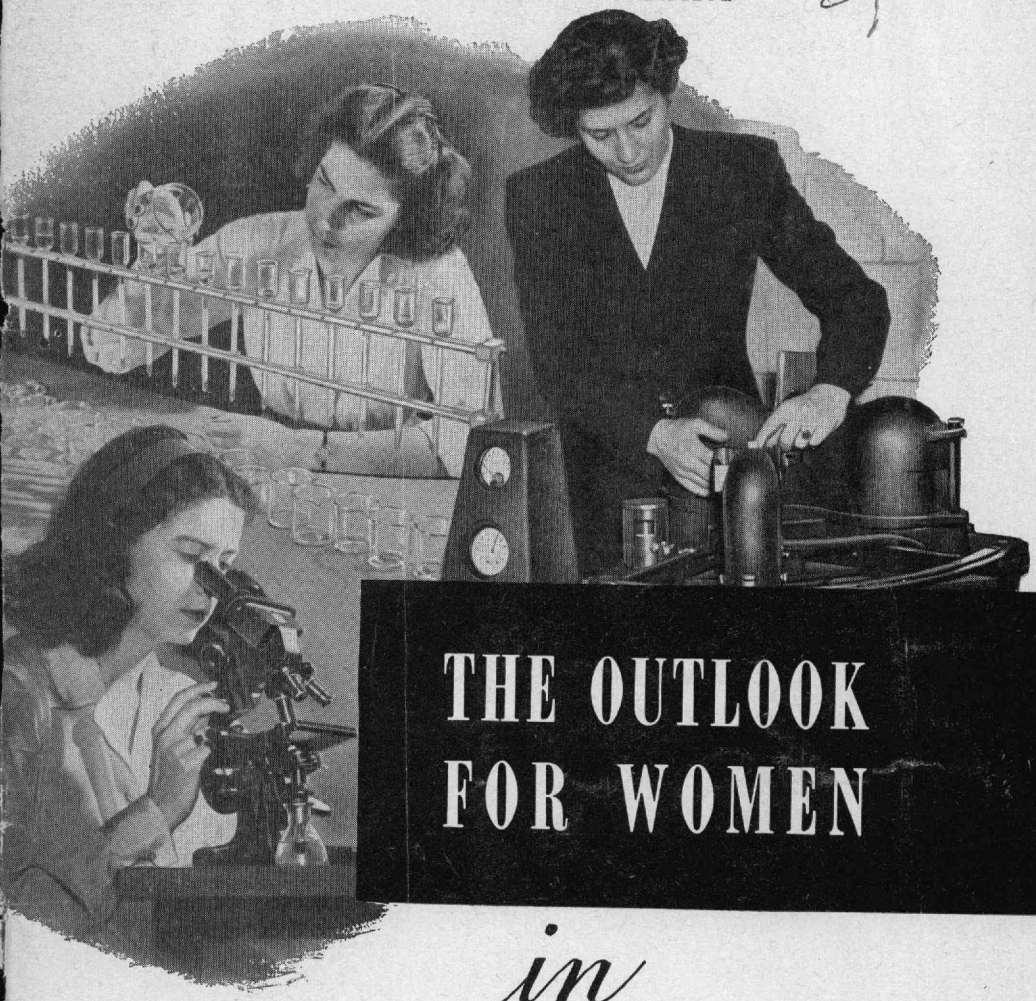

THE OUTLOOK FOR WOMEN *in* PHYSICS AND ASTRONOMY

Bulletin No. 223–6

U. S. DEPARTMENT OF LABOR

WOMEN'S BUREAU

UNITED STATES DEPARTMENT OF LABOR
L. B. SCHWELLENBACH, SECRETARY
WOMEN'S BUREAU
FRIEDA S. MILLER, DIRECTOR

The Outlook for Women in Physics and Astronomy

Bulletin of the Women's Bureau No. 223–6

U. S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1948

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 15 cents

This bulletin is No. 223–6 in the following series on

THE OUTLOOK FOR WOMEN IN SCIENCE

No. 223–1 *The Outlook for Women in Science*
No. 223–2 *The Outlook for Women in Chemistry*
No. 223–3 *The Outlook for Women in the Biological Sciences*
No. 223–4 *The Outlook for Women in Mathematics and Statistics*
No. 223–5 *The Outlook for Women in Architecture and Engineering*
No. 223–6 *The Outlook for Women in Physics and Astronomy*
No. 223–7 *The Outlook for Women in Geology, Geography, and Meteorology*
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LETTER OF TRANSMITTAL

United States Department of Labor,
Women's Bureau,
Washington, December 22, 1947.

Sir: I have the honor of transmitting a description of the outlook for women in physics and astronomy which has been prepared as a part of a study on the outlook for women in science. The extraordinary demand for women with scientific training during World War II and the resulting questions which came to the Women's Bureau prompted us to undertake this study. The paucity of published information on women in science and the encouragement of the scientists and educators who were consulted in the course of this study confirmed the need for the information here assembled and synthesized. The study was planned and directed by Marguerite Wykoff Zapoleon and completed with the assistance of Elsie Katcher Goodman and Mary H. Brilla of the Employment Opportunities Section of the Bureau's Research Division. Other members of the Bureau staff who helped to broaden the coverage of this study through interviews in the field were regional representatives Margaret Kay Anderson, Martha J. Ziegler, Rebecca G. Smaltz, and another member of the research staff, Jennie Mohr. Corinne LaBarre, research assistant, of the Western Personnel Institute, Pasadena, Calif., furnished the information obtained from western colleges.

The part of the study here transmitted was written by Elsie Katcher Goodman.

Respectfully submitted.

Frieda S. Miller, *Director.*

Hon. L. B. Schwellenbach,
Secretary of Labor.

FOREWORD

Much has been written about science and scientists, but little has been told about the work women trained in science have done and can do in the future.

Although these women are few in number when compared to men in science or to women in such occupations as teaching and nursing, their contribution to the national welfare, so strikingly demonstrated in World War II, goes forward daily in the laboratories, classrooms, offices, and plants in which they work.

The every-day story of where these women work, of what kind of work they are doing, and of what other young women who join their ranks in the future may do has been the subject of this report on the outlook for women in science. Unlike the usual monograph which describes an occupation in detail at a particular point in time, this study, like the Women's Bureau series on occupations in the medical and health services which preceded it, is concerned primarily with changes and trends.

Although more than 800 books, articles, or pamphlets were culled for background information, the principal raw material for the entire study of which this bulletin is a part came from such primary sources as scientific organizations, employers and trainers of women scientists, and men and women scientists themselves. Principal sources were as follows:

Scientific organizations: The National Research Council supplied useful directories of scientific laboratories and organizations. Helpful criticism and direction to other authorities were obtained from its Office of Scientific Personnel. Sixty separate organizations of scientists supplied information on their women members, by interview or correspondence.

Federal agencies: Unpublished information on personnel in scientific fields was supplied by:

The United States Bureau of Labor Statistics,
The National Roster of Scientific and Specialized Personnel,
The United States Office of Education,
The United States Civil Service Commission, and
The United States Public Health Service.

In addition, 52 separate bureaus, offices, or other operating units of the Federal Government known to employ scientists were solicited for information regarding the number of women

employed on jobs requiring scientific training and the type of work they were doing. Detailed statistics over a period of years were available from some agencies, while only fragmentary data were obtained from others. The women's military services likewise supplied information on the wartime use of women trained in science in the WAC, WAVES, and the Marine Corps.

