

## **UNDERGRADUATE STUDY IN PHYSICS AND ASTRONOMY**

Physics and astronomy have had a tremendous influence on our view of the universe in which we live, and have enhanced our ability to understand nature to an extent hardly imaginable fifty years ago.

The study of physics may be approached with a variety of goals in mind. One may want to make a career of physics, as a research worker, as a teacher, or as an applier of physics to problems outside of physics itself. Even at times when the job market is poor for positions in pure physics, the background provided by a study of physics is an excellent basis for branching out into a variety of areas. Physics majors frequently find it stimulating and profitable to enter high-demand borderline fields such as medical physics, where physics is applied to meeting the challenge of research attacks on cancer, heart disease, and the medical problems of space travel. Our B.S. program in physics provides appropriate training for all of these purposes.

Since much of astronomy is based on concepts of physics, a major in physics and astronomy is an excellent way to prepare for a career in astronomy. At the University of Pittsburgh, a B.S. program in physics and astronomy has been designed to give the right balance of training for students interested in careers in astronomy.

Still others may want to understand the fundamental principles of physics and astronomy and the ways in which research scientist's work, not in preparation for a career in science or technology, but as background for the many other fields in today's society where science and technology have an important impact. Our B.A. program in physics and astronomy has been designed especially for such students.

Many students planning careers in other fields – medicine, law, or history and philosophy of science, for example – major in physics or physics and astronomy as undergraduates. In so doing they benefit both from a rich background in basic science and, what is equally valuable, they develop the rigorous habits of thought that stem from such training.

All of these possibilities involve the satisfaction and challenge of intellectual activity, and all can lead to rewarding careers.

### ***SHOULD I STUDY PHYSICS OR ASTRONOMY?***

Many young people have known since early childhood that they were destined to become physicists or astronomers. Some were radio "hams", amateur astronomers, rocket enthusiasts, avid readers of popular science, or home-appliance tinkerers.

Perhaps just as many first discovered the attractions of physics or astronomy through the stimulation of an introductory college course.

Most physicists and astronomers have in common a driving desire to understand the nature of things and a flair for mathematical argumentation. But these attitudes may develop early or late

depending on one's home and school background.

If you are not sure whether physics or astronomy is for you, try an introductory course and find out for yourself.

### ***SHOULD I STUDY PHYSICS OR ASTRONOMY AT A LARGE UNIVERSITY?***

The considerations of overall school size and urban versus rural campus are largely matters of personal preference. For those wishing to prepare for careers in physics or astronomy, however, there is an important point to consider.

It is in the very nature of physics and astronomy that their practitioners are engaged in research. Whether their formal training ended at the B.S., M.S., or Ph.D. level, physicists and astronomers apply their fund of knowledge to new problems and situations. Thus, in addition to formal schooling in textbook material and laboratory experiments, the developing physicist or astronomer should acquire appreciation for the spirit and techniques of scientific research. At the larger, modern institutions, such as the University of Pittsburgh, virtually all of the faculty members are involved in current research as well as in teaching. This assures the maximum opportunity for the undergraduate to become familiar with a variety of research programs and their directors.

A natural question you may have at this point is, "If the department is deeply committed to research, will the undergraduate major be regarded as being of little importance?" At the University of Pittsburgh, we have been especially concerned with this problem and have taken strong measures to address it. The undergraduate major now benefits from close personal contact with many very devoted teachers who are also scientists of international reputation. Intermediate and advanced classes are normally small, so that the student is not just a name to the professor. Furthermore, there are opportunities for advanced undergraduates to become involved in some of the research programs of faculty members. In many cases, undergraduates can be employed as research assistants, earning money at the same time that they are gaining valuable educational experiences.

An additional advantage to be found at larger institutions is the variety of related programs in other fields. At the University of Pittsburgh, there are strong programs in many related areas of science, engineering, and mathematics, as well as in the history and philosophy of science. These, plus many strong programs in other, less closely related areas, provide much of interest for majors in physics or physics and astronomy.

### ***FACILITIES FOR UNDERGRADUATE MAJORS***

#### ***Buildings***

Most of the department's facilities are located in an interconnected complex of buildings a short distance from the Cathedral of Learning. The department's Allegheny Observatory, a 15-minute drive away, houses the Thaw refractor, one of the world's finest telescopes for astrometrical research, and related facilities.

