
</tr>
<tr>
<td>AS.171.625</td>
<td>Experimental Particle Physics</td>
</tr>
<tr>
<td>AS.171.639</td>
<td>Group Theory in Physics</td>
</tr>
<tr>
<td>AS.171.644</td>
<td>Exoplanets and Planet Formation</td>
</tr>
<tr>
<td>AS.171.646</td>
<td>General Relativity</td>
</tr>
<tr>
<td>AS.171.648</td>
<td>Physics of Cell Biology: From Mechanics to Information</td>
</tr>
<tr>
<td>AS.171.697</td>
<td>Astro-Particle Physics</td>
</tr>
<tr>
<td>AS.171.672</td>
<td>Introduction Plasma Physics</td>
</tr>
<tr>
<td>AS.171.699</td>
<td>Planets, Life and the Universe</td>
</tr>
<tr>
<td>AS.171.701</td>
<td>Quantum Field Theory</td>
</tr>
<tr>
<td>AS.171.702</td>
<td>and Quantum Field Theory II</td>
</tr>
<tr>
<td>AS.171.704</td>
<td>Phase Transitions and Critical Phenomena</td>
</tr>
<tr>
<td>AS.171.732</td>
<td>Elementary Particle Physics</td>
</tr>
<tr>
<td>AS.171.750</td>
<td>Cosmology</td>
</tr>
<tr>
<td>AS.171.751</td>
<td>Neutron Scattering and Quantum Condensed Matter Physics</td>
</tr>
<tr>
<td>AS.171.752</td>
<td>Black Hole Astrophysics</td>
</tr>
<tr>
<td>AS.171.753</td>
<td>String Theory</td>
</tr>
<tr>
<td>AS.171.755</td>
<td>Fourier Optics and Interferometry in Astronomy</td>
</tr>
<tr>
<td>AS.171.762</td>
<td>Advanced Condensed Matter</td>
</tr>
<tr>
<td>AS.171.783</td>
<td>Black Hole Physics</td>
</tr>
<tr>
<td>AS.171.784</td>
<td>Advanced Particle Theory: &quot;What to Expect at the LHC&quot;</td>
</tr>
<tr>
<td>AS.171.785</td>
<td>Advanced Particle Theory: Dark Matter</td>
</tr>
<tr>
<td>AS.173.608</td>
<td>Advanced Laboratory</td>
</tr>
</tbody>
</table>

Students in both programs must receive at least a B- in each required course, or they will be required to retake the specific course once more and pass it.

Advising

All entering students are assigned to a first-year advisor who works closely with the student through the first two years of graduate study, or until a thesis advisor is found. The first-year advisor advises the student on courses of study, helps familiarize them with the department and provides guidance in finding research opportunities. In the beginning of each fall semester, the department holds a “research jamboree” where incoming students are introduced to the research in the department through a series of brief talks, lab tours, and research group open houses. Thus, the students are familiar, immediately upon their arrival, with the scope of research in the department and can identify prospective research advisors they may wish to work with.

First and Second-Year Research Requirement

First-year students must find, by the end of the third week of class in the fall semester, and by the end of the first week of class the second semester, as well as before the summer term begins, a member of the professorial faculty to advise them in some type of research project. The students are required to submit a short written summary of their research experience at the end of the semester. Students may continue with one advisor through all three semesters, or they may choose to cycle through several different research advisors. In some cases, one of these first-year research advisors may become a thesis advisor, but in others, the thesis advisor may change. This research requirement continues until the end of the second year, or until the student finds a thesis advisor.

The nature of these first-year research projects may vary from student to student, from one advisor to another, and from one sub-field of physics to another. In some cases they lead to published research. In
other cases, they may be first steps in a longer-term research project. And in some cases, they may comprise reading or independent-study projects to develop background for subsequent research. It is left to the individual advisor to determine what the written summary should entail. These research projects are not research assistantships and are performed in addition to other graduate student responsibilities (teaching and graduate coursework), although they are typically merged with RA-supported research for those students supported by RAs.

**Thesis Research and Defense**

Students are required to find a thesis advisor no later than the beginning of the third year. After the student chooses a thesis advisor, the student forms their Thesis Committee consisting of the advisor and two other faculty members (all Thesis Committees contain at least two full-time faculty from the department). These committees function as extended advisory bodies; students have the opportunity to discuss their progress and problems with several faculty. They also conduct one formal annual review of each student’s progress. Research leading to the dissertation can be carried out not only within the Department of Physics and Astronomy, but with appropriate arrangements, either partly or entirely at other locations if necessitated by the project goals. At the conclusion of thesis research, the student presents the written dissertation to the faculty committee and defends the thesis in an oral examination.

**Requirements for the M.A. Degree**

Although the department does not admit students who intend to pursue the master’s degree exclusively, students in the department’s Ph.D. program and students in other Ph.D. programs at Johns Hopkins may apply to fulfill the requirements for the M.A. degree in the Department of Physics and Astronomy. Students from other JHU departments must seek approval from their home department and from the Department of Physics and Astronomy before beginning their M.A. studies.

**Course Requirements for the M.A.**

Students must master the basic undergraduate material covered by the following courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.171.204</td>
<td>Classical Mechanics II</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.301</td>
<td>Electromagnetic Theory II</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.303</td>
<td>Quantum Mechanics I</td>
<td>8</td>
</tr>
<tr>
<td>&amp; AS.171.304</td>
<td>and Quantum Mechanics II</td>
<td></td>
</tr>
<tr>
<td>AS.171.312</td>
<td>Statistical Physics/Thermodynamics</td>
<td>4</td>
</tr>
</tbody>
</table>

Courses taken elsewhere may qualify at the discretion of the Graduate Program Committee.

Students must also complete six one-semester graduate-level (at least three hours/week) courses offered by the Department of Physics and Astronomy. AS.171.801 Independent Research-Graduates AS.171.802 Independent Research-Graduate may be substituted for any of the above-mentioned graduate or undergraduate courses. The research course must include an essay supervised and approved by a faculty member of the Department of Physics and Astronomy.

The student must receive a grade of B- or above in each of the courses. The graduate-level courses may be retaken once; the undergraduate courses cannot be repeated.

Furthermore, the student must complete at least two semesters of research projects, as described in the requirements for the Ph.D., and complete the departmental research exam. The deadline to fulfill all requirements is the date of the Ph.D. thesis defense.

**Facilities**

The Department of Physics and Astronomy’s first facility was Rowland’s measuring engine for determining the solar spectrum in the 1880s. Ever since that time the Department has maintained a long and continuous history in instrumentation. In recent decades this has extended to instrumentation for space missions. The Department maintains a Class-1000 clean room for microfabrication and nanofabrication, a high bay lab, professional and student machine shops, and supports a world-renowned Instrument Development Group (IDG) with six full-time engineers and three full-time machinists.