Private industry: One hundred industrial firms were visited in 1945 and 1946 to obtain information, usually by interview with the director of research or the personnel director, on the women employed by any part of the organization in any capacity requiring scientific training of college level. Prewar, wartime, and postwar statistics were obtained where available, as well as suggestions and comments. In many instances, some of the women in scientific work were interviewed on the job. The firms visited included:

Seventy-eight firms listed in the National Research Council's 1946 directory of 2,443 firms having research laboratories. The firms visited are listed in the directory as employing 24,816 persons as scientific or technical personnel in their laboratories. This number represented 28 percent of the total personnel of this type estimated as employed in all the laboratories listed. In addition to this numerical coverage, an attempt was made to include among the 78 firms visited small as well as large firms, plants in all parts of the United States, and a variety of industries. However, the intricate industrial organization, inter-relationships, and variety of research revealed in the directory, added to the fact that some firms did not report personnel statistics and none reported women separately, made the selection of a true sample complicated beyond its value for this purpose. The firms visited were chosen rather as a clue to industrial firms most likely to be engaged in the type of work in which women trained in science are used. In all firms, information was requested for the entire organization rather than for the research laboratory only.

Eighteen commercial testing laboratories which offer testing services to industry and individuals and which employed women were also visited. Seven others contacted did not employ women. These 25 laboratories represented 10 percent of the 244 commercial testing laboratories listed in the National Bureau of Standard's 1942 Directory of Commercial Testing and College Research Laboratories. Since

personnel is not reported in the Directory, there is no clue to the coverage of workers.

Three large additional industrial firms which employed women in laboratory work, but were not listed as having research laboratories, were visited, as was one biological supply house.

Research institutions: Eight research institutions or centers, some of them identified with a particular college or university, also supplied information on women members of the scientific staff.

Colleges and universities: Statistical information on the number of women graduated with degrees in science, mathematics, and engineering over a period of years from 1939–40 to 1946 was obtained from 30 colleges and universities and from 9 engineering schools. Again an attempt was made to obtain wide geographical coverage and to cover different types of institutions, such as women's colleges, State universities, and small liberal arts colleges. The information available from these sources, too, varied. Placement bureaus and heads of science departments as well as deans of women at these institutions and at six other colleges contributed reports on the demand for women trained in the sciences. The Western Personnel Institute made possible the inclusion of data which it collected for the Bureau from its affiliated colleges and universities in the far West.

Since no recent data were available on the number of women teaching science in the colleges, a count was made in 1947 of the women identifiable by name who were listed on science faculties in the catalogs of 330 institutions of higher learning which were then available in the United States Office of Education Library. These institutions were selected because they are believed by the United States Office of Education to be representative in their enrollments of the 1,749 institutions of higher education in the United States and, therefore, are likely to have faculties equally representative.

Other sources: In addition, 97 individuals not included in the afore-mentioned sources, most of them women scientists, contributed information, suggestions, or helpful criticisms of the preliminary manuscripts circulated before revision for publication.

While every effort has been made to obtain wide coverage, there remain some dark corners still unexplored because of the range and variety of these fields and the difficulty of obtaining information from widely scattered sources. Perhaps this beginning will result in further additions to our so-little knowledge.

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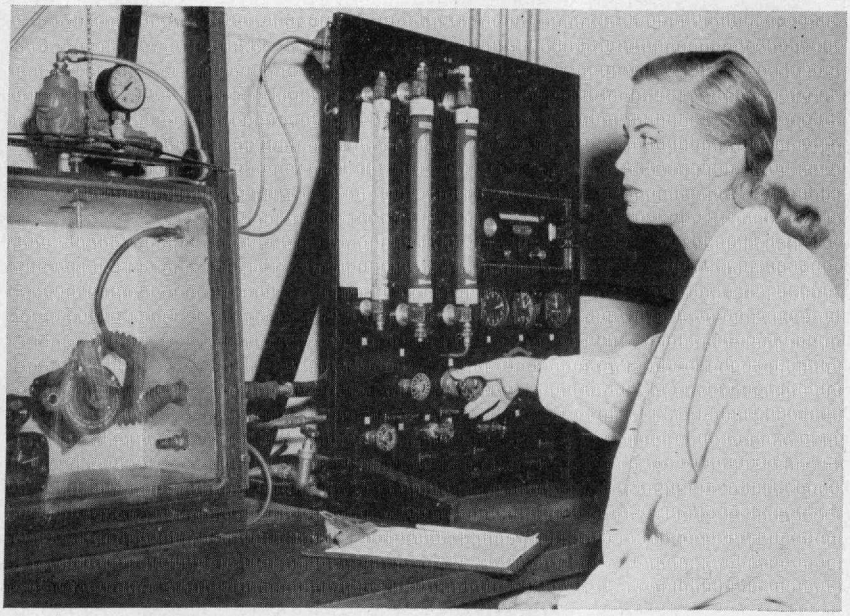

Courtesy National Bureau of Standards

Figure 1.—A physicist testing the performance of oxygen regulators at high altitude in the Aeronautical Instruments Section of the National Bureau of Standards.

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Definition of Physicist by the War Policy Committee of the American Institute of Physics (*4*)

"A. A *physicist* is one whose training and experience lie in the study and applications of the interactions between matter and energy in the fields of mechanics, acoustics, optics, heat, electricity, magnetism, radiation, atomic structure, and nuclear phenomena.

"B. To qualify as a *professional physicist* one must have had at least 8 years of training and experience in physics. Toward this experience 4 years of formal collegiate education with major emphasis on physics may be credited, year for year, if it leads to a bachelor's degree, 5 years if it leads to a master's degree, and 7 years if it leads to a doctor's degree, from a recognized institution. Years of teaching of physics in a recognized institution may be credited as years of experience in physics. By a recognized institution is meant one which appears in the list of institutions approved by the Association of American Universities."

Occupational Summary of the Profession of Physicist by the National Roster of Scientific and Specialized Personnel (*43*)

"Physics is the science that deals with matter, motion, and energy. Recognized areas of specialization within this field are mechanics, heat, sound, light, electricity and magnetism, electronics and ionics, radio, atomic and nuclear physics, properties of materials, theoretical physics and biophysics. Other specialties relate to the application of the fundamental principles of the science to industrial problems, especially with highly precise and delicate measuring instruments, radio design and manufacture, optical instruments, and physical testing of materials."

THE OUTLOOK FOR WOMEN IN PHYSICS

Recent research in nuclear physics and its wartime applications to the atomic bomb have brought unusual prominence to the 12,000 men and women physicists of the United States (*41*). Their work in fundamental scientific research also made possible the recent and, from the point of view of wartime strategy, the equally important developments in radar and electronics. In these fields, as well as in others less popularly known, the contributions of some 500 American women trained in physics have not gone unrecognized, although they form only 4 percent of all physicists (*47*).

Prewar Distribution

The number of physicists in the United States before the war varied from an estimated 4,000 to 6,000, depending upon how physicists were defined (*29*). The more conservative defined the profession rigidly and usually included graduate training or its equivalent as a criterion. Most of the physicists were employed in university and college teaching, in industrial research and development, or in fundamental research in Government agencies or research foundations.

By far the largest number, some 3,000, were in universities and colleges, engaged in teaching, and sometimes in research, as time and facilities permitted (*12*). Qualifications set for physics faculties were very high; probably more than half had the Ph. D. (*42*). That teaching was the principal prewar outlet for physicists is further indicated by the fact that, in 1940, more than 60 percent of the 1,100 persons who had received the doctorate in physics in the previous decade were employed in institutions of higher education (*21*).