### ***Special Undergraduate Laboratories***

Facilities in the undergraduate laboratories are continually updated in order to acquaint students with new devices and concepts. An honors-level laboratory is equipped with special instrumentation designed to acquaint students with modern techniques of making many types of physical measurements. As students follow the sequence of introductory, intermediate, and advanced laboratories, they will progress from equipment designed primarily for teaching purposes to equipment designed primarily for use in research.

### ***Computers***

The increased role of electronic computers in research has motivated the department to encourage computer training in the undergraduate program. Undergraduates may use the facilities of the University's Computer Center, which maintains an access station in one of the buildings in the department's complex, and, as appropriate, the Pittsburgh Supercomputing Center. There are also numerous computers located in some of the department's teaching and research laboratories.

### ***Library Facilities***

The physics collection is housed in Benedum Engineering Library. The collection of books and bound periodicals is supplemented continually by new acquisitions as well as subscriptions to hundreds of technical journals from many countries. The library also provides access to national information-retrieval networks. Undergraduates have regular access to this library as well as to several others within easy walking distance. An additional astronomy library is located at the Allegheny Observatory.

### ***Undergraduate Lounge***

A room is available for the exclusive use of the department's undergraduate majors. The room is furnished with computers, a comfortable seating area, a microwave, a refrigerator, and work tables. The door to this area is normally locked to provide privacy for studying or small meetings. Keys are available to undergraduate majors in the main office. There is a small key deposit required which is refundable upon return of the key. Since undergraduates are the main users of this room, it is important that they inform the department of any needed repairs or requested improvements. We are happy to entertain all reasonable requests.

## ***UNDERGRADUATE PROGRAMS***

### ***Advising***

Several faculty members serve as advisors for undergraduate majors in the department. The number of advisees per advisor is kept small so that students have ample opportunity to consult their advisors, even during the hectic registration periods.

### ***Teaching***

Almost all faculty members participate actively in the undergraduate program. Even in the large introductory courses, lecturers, with rare exceptions, are members of the faculty. Introductory course recitation sections are taught by graduate teaching assistants.

### ***Baccalaureate Programs in Physics and Astronomy***

The department offers six tracks to the bachelor's degree in physics or physics and astronomy. They have rather different goals and provide for a wide range of possible activities after graduation. It is desirable for students intending to major in the department, or simply wondering whether they should, to discuss their plans with one of the department's advisors as soon as possible. An appointment may be made by stopping in at the departmental office, room 100 in Allen Hall, or by calling the office at 412-624-9000. It is also possible for prospective students to visit the department prior to admission to the University or registration for classes. Such a visit may be arranged by contacting the department.

***(a) BACHELOR OF SCIENCE IN PHYSICS.*** This program is designed for those who wish to use their knowledge of physics professionally. A minimum program is specified which provides the student with a mastery of essential aspects of physics and related areas. Elective courses beyond the basic requirements may be chosen to suit the individual interests and needs of the student, such as courses required for admission to medical school or courses in the School of Engineering. A grade average of C or better in the required science courses is required in this program.

***(b) BACHELOR OF SCIENCE IN PHYSICS AND ASTRONOMY.*** The B.S. in physics and astronomy degree is intended primarily for students with an interest in astronomy or related aspects of space science. It provides the solid foundation in physics needed for such careers, and also provides a background in astronomy. A grade average of C or better in the required science courses is required in this program.

***(c) BACHELOR OF SCIENCE IN PHYSICS WITH HONORS.*** This program, which requires more courses in both physics and mathematics than does the standard B.S. physics program, is meant for those students who wish to prepare for graduate study in physics and who show promise of success in such study. The honors curriculum offers an intensive scientific education that prepares a capable student to pursue a graduate degree in physics at any university. A grade average of B or better in the required science courses is required in the honors program.

**(d) BACHELOR OF SCIENCE IN PHYSICS AND ASTRONOMY WITH HONORS.** This program, which requires more courses in both physics and mathematics than in the standard B.S. in Physics and Astronomy program, is meant for those students who are interested in preparing for graduate study in astronomy or astrophysics. Students who successfully complete this program are qualified to pursue a graduate degree at any university. A grade average of B or better in the required physics, science courses is required in the honors program.