Among the diverse techniques used for studying condensed matter physics are magnetometry/susceptometry, specific heat and transport measurements, atomic force and magnetic force microscopy, X-ray and electron diffraction, terahertz spectroscopy, and neutron scattering at the nearby NIST Center for Neutron Research and at the Spallation Neutron Source, ORNL. A variety of cryostats, He3 refrigerators, and He3-He4 dilution refrigerators together with high temperature ovens, electromagnets, and superconducting magnets allow measurements to be made from 0.05 K to 1100 K and in magnetic fields up to 14 Tesla. Apparatus for the preparation of samples includes two image furnaces for floating zone growth, single-crystal growth vacuum furnaces, box and tube furnaces, arc furnaces, several high vacuum and ultra-high vacuum chambers for thin film fabrication using evaporation, MBE, pulsed laser deposition, sputtering, and focused ion beam (FIB) milling. Also available on campus are cutting-edge transmission electron microscopes and scanning electron microscopes.

In astrophysics, research groups have state-of-the-art laboratories for testing cryogenic transition-edge bolometer detectors with SQUID read-out electronics, and closed-cycle helium cryocogens. Recent instrumentation advances include the design and manufacture of large free-standing polarization grids and novel high-bandwidth smooth-wall feed horns. Current activities include development of microwave and millimeter-wave instruments for far-infrared and microwave astronomy and cosmology.

The research groups in the department have a wide range of state-of-the-art computer facilities including high performance clusters with over a thousand processors and the largest database at a university—over a petabyte. All undergraduate majors and graduate students have access to high performance workstations.

**Financial Aid**

Students in good standing are normally supported by a combination of fellowships, research assistantships and teaching assistantships. The financial package covers full tuition, individual health insurance, and an academic year salary commensurate with that of other leading research institutions. Teaching assistantship is a common mode of financial support; experience in teaching is a valuable part of the Ph.D. program. A teaching assistantship supports the student during the academic year and is supplemented by a research assistantship during the summer. The assistant is expected to help in the teaching of the general physics course and other introductory and major courses. The typical teaching duties include leading a problem-solving section or laboratory exercises and homework grading. Research assistantships are based on the availability of funding to the research advisor and are arranged directly with him/her. Research assistantships provide an opportunity for deep engagement in ongoing experimental or theoretical
research. In addition, the department and the University offer several fellowships on a competitive basis, some covering travel, supplies or research expenses and some covering a semester’s or a year’s worth of the entire financial package. Some students are supported by external fellowships, such as the pre-doctoral fellowship of the National Science Foundation.

All fellows and teaching and research assistants in the Department of Physics and Astronomy register as full-time students and thus fulfill their residence requirements while holding appointments. Loans and work-study arrangements are available from the Office of Financial Aid.

For current faculty and contact information go to http://physics-astronomy.jhu.edu/people/

Faculty

Chair
Timothy Heckman
Chair and A. Hermann Pfund Professor

Professors
N. Peter Armitage
experimental condensed matter physics.

Charles L. Bennett
Bloomberg Distinguished Professor and Alumni Centennial Professor: experimental astrophysics; cosmology; radio/submillimeter/infrared astronomy; astronomical instrumentation.

Barry J. Blumenfeld
experimental high-energy physics; neutrino physics, hadron colliders.

Collin Broholm
Gerhard H. Dieke Professor (Director, Institute for Quantum Matter): experimental condensed matter physics, using neutron scattering.

Chia-Ling Chien
Jacob L. Hain Professor: experimental condensed matter physics, nanostructured solids.

Andrei V. Gritsan
experimental high-energy physics; colliders.

Marc Kamionkowski

David Kaplan
theoretical particle physics and cosmology.

Julian H. Krolak
theoretical astrophysics, particularly high-energy and relativistic astrophysics.

Robert Leheny
experimental condensed matter physics; disordered materials, soft matter.

Petar Maksimovic
experimental high-energy physics; hadron colliders.

David A. Neufeld
theoretical astrophysics, interstellar medium, astrophysical masers.

Colin A. Norman
theoretical and observational astrophysics.

Daniel H. Reich
experimental condensed matter physics; biological physics.

Adam Riess
Bloomberg Distinguished Professor, Thomas J. Barber Professor, Krieger Eisenhowe Professor and Nobel Laureate: observations of physical cosmology, primarily through the use of distance indicators like supernovae; measurements of dark energy and the expansion history of the universe using optical and near-infrared instruments from space and the ground.

Mark O. Robbins
theoretical condensed matter physics; non-equilibrium processes, atomic origins of macroscopic phenomena.

Morris Swartz
experimental high-energy physics; precision tests of and searches for physics beyond the Standard Model.

Alexander Szalay
Bloomberg Distinguished Professor (Director, IDIES): theoretical astrophysics, galaxy formation.

Oleg Tchernyshyov
theoretical condensed matter physics.

Rosemary F. G. Wyse
astrophysics, galaxy formation and evolution (Director, Theoretical Interdisciplinary Physics and Astrophysics Center).

Associate Professors

Jared Kaplan
effective field theory, particle physics, and cosmology.

Tobias Marriage
cosmology and astrophysics.

Brice Menard
extragalactic astrophysics, cosmology, large surveys.

Nadia Zakamska
observational and theoretical astrophysics.

Assistant Professors

Ibrahima Bah
theoretical high-energy physics and cosmology

Brian Camley
physics of cell biology

Yi Li
theoretical condensed matter physics.

Kevin Schlaufman
observational and theoretical astrophysics.

Francesca Serra
soft matter physics and liquid crystals.

Research Professor

Jonathan A. Bagger
Krieger-Eisenhower Professor: particle theory; theory and phenomenology of supersymmetry, supergravity, and superstrings.

Luciana Bianchi
observational astrophysics, nearby galaxies, stellar populations, hot stars, UV instrumentation.

William P. Blair
experimental astrophysics, supernova remnants; cataclysmic variable stars.

Paul D. Feldman
Academy Professor: experimental astrophysics, spectroscopy, space physics, planetary and cometary atmospheres.

Michael Finkenthal
experimental plasma and atomic physics.

Holland Ford
experimental astrophysics; stellar dynamics, evolution of galaxies, active galactic nuclei, astronomical instrumentation.

Riccardo Giacconi
University Professor and Nobel Laureate: experimental astrophysics, extragalactic astronomy, the early universe.

Richard Conn Henry
Academy Professor (Director, Maryland Space Grant Consortium): astronomy and astrophysics.

Stephan McCandliss
experimental astrophysics; sounding rocket space astronomy in the far UV (Director, Center for Astrophysical Sciences).

H. Warren Moos
the interstellar medium; stellar processes; the solar system; space instrumentation.

Joseph Silk
Homewood Professor: cosmology.

Ethan Vishniac
theoretical astrophysics.

Harold Weaver
ultraviolet, optical, infrared, X-ray, and radio spectroscopy and imaging of comets, planets, and satellites.

Associate Research Professor
Tamas Budavari
observational cosmology, large-scale structure, galaxy clustering; data-intensive parallel computing.

Natalia Drichko
condensed matter physics.

Professors Emeriti
Bruce Barnett
Academy Professor: experimental high energy physics; hadron colliders.

Chih-Yung Chien
experimental high-energy physics; hadron colliders.

Gabor Domokos
theoretical elementary particle physics, astroparticle physics.

Brian R. Judd
Gerhard H. Dieke Professor Emeritus: theoretical atomic and molecular physics, group theory, solid state theory.

Chung W. Kim
theory of elementary particles, nuclear theory, cosmology.