The number of women physicists engaged in college teaching before the war is not known, but the proportion in teaching was possibly as high as or higher than that of the men. For example, of the 12 women graduated with a degree in physics by the Massachusetts Institute of Technology whose 1940 employment is known, half were teaching. Two of the women were serving as full professors, two as assistant professors, one as a teaching assistant, and one was a teacher part time in addition to her work as an astronomer. About three-fourths of the 42 women physicists listed in the 1938 directory of American Men of Science were teaching. Twenty-nine of these women held the doctorate and 11 the master's degree (*33*).

Physics teachers in secondary schools usually cannot be classified as physicists, since most of them do not have even undergraduate de-

grees in physics. A survey made of physics teachers in Pennsylvania high schools before the war revealed that more than 40 percent had less than 12 semester hours in physics, whereas double that number would ordinarily be the minimum required for a college major in physics. Most of these physics teachers also taught other high-school subjects, usually chemistry or mathematics; many of the men served as athletic coaches or as administrators (*35*).

In 1940, 2,030 physicists were engaged in industrial research (*51*). They were employed in such industries as the manufacture of electrical, radio, and communications equipment; professional and scientific instruments; automobiles and airplanes; glass; iron and steel and machinery; and petroleum and chemicals (*41*). But opportunities for women physicists in industrial research laboratories were very limited. Of the 12 women physicists graduated by the Massachusetts Institute of Technology whose prewar employment is known, only 2 secured jobs in industry; 1 was employed as a technician, and the other was working in a chemical laboratory. Of the 78 firms having industrial research laboratories surveyed by the Women's Bureau in 1945–46, only 4 reported that they employed women trained in physics before the war.

With rare exceptions, the few women found in industry were engaged in fairly routine duties, involving some knowledge of physics, or mathematics and physics. For example, in an engineering and physical testing laboratory a woman with a major in physics divided her time between working in the technical library and assisting a theoretical physicist with computations. Another young woman with an M. S. in physics was working as an assistant spectroscopist with a company manufacturing chemicals and chemical products.

In 1939, the American Physical Society reported that more than 100 of its members were employed in the Federal Government, over half of them in the National Bureau of Standards. The others were employed in the Naval Research Laboratory, the Department of Agriculture, the Coast and Geodetic Survey, the Bureau of Mines, the Smithsonian Institution, the Washington Navy Yard, the Public Health Service, or the Geological Survey (*13*). The small number of women physicists in the Federal Government before the war is indicated by a Women's Bureau study of 1938, which reported only 25 women, excluding chemists and mathematicians, classified as geologists and physical scientists, and most of these 25 women were probably geologists (*48*). Reports from college placement bureaus suggest that the few employed as physicists were hired by the Navy Department or the National Bureau of Standards.

On the whole, the prewar employment of women physicists tended to be similar to that of men. A report from five colleges on the initial

placements of 19 women graduated with a degree in physics just before the war indicated that: 5 went into teaching, 4 into Government, 3 into industry, 2 continued with further graduate work, 2 had no occupation, and 3 were engaged in miscellaneous pursuits.

Annual Addition to the Supply

Before the war, the universities and colleges produced annually about 400 physicists with advanced degrees, of whom about 160 men and women were Ph. D.'s (*42*) (*52*). Probably less than 4 percent of these degrees were awarded to women, essentially the same proportion that women formed of all physicists.

The interest of women science students in undergraduate courses in physics was low. In the midthirties, the ratio of women majoring in physics to those majoring in chemistry was 1 to 6, and to those majoring in biology it was 1 to 10, according to a survey of women's colleges (*14*). The prevailing attitude was that physics was very difficult, and girls were advised not to attempt it. The college woman who wished to major in physics was sometimes discouraged by being told that there would be no opportunities to use it professionally. In 1940, in spite of efforts to make courses in physics more attractive because of their growing importance in national defense, there was little increase in the interest of women students (*2*). The small number of women majoring in physics before the war was reflected later in a survey made by the National Roster, which found that only 125 women seniors were expected to graduate with bachelor's degrees in physics in 1942–43 (*40*).

Wartime Changes

Early in the war, the supply of persons trained in physics was found to be far short of the needs of the country's wartime program. At a time when industry, Government, and the armed services were clamoring for more physicists, the universities and colleges were struggling to get along with diminishing faculties and a depleted student body. By 1942, the shortage of manpower in physics, especially that available for teaching, had reached the proportions of a national emergency, according to the War Policy Committee of the American Institute of Physics (*31*).

In 1942, only 1,000 graduate students in physics, 95 of whom were women, were enrolled in universities and colleges throughout the country. There were 7,000 undergraduates, including about 630 college women enrolled as physics majors (*40*).

As a result of the concentration of physics teachers in schools devoted largely to the training of Army and Navy Reserves, women physics majors found themselves in a peculiar position. On the one

hand, their instructors were being drawn away to teach military personnel or to engage in war research; on the other hand, they were urged to continue their training by taking graduate work. And in the meantime, well-paying jobs in industry became available to women with even limited training in physics.

Consequently in 1944 the number of women students declined along with the decrease in male civilian enrollments. In January 1944 there were only 2,260 undergraduate students enrolled as physics majors, and although women composed 20 percent of this group, their number had dropped to 457. On the graduate level, there were only 386 students, of whom women numbered 28 (*45*). As the war continued, the number of Ph. D.'s awarded annually, which had reached an all-time high of 191 in 1941, continued to decrease until in 1945 only 39 such degrees were granted (*34*).

During the war, colleges and universities all over the country aided in the tremendous task of training persons in the newer fields of electronics and radar. Hundreds of schools cooperated in publicizing the training available through the federally financed Engineering, Science, and Management War Training program. During 1940–45, some 870 courses in physics were given, usually for evening students, many of whom were employed in related technical fields in which new scientific developments made further training essential. More than 32,000 men and women attended these physics courses, which included subjects ranging from the fundamentals of physics to highly specialized courses in ultra-high-frequency techniques. About two-thirds of the students were enrolled in physics courses dealing with electricity and magnetism, so important in the development of electrical and communications equipment for military use. Courses in electronics were given as part of the electrical engineering program and were attended by almost 60,000 students, many of whom were trained primarily in physics (*49*).

The number of women taking courses in physics under the program is not known. Although women formed approximately one-sixth of the trainees in all Engineering, Science, and Management War Training courses, their proportion in physics and electronics was undoubtedly much smaller (*49*).

World War II has frequently been referred to as a "war of physics," just as the First World War was called a "war of chemistry." There were two or three essential jobs waiting for every newly trained physicist as he became available, and persons trained at all levels from high-school graduates to doctors of philosophy were urgently needed (*18*) (*5*). In universities and colleges, in industry and Government, the demand for men and women trained in physics far exceeded the supply.

Strenuous efforts were made to recruit from all sources persons with some training in physics. Scientists in related fields and those who had originally secured their training in physics but were employed in other work were given the opportunity to take refresher courses in order to qualify for positions in physics. This transfer of persons from other fields and the concentrated efforts of universities to produce more physicists finally brought forth about double the number who had been employed before the war.

In December 1944, almost 12,000 persons in physics voluntarily registered with the National Roster of Scientific and Specialized Personnel. Women formed about 4 percent of this group and, like the men, more than half had graduate degrees (*47*). (See table 1.)

Table 1. Distribution by Highest Academic Degree Held of 11,615 Men and Women Registered in Physics With the National Roster of Scientific and Specialized Personnel, 1944

Highest academic degree held	Number			Percent		
	Total	Men	Women	Total	Men	Women
Total	11,615	11,204	411	100	100	100
Ph. D	2,785	2,692	93	24	24	23
Master's	3,227	3,099	128	28	28	31
Bachelor's	4,720	4,578	142	41	41	35
4 years of college, no degree	262	252	10	2	2	2
Others	621	583	38	5	5	9

Source: National Roster of Scientific and Specialized Personnel (*47*).