**(e) BACHELOR OF ARTS IN PHYSICS AND ASTRONOMY.** This program is intended to give students a thorough background in basic physics and astronomy, as well as the historical development of modern physical concepts and the relationship of these basic sciences to other fields. It is a particularly appropriate program for those planning to enter careers on which science and technology have a large impact, such as certain kinds of law, business administration, governmental administration, technical writing, and science education. It is not intended to prepare students for scientific or technical careers, but to enable students to understand and evaluate the ever increasing influence of science and technology on other areas. A grade average of C or better in the required science courses is required in this program.

**(f) BACHELOR OF SCIENCE IN PHYSICS WITH A CERTIFICATE IN PHOTONICS.** Photonics is one of the fastest growing high-tech industries in the world today. It includes communications (e.g., fiber optics, lasers, and infrared links), optical imaging (e.g., spy and weather satellites, night vision, holography, flat screen display, and CCD video cameras), optical data storage (e.g., CDs and CD-ROMs), optical detectors (e.g., supermarket scanners, medical optics, and nondestructive evaluation of materials), lasers (e.g., welding lasers, laser surgery, laser shows, and laser rangefinders), spectroscopy (e.g., chemical analysis and detection), and quantum optics (e.g., quantum cryptography, quantum computing, and single-photon detection).

Although the photonics industry is growing rapidly, photonics companies have a hard time finding qualified people because it is an interdisciplinary field crossing physics, physical chemistry, and electrical engineering. The photonics certificate program at the University of Pittsburgh will give this kind of cross-cutting experience and allow students to move directly into the photonics industry. The Certificate in Photonics will also serve as good preparation for graduate school in solid state physics, physical chemistry, or electrical engineering with optoelectronics emphasis.

Students in the certificate program will have opportunities for laboratory research with professors at the University of Pittsburgh and will also receive special job placement referral. A grade average of C or better in the required science courses is required in this program.

**(g) PHYSICS AS A MINOR.** Students wishing to minor in physics may do so by taking 16 credits of prescribed physics courses. This program provides the student with a broad overview of both classical and modern physics, and is an excellent complement to many major fields, even outside of the natural sciences. Beginning science and engineering majors who switch their majors after their 1st or 2nd years will find it particularly simple to earn a minor in physics by simply adding the modern physics sequence, physics 0479 and 0481, to the courses that they

have already taken. Students taking the minors sequence will have to satisfy the course prerequisites as specified in the course descriptions below.

### ***Grading Policy***

A grade of C or better indicates satisfactory competence at the baccalaureate level. A grade of B or better indicates potential for graduate study.

### ***Related Areas of Study***

Some students like to use their elective courses to sample a wide variety of subjects, while others prefer to concentrate on one or two of particular interest to them. Physics majors sometimes take enough courses in areas such as mathematics or computer science to satisfy the requirements for a second major, and majors in physics and astronomy may complete a second major in any of a number of areas of interest to them.

Because of the large role that computers play in many areas, physics majors are expected to have acquired some knowledge of simple computer programming by the end of their sophomore year. Students are required to take Physics 1321 Computation Methods in Physics in their junior year.

Physics majors whose interests lie more toward applied areas often supplement the B.S. program with several courses in the School of Engineering. Students with deeper interests in engineering may wish to consider the five-year CAS-Engineering program, which would lead to a second bachelor's degree in engineering.

There are many other areas of possible interest to physics or physics and astronomy majors, including strong programs in other sciences and in history and philosophy of science.

## **GRADUATION REQUIREMENTS**

The general requirements for graduation are set forth in the Bulletin of the College of Arts and Sciences. The specific requirements for a major in physics or in physics and astronomy are as follows:

### ***(a) B.S. IN PHYSIC***

1. Introductory physics: 0174, 0175, 0219; or the corresponding honors courses.
2. Additional physics: 0479, 0481, 0525, 1310, 1311, 1321, 1331, 1341, 1351, 1361, 1426.
3. Mathematics: 0220, 0230, 0240, 0280, 0290 or the corresponding honors courses. (0250 may substitute for both 0280 and 0290, but 0280,0290 is preferred.)
4. Chemistry: 0110, 0120, or CS 0401, 0445 (unless Certificate in Photonics sought).

