

Median annual earnings in the industries employing the largest number of environmental scientists in 2000 were as follows:

Federal Government	\$59,590
Engineering and architectural services	43,920
Management and public relations	43,900
Local government	42,880
State government	39,330

According to the National Association of Colleges and Employers, beginning salary offers in 2001 for graduates with bachelor's degrees in geology and the geological sciences averaged about \$35,568 a year; graduates with a master's degree averaged \$41,100; graduates with a doctoral degree averaged \$57,500.

In 2001, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was \$70,763; for geophysicists, \$79,660; for hydrologists, \$64,810; and for oceanographers, \$71,881.

The petroleum, mineral, and mining industries offer higher salaries, but less job security, than other industries. These industries are vulnerable to recessions and changes in oil and gas prices, among other factors, and usually release workers when exploration and drilling slow down.

Related Occupations

Many geoscientists work in the petroleum and natural gas industry. This industry also employs many other workers in the scientific and technical aspects of petroleum and natural gas exploration and extraction, including engineering technicians, science technicians, petroleum engineers, and surveyors, cartographers and photogrammetrists. Also, some physicists, chemists, and atmospheric scientists—as well as mathematicians and systems analysts, computer scientists, and database administrators—perform related work in both petroleum and natural gas exploration and extraction and in environment-related activities.

Sources of Additional Information

Information on training and career opportunities for geologists is available from:

- ▶ American Geological Institute, 4220 King St., Alexandria, VA 22302-1502. Internet: <http://www.agiweb.org> Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140. Telephone: (717) 447-2020. Internet: <http://www.geosociety.org>.
- ▶ American Association of Petroleum Geologists, P.O. Box 979, Tulsa, OK 74101. Internet: <http://www.aapg.org>

Information on training and career opportunities for geophysicists is available from:

- ▶ American Geophysical Union, 2000 Florida Ave. NW., Washington, DC 20009. Telephone: (202) 777-7512. Internet: <http://www.agu.org>
- ▶ Society of Exploration Geophysicists, 8801 South Yale, Tulsa, OK 74137. Telephone: (918) 497-5500. Internet: <http://www.seg.org>

A packet of free career information, and a list of education and training programs in oceanography and related fields priced at \$6.00, is available from:

- ▶ Marine Technology Society, 1828 L St. NW., Suite 906, Washington, DC 20036. Internet: <http://www.mtsociety.org>

Information on acquiring a job as a geologist, geophysicist, hydrologist, or oceanographer with the Federal Government may be obtained through a telephone-based system from the Office of Personnel Management. Consult your telephone directory under U.S. Government for a local number, or call (912) 757-3000; Federal Relay Service (800) 877-8339. This number is not tollfree, and charges may result. Information also is available from the Internet site: <http://www.usajobs.opm.gov>.

Physicists and Astronomers

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Significant Points

- A doctoral degree is the usual educational requirement because most jobs are in basic research and development; a bachelor's or master's degree is sufficient for some jobs in applied research and development.
- Because funding for research grows slowly, new Ph.D. graduates will face competition for basic research jobs.

Nature of the Work

Physicists explore and identify basic principles governing the structure and behavior of matter, the generation and transfer of energy, and the interaction of matter and energy. Some physicists use these principles in theoretical areas, such as the nature of time and the origin of the universe; others apply their physics knowledge to practical areas, such as the development of advanced materials, electronic and optical devices, and medical equipment.

Physicists design and perform experiments with lasers, cyclotrons, telescopes, mass spectrometers, and other equipment. Based on observations and analysis, they attempt to discover and explain laws describing the forces of nature, such as gravity, electromagnetism, and nuclear interactions. Physicists also find ways to apply physical laws and theories to problems in nuclear energy, electronics, optics, materials, communications, aerospace technology, navigation equipment, and medical instrumentation.

Astronomy is sometimes considered a subfield of physics. *Astronomers* use the principles of physics and mathematics to learn about the fundamental nature of the universe, including the sun, moon, planets, stars, and galaxies. They also apply their knowledge to solve problems in navigation, space flight, and satellite communications, and to develop the instrumentation and techniques used to observe and collect astronomical data.

Most physicists work in research and development. Some do basic research to increase scientific knowledge. Physicists who conduct applied research build upon the discoveries made through basic research and work to develop new devices, products, and processes. For example, basic research in solid-state physics led to the development of transistors and, then, of integrated circuits used in computers.

Physicists also design research equipment. This equipment often has additional unanticipated uses. For example, lasers are used in surgery, microwave devices are used in ovens, and measuring instruments can analyze blood or the chemical content of foods. A small number of physicists work in inspection, testing, quality control, and other production-related jobs in industry.

Much physics research is done in small or medium-size laboratories. However, experiments in plasma, nuclear, and high energy and in some other areas of physics require extremely large, expensive equipment, such as particle accelerators. Physicists in these subfields often work in large teams. Although physics research may require extensive experimentation in laboratories, research physicists still spend time in offices planning, recording, analyzing, and reporting on research.