During the war, college placement officers reported an "incredible" demand for their graduates with courses in physics. Even girls with only 1 year of physics were readily placed; those who had secured their degrees in physics had many choices. One university placement bureau, for example, which had had only one employer request for a woman trained in physics in the academic year 1941–42, received 21 calls in 1942–43, and 19 in 1943–44. "Multiple" calls, which meant an employer said: "I will take as many as you can provide," became common.

Whereas teaching had formerly been the greatest outlet for women physicists, during the war this field dropped to third place. Reports from five colleges on the placement of 37 women graduated with majors in physics between 1942 and 1945 indicated that 17 had secured jobs in industry, 10 in Federal Government or Government-sponsored research projects, 5 had become teachers, and 5 entered other fields.

Job transfers also were encouraged by the wartime situation. One woman, for example, who before the war had been working as a high-school laboratory assistant while she continued her graduate training, took a position in a naval ordnance laboratory during the war.

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Another left her job with a firm manufacturing electrical and communications equipment to go into military service, where she used her training in physics in the highly important field of communications intelligence. Another who secured her degree in 1943 accepted an immediate appointment as a junior high-school teacher, but later left for a position with a firm manufacturing electrical equipment.

One of the most significant but less publicized contributions which physicists made during the war was in the training of thousands of students in physics. But in the summer of 1942 the National Roster reported that over one-third of the physicists ordinarily employed in universities and colleges had left their campuses for war-related work, and in December of that year only 2,328 resident faculty members remained. Among them were 178 women physicists, over 7 percent of the total, a higher percentage than that which they formed of all physicists (*47*) (*40*).

The needs of the Army, Navy, and Air Force specialized training programs for full-time physics instructors were almost double the number available. In the institutions which had been certified for possible contract with the armed forces for the specialized training of Reserve forces, there were 1,700 instructors in physics, and only 650 remained in other institutions that were completely devoted to the instruction of civilian men and women. To meet the demands of the armed forces training programs alone, it was estimated that 600 additional experienced teachers and 1,900 persons qualified for physics laboratory duties would be needed (*46*).

All sources were combed for additional instructors. Universities were asked to take inventory of their faculty members and graduate students to discover suitable teachers and to encourage qualified women and others permanently deferred from military service to teach physics. Persons teaching in other fields who could transfer to physics were encouraged to do so. Survey courses in physics and other sciences were eliminated to enable trained teachers to concentrate on war-related physics training or research. In addition, local industries and laboratories were surveyed to locate part-time teachers (*46*).

The extensive use of part-time teachers was shown in a survey made by the American Institute of Physics in the spring of 1943 which revealed approximately 4,000 persons (exclusive of undergraduate assistants) engaged in full- or part-time teaching of physics (*8*). This number was 40 percent higher than the number of full-time resident faculty members shown in the National Roster's survey.

In this period, college women were given unusual opportunities to continue their graduate work and to remain on the campus as teaching assistants. However, the women who chose to remain in this field

during the war were those who turned down the tempting offers of jobs at higher pay made by industry and Government. And partially as a result of this, high-school teaching jobs, formerly sought after, went begging during the war.

Early in the defense period, employment opportunities for physicists began to change rapidly as industrial research laboratories began hiring physicists in large numbers. In 1941, the American Institute of Physics reported that 2,500 physicists were employed in industry, many of whom were already working for national defense (*10*). During the war the limited supply of persons trained in physics and the speed with which new graduates were hired by industry made the demand for their services appear almost insatiable. Most of the large manufacturers of electrical and communications equipment, scientific instruments, glassware, auto and airplane parts, and others producing chemicals greatly expanded their research laboratories and in a few instances doubled their scientific staffs. Many industries that had not used physicists before learned that physicists could be practical as well as theoretical scientists and could operate under the pressure of production planning. As it became evident that physicists were especially valuable in some industries in process development, improvement, and control, the competition for their services increased (*17*).

In January 1944, a survey made by the National Roster of 18,700 industrial war establishments and 645 industrial research laboratories indicated that 649 physicists would be needed to fill new openings in the following 6 months. In addition, it was predicted that 335 more physicists would be required to compensate for losses to the armed forces and normal losses due to death and retirement (*44*).

A survey of 78 industrial research laboratories made by the Women's Bureau in 1945–46 revealed that women physicists were employed during the war in 18 of these laboratories, as compared with 4 before the war. Like men, women trained in physics were found employed in industries manufacturing electrical and communications equipment, machinery and transportation equipment, scientific instruments, photographic apparatus, glass and glassware, chemicals, rubber, and petroleum.

Women with bachelors' degrees in physics were working as junior physicists assisting senior staff members in research projects. In such positions they were responsible for setting up and operating laboratory apparatus, carrying on simple experiments, recording and accumulating data based on their research, and assisting their supervisors in the analysis of the data. Sometimes they were also required to do library research on a particular problem, before laboratory investigations were initiated. Some women physicists were directing the work of

one or more technical laboratory assistants who were making routine physical tests or analyses.

During the war, when many industrial research laboratories were unable to secure fully trained scientific personnel, employers were often forced to break jobs down into routine duties which could be handled by persons with limited training. Frequently, in-service training courses were given to qualify persons for specific duties as technical assistants or engineering aids. (See Bull. 223–5, engineering aid.) College women with majors in other fields qualified for some of these jobs, but those with courses in physics or mathematics were especially welcome. In one large establishment manufacturing electrical and communications equipment, the number of women employed as technical assistants was four or five times the number of women scientists employed. This pattern of occupational distribution was the result of the wartime emergency when persons fully trained in the sciences were at a premium.

Women with very limited knowledge of physics, sometimes not beyond high-school training, were also employed as laboratory assistants, to give assistance to technical staff members and to perform very routine duties. For example, in a drug manufacturing plant, women with high-school training in chemistry, physics, and mathematics were working under close supervision on routine testing, involving simple mathematical calculations and an elementary knowledge of physics or chemistry. In a machinery manufacturing concern, after a brief in-service training course, women laboratory assistants ran instruments through pressure and heat tests, being responsible for inspecting them and tabulating the results. In a metal products company a high-school girl, after an Engineering Science Management War Training course in metal techniques, was taking readings on tensile testing machines, doing microscopic readings and plotting the results of various tests on a 52-bar chart.

During the war the Federal Civil Service Commission was constantly recruiting physicists, and women in this field were able to secure positions in Government research laboratories that had formerly never employed women physicists. In April 1943, the Commission stated that there were not enough physicists in the country to meet the Government needs, especially in the fields of electronics and radio, electricity, sound, and optics. They asked that women be encouraged to enter the field, since there were a large number of openings for women, particularly in the lower grades (*37*).

There is no record on the total number of women physicists employed in the Federal Government during the war, but reports available to the Women's Bureau on 50 women physicists in Civil Service indicated

that the largest group was employed in the National Bureau of Standards; the others were working in Ordnance armories and arsenals of the War Department, and in the Patent Office, the Navy Department, and the National Advisory Committee for Aeronautics.

Among Federal agencies, the National Bureau of Standards has always employed a large number of physicists. During the war it employed women physicists in such specialized fields as weights and measures, optics, heat, electricity, electronics, and radio. Most of the women, however, were employed in the lower professional grades, and none were employed at the top professional grade. The duties of these women, dependent upon the field in which they were working, might include such assignments as: the determination of the capacity, internal resistance, and voltage drop of storage batteries; the examination of photographed spectra with a microphotometer and a micrometer comparator; making computations in optical design involving ray tracing; the solution of simultaneous differential equations and the evaluation of determinants of the third order; or carrying on investigations in theoretical physics relating to atomic nuclei.