**(b) B.S. IN PHYSICS AND ASTRONOMY**

1. Introductory physics: 0174, 0175, and 0219; or the corresponding honors courses.
2. Introductory astronomy: 0113.
3. Additional physics: 0479, 0481, 0525, 1310, 1311, 1321, 1331, 1351, 1361.
4. Additional astronomy: 1120, 1121, 1263
5. Geology: 1701
6. Mathematics: 0220, 0230, 0240, 0250; or the corresponding honors courses.
7. Chemistry: 0110, 0120; or the corresponding honors courses, or CS 0401, 0445.

**(c) PHYSICS HONORS PROGRAM**

Physics 1370, 1371, 1372 and Math 1550, 1560 are added to the standard B.S. program. Although not required for the program, the introductory-level honors courses Physics 0475 and 0476, and the honors laboratory Physics 0520 are particularly appropriate for honors majors.

**(d) PHYSICS AND ASTRONOMY HONORS PROGRAM**

The honors B.S. in physics and astronomy program requires adding the following courses to those required for the regular B.S. in Physics and Astronomy: Physics 1341, 1370, 1371, 1372, and Math 1550 and 1560.

**(e) B.A. IN PHYSICS AND ASTRONOMY**

1. Introductory physics: 0174, 0175, and 0219 or the corresponding honors courses.
2. Introductory astronomy: 0113.
3. Two of the following upper-level courses: Astronomy 1120, 1121, 1263; Geology 1701.
4. Mathematics: 0220, 0230, 0240; or the corresponding honors courses.
5. Additional physics: 0479, 0481, 1310.
6. At least one course in history or philosophy of science.

**(f) B.S. IN PHYSICS WITH A CERTIFICATE IN PHOTONICS**

1. Introductory physics 0174, 0175, 0219 (alternatively, 0475, 0476, 0520), and 0525.
2. Additional physics: 0479, 1321, 1331, 1341, 1351, 1361, 1370, 1426, Photonics 1 & 2 (1363 & 1364).
3. Mathematics: 0220, 0230, 0240, 0250; or the corresponding honors courses.
4. Chemistry: 0110, 0120; or the corresponding honors courses. Also 1410/1530, 1250/1255.
5. Electrical Engineering: 0247, 1232

**(g) PHYSICS AS A MINOR**

1. Introductory physics: 0174, 0175, and 0219 or the corresponding honors courses.
2. Additional physics: 0479, 0481.

**TYPICAL COURSE SEQUENCES**

Typical sequences of courses in the standard and honors physics programs are shown in the following charts. Departures from these sequences should be carefully planned in consultation with a departmental advisor, since physics courses beyond the introductory level are normally offered only in the term (i.e., fall or spring) indicated in the charts.

*A typical sequence of courses in the standard physics B.S. program:*

	1	2	3	4	5	6	7	8
<b>Term</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>
<b>Physics</b>	<b>0174</b>	<b>0175</b>	<b>0219, 0479</b>	<b>0481, 0525, 1321</b>	<b>1310, 1331, 1351</b>	<b>1311, 1341</b>	<b>1361</b>	<b>1426</b>
<b>Math</b>	<b>0220</b>	<b>0230</b>	<b>0240, 0290</b>	<b>0280</b>				
<b>Chem</b>	<b>0110</b>	<b>0120</b>		<b>or CS 0401, 0445 unless Certificate in Photonics sought</b>				

*A typical sequence of courses in the physics honors program:*

	1	2	3	4	5	6	7	8
<b>Term</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>
<b>Physics</b>	<b>0475</b>	<b>0476</b>	<b>0479, 0520, 1351</b>	<b>0481, 0525, 1321</b>	<b>1310, 1331, 1361</b>	<b>1311, 1341, 1372,</b>	<b>1370, 1373</b>	<b>1371, 1426</b>
<b>Math</b>	<b>0235</b>	<b>0240</b>	<b>0290</b>	<b>0280</b>	<b>1550</b>	<b>1560</b>		
<b>Chem</b>	<b>0110</b>	<b>0120</b>		<b>or CS 0401, 0445</b>				

*A typical sequence in the standard Physics and Astronomy B.S. Program (The courses in parentheses are additional courses required for the Honors B.S. in Physics and Astronomy)*