Susan Kovesi-Domokos
theoretical elementary particle physics, astroparticle physics.

Yung Keun Lee
experimental nuclear physics.

Aihud Pevsner
Jacob L. Hain Professor Emeritus: experimental elementary particle physics.

Adjunct and Visiting Appointments
Ronald J. Allen
Adjunct Professor (Space Telescope Science Institute): observational astronomy; spiral structure of galaxies, interstellar medium, radio and optical imaging.

Henry Ferguson
Adjunct Professor (Space Telescope Science Institute): observational cosmology, galaxy evolution, dwarf galaxies, space astronomy instrumentation, and calibration.

Ann E. Hornschemeier
Adjunct Associate Professor (NASA Goddard Space Flight Center): studies of x-ray emission from star formation in galaxies at cosmologically interesting distances.

John MacKenty
Adjunct Professor (Space Telescope Science Institute): Astronomy and Astrophysics.

Roeland van der Marel
Adjunct Professor (Space Telescope Science Institute): extragalactic observational and theoretical astronomy; galaxy structure, dynamics, and formation; black holes.

Peter McCullough
Adjunct Associate Professor (Space Telescope Science Institute): astronomy.

Predrag Nikolic
Adjunct Associate Professor (George Mason University): theoretical condensed matter physics.

Cedomir Petrovic
Adjunct Professor (Brookhaven National Laboratory): experimental condensed matter physics.

Kimberly Weaver
Adjunct Professor (NASA Goddard Space Flight Center): experimental astrophysics.

Joint Appointments
Tamas Budavari
Assistant Professor (Applied Mathematics) observational cosmology, large-scale structure, galaxy clustering; data-intensive parallel computing.

Gregory Eyink
Professor (Applied Mathematics and Statistics): mathematical physics, fluid mechanics, turbulence, dynamical systems.

Michael Falk
Associate Professor (Materials Science and Engineering): theoretical and computational research.
Taekjip Ha
Bloomberg Distinguished Professor (Department of Biophysics, Department of Biomedical Engineering, Department of Biophysics and Biophysical Chemistry)

Tyrel McQueen
Associate Professor (Chemistry): solid state and inorganic chemistry/condensed matter physics.

Jack Morava
Professor (Mathematics): algebraic topology, mathematical physics.

Peter C. Searson
Professor (Materials Science and Engineering): electronic, nanophase, and semiconductor materials.

Sabine Stanley

Darrell F. Strobel
Professor (Earth and Planetary Sciences): planetary atmospheres and astrophysics.

For current course information and registration go to https://sis.jhu.edu/

Courses

**AS.171.101. General Physics: Physical Science Major I. 4.0 Credits.**
First semester of a two-semester sequence in general physics covers mechanics, heat, sound, electricity and magnetism, optics, and atomic physics. Midterm exams for every section are given during the 8 AM section time! Accordingly, students registering for sections at times other than 8 AM must retain availability for 8 AM sections as needed. Corequisite: AS.110.108-AS.110.109, AS.173.111-AS.173.112
Instructor(s): M. Swartz
Area: Engineering, Natural Sciences.

**AS.171.102. General Physics: Physical Science Major II. 4.0 Credits.**
Second semester of a two-semester sequence in general physics covers mechanics, heat, sound, electricity and magnetism, optics, and atomic physics. Midterm exams for every section are given during the 8 AM section time! Accordingly, students registering for sections at times other than 8 AM must retain availability for 8 AM sections as needed. Recommended Course Background: A grade of C- or better in either Physics I or the first semester of Intro to Mechanics I (AS.171.101 OR AS.171.103 OR AS.171.105 OR AS.171.107 OR EN.530.103)
Prerequisites: A grade of C- or better in either Physics 1 or the two-semester sequence of Engineering Mechanics: A(S.171.101 OR AS.171.103 OR AS.171.105 OR AS.171.107) OR (EN.530.103 OR EN.530.123)
Instructor(s): P. Maksimovic
Area: Engineering, Natural Sciences.

**AS.171.103. General Physics I for Biological Science Majors. 4.0 Credits.**
First-semester of two-semester sequence in calculus-based general physics, tailored to students majoring in one of the biological sciences. In this term, the topics covered include the basic principles of classical mechanics and fluids as well as an introduction to wave motion. Recommended Corequisites: (AS.173.111) AND (AS.110.106 or AS.110.108 or AS.110.113). Midterm exams are given at 8am Tuesdays, so students must leave their schedules open at this time in order to be able to take these exams
Instructor(s): C. Broholm
Area: Engineering, Natural Sciences.

**AS.171.104. General Physics/Biology Majors II. 4.0 Credits.**
This two-semester sequence is designed to present a standard calculus-based physics preparation tailored to students majoring in one of the biological sciences. Topics in electricity & magnetism, optics, and modern physics will be covered in this semester. Midterm exams for every section are given during the 8AM section time! Accordingly, students registering for sections at times other than 8 AM must retain availability for 8 AM sections as needed. Recommended Course Background: C- or better in AS.171.101 or AS.171.103; Corequisite: AS.110.109, AS 173.112.
Instructor(s): N. Armitage
Area: Engineering, Natural Sciences.

**AS.171.105. Classical Mechanics I. 4.0 Credits.**
An in-depth introduction to classical mechanics intended for physics majors/minors and other students with a strong interest in physics. This course treats fewer topics than AS.171.101 and AS.171.103 but with greater mathematical sophistication. It is particularly recommended for students who intend to take AS.171.201-AS.171.202 or AS.171.309-AS.171.310. Recommended Corequisites: AS.173.115 and AS.110.108
Instructor(s): M. Robbins
Area: Engineering, Natural Sciences.

**AS.171.106. Electricity and Magnetism I. 4.0 Credits.**
Classical electricity and magnetism with fewer topics than 171.101-103, but with greater mathematical sophistication. Particularly recommended for students who plan to take AS.171.201-AS.171.202. Recommended Course Background: C- or better in AS.171.105; Corequisite: AS.173.116, AS.110.109
Instructor(s): C. Bennett
Area: Engineering, Natural Sciences.

**AS.171.107. General Physics for Physical Sciences Majors (AL). 4.0 Credits.**
This two-semester sequence in general physics is identical in subject matter to AS.171.101-AS.171.102, covering mechanics, heat, sound, electricity and magnetism, optics, and modern physics, but differs in instructional format. Rather than being presented via lectures and discussion sections, it is instead taught in an "active learning" style with most class time given to small group problem-solving guided by instructors. Midterm exams for every section are given during the 8AM section time! Accordingly, students registering for sections at times other than 8 AM must retain availability for 8 AM sections as needed. Recommended Corequisites: (AS.173.111) AND (AS.110.106 or AS.110.108 or AS.110.113)
Instructor(s): R. Leheny, R. Wyse
Area: Engineering, Natural Sciences.
AS.171.108. General Physics for Physical Science Majors (AL). 4.0 Credits.
This two-semester sequence in general physics is identical in subject matter to AS.171.101-AS.171.102, covering mechanics, heat, sound, electricity and magnetism, optics, and modern physics, but differs in instructional format. Rather than being presented via lectures and discussion sections, it is instead taught in an “active learning” style with most class time given to small group problem-solving guided by instructors. Recommended Course Background: A grade of C- or better in either Physics I or the first semester of Engineering Mechanics (AS.171.101 OR AS.171.103 OR AS.171.105 OR AS.171.107 OR EN.530.103)
Prerequisites: Corequisite: (AS.110.107 OR AS.110.109 OR AS.110.211 OR AS.110.113)
Instructor(s): D. Reich; P. Maksimovic
Area: Engineering, Natural Sciences.