The Bureau of Standards also employed more than 100 women in subprofessional positions as physical science aids. More than a fourth of these women were doing work requiring some training in physics. Those with only high-school training were doing very routine work, but those with a year or more of college training were engaged in subprofessional scientific or technical work, assisting in physical testing or analysis and making appropriate calculations. However, their duties varied considerably according to the section in which they were employed.

The knowledge and skills peculiar to physicists were particularly adapted to the development of programs for National defense. Only a few months after the Office of Scientific Research and Development had been created, three-fourths of the outstanding physicists in the country were declared to be heading Government-sponsored research projects (*22*). According to college placement officers, there was a great demand for women trained in physics for research projects sponsored by the War and Navy Departments and for those of the Office of Scientific Research and Development, such as the Argonne Laboratory at the University of Chicago, where fundamental research on atomic energy was done, and the Radiation Laboratory at the Massachusetts Institute of Technology, the largest radar laboratory. The women's military services, too, were recruiting women with science backgrounds for training in aerology, radar, and communications work. Only a small number of women physicists entered each of these fields, but they made an important contribution to the war effort.

Earnings and Advancement

Before the war, entrance salaries for physicists in industry ranged from $1,200 to $2,000 a year (*41*). In 1946, however, women physicists employed in industrial research laboratories were reported to be earning $2,500—$3,000 a year, and a few were earning over $4,000 a year.

The earnings of college teachers vary with the income and type of institution in which the teacher is employed, as well as with the rank and qualifications of the individual. Before the war, the median salaries of professors in different types of publicly controlled institutions ranged from $2,900 to $5,000, and in privately controlled institutions, from $1,800 to $5,000. However, associate and assistant professors and lecturers received less (*50*). In 1947 these salaries were undoubtedly higher, but there were no adequate statistics available to indicate what increases had taken place.

Salaries paid to high-school teachers of physics are the same as those paid other high-school teachers and vary with the size of the city in which the teacher is employed. Before the war, the median salary paid to a high-school teacher in a town having a population of from 2,500 to 5,000 was $1,428 a year, but in large cities having a population over 100,000 the median salary was $2,768 a year. In 1946–47, the median salaries of high-school teachers in comparable communities were $2,274 and $3,593, respectively (*25*).

In 1940, junior physicists in the Federal Government earned $2,000 a year. During the war, with overtime, the earnings on the same job were $2,433, and in 1947 the basic salary had risen to $2,644 a year.

In physics, as in many of the other sciences, advancement for women has been slow. Those with graduate training have had much better opportunities, for the Ph. D. is practically a prerequisite to advancement in physics, especially in college teaching. The importance of graduate training in this field is indicated by the fact that in 1944 more than half the men and women physicists registered with the National Roster of Scientific and Specialized Personnel had master's or doctor's degrees (*47*). Industrial employers, however, usually rate women physicists more in terms of the results they can produce. They hesitate to advance women who have not been with the company long enough to give evidence of an active and continuing interest in physics as a career.

The few women who have received recognition in this field have all had their doctorates. One, for example, began her work as a research physicist in an industrial research laboratory during the last war. Later, she was awarded the first Ph. D. ever conferred on a woman by Cambridge University. Her discovery of "invisible glass" has contributed much to the improvement of lenses in cameras, periscopes,

and optical instruments. In 1945, the American Association of University Women presented her with an award in recognition of distinguished achievement (*53*).

Because of the increasing importance of electronics and nuclear physics, young physicists who recently completed work for their doctorates in these fields have been able to advance very rapidly. Since these specialties have developed only in the past two decades, there are relatively more young scientists who have pioneered in research in these areas.

Organizations

In 1941, the American Institute of Physics estimated that 4,100 physicists were members of at least one of the national professional societies in physics (*29*). In 1946, about 10,000 physicists were members of the societies coordinated by the Institute, about half of them members of the American Physical Society. Membership in the American Physical Society requires only the recommendation of two other members, but the applicant must be really interested in physics, although not necessarily a professional physicist. The others were members of one or more of the following: The Optical Society of America, interested in the science of light; the Acoustical Society of America, devoted to the science of sound; the Society of Rheology, for the advancement of knowledge concerning the deformation and flow of matter; and the American Association of Physics Teachers. There are women physicists in each of these organizations, their numbers in 1946 ranging from about 2 to 4 percent of the membership in the different societies. (See p. 6–29 for membership requirements in the American Association of Physics Teachers.)

The Outlook

The effective role played by physicists in applied research during the war and the present undersupply of persons trained in physics promise a favorable outlook for women in physics for the next few years. The increased use of physical methods in industrial research, the renewed interest of governmental and other research agencies in fundamental scientific investigation, and the growing recognition of the importance of a basic knowledge of physics to all scientists have increased the demand for physicists in all fields, as compared with that existing before World War II.

However, this demand is primarily for those with graduate training. In fact, the shortage of physicists with graduate training, occasioned by the war, is expected to continue for a number of years. The newer industrial demand for physicists is also expected to create a deficit

in the number of persons trained at the master's and doctor's levels. In 1945 a deficit of 2,000 physicists at the doctorate level in 1955 was predicted (*52*). But in view of the increased number of students preparing for the Ph. D. subsequent to the war, under the benefits of the GI bill and the Predoctoral Fellowship program of the National Research Council, or through the aid of part-time jobs in Government-financed research projects at universities, this estimate appears to be high. Two years after the war had ended, women with Ph. D.'s in physics were still being sought by universities and government research laboratories. Of the women Ph. D.'s employed in industrial establishments covered in the present study, all were retained during the reconversion period.

But the extraordinary need for women with a minimum amount of work in physics, caused by the wartime emergency, has terminated, according to reports from college placement bureaus and departments of physics. College women with only the bachelor's degree no longer have a wide choice of jobs. In some instances, such women who were employed in establishments that were operating under wartime Government contracts have been released. Nevertheless, the small number of women graduating with these degrees in 1946 were being placed.

Statistics furnished the Women's Bureau by nine of the colleges and universities which regularly graduate women with degrees in physics indicate that more women were enrolled in this field in 1945 and 1946 than there were during the war. But the number is still very small. In these schools there were only 50 to 60 women enrolled as physics majors in each of the years 1945 and 1946. Nevertheless, this was about twice the prewar number. Apparently there has been a general increase in interest in physics on the part of both college and high-school students. During the war, when the total enrollments of all high-school students showed a decrease, the number of boys and girls enrolled in physics increased more than 10 percent (*9*). It is too early to predict whether or not this trend will continue.

The increased postwar demand for women physicists appears to be following the prewar pattern, since teaching again ranks first as an outlet for women in physics. As a result of increased enrollments of students in physics the demand for physics teachers is expected to remain high. At the close of the war, college teaching staffs had to be reorganized to accommodate the increased numbers of students, and many openings for physics instructors were created. Although women with graduate training in physics are currently in demand as research and teaching assistants, by 1950 they will face greater competition from men veterans who are preferred by some institutions of higher education. It is likely that qualifications for such positions will be restored to prewar standards; women physicists who plan to

Courtesy Purdue University

Figure 2.—A faculty member of the Purdue University Department of Physics

teach will need more thorough training than the men with whom they must compete.

The increased demand for women trained in physics in colleges and universities was reflected in a count made in 1947 of women physics faculty members listed in the catalogs of institutions of higher education included in a sample of such institutions selected on the basis of enrollments by the United States Office of Education. There were 86 women on physics faculties in the 330 institutions included in the sample. Seventy of them were teaching physics only, and 16 taught another science as well, such as astronomy, chemistry, or mathematics.