	1	2	3	4	5	6	7	8
<b>Term</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>
<b>Physics</b>	<b>0174</b>	<b>0175</b>	<b>0219, 0479</b>	<b>0481, 0525</b>	<b>1310, 1331, 1351</b>	<b>1311, 1321 (1372)</b>	<b>1361 (1370)</b>	<b>(1341) (1371)</b>
<b>Astronomy</b>			<b>0113</b>	<b>1263**</b>	<b>1120*</b>	<b>1121*</b>		
<b>Geology</b>							<b>1701**</b>	
<b>Math</b>	<b>0220</b>	<b>0230</b>	<b>0240</b>	<b>0250</b>			<b>(1550)</b>	<b>(1560)</b>
<b>Chem</b>	<b>0110</b>	<b>0120</b>	<i>or CS 0401, 0445</i>					

*\* Astronomy 1120 and 1121 are offered every other year and will be taught during the even academic years (04-1, 04-2, 06-1, 06-2, etc.)*

*\*\*Geology 1701 and Astronomy 1263 are offered every other year and will be taught during the odd academic years (03-1, 05-1, etc.)*

*A typical sequence of courses in the physics B.S. program with Photonics Certificate:*

	1	2	3	4	5	6	7	8
<b>Term</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>	<b>F</b>	<b>S</b>
<b>Physics</b>	<b>0174</b>	<b>0175</b>	<b>0219, 0479</b>	<b>0525</b>	<b>1313, 1331, 1351</b>	<b>1310, 1313, 1321</b>	<b>1311, 1361, 1363, 1370</b>	<b>1341, 1364, 1426</b>
<b>Math</b>	<b>0220</b>	<b>0230</b>	<b>0240</b>	<b>0250</b>				
<b>El. En.</b>					<b>0247</b>	<b>1232</b>		
<b>Chem.</b>	<b>0110</b>	<b>0120</b>				<b>1410/ 1430</b>	<b>1250/ 1255</b>	

## ***THE THREE-TERM CALENDAR***

The University of Pittsburgh's academic year is divided into three terms, each lasting approximately 15 weeks. The third term is further divided into two 6-week sessions. Some third-term courses are spread over the full term, as in the first and second terms. Many, however, are given at an accelerated pace in one of the sessions. This three-term calendar has many advantages. Students have the choice of enrolling for two terms per year or three, and may change at will from one option to the other. Those who elect to attend all three terms can complete their undergraduate education in two and two-thirds years, instead of the four years required under the standard academic calendar. This has the obvious advantage of enabling a student to begin graduate or professional training sooner and to enter a career at an earlier age, either after additional training or immediately upon receiving the bachelor's degree. It should be emphasized, however, that such a program must be carefully planned with a departmental advisor, since the required physics or astronomy courses beyond the introductory level are not normally offered in the third term. Students who must work in order to remain in school will also find great advantage in the three-term calendar. By attending only the first two terms in the three-term calendar, they have four months free for employment, and so can earn more than is normally possible during the summer.

## ***UNDERGRADUATE COURSES***

### ***Introductory Physics***

**Physics 0174, 0175** (4 credits each) Basic **Physics for Science and Engineering**: A two term introduction to both classical and modern physics, with the use of calculus. Co requisites: Math 0220 for Physics 0174, Math 0230 for Physics 0175.

**Physics 0219** (2 credits) Basic **Laboratory Physics for Science and Engineering**: An introductory laboratory associated with Physics 0174 and 0175. Experiments from many areas of physics are performed. Co requisite: Physics 0175.

**Physics 0475, 0476** (4 cr. each) **UHC Introductory Physics for Science and Engineering**: Honors version of Physics 0174, 0175. Prerequisite: One year of high-school physics, Math 0230 or Math 0235 as a Co requisite for 0475. Math 0230 or 0235 for 0476.

**Physics 0577** (4 cr.) **UHC Modern Physics Measurements**: An introduction to the scientific basis of modern physical measurements. Prerequisite: A grade of C or better in Physics 0476, or a grade of B or better in Physics 0175, or permission of the instructor.