AS.171.113. Subatomic World. 3.0 Credits.
Introduction to the concepts of physics of the subatomic world: symmetries, relativity, quanta, neutrinos, particles and fields. The course traces the history of our description of the physical world from the Greeks through Faraday and Maxwell to quantum mechanics in the early 20th century and on through nuclear physics and particle physics. The emphasis is on the ideas of modern physics, not on the mathematics. Intended for non-science majors.
Instructor(s): B. Blumenfeld
Area: Natural Sciences.

AS.171.118. Stars and the Universe: Cosmic Evolution. 3.0 Credits.
This course looks at the evolution of the universe from its origin in a cosmic explosion to emergence of life on Earth and possibly other planets throughout the universe. Topics include big-bang cosmology; origin and evolution of galaxies, stars, planets, life, and intelligence; black holes; quasars; and relativity theory. The material is largely descriptive, based on insights from physics, astronomy, geology, chemistry, biology, and anthropology.
Instructor(s): W. Zheng
Area: Natural Sciences.

AS.171.123. How to build an iPhone: physics in modern life. 3.0 Credits.
As the famous author Arthur C. Clarke posited, “Any sufficiently advanced technology is indistinguishable from magic.” The goal of this course is to understand the workings of and the science behind modern technologies such as the iPhone, internet, GPS, and others. We will discuss the technology itself, as well as the story of how it came to be and the people involved. Emphasis will be on the ideas behind these technologies, not the mathematics. Intended for both nonscience and science majors, every attempt will be made to keep any math at the level of simple algebra.
Instructor(s): C. Morris; L. Pan
Area: Natural Sciences.

AS.171.125. It's not magic, it's physics: Extraordinary Experiments. 3.0 Credits.
Students will learn key concepts of everyday physics through experimentation. They will design, build, and run experiments themselves. The course will be graded on participation and a graded final presentation.
Instructor(s): M. Valdivia Leiva
Area: Natural Sciences.

AS.171.127. Freshman Seminar: The Unsolved Mysteries of the Cosmos. 3.0 Credits.
While our knowledge of the universe has expanded greatly over the past century, there are some very basic problems that stump astronomers to this very day. In this course, we will explore some of the unsolved mysteries that astronomers are actively working on, including the formation of planets to the composition of the universe. This course will be a freshman seminar directed towards non-physical science majors. The focus will be on qualitative questions and phenomena rather than numerical details.
Instructor(s): M. Rahman
Area: Natural Sciences.

AS.171.131. Physics and Technology in Society. 3.0 Credits.
This course presents technology and science issues and how they shape public policy. Students will learn how institutions carry out scientific research while exploring the interactions between the scientific community and policy makers.
Instructor(s): M. Valdivia Leiva
Area: Natural Sciences.

AS.171.132. Now I See! Optical Phenomena Explained. 1.0 Credit.
Could you explain why rainbows form an arc or how it is possible to bend light to make an object invisible? This course aims to clearly explain some of the most beautiful optical phenomena encountered in nature or in a lab by teaching simple physics principles and using in-class demonstrations. The course is not math intensive and, rather, seeks to help the student gain an appreciation for the basic principles behind these optical effects without becoming lost in complex mathematics. An emphasis will be placed on current research that directly makes use of the physics underlying the phenomena. The ultimate goal of this course is to show students that physics is powerfully beautiful and to build their appreciation for it.
Instructor(s): G. Bosse
Area: Natural Sciences.

AS.171.133. Black Holes and Other Compact Objects: For Non-Majors. 3.0 Credits.
This is a lecture and discussion course aimed at undergraduate students who are not physics and astronomy majors. The topic of the lectures will be a basic overview of the qualitative properties of and historical work on compact astrophysical objects (such as black holes, neutron stars, white dwarfs) and related phenomena.
Instructor(s): J. Bankert
Area: Natural Sciences.

AS.171.201. Special Relativity/Waves. 4.0 Credits.
Course continues introductory physics sequence (begins with AS.171.105-AS.171.106). Special theory of relativity, forced and damped oscillators, Fourier analysis, wave equation, reflection and transmission, diffraction and interference, dispersion. Meets with AS.171.207.
Prerequisites: Corequisite: AS.110.202 OR AS.110.211; Students must have completed Lab Safety training prior to registering for this class.; (AS.171.106 OR AS.171.108 OR AS.171.102 OR AS.171.104 AND Calculus II (AS.110.107 OR AS.110.109 OR AS.110.113))
Instructor(s): D. Reich
Area: Engineering, Natural Sciences.
AS.171.202. Modern Physics. 4.0 Credits.
Course completes four-semester introductory sequence that includes AS.171.105-AS.171.106 and AS.171.201. Planck's hypothesis, de Broglie waves, Bohr atom, Schrödinger equation in one dimension, hydrogen atom, Pauli exclusion principle, conductors and semiconductors, nuclear physics, particle physics.
Instructor(s): F. Serra
Area: Natural Sciences.

AS.171.204. Classical Mechanics II. 4.0 Credits.
Principles of Newtonian and Lagrangian mechanics; application to central-force motion, rigid body motion, and the theory of small oscillations. Recommended Course Background: AS.110.108 and AS.110.109, AS.110.202, AS.171.201, or AS.171.309. AS.110.201 or equivalent is strongly recommended.
Prerequisites: Pre-req: AS.110.302 or equivalent.
Instructor(s): B. Blumenfeld
Area: Natural Sciences.

AS.171.205. Introduction to Practical Data Science: Beautiful Data. 3.0 Credits.
The class will provide an overview of data science, with an introduction to basic statistical principles, databases, fundamentals of algorithms and data structures, followed by practical problems in data analytics. Recommend Course Background: Familiarity with principles of computing.
Instructor(s): S. Szalay
Area: Natural Sciences, Quantitative and Mathematical Sciences.

AS.171.207. Special Relativity. 1.0 Credit.
Three-week introduction to special relativity for students who elect to take AS.171.209 in place of AS.171.201.
Prerequisites: Corequisite: AS.110.202 or AS.110.211; Prerequisite: AS.171.106 preferred or AS.171.108 or AS.171.102 OR AS.171.104 AND (AS.110.107 OR AS.110.109 OR AS.110.113)
Instructor(s): D. Reich
Area: Natural Sciences.

AS.171.301. Electromagnetic Theory II. 4.0 Credits.
Static electric and magnetic fields in free space and matter; boundary value problems; electromagnetic induction; Maxwell's equations; and an introduction to electrodynamics.
Prerequisites: Prereqs: (AS.171.102 OR AS.171.104 OR AS.171.106 OR AS.171.108) AND Calculus III (AS.110.202 OR AS.110.211) AND Linear Algebra (AS.110.201 OR AS.110.212)
Instructor(s): K. Schlauffman
Area: Natural Sciences.