Undoubtedly a few of these women were on temporary teaching appointments, since they held such titles as those of temporary instructor, acting instructor, and teaching fellow. A large number were listed as assistants, research assistants, or graduate assistants and may have been devoting time to research as well as to teaching. There were 22 women, however, more than one-fourth of the total, who held professorship appointments. The importance of the Ph. D. in college teaching is indicated by the fact that more than two-thirds of the women professors held the doctorate.

If these schools are representative of all institutions of higher education, there were about 347 women teaching physics only in addition to about 93 who combined instruction in physics with that in

another science. More than 40 percent were employed by colleges of liberal arts and science, and about 30 percent by publicly and privately controlled universities. The remainder were in technological and professional schools, teachers' colleges, and junior colleges.

As a result of the emphasis on science during the war, the enrollment of high-school students in physical science courses is expected to remain high. The proportion of women teaching physics in secondary schools in 1947 was probably greater than it had ever been, and opportunities were expected to increase. In many high schools there has been a general trend away from the formal college preparatory courses in physics and chemistry (where men teachers have been preferred), toward courses in applied science of general interest. In some of these newer courses, such as consumer science, laboratory techniques, the science of photography, and general physical science, there appears to be more opportunity for women. Those women who combine a minor in chemistry or mathematics with their major in physics will be better able to meet the demands of high-school teaching, since they will almost always be called upon to teach several subjects, except in unusually large schools.

In 1946, the National Research Council reported that 2,660 physicists were employed in industrial research laboratories in the United States, as compared to 2,030 in 1940. However, this is still only about one-eighth the number of chemists so employed (*27*). But with the application of new principles and methods to practical problems, the number of physicists in industrial research is expected to increase. Physical tools like X-ray diffraction, electron diffraction, the electron microscope, and modern spectroscopy are being applied to biological, chemical, and geological problems encountered in industry (*23*). Physicists with their broad knowledge of principles and methods are being called upon more and more to solve the practical problems that arise in the production of electrical and communications equipment, optical and other scientific instruments, glassware, petroleum, chemical, and many other products. The long-range trend seems to be toward more physicists in industrial research.

In the period immediately following the war, some of the women physicists employed in industrial manufacturing establishments were adversely affected by the reconversion to peacetime production. However, among the 78 firms with industrial research laboratories surveyed by the Women's Bureau in 1945–46, women trained in physics were still employed in 17 of the 18 laboratories which had employed them in wartime. Separate statistics on physicists were not available from all of the 17 laboratories, but in 7 of them, 38 women were classified as junior physicists or research physicists. A number of other women trained in physics and mathematics were employed under other

titles, such as those of research assistant, aerodynamicist, technical assistant, and patent research assistant. For example, one woman who had her bachelor's degree in physics and mathematics, and was working toward her master's degree in physics, was employed as a junior professional engineer. She was engaged in research in a corporation manufacturing radio parts and was making investigations on impulse communications. Two others with a degree in physics were employed as technical librarians.

Besides the 38 women identified as physicists there were about 475 women, most of whom held degrees in chemistry, physics, and mathematics, employed as staff members in 13 of the 17 laboratories, together with 375 women science majors working as engineering assistants, and more than 100 women with high-school training in physics, mathematics, and chemistry, hired as laboratory assistants and scientific testers.

Future opportunities for women trained in science differ from laboratory to laboratory. A few employers indicated that as women with a minimum of training left, they would be replaced by men. One industrial concern which had doubled its laboratory staff during the war planned to return to its prewar size and to release many technical and laboratory assistants. Another reported a need for more engineering and technical aids, and women with some training in physics were wanted as technical librarians, editorial assistants, and secretaries by another. In general, industrial employers are no longer actively seeking women physicists, but women trained in physics can still secure good positions in industry. The situation can be expressed in the comment of one industrial research laboratory director who stated, "We are not recruiting, but we can use a woman with a B. S. in physics."

In 1947, the Civil Service Commission reported that women physicists were in demand in almost all science laboratories maintained by the Federal Government. The need has continued, especially in radar, electronics, and nuclear physics.

Although some wartime research activities were completed, others have been begun. Most of the peacetime research agencies, like the National Bureau of Standards and the National Advisory Committee for Aeronautics, were returning to problems of fundamental scientific research abandoned during the war.

At least 61 women physicists were employed in the Federal Government in 1946, according to reports obtained by the Women's Bureau from the principal agencies employing physicists. Forty-six of them were employed by the National Bureau of Standards in Washington, D. C. Other Federal employers included the Bureau of Ordnance and the Office of Research and Inventions of the Navy Department, the

Ordnance Department of the War Department, the United States Patent Office, the Atomic Energy Commission at Oak Ridge, and the National Advisory Committee for Aeronautics.

Some of the women employed as physicists during the war were barely qualified; it is possible that a few may not be able to qualify for permanent appointments. In the future, qualifications for physicists in the Federal Government may be raised, but, in 1947, 24 semester hours in physics was required for probational appointments at the beginning professional level. Women with these requirements and a bachelor's degree in physics were eligible for appointment. (See p. 6–28 for requirements for application.)

Finally, there is the area of pure research in which the especially gifted woman physicist may make important contributions in the future. During the war little progress was made in answering some of the fundamental problems of the science of physics. The applied research that was done added little to the understanding of natural phenomena, although the technological applications of nuclear physics have already produced the atomic bomb (*30*). Opportunities for pure research will be available mainly in university and Government research laboratories, research foundations, and in a few of the large industrial research laboratories which engage in pure research as well as in applied and developmental work.

The application of the principles of physics to other physical sciences, as in physical chemistry, geophysics, and astrophysics, for the solution of basic problems is rapidly gaining headway. In biology and medicine too, physical equipment and techniques applicable to biological and biochemical problems are receiving greater emphasis in the expansion of biophysics research programs (*7*). The interest of women in biophysics and the relative lack of prejudice against them in this field combine to make it a promising field for women physicists interested in research. Recent discoveries in these fields and the advances that physicists have made in an understanding of the nature of the atomic nucleus suggest that the men and women physicists of the future are within reach of a satisfactory understanding of the fundamental laws governing the nature of matter and energy (*23*).

Despite the need for training thousands of physicists in the next decade, only women with superior mathematical and scientific abilities should be encouraged to enter this field. Some of the qualifications which women physicists deem especially important in potential physicists are a scientific curiosity and an independence of spirit, combined with a willingness to try new things and the ability to persist in the solution of a problem, even in the face of possible failure.

Girls who wish to become physicists should begin to prepare themselves in high school, particularly in basic mathematics, and should