### ***Introductory Astronomy***

**Astronomy 0113** (3 credits) **Introduction to Astronomy**: An introduction to the study of the solar system, stars, galaxies, extragalactic objects and the universe at large. Prerequisite: none. This course is intended for students majoring in the natural sciences. Although calculus is not used in this course, algebra and trigonometry are used extensively. Students not majoring in the natural sciences and who are not comfortable with algebra and trigonometry are advised to take

the Astronomy 0089 course instead.

### ***Intermediate and Advanced Physics***

**Physics 0210** (2 credits) **Introduction to Physics Teaching:** This course is aimed at science and engineering majors in learning more about science teaching at any level. It will introduce principles of learning and quality instruction using an examination of physics educational research papers and decomposition of concrete examples of high-quality curriculum designed using these principles.

**Physics 0479** (3 credits) **Principles of Modern Physics I:** A survey of basic principles of relativity and quantum physics, with applications to the physics of atoms. Prerequisite: Physics 0175 (or 0476) Co requisite: Math 0240.

**Physics 0481** (3 credits) **Principles of Modern Physics II:** A continuation of Physics 0480, including treatments of multi-electron atoms, molecules, solids, nuclei, and particles. Prerequisite: Physics 0479.

**Physics 0525** (3 credits) **Modern Electronics:** A laboratory course in analog and digital semiconductor electronics. Prerequisite: Physics 0219 or 0520. This course may also be taken by students who have previously taken Physics 0577 and wish to improve their electronics skills.

**Physics 0680** (1 credit) **Principles of Modern Physics; "W" component.** This course is the "W" component option to Physics 0480.

**Physics 1310/1311** (1 credit) **Undergraduate Seminar:** An informal, weekly meeting on various topics of interest. Students will also make presentations in class. Prerequisite: Physics 0479, and either 0219 or 0520.

**Physics 1313** (1 credit) **Photonics Seminar:** This seminar provides exposure to current topics in photonics, in industry and research. Each week, a representative of the photonics community will give a talk on his or her field of expertise. Prerequisites: none.

**Physics 1321** (3 credits) **Computational Methods in Physics:** This course will cover problems solving techniques using a computer. Students will learn the steps needed to solve a problem and gain familiarity with approximation schemes. Prerequisites: Physics 0479, (0219 or 0520); Math 0240, and 0290 or 0250.

**Physics 1331** (3 credits) **Mechanics:** Classical mechanics, with vector calculus and differential equations as tools. Prerequisites: Physics 0175 (or 0476), Math 0250 or 0290, and some knowledge of simple computer programming.

**Physics 1341** (3 credits) **Thermodynamics and Statistical Mechanics:** The properties of matter as described by thermodynamics, in which atomic structure is irrelevant, and by statistical mechanics, which is based on the atomic point of view. Prerequisites: Physics 1331,

Math 0290 or 0250.

**Physics 1351** (3 credits) **Electricity and Magnetism:** Electromagnetic theory is formulated with the use of vector calculus. Prerequisites: Physics 0175 (or 0476), and some knowledge of simple computer programming. Prerequisites: Math 0240, corequisite 0290 or 0250.

**Physics 1361** (3 credits) **Wave Motion and Optics:** An intermediate course in waves and optics which includes a laboratory. Prerequisites: Physics 0219, Math 0240 and Math 0280 or 0250.

**Physics 1363** (3 credits) **Photonics I:** Part 1 of a two-term series on modern photonics methods, including optical system design, waveguides and fiber optics, electro-optics and acousto-optics, nonlinear optics and ultrafast laser systems. Prerequisites: Physics 1351, 1361, EE 1232.

**Physics 1364** (3 credits) **Photonics II:** Part 2 of a two-term series on modern photonics methods as actually used in industry and research labs. Prerequisites: Physics 1351, 1361; EE 1232.

**Physics 1370, 1371** (3 cr. each) **Introduction to Quantum Physics:** A basic course in quantum mechanics. Prerequisite: Physics 0479, 1331, 1351; Math 0250 or both 0280 and 0290.

**Physics 1372** (3 cr.) **Electromagnetic Theory:** Advanced topics, including boundary-value problems and radiation theory. Prerequisites: Physics 1351, 1331; Math 0240 and either 0250 or 0280 and 0290.