Almost all astronomers do research. Some are theoreticians, working on the laws governing the structure and evolution of astronomical objects. Others analyze large quantities of data gathered by observatories and satellites, and write scientific papers or reports on their findings. Some astronomers actually operate, usually as

part of a team, large space- or ground-based telescopes. However, astronomers may spend only a few weeks each year making observations with optical telescopes, radio telescopes, and other instruments. For many years, satellites and other space-based instruments have provided tremendous amounts of astronomical data. New technology resulting in improvements in analytical techniques and instruments, such as computers and optical telescopes and mounts, is leading to a resurgence in ground-based research. A small number of astronomers work in museums housing planetariums. These astronomers develop and revise programs presented to the public and may direct planetarium operations.

Physicists generally specialize in one of many subfields—elementary particle physics, nuclear physics, atomic and molecular physics, physics of condensed matter (solid-state physics), optics, acoustics, space physics, plasma physics, or the physics of fluids. Some specialize in a subdivision of one of these subfields. For example, within condensed matter physics, specialties include superconductivity, crystallography, and semiconductors. However, all physics involves the same fundamental principles, so specialties may overlap, and physicists may switch from one subfield to another. Also, growing numbers of physicists work in combined fields, such as biophysics, chemical physics, and geophysics.

Working Conditions

Physicists often work regular hours in laboratories and offices. At times, however, those who are deeply involved in research may work long or irregular hours. Most do not encounter unusual hazards in



A doctoral degree usually is necessary for most basic research and development positions.

their work. Some physicists temporarily work away from home at national or international facilities with unique equipment, such as particle accelerators. Astronomers who make observations using ground-based telescopes may spend long periods in observatories; this work usually involves travel to remote locations. Long hours, including routine night work, may create temporarily stressful conditions.

Physicists and astronomers whose work is dependent on grant money often are under pressure to write grant proposals to keep their work funded.

Employment

Physicists and astronomers held about 10,000 jobs in 2000. Jobs for astronomers accounted for only a small number—10 percent—of the total. About 40 percent of all nonfaculty physicists and astronomers worked for commercial or noncommercial research, development, and testing laboratories. The Federal Government employed almost 35 percent, mostly in the U.S. Department of Defense, but also in the National Aeronautics and Space Administration (NASA), and in the U.S. Departments of Commerce, Health and Human Services, and Energy. Other physicists and astronomers worked in colleges and universities in nonfaculty positions, or for State governments, drug companies, or electronic equipment manufacturers.

Besides the jobs described above, many physicists and astronomers held faculty positions in colleges and universities. (See the statement on postsecondary teachers elsewhere in the *Handbook*.)

Although physicists and astronomers are employed in all parts of the country, most work in areas in which universities, large research and development laboratories, or observatories are located.

Training, Other Qualifications, and Advancement

Because most jobs are in basic research and development, a doctoral degree is the usual educational requirement for physicists and astronomers. Additional experience and training in a postdoctoral research appointment, although not required, is important for physicists and astronomers aspiring to permanent positions in basic research in universities and government laboratories. Many physics and astronomy Ph.D.-holders ultimately teach at the college or university level.

Master's degree holders usually do not qualify for basic research positions but do qualify for many kinds of jobs requiring a physics background, including positions in manufacturing and applied research and development. Physics departments in some colleges and universities are creating professional master's degree programs to specifically prepare students for physics-related research and development in private industry that do not require a Ph.D. degree. A master's degree may suffice for teaching jobs in 2-year colleges. Those with bachelor's degrees in physics are rarely qualified to fill positions as research or teaching physicists. They are, however, usually qualified to work in engineering-related areas, in software development and other scientific fields, as technicians, or to assist in setting up computer networks and sophisticated laboratory equipment. Some may qualify for applied research jobs in private industry or nonresearch positions in the Federal Government. Some become science teachers in secondary schools. Astronomy bachelor's or master's degree holders often enter a field unrelated to astronomy, and they are qualified to work in planetariums running science shows, to assist astronomers doing research, and to operate space- and ground-based telescopes and other astronomical instrumentation. (See the statements on engineers; geologists, geophysicists, and oceanographers; computer programmers; and computer systems analysts, engineers, and scientists elsewhere in the *Handbook*.)

About 507 colleges and universities offer a bachelor's degree in physics. Undergraduate programs provide a broad background in

the natural sciences and mathematics. Typical physics courses include electromagnetism, optics, thermodynamics, atomic physics, and quantum mechanics.

In 2000, 183 colleges and universities had departments offering Ph.D. degrees in physics. Another 72 departments offered a master's as their highest degree. Graduate students usually concentrate in a subfield of physics, such as elementary particles or condensed matter. Many begin studying for their doctorate immediately after receiving their bachelor's degree.