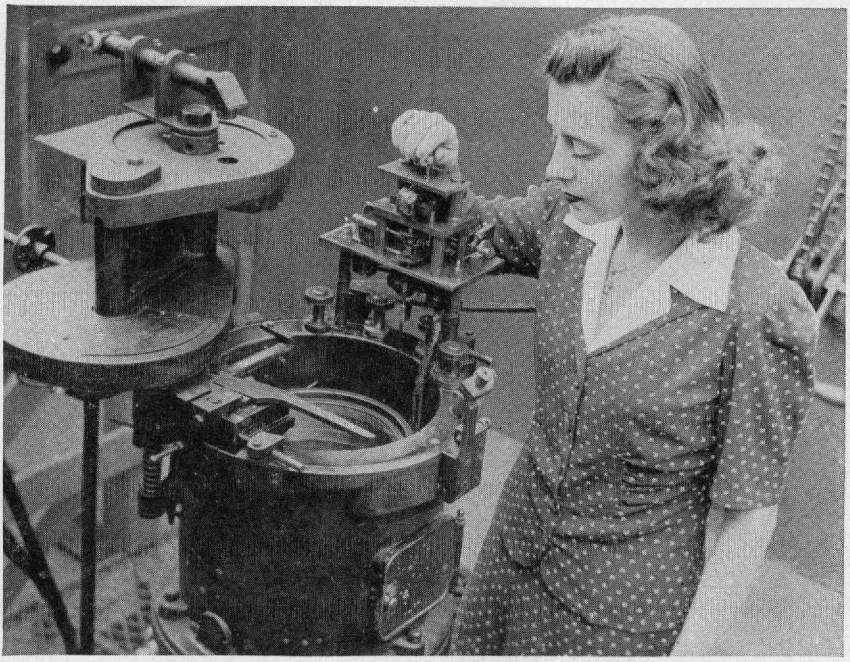
start the study of French and German as soon as possible. Their undergraduate courses in college should give them extensive experience with laboratory procedures and develop their ability to use mathematics, both in expressing theory and in solving problems. The training of the professional physicist should be planned to develop scientists rather than technicians. It should be broad and fundamental and directed toward preparation in a field of work, rather than toward a specific job, for the opportunities which arise in the new developments of the science require the ability to turn the older theories and applications to new uses.

The selection of a specialized field of physics for advanced study and graduate work should be determined by the general vocational objectives of the student. The woman who is interested in developmental research in industry will find that, in addition to a fundamental knowledge of the principles of physics, courses in physical chemistry, metallurgy, and electrical engineering will be helpful and should be supplemented by a thorough grounding in the use of scientific instruments (*16*). However, the woman who is interested in teaching and pure research might select more courses devoted to the theory of physics. No matter which fields are selected, women physicists whose educational background and training have been carefully planned will find opportunity for a growing part in the Nation's life (*11*).

Astronomy and Astrophysics as Defined in a Revision of the Occupational Summary of the National Roster of Scientific and Specialized Personnel (*43*)

Astronomers are primarily concerned with the study of the heavenly bodies, their sizes, masses, shapes, positions, distances, motions, and orbits. Astronomers observe the celestial bodies with telescopes equipped with cameras, photometers, micrometers, and various other optical devices. With the aid of mathematics they determine the positions of the stars and planets, calculate orbits of comets, asteroids, etc., and make statistical studies of stars and galaxies. They prepare mathematical tables giving the positions of the sun, moon, planets, and stars at a given time; including the almanacs used by the air or marine navigator to locate his position on land or sea.

At the present time, astrophysics plays a prominent part in the programs of most astronomical institutions. It deals with the study of the temperatures, luminosities, chemical composition, and internal structure of the stars and other celestial objects. For this work, telescopes are equipped with spectroscopes, photometers, bolometers, and in general with instruments that record the radiation received from the objects under investigation. The interpretation of these data requires training in physics as well as in mathematics.



Courtesy U. S. Naval Observatory

Figure 3.—An astronomer at the U. S. Naval Observatory adjusting the Photographic Zenith Telescope, which is used in determining time by the stars.

THE OUTLOOK FOR WOMEN IN ASTRONOMY

The number of astronomers has always been small, but their contribution to the knowledge of science and the universe has been great. The outstanding work of a few American women who pioneered in this field has eased the entrance of the women who followed. In 1945, 102 of the 600 members of the American Astronomical Society were women. This proportion, 17 percent, approximates that of women in the field itself and is high compared to the proportion that women comprise in the other physical sciences. In the field of mathematics, for example, women in 1944 were 13 percent of the total, in physics, only 4 percent, whereas they were 17 percent of all astronomers.

Prewar Distribution

Before the war most astronomers worked in universities or in research foundations which maintained astronomical observatories. For instance, in 1940, half of the 68 astronomers who had received their Ph. D.'s in the preceding decade were engaged in teaching or combined teaching with research. Two-fifths were engaged in research alone (*21*).

If an astronomical observatory is defined as a building designed or adapted to house a telescope permanently mounted, there were 273 observatories in the United States in 1945, located in 42 States and the District of Columbia (*32*). But most of the astronomers were employed in a few large observatories that are either connected with a university or identified exclusively with research programs, like the Harvard, Lick, Yerkes, McDonald Observatories, and the Mount Wilson Observatory of the Carnegie Institution of Washington. Some astronomers were employed by the Federal Government in the United States Naval Observatory and in the Astrophysical Observatory of the Smithsonian Institution. These observatories and the universities which before the war offered graduate training in astronomy were the principal employers of astronomers. A few were also employed as curators of astronomy and lecturers in the five planetaria in the United States located at Chicago, New York, Philadelphia, Los Angeles, and Pittsburgh.

For women who had secured an advanced degree in astronomy or astrophysics, teaching at the college level provided one outlet. Such openings were few in number, however, and were largely concentrated in those women's colleges in the East which had departments of astronomy. Some women highly trained in astronomy were also en-

gaged in original research. For example, a woman was on the staff of the Harvard College Observatory with the full rank of astronomer, and another was a research associate in spectroscopy at Princeton.

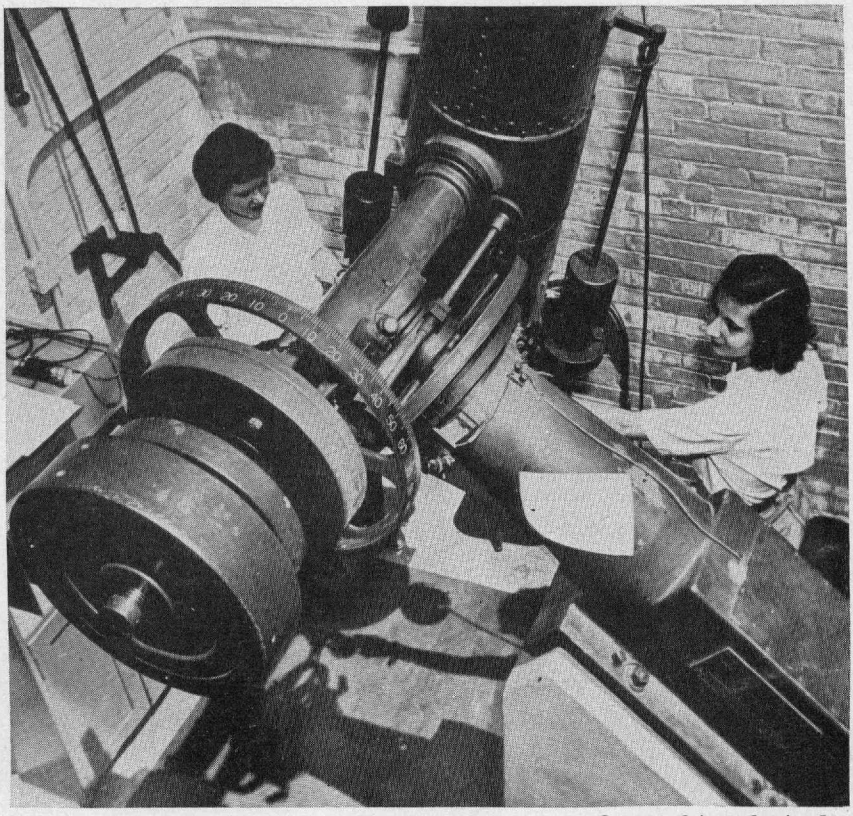
However, more of the women held positions as computers or as research assistants at observatories. Depending upon the research program and staff at a particular observatory, a computer made measurements on astronomical photographs or spectrograms or computed tables of observations for analysis by an astronomer. In some of the smaller observatories computers determined the orbits of comets or minor planets and predicted eclipses. In addition to such duties a research assistant, with a greater degree of responsibility, participated in some phase of the observatory's research program, working as part of a team in the usually congenial and often exciting atmosphere of an observatory. These jobs customarily required undergraduate training in mathematics or astronomy. Since this work at the astronomical observatories that are connected with universities was often done by graduate students, openings were rare except in the larger observatories, such as the Harvard College Observatory in Cambridge, and the Mount Wilson Observatory in California, both of which were engaged in extensive research programs.