**Physics 1373** (3 cr.) **Mathematical Methods:** The course is primarily concerned with the mathematical techniques used most frequently in physics. Prerequisites: Physics 0479, 1331, 1351; Math 0240 and either 0280 and 0290 or 0250.

**Physics 1426** (2 credits) **Modern Physics Laboratory:** An introduction to the research laboratory environment. Prerequisites: Physics 0525, 1351.

**Physics 1626** (1 credit) **Modern Physics Laboratory; "W" component.** This course is the "W" component option to Physics 1426.

**Physics 1661** (1 credit) **Wave Motion and Optics; "W" component.** Students taking the Physics 1361 option will be expected to submit Physics 1661 laboratory reports that are more detailed and exhibit greater attention to writing style.

**Physics 1900** (variable credit) **Internship:** There are occasional opportunities for students to work (not necessarily for pay) in a nonacademic position that has academic value.

**Physics 1901** (variable credit) **Independent Study:** An opportunity for qualified students to work independently, usually off campus, but with guidance from a sponsoring faculty member.

**Physics 1901** (variable credit) **UHC Independent Study:** An opportunity for qualified UHC students to work independently under faculty supervision.

**Physics 1902** (variable credit) **Directed Reading:** An opportunity for qualified students to pursue a course of study outside of the classroom, under faculty supervision.

**Physics 1903** (variable credit) **Directed Research:** An opportunity for qualified students to pursue research under faculty supervision.

### *Intermediate and Advanced Astronomy*

**Astronomy 1120** (3 cr.) **Stars, Stellar Structure and Stellar Evolution:** A study of the properties, formation, structure, and evolution of stars. Prerequisites: Physics 0175, Astronomy 0113 and Math 0250 or 0290.

**Astronomy 1121** (3 cr.) **Galaxies and Cosmology:** A study of the nature of our Milky Way Galaxy, objects outside of our Galaxy and the structure of evolution of the universe. Prerequisites: Physics 0175, Astronomy 0113 and Math 0250 or 0290.

**Astronomy 1263** (3 cr.) **Techniques of Astronomy:** This course offers an introduction to the use of astronomical instruments and techniques to process and analyze data. Prerequisites: Physics 0175,(0219 or 0520), Astronomy 0113.

**Astronomy 1900** (var. cr.) **Internship:** There are occasional opportunities for students to work (not necessarily for pay) in a nonacademic position that has academic value.

**Astronomy 1901** (var. cr.) **Independent Study:** An opportunity for qualified students to work independently, usually off campus, but with guidance from a sponsoring faculty member.

**Astronomy 1902** (var. cr.) **Directed Reading:** An opportunity for qualified students to pursue a course of study outside of the classroom, under faculty supervision.

**Astronomy 1903** (var. cr.) **Directed Research:** An opportunity for qualified students to pursue research under faculty supervision.

### **UNDERGRADUATE ACTIVITIES**

#### *Seminar and Society of Physics Students*

Although the Undergraduate Seminar, Physics 1311, is required only for upper-class majors in the B.S. programs, all interested students are welcome at these weekly meetings. The University of Pittsburgh Chapter of the Society of Physics Students, affiliated with the American Institute of Physics, meets jointly with the seminar. Topics at the seminar usually range through various areas of current research, presented by faculty members and students, as well as such subjects as employment opportunities.

Our SPS chapter has won recognition as an Outstanding Chapter, and has received awards for projects designed to enhance interest in physics among students and the general public. There is also a local chapter of Sigma Pi Sigma, a physics honorary society within the Society of Physics Students.

Physics majors are encouraged to join the SPS chapter. Dues are small, and members receive the AIP's monthly magazine *Physics Today*.

### ***Colloquium***

Interested undergraduate students are welcome at the weekly colloquia held jointly by this department and Carnegie Mellon University's physics department.

### ***Undergraduate Research Assistants***

As a means of encouraging students contact with research, the department grants a number of research assistantships to undergraduates. These appointments carry an hourly stipend and are very flexible in working hours, including allowances for heavy exam periods. The assistants work closely with faculty members and advanced graduate students. It is expected that, occasionally, credit on research publications will be given to such assistants.

### ***Departmental Affairs***

Undergraduate majors have voting representation at general department meetings and on certain departmental committees. Representatives are chosen by the students attending the Undergraduate Seminar.