About 69 universities grant degrees in astronomy, either through an astronomy, physics, or combined physics/astronomy department. Applicants to astronomy doctoral programs face competition for available slots. Those planning a career in astronomy should have a very strong physics background. In fact, an undergraduate degree in either physics or astronomy is excellent preparation, followed by a Ph.D. in astronomy.

Mathematical ability, problem-solving and analytical skills, an inquisitive mind, imagination, and initiative are important traits for anyone planning a career in physics or astronomy. Prospective physicists who hope to work in industrial laboratories applying physics knowledge to practical problems should broaden their educational background to include courses outside of physics, such as economics, computer technology, and business management. Good oral and written communication skills also are important because many physicists work as part of a team, write research papers or proposals, or have contact with clients or customers with nonphysics backgrounds.

Many physics and astronomy Ph.D.'s begin their careers in a postdoctoral research position, where they may work with experienced physicists as they continue to learn about their specialty and develop ideas and results to be used in later work. Initial work may be under the close supervision of senior scientists. After some experience, physicists perform increasingly complex tasks and work more independently. Those who develop new products or processes sometimes form their own companies or join new firms to exploit their own ideas.

Job Outlook

Historically, many physicists and astronomers have been employed on research projects—often defense-related. Because defense expenditures are expected to increase over the next decade, employment of physicists and astronomers is projected to grow about as fast as the average for all occupations, through the year 2010. The need to replace physicists and astronomers who retire will, however, account for most expected job openings. The Federal Government funds numerous noncommercial research facilities. The Federally Funded Research and Development Centers (FFRDCs), whose missions include a significant physics component, are largely funded by the Department of Energy (DOE) or the Department of Defense (DOD), and their R&D budgets did not keep pace with inflation during much of the 1990s. However, Federal budgets have recently increased for physics-related research at these centers, as well as other agencies such as NASA. If R&D funding continues to grow at these agencies, job opportunities for physicists and astronomers, especially those dependent on Federal research grants, should be better than they have been in many years.

Although research and development budgets in private industry will continue to grow, many research laboratories in private industry are expected to continue to reduce basic research, which includes much physics research, in favor of applied or manufacturing research and product and software development. Nevertheless, many persons with a physics background continue to be in demand in the areas of information technology, semiconductor technology, and other applied sciences. This trend is expected to continue;

however, many of these positions will be under job titles such as computer software engineer, computer programmer, engineer, and systems developer, rather than physicist.

For several years, the number of doctorates granted in physics has been much greater than the number of openings for physicists, resulting in keen competition, particularly for research positions in colleges and universities and in research and development centers. Competitive conditions are beginning to ease, because the number of doctorate degrees awarded has begun dropping, following recent declines in enrollment in graduate physics programs. However, new doctoral graduates should still expect to face competition for research jobs, not only from fellow graduates, but also from an existing supply of postdoctoral workers seeking to leave low-paying, temporary positions and non-U.S. citizen applicants.

Opportunities may be more numerous for those with a master's degree, particularly graduates from programs preparing students for applied research and development, product design, and manufacturing positions in industry. Many of these positions, however, will have titles other than physicist, such as engineer or computer scientist.

Persons with only a bachelor's degree in physics or astronomy are not qualified to enter most physicist or astronomer research jobs but may qualify for a wide range of positions in engineering, technician, mathematics, and computer- and environment-related occupations. Those who meet State certification requirements can become high school physics teachers, an occupation reportedly in strong demand in many school districts. (See the statements on these occupations elsewhere in the *Handbook*.) Despite competition for traditional physics and astronomy research jobs, individuals with a physics degree at any level will find their skills useful for entry to many other occupations.

Earnings

Median annual earnings of physicists and astronomers in 2000 were \$82,535. Median annual earnings of astronomers were \$74,510, while physicists earned \$83,310. The middle 50 percent of physicists earned between \$65,820 and \$102,270. The lowest 10 percent earned less than \$51,680, and the highest 10 percent earned more than \$116,290.

According to a 2001 National Association of Colleges and Employers survey, the average annual starting salary offer to physics doctoral degree candidates was \$68,273.

The American Institute of Physics reported a median annual salary of \$78,000 in 2000 for its members with Ph.D.'s (excluding those in postdoctoral positions); with master's degrees, \$63,800; and with bachelor's degrees, \$60,000. Those working in temporary postdoctoral positions earned significantly less.

The average annual salary for physicists employed by the Federal Government was \$86,799 in 2001; for astronomy and space scientists, \$89,734.

Related Occupations

The work of physicists and astronomers relates closely to that of engineers, chemists, atmospheric scientists, computer scientists, computer programmers, and mathematicians.

Sources of Additional Information

General information on career opportunities in physics is available from:

- ▶ American Institute of Physics, Career Services Division and Education and Employment Division, One Physics Ellipse, College Park, MD 20740-3843. Internet: <http://www.aip.org>
- ▶ The American Physical Society, One Physics Ellipse, College Park, MD 20740-3844. Internet: <http://www.aps.org>