When prices were low, oil and gas producers curtailed exploration activities and laid off geologists. When prices were up, companies had the funds and incentive to renew exploration efforts and hire geoscientists in large numbers. In recent years, a growing worldwide demand for oil and gas and new exploration and recovery techniques—particularly in deep water and previously inaccessible sites—have returned some stability to the petroleum industry, with a few companies increasing their hiring of geoscientists. Growth in this area, though, will be limited due to increasing efficiencies in finding oil and gas. Geoscientists who speak a foreign language and who are willing to work abroad should enjoy the best opportunities.

In the environmental field, the need for companies to comply with an increasing number of laws and regulations will contribute to the demand for geoscientists, especially hydrologists and engineering geologists. As the population increases and moves to more environmentally sensitive locations, geoscientists will be needed to assess building sites for potential geologic hazards and to address issues of pollution control and waste disposal. An expected increase in highway building and other infrastructure projects will be an additional source of jobs for engineering geologists.

Jobs with the Federal and State governments and with organizations dependent on Federal funds for support will experience little growth over the next decade, unless budgets increase significantly. This lack of funding will affect mostly oceanographers and those geoscientists performing basic research.

Earnings

Median annual earnings of geologists, geophysicists, and oceanographers were $53,890 in 1998. The middle 50 percent earned between $39,830 and $79,630 a year. The lowest 10 percent earned less than $30,950 and the highest 10 percent earned more than $101,390. Median annual earnings in the industries employing the largest number of geoscientists in 1997 were as follows.

Crude petroleum and natural gas	$81,900
Management and public relations	44,900
Engineering and architectural services	44,700

According to the National Association of Colleges and Employers, beginning salary offers in 1999 for graduates with bachelor's degrees in geology and the geological sciences averaged about $34,900 a year; graduates with a master's degree averaged $44,700.

In 1999, the Federal Government's average salary for geologists in managerial, supervisory, and nonsupervisory positions was $64,400; for geophysicists, $72,500; for hydrologists, $58,900; and for oceanographers, $66,000.

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 geologists and geophysicists 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. Also, some life scientists, physicists, chemists, and atmospheric scientists—as well as mathematicians, computer scientists, soil scientists, and cartographers—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. 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. Internet**: http://www.agu.org**

☛ Society of Exploration Geophysicists, 8801 South Yale, Tulsa, OK 74137. Internet: **http://www.seg.org**

A list of education and training programs in oceanography and related fields 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 (TDD 912 744-2299). This number is not toll-free, and charges may result. Information also is available from the Internet site: **http://www.usajobs.opm.gov**

Physicists and Astronomers

(O*NET 24102A and 24102B)

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.
- As funding for research grows slowly or not at all, 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 instance, basic research in solid-state physics led to the development of transistors and then to the 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 for 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, high energy, and 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 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 of time in observatories; this work usually involves travel to remote locations. Long hours, including routine night work, may create temporarily stressful conditions.

Physicists and astronomers need mathematical and computer skills.

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

Employment

Physicists and astronomers held nearly 18,000 jobs in 1998. About 2 in 10 nonfaculty physicists and astronomers worked for commercial or noncommercial research, development, and testing laboratories. The Federal Government employed almost 2 in 10, mostly in the Department of Defense, but also in the National Aeronautics and Space Administration (NASA), and the 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, and electronic equipment manufacturers.

Besides the jobs described above, many physicists and astronomers held faculty positions in colleges and universities. (See the statement on college and university faculty 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

A doctoral degree is the usual educational requirement for physicists and astronomers, because most jobs are in basic research and development. 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 does 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 an engineering-related area, software development and other scientific fields, to work 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 760 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 1998, 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 70 universities grant degrees in astronomy, either through an astronomy, physics, or a 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 are also important because many physicists work as part of a team, write research papers or proposals, or have contact with clients or customers with non-physics 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. Small or no increases in defense-related research and a continued slowdown in the growth of civilian physics-related basic research will result in little change in employment of physicists and astronomers through the year 2008. The need to replace physicists and astronomers who retire will account for almost all expected job openings. Budget tightening in the Federal Government may also affect employment of physicists, especially those dependent on Federal research grants. 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 have not kept pace with inflation in recent years. Continuing budget tightening may limit funding and, consequently, the scope of physics-related research in these facilities.

In recent years, many persons with a physics background have found employment in private industry 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 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. Also, the competition for grant money for physics-related research projects is likely to remain intense during the projection period.

Although research and development budgets in private industry will continue to grow, many research laboratories in private industry are expected to reduce basic research, which includes much physics research, in favor of applied or manufacturing research and product and software development. Although many physicists and astronomers will be eligible for retirement over the next decade, it is probable not all of them will be replaced when they retire.

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 1998 were $73,240. The middle 50 percent earned between $56,230 and $90,440. The lowest 10 percent earned less than $41,830 and the highest 10 percent earned more than $113,800.

According to a 1999 National Association of Colleges and Employers survey, the average annual starting salary offer to physics doctoral degree candidates was $60,300.

The American Institute of Physics reported a median annual salary of $70,000 in 1998 for its members with Ph.D.'s; with master's degrees, $57,000; and with bachelor's degrees, $54,000. Those working in temporary postdoctoral positions earned significantly less.

The average annual salary for physicists employed by the Federal Government was $79,400 in early 1999 and for astronomy and space scientists, $81,300.

Related Occupations

The work of physicists and astronomers relates closely to that of engineers, chemists, atmospheric scientists, geophysicists, 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**

For a brochure containing information on careers in astronomy, send your request to:

☛ American Astronomical Society, Education Office, University of Chicago, 5640 South Ellis Ave., Chicago IL 60637.
Internet: **http://www.aas.org**