AS.171.303. Quantum Mechanics I. 4.0 Credits.
Fundamental aspects of quantum mechanics. Uncertainty relations, Schrödinger equation in one and three dimensions, tunneling, harmonic oscillator, angular momentum, hydrogen atom, spin, Pauli principle, perturbation theory (time-independent and time-dependent), transition probabilities and selection rules, atomic structure, scattering theory. Recommended Course Background: AS.110.302 or AS.110.306.
Prerequisites: (AS.171.202 AND AS.171.204) AND (AS.110.201 OR AS.110.212) AND (AS.110.202 OR AS.110.211)
Instructor(s): C. Chien
Area: Natural Sciences.

AS.171.304. Quantum Mechanics II. 4.0 Credits.
Instructor(s): Y. Li
Area: Natural Sciences.

AS.171.309. Wave Phenomena with Biophysical Application. 4.0 Credits.
Introduction to wave phenomena, primarily through study of biophysical probes that depend on the interaction of electromagnetic radiation with matter. Topics include Fourier Analysis; standing waves; sound and hearing; diffraction and crystallography; geometrical and physical optics - the physics of modern light microscopy; quantum mechanics - how living things absorb light; NMR and MRI. Occasional laboratory exercises are included.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): D. Reich
Area: Natural Sciences.

AS.171.310. Biological Physics. 4.0 Credits.
Introduces topics of classical statistical mechanics. Additional topics include low-Reynolds number hydrodynamics and E&M of ionic solutions, via biologically relevant examples.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.; (AS.171.106 OR AS.171.108 OR AS.171.102 OR AS.171.104) AND (AS.110.107 OR AS.110.109 OR AS.110.113)
Instructor(s): F. Serra
Area: Natural Sciences.

AS.171.312. Statistical Physics/Thermodynamics. 4.0 Credits.
Undergraduate course that develops the laws and general theorems of thermodynamics from a statistical framework.
Prerequisites: AS.171.202 and Calculus II (AS.110.107 or AS.110.109 or AS.110.113). It is recommended that students have also taken Quantum Mechanics (AS.171.303), Linear Algebra (AS.110.201 or AS.110.212) and Calculus III (AS.110.202 or AS.110.211)
Instructor(s): J. Kaplan
Area: Natural Sciences.

AS.171.313. Introduction to Stellar Physics. 3.0 Credits.
Survey of stellar astrophysics. Topics include stellar atmospheres, stellar interiors, nucleosynthesis, stellar evolution, supernovae, white dwarfs, neutron stars, pulsars, black holes, binary stars, accretion disks, protostars, and extrasolar planetary systems. Recommended Course Background: AS.110.108-AS.110.109, AS.171.202
Instructor(s): R. Wyse
Area: Natural Sciences.

AS.171.314. Introduction to Galaxies and Active Galactic Nuclei. 3.0 Credits.
This course will introduce student to the physics of galaxies and their constituents: stars, gas, dust, dark matter and a supermassive black hole in the central regions.
Instructor(s): R. Wyse
Area: Natural Sciences.
AS.171.321. Introduction to Space, Science, and Technology. 3.0 Credits.
Topics include space astronomy, remote observing of the earth, space science, planetary exploration, human space flight, space environment, orbits, propulsion, spacecraft design, attitude control and communication. Crosslisted by Departments of Earth and Planetary Sciences, Materials Science and Engineering and Mechanical Engineering. Recommended Course Background: AS.171.101-AS.171.102 or similar; AS.110.108-AS.110.109.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): J. MacKenty; S. McCandliss
Area: Engineering, Natural Sciences.

AS.171.324. Statistical thinking and data analysis. 3.0 Credits.
We live in a complex, data-rich world with a flux of information increasing exponentially. We will start from information theory concepts and learn how to *understand* statistics. We will then learn techniques to reveal structure in a variety of datasets: news reports, scientific articles, geography, cities, social networks, etc. and how to use this knowledge to make decisions and predictions. We will explore patterns, correlations, fractals. This course will allow the student to better understand the complex world we live in. It will involve some python coding. Junior, senior and graduate students only.
Instructor(s): B. Menard
Area: Natural Sciences.

AS.171.333. Planets, Life and the Universe. 3.0 Credits.
This multidisciplinary course explores the origins of life, planets’ formation, Earth’s evolution, extrasolar planets, habitable zones, life in extreme environments, the search for life in the Universe, space missions and planetary protection. Co-listed with AS.020.334, AS.020.616 and AS.270.335
Prerequisites: Students may not register for this class if they have already received credit for AS.020.334 or AS.270.335.
Instructor(s): C. Norman; J. Diruggiero; N. Levin
Area: Engineering, Natural Sciences.

AS.171.405. Condensed Matter Physics. 3.0 Credits.
Undergraduate course covering basic concepts of condensed matter physics: crystal structure, diffraction and reciprocal lattices, electronic and optical properties, band structure, phonons, superconductivity and magnetism. Co-listed with AS.171.621 Recommended Course Background: AS.171.304, AS.110.201-AS.110.202.
Instructor(s): O. Tchernyshyov
Area: Natural Sciences.

AS.171.406. Condensed Matter Physics. 3.0 Credits.
Instructor(s): C. Broholm
Area: Natural Sciences.

AS.171.408. Nuclear and Particle Physics. 3.0 Credits.
Basic properties of nuclei, masses, spins, parity. Nuclear scattering, interaction with electromagnetic radiation, radioactivity, Pions, muons, and elementary particles, including resonances. Recommended Course Background: AS.171.303
Instructor(s): A. Gritsan
Area: Natural Sciences.

AS.171.410. Physical Cosmology. 3.0 Credits.
This course provides an overview of modern physical cosmology. Topics covered include: the contents, shape, and history of the universe; the big bang theory; dark matter; dark energy; the cosmic microwave background; Hubble’s law; the Friedmann equation; and inflation. Recommended Course Background: (AS.171.101-AS.171.102), or (AS.171.103-AS.171.104), or (AS.171.105-AS.171.106), or (AS.171.107-AS.171.108), or equivalent.
Instructor(s): C. Bennett
Area: Natural Sciences.

AS.171.411. Light and Optics. 3.0 Credits.
What is light? How does it propagate and interact with matter? How do we use it to transmit information? How does technology make use of light? This course is designed for majors in physics as well as other science and engineering departments.
Instructor(s): B. Menard
Area: Engineering, Natural Sciences.

AS.171.416. Numerical Methods for Physicists. 4.0 Credits.
Instructor(s): K. Schlaufman
Area: Natural Sciences, Quantitative and Mathematical Sciences.

AS.171.425. Group Theory in Physics. 3.0 Credits.
Introduction to finite and Lie groups, representations and applications to quantum mechanics, condensed matter physics, and other fields of physics; selected topics from differential geometry and algebraic topology. Recommended Prerequisite: AS.171.304
Instructor(s): Y. Li
Area: Natural Sciences.

AS.171.472. Introduction to Plasma Physics & Atomic Processes in Hot Plasmas. 3.0 Credits.
Course will be a combination between an introduction to plasma physics and an overview of the basic atomic processes which determine the properties of hot, laboratory and astrophysical plasmas. Undergraduate students may register online for this course and will be assigned 3 credits during the add/drop period. Co-taught with AS.171.672
Instructor(s): M. Finkenthal
Area: Natural Sciences.

AS.171.501. Independent Research- Undergraduate. 3.0 Credits.
Students may register for independent research with a faculty member in the Department of Physics and Astronomy. A research plan should be submitted to the Director of Undergraduate Study before the add/drop date that includes project details, the number of hours of effort each week and the number of credits. This course may not be used as one of the two electives required for a BA, but one semester of research may be used as one of four focused electives in a BS program.
Instructor(s): Staff.

AS.171.502. Undergraduate Independent Research. 0.0 - 3.0 Credits.
Research done in senior year in conjunction with experimental equipment of intermediate laboratory or as special project in research group. Credit for independent study given to junior and senior students who act as tutors.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): Staff.
AS.171.503. Senior Thesis. 3.0 Credits.
Preparation of a substantial thesis based upon independent student research, supervised by at least one faculty member in Physics and Astronomy. This course may only be taken for credit during one semester. However, students are expected to have engaged in their research project during previous semesters through 171.501-502, summer research, etc. This course may not be used as one of the two electives required for a BA, but can be used as one of the four focused electives in a BS program. Open to senior department majors only.
Instructor(s): N. Markovic; R. Wyse; T. Marriage Writing Intensive.

AS.171.504. Senior Thesis. 0.0 - 3.0 Credits.
Preparation of a substantial thesis based upon independent student research, supervised by at least one faculty member in Physics and Astronomy.
Instructor(s): M. Kamionkowski; O. Tchernyshyov; R. Leheny; T. Marriage Writing Intensive.

AS.171.595. Internship. 1.0 Credit.
Instructor(s): Staff.

AS.171.597. Independent Research. 3.0 Credits.
Instructor(s): Staff.

AS.171.603. Electromagnetic Theory.
Theory of the Maxwell equations, with static and dynamic applications, boundary-value problems, guided and free waves, diffraction, scattering, special relativity, electron theory.
Instructor(s): J. Krolik.

AS.171.605. Quantum Mechanics.
Review of wave mechanics and the Schrödinger equation, Hilbert space, harmonic oscillator, the WKB approximation, central forces and angular momentum, scattering, electron spin, density matrix, perturbation theory (time-independent and time-dependent), quantized radiation field, absorption and emission of radiation, identical particles, second quantization, Dirac equation.
Instructor(s): O. Tchernyshyov.

AS.171.606. Quantum Mechanics.
Review of wave mechanics and the Schrödinger equation, Hilbert space, harmonic oscillator, the WKB approximation, central forces and angular momentum, scattering, electron spin, density matrix, perturbation theory (time-independent and time-dependent), quantized radiation field, absorption and emission of radiation, identical particles, second quantization, Dirac equation. Recommended Course Background: AS.171.303 and AS.171.304
Instructor(s): I. Bah.

Topics in applied mathematics used by physicists, covering numerical methods: linear problems, numerical integration, pseudo-random numbers, finding roots of nonlinear equations, function minimization, eigenvalue problems, fast Fourier transforms, solution of both ordinary and partial differential equations. Undergraduate students may register online for this course and will be assigned 3 credits during the add/drop period.
Instructor(s): K. Schlaufman.

AS.171.611. Stellar Structure and Evolution.
Basic physics of stellar structure and evolution will be discussed with emphasis on current research.
Instructor(s): E. Vishniac.

AS.171.612. Interstellar Medium and Astrophysical Fluid Dynamics.
Instructor(s): C. Norman.

AS.171.613. Radiative Astrophysics.
A one-term survey of the processes that generate radiation of astrophysical importance. Topics include radiative transfer, the theory of radiation fields, polarization, and space-based observations. For each wavelength range (gamma rays, X-rays, UV, visible, IR, radio) we will discuss the type of detector used, the range of possible observations and current open questions. We will also discuss the dominant astronomical and terrestrial sources across the spectrum, and study the differences between ground- and space-based observations.
Instructor(s): D. Neufeld.

AS.171.618. Observational Astronomy.
How do we observe the Universe at each wavelength and what do we see? This course will present the knowledge required for astronomical observations across the entire spectrum. For each wavelength range (gamma rays, X-rays, UV, visible, IR, radio) we will discuss the type of detector used, the range of possible observations and current open questions. We will also discuss the dominant astronomical and terrestrial sources across the spectrum, and study the differences between ground- and space-based observations.
Instructor(s): B. Menard.

An advanced graduate level course that emphasizes the importance of molecules in astrophysical environments as diverse as interstellar clouds, circumstellar outflows, cometary comae, and active galactic nuclei. Topics will include the chemistry and photochemistry of astrophysical molecules; molecular excitation; astrophysical masers; interstellar molecular clouds; circumstellar shock waves; circumstellar outflows; cometary comae; molecular accretion disks.
Instructor(s): D. Neufeld.

This sequence is intended for graduate students in physics and related fields. Topics include: metals and insulators, diffraction and crystallography, phonons, electrons in a periodic potential, transport. Co-listed with AS.171.405
Instructor(s): O. Tchernyshyov.

This sequence is intended for graduate students in physics and related fields. Topics include superconductivity, magnetism, metal-insulator transitions, low dimensional materials, quantized hall effect.
Instructor(s): C. Broholm.

AS.171.625. Experimental Particle Physics.
For graduate students interested in experimental particle physics, or theory students, or students from other specialties. Subjects covered: experimental techniques, including particle beams, targets, electronics, and various particle detectors; and a broad description of high energy physics problems. Undergraduate students may register online for this course and will be assigned 3 credits during the add/drop period.
Instructor(s): A. Gritsan.

AS.171.627. Astrophysical Dynamics.
This is a graduate course that covers the fundamentals of galaxy formation, galactic structure and stellar dynamics and includes topics in current research.
Instructor(s): C. Norman.

AS.171.629. First Year Research.
Instructor(s): P. Maksimovic.

AS.171.630. First Year Research.
Instructor(s): P. Maksimovic; R. Wyse.
**AS.171.639. Group Theory in Physics.**
Introduction to finite and Lie groups, representations and applications to quantum mechanics, condensed matter physics, and other fields of physics; selected topics from differential geometry and algebraic topology.
Instructor(s): Y. Li
Area: Natural Sciences.

**AS.171.641. Second Year Research.**
Instructor(s): P. Maksimovic.

**AS.171.642. Second Year Research.**
Instructor(s): P. Maksimovic; R. Wyse.

**AS.171.644. Exoplanets and Planet Formation.**
A graduate-level introduction to the properties of the solar system, the known exoplanet systems, and the astrophysics of planet formation and evolution. Topics also include the fundamentals of star formation, protoplanetary disk structure and evolution, exoplanet detection techniques, and the status of the search for other Earths in the Galaxy. Upper-level undergraduates may enroll with the permission of the instructor.
Instructor(s): K. Schlaufman.

**AS.171.646. General Relativity.**
An introduction to the physics of general relativity. Principal topics are: physics in curved spacetimes; the Equivalence Principle; the Einstein Field Equations; the post-Newtonian approximation and Solar System tests; the Schwarzschild and Kerr solutions of the Field Equations and properties of black holes; Friedmann solutions and cosmology; and gravitational wave propagation and generation.
Instructor(s): D. Kaplan
Area: Natural Sciences.

**AS.171.648. Physics of Cell Biology: From Mechanics to Information.**
Cells are actively-driven soft materials – but also efficient sensors and information processors. This course will cover the physics of those cellular functions, from the mechanics of DNA to the sensing of chemical signals. Questions answered include: How does polymer physics limit how quickly chromosomes move? Why do cells use long, thin flagella to swim? What limits the accuracy of a cell's chemotaxis? Some experience with partial differential equations required. No biology knowledge beyond the high school level necessary. Some problem sets will require minimal programming.
Instructor(s): B. Camley
Area: Natural Sciences.

**AS.171.672. Introduction Plasma Physics.**
Course will be a combination between an introduction to plasma physics and an overview of the basic atomic processes which determine the properties of hot, laboratory and astrophysical plasmas. Undergraduate students may register online for this course and will be assigned 3 credits during the add/drop period. Co-taught with AS.171.472
Instructor(s): M. Finkenthal.

**AS.171.697. Astro-Particle Physics.**
Topics include: Dark matter, dark energy, ultra-high energy cosmic rays, neutrino astrophysics, black holes, WIMPS, sterile neutrinos, axions, gamma ray bursts, particle acceleration, cosmic backgrounds, dark energy equation-of-state. Senior undergraduates with permission.
Instructor(s): M. Kamionkowski.

**AS.171.699. Planets, Life and the Universe.**
This multidisciplinary course explores the origins of life, planets' formation, Earth's evolution, extrasolar planets, habitable zones, life in extreme environments, the search for life in the Universe, space missions and planetary protection. Graduate students only. Meets with AS.171.333.
Instructor(s): C. Norman.

**AS.171.701. Quantum Field Theory.**
Introduction to relativistic quantum mechanics and quantum field theory. Canonical quantization; scalar, spinor, and vector fields; scattering theory; renormalization; functional integration; spontaneous symmetry breaking; Standard Model of particle physics.
Instructor(s): M. Kamionkowski.

**AS.171.702. Quantum Field Theory II.**
Introduction to relativistic quantum mechanics and quantum field theory. Recommended Course Background: AS.171.605-AS.171.606 or equivalent.
Instructor(s): M. Kamionkowski.

**AS.171.703. Advanced Statistical Mechanics.**
Brief review of basic statistical mechanics and thermodynamics. Then hydrodynamic theory is derived from statistical mechanics and classical treatments of phase transitions, including Ginzburg-Landau theory.
Instructor(s): R. Leheny.

**AS.171.704. Phase Transitions and Critical Phenomena.**
Course covers phase transitions and critical phenomena. Building on the ideas of spontaneous symmetry breaking and scale invariance at a critical point we develop Landau's theory of phase transitions and the apparatus of renormalization group using both analytic and numerical techniques for studying interacting systems.
Instructor(s): O. Tchernyshyov.

**AS.171.732. Elementary Particle Physics.**
Description TBA
Instructor(s): M. Swartz.

**AS.171.750. Cosmology.**
Review of special relativity and an introduction to general relativity, Robertson-Walker metric, and Friedmann equation and solutions. Key transitions in the thermal evolution of the universe, including big bang nucleosynthesis, recombination, and reionization. The early universe (inflation), dark energy, dark matter, and the cosmic microwave background. Development of density perturbations, galaxy formation, and large-scale structure.
Instructor(s): C. Norman.

**AS.171.751. Neutron Scattering and Quantum Condensed Matter Physics.**
Introduction to the use of neutron scattering techniques to probe atomic scale structure and dynamics of hard condensed matter. Subjects covered include basic theory of nuclear and magnetic neutron scattering, neutron sources and instrumentation, polarized neutrons, Larmor labeling, structural refinement methods, surfaces and interfaces, group theoretical analysis of magnetic structures, phonons, magnetic excitations, and critical phenomena.
Prerequisites: AS.171.621 OR AS.171.622
Instructor(s): C. Broholm.
Instructor(s): D. Kaplan.

experiments. that can be tested at the CERN Large Hadron Collider and other particle
The course will focus on scenarios and principles for new particle physics
AS.171.784. Advanced Particle Theory: “What to Expect at the LHC”.

AS.171.785. Advanced Particle Theory: Dark Matter.
The overwhelming evidence that dark matter exists and that it is not part
of the fundamental theory of matter (the standard model) suggests the
need for a graduate course. I will cover what is known and not known
about dark matter, being specific enough to open lines of inquiry. I will
cover what the rules of quantum field theory would allow it to be and
how it could interact with us. I will go over possible mechanisms that
explain the generation of dark matter in our universe in the first place. In
addition, I will go over the ways to potentially discover (interact with) it
directly. The first half or more of the course should be mostly accessible
to advanced graduate students in astrophysics and high-energy particle
experimentists. The last half/third will be more field-theory oriented
Instructor(s): D. Kaplan
Area: Natural Sciences.

Sec. 03 Swartz, Morris Sec. 04 Chien, Chia-ling Sec. 05 Kamionkowski
Sec. 06 Reich Sec. 07 McCandliss Sec. 08 Krolik Sec. 10 Norman Sec.
11 Blumenfeld Sec. 12 Heckman Sec. 14 Szalay Sec. 15 Ford Sec. 16
Drichko Sec. 17 Wyse Sec. 18 Vishniac Sec. 19 Neufeld Sec. 20 Turner
Sec. 21 Blair Sec. 22 Robbins Sec. 23 Kaiser Sec. 24 Broholm Sec 25
Bianchi Sec. 26 Zakamska Sec. 27 Kaplan, David Sec. 28 Finkenthal Sec.
29 Leheny Sec. 30 Bah Sec. 31 Tchernyshyov Sec. 32 Bennett Sec. 33
Kaplan, Jared Sec. 34 Gritsan Sec. 35 Armitage Sec. 36 Maksimovic Sec.
37 Riess Sec. 38 Marriage Sec. 39 Menard Sec. 40 McQueen
Instructor(s): Staff.

AS.171.802. Independent Research-Graduate.
Sec. 03 - Swartz, Morris Sec. 04 - Chien, Chia-ling Sec. 05 - Kamionkowski
Sec. 06 - Reich Sec. 07 - McCandliss Sec. 08 - Krolik Sec. 10 - Norman
Sec. 11 - Blumenfeld Sec. 12 - Heckman Sec. 14 - Szalay Sec. 15 - Ford
Sec. 16 - Drichko Sec. 17 - Wyse Sec. 18 - Vishniac Sec. 19 - Neufeld Sec.
20 - Turner Sec. 21 - Blair Sec. 22 - Robbins Sec. 23 - Kaiser Sec. 24 -
Broholm Sec. 25 - Bianchi Sec. 26 - Zakamska Sec. 27 - Kaplan, David
Sec. 28 - Finkenthal Sec. 29 - Leheny Sec. 31 - Tchernyshyov Sec. 32 -
Bennett Sec. 33 - Kaplan, Jared Sec. 34 - Gritsan Sec. 35 - Armitage Sec.
36 - Maksimovic Sec. 37 - Riess Sec. 38 - Marriage Sec. 39 - Menard Sec.
40 - McQueen
Instructor(s): Staff.

AS.172.203. Contemporary Physics Seminar. 1.0 Credit.
This seminar exposes physics majors to a broad variety of contemporary
experimental and theoretical issues in the field. Students read and
discuss reviews from the current literature, and are expected to make
an oral or written presentation. Recommended Course Background:
AS.171.101-AS.171.102, AS.171.103-AS.171.104, or AS.171.105-
AS.171.106.
Instructor(s): N. Drichko
Area: Natural Sciences.

AS.172.601. Department Colloquium.
Instructor(s): Staff.

AS.172.604. Joint JHU/STScI Colloquium.
A joint JHU Department of Physics and Astronomy and Space Telescope
Science Institute Colloquium Series.
Instructor(s): Staff.

Intended for beginning graduate students. Study of the methods and
results of modern physics and other topics of interest. Each student will
discuss some phase of the subject. Graduate students only.
Instructor(s): Staff.
AS.173.633. Language Of Astrophysics.
Survey of the basic concepts, ideas, and areas of research in astrophysics, discussing general astrophysical topics while highlighting specialized terms often used compared to physics.
Instructor(s): E. Vishniac.

During the Spring 2015 Planets Life and the Universe Seminar, we will read and discuss classic papers and (later in the semester) frontier research on the fundamental issues concerning the Origin of Life on our planet Earth and Exoplanets in general. The recent Kepler mission has now shown that are typical earth-like planets around every typical star in the Universe-- giving almost Avagadro's number of earthlike planets in our Universe. The study of Life in the Universe consequently becomes an observational science. The intellectual framework underpinning these endeavors becomes one of the central intellectual issues of our age (possibly any age!). We will have relaxed and enjoyable discussions of these topics on Friday afternoons. At times mathematical and physics based fluency will be useful. Recommended Course Background: AS.171.333/AS.171.699 or AS.020.334/AS.020.616
Instructor(s): Staff.

AS.172.722. Hot Topics in Astrophysics.
Instructor(s): C. Norman.

AS.172.731. CAS Research Seminar.
Instructor(s): S. McCandliss.

AS.172.732. CAS Research Seminar.
Instructor(s): S. McCandliss.

Instructor(s): Staff.

AS.172.751. Elementary Particle Physics Seminar.
Instructor(s): Staff.

AS.172.752. Elementary Particle Physics Seminar.
Instructor(s): P. Maksimovic.

AS.172.753. Advanced Particle Theory Seminar.
Instructor(s): Staff.

AS.172.754. Advanced Particle Theory Seminar.
Instructor(s): J. Kaplan.

Instructor(s): Staff.

Instructor(s): N. Armitage.

AS.173.111. General Physics Laboratory I. 1.0 Credit.
Experiments are chosen from both physical and biological sciences and are designed to give students background in experimental techniques as well as to reinforce physical principles. Corequisite: AS.171.101, AS.171.103, or AS.171.105
Instructor(s): C. Chien; J. Mumford
Area: Natural Sciences.

AS.173.112. General Physics Laboratory II. 1.0 Credit.
Experiments are chosen from both physical and biological sciences and are designed to give students background in experimental techniques as well as to reinforce physical principles. Recommended Course Background: AS.173.111; Corequisite: AS.171.102.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.;AS.171.101 OR AS.171.102 OR AS.171.104 OR AS.171.106 OR AS.171.108
Corequisites: AS.171.102
Instructor(s): J. Mumford
Area: Natural Sciences.

AS.173.115. Classical Mechanics Laboratory. 1.0 Credit.
Experiments chosen to complement the lecture course Classical Mechanics I, II AS.171.105-AS.171.106 and introduce students to experimental techniques and statistical analysis. Corequisite: AS.171.105.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): C. Chien; J. Mumford
Area: Natural Sciences.

AS.173.116. Electricity and Magnetism Laboratory. 1.0 Credit.
Experiments chosen to complement Electricity and Magnetism AS.171.106 and introduce students to experimental techniques and statistical analysis.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): C. Chien; J. Mumford
Area: Natural Sciences.

AS.173.125. Understanding the World through Physics: An experimental approach. 3.0 Credits.
Students will learn key concepts of everyday physics through experimentation. They will design, build, and run experiments themselves. The course will be graded on participation and a graded final presentation.
Instructor(s): M. Valdivia Leiva
Area: Natural Sciences.

AS.173.308. Advanced Physics Laboratory. 3.0 Credits.
A broad exposure to modern laboratory procedures such as holography, chaos, and atomic, molecular, and particle physics.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): T. Marriage
Area: Natural Sciences
Writing Intensive.

AS.173.311. Mentoring in General Physics Laboratory. 1.0 Credit.
This course provides students who have take General Physics I and II and General Physics Laboratory I and II with the opportunity to mentor new students in General Physics Laboratory I and II. Mentors collaborate General Physics laboratory Teaching Assistants to interact with students to help them to complete laboratory assignments and to master the concepts of General Physics. Mentors must have a strong background in Physics. They are expected to interact with students during one three-hour laboratory section per week and to attend the associated TA training once per week. Permission of the instructor required. S/U only.
Prerequisites: AS.173.111 and AS.173.112;Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): J. Mumford
Area: Natural Sciences.
AS.173.312. Mentoring in General Physics Laboratory. 1.0 Credit.
This course provides students who have to take General Physics I and II and General Physics Laboratory I and II with the opportunity to mentor new students in General Physics Laboratory I and II. Mentors collaborate General Physics laboratory Teaching Assistants to interact with students to help them to complete laboratory assignments and to master the concepts of General Physics. Mentors must have a strong background in Physics. They are expected to interact with students during one three-hour laboratory section per week and to attend the associated TA training once per week. Permission of the instructor required. S/U only.
Prerequisites: AS.173.111 AND AS.173.112; Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): C. Chien
Area: Natural Sciences.

AS.173.608. Advanced Laboratory.
Experiments carried out on cosmic rays, X-ray scattering Mössbauer effect, atomic beams, and optical spectroscopy.
Instructor(s): T. Marriage.

Cross Listed Courses
Chemistry
The course is designed to provide the essential principles and concepts underlying the modern study of the structure and properties of solids in bulk crystals, thin films, and nanoscale objects. Topics include basic crystallography, structure determination by x-ray, neutron, and electron diffraction, fundamental concepts of bonding in solids, lattice dynamics, electronic band structure, magnetism, and strongly correlated electron behavior. Particular emphasis is placed on the impact of the structure, dimensionality, and electron count on electrical and magnetic properties (electric conduction, superconductivity, thermoelectricity, etc). More course info available at <a href="http://occamy.chemistry.jhu.edu">http://occamy.chemistry.jhu.edu</a>. Cross-listed with Physics and Astronomy
Instructor(s): T. Mcqueen.

Applied Mathematics Statistics
EN.553.793. Turbulence Theory. 3.0 Credits.
An advanced introduction to turbulence theory for graduate students in the physical sciences, engineering and mathematics. Both intuitive understanding and exact analysis of the fluid equations will be stressed. Previous familiarity with fluid mechanics is not required, although it could be helpful.
Instructor(s): G. Eyink.