At least two of the five planetaria in the United States employed one or more women astronomers as lecturers, and a woman was in charge of the Adler Planetarium in Chicago.

Annual Addition to the Supply

Before the war few women were graduated with a bachelor's degree in astronomy. College women were not encouraged to major in this science unless they had an unusually strong interest and sufficient financial resources to carry them through for a number of years. In the women's colleges offering a major in this science as well as in most State universities and other coeducational institutions with departments of astronomy, there were often years in which no degrees were granted in astronomy to women. With few exceptions, there was only one woman or at most two women who were given degrees in astronomy in any one year. Occasionally a woman with an undergraduate degree in mathematics or physics chose to do her graduate work in astronomy. But in the years before the war, doctorates in astronomy were rare, an annual average of only eight doctorate degrees having been awarded to men and women combined (*52*). Probably less than 10 women received the doctorate in astronomy in the decade preceding the war.

Although there were few entering the field, there were also few leaving it. Astronomers were reported to have a very high rate of



Courtesy Science Service, Inc.

Figure 4.—Student assistants in astronomy "manning" a telescope at the Oak Ridge Station of the Harvard College Observatory.

longevity, second only to that of ministers (*19*); and losses due to retirement were thought to be very low. In spite of relatively low salaries, women, like the men, appeared to gain satisfaction from the contribution they were making to the advancement of their science and to find their working environment pleasant.

Wartime Changes

The war had little immediate effect upon the supply of women with undergraduate degrees in astronomy, according to reports available to the Women's Bureau on degrees granted in astronomy to women over a period of years at eight colleges and universities. It is likely, although no statistics are available as proof, that very few men obtained undergraduate degrees in this field during the war period. At the doctorate level, the prewar annual average of eight Ph. D.'s

awarded to men and women was also maintained until 1945 when only two women, and no men, received a doctor's degree in astronomy (*20*) (*34*).

During the years of the war, fundamental research in astronomy continued to advance, although there was no marked expansion deriving directly from military needs, as there was in some of the other sciences. In the applied field, however, astronomers helped to solve some of the problems of air navigation by adapting their findings from two fundamentally stellar problems, direction and time (*15*).

Because they necessarily have a good background in mathematics and physics, some women astronomers transferred during the war to work in these related fields where the shortage of technically trained persons became acute. Opportunities for such employment developed in industrial research laboratories where astronomers found that they could continue research usually in closely allied fields. A number of women who had been employed as computers or research assistants in the observatories and a few who had been teaching transferred to research jobs of this sort.

Women trained in astronomy also found opportunity for mathematical and physical research in Government-sponsored research programs, such as that carried on at the Massachusetts Institute of Technology. A few who were willing to take additional specialized training transferred to meteorology. As young men were drafted into the armed services, the few highly desirable university assistant jobs in the teaching of astronomy and in research became available to women with advanced degrees.

The war need for instructors to teach mathematics and such technical subjects as navigation to military personnel attracted persons trained in astronomy to these related fields. In some instances navigation was actually taught at a planetarium, the facilities of which were ideal for this purpose.

In May 1945, of the 102 women who were members of the American Astronomical Society, almost two-thirds were research workers; only one-sixth were primarily teachers, as compared with one-fourth of the men. The larger proportion of men teaching in colleges and universities indicated by these statistics is directly related to the larger proportion of men with Ph. D.'s. Of the 346 voluntary registrants in astronomy listed by the National Roster of Scientific and Specialized Personnel in 1946, 56 percent of the men held the Ph. D. degree, compared with only 38 percent of the women (*39*). (See table 2.)

It is difficult, however, to separate teaching from research in astronomy, since most observatories are connected with colleges or universities, and staff members are likely to engage in both teaching and research.

Table 2. Distribution by Highest Academic Degree Held of 346 Men and Women Registered in Astronomy With the National Roster of Scientific and Specialized Personnel, 1946

Highest academic degree held	Number			Percent		
	Total	Men	Women	Total	Men	Women
Total	346	285	61	100	100	100
Ph. D	184	161	23	53	56	38
Master's	81	59	22	24	21	36
Bachelor's	67	54	13	19	19	21
Others	14	11	3	4	4	5

Source: National Roster of Scientific and Specialized Personnel (*39*).

Earnings, Hours, and Advancement

Before the war an important factor affecting the earnings of astronomers was their lack of employment in industry. Consequently the institutions of higher education and research, which were the principal employers of astronomers, competed only among themselves for the services of qualified personnel. A professor of astronomy, therefore, was likely to receive a lower salary than that of a professor of chemistry working on the same campus, who might more easily find employment in industry. The war changed this somewhat by increasing the industrial demand for mathematical and physical research jobs for which many astronomers could qualify. But, as one woman astronomer stated, "Astronomers must love their work, they are so poorly paid for it."

In 1947 assistant teaching jobs in women's colleges began at about $1,300 to $1,400 a year. Salaries for full professors of astronomy in women's colleges seldom go beyond $5,000 a year, although the income of astronomers teaching in coeducational institutions may be somewhat higher.

In 1947 the Federal Government paid junior astronomers $2,644 a year, compared with $2,000 in 1940.

Although no studies are available on the earnings of computers in observatories, before the war such computers often earned from $1,000 to $1,200 a year. Salaries during the war were raised to over $2,000 a year, some approaching $2,500. Some women preferred to remain at these jobs during the war, in spite of the opportunity to earn more elsewhere; others, however, transferred at much higher salaries to computing jobs in industry, at which some have preferred to remain. (See Bull. 223–4, on Mathematics.)

The hours of astronomers are determined by the particular type of scientific investigations they are pursuing. Teachers have rather long but fairly regular hours. Each week they may have several laboratory periods scheduled which may last until midnight. Women working

as computers or as research or editorial assistants usually have regular office hours. But astronomers who are making direct telescopic observations at an observatory may work during a part of each clear night for a given period or all night long on a number of good nights (*24*).

Advancement for women as well as for men astronomers seems to depend upon their opportunities for long periods of graduate work and original research. For example, the woman astronomer now on the staff of the Harvard College Observatory received her doctorate in astrophysics. She later was one of seven persons to receive a fellowship in astronomy from the National Research Council to carry on further research in her field (*28*). She is noted for her books on "Stellar Atmospheres" and "The Stars of High Luminosity," as well as for many other studies.

In general, the preference in most observatories and universities for men tends to retard the promotion of women in astronomy. Recognition as a scientist is often more readily achieved by women astronomers than is promotion in position and salary.

Organizations

The advancement of a science in which so few people are engaged depends relatively more upon the contributions and publications of a professional society than do other sciences that receive more aid from industry, Government, and research foundations. This important function is fulfilled by the American Astronomical Society, which was organized by a conference of astronomers and physicists meeting at the Yerkes Observatory at Williams Bay, Wis., in 1899 (*6*). (See p. 6–29 for requirements for membership.) In 1945 the society had about 600 members, of whom 102 were women, some of whom have served as members of its council or have represented the society on international committees. Not oftener than every 3 years the society awards a prize to a woman for distinguished work in astronomy, in honor of Annie Jump Cannon, formerly curator of astronomical photographs at Harvard, who was noted for her extensive work on the classification of stellar spectra (*26*).

In the West an active organization including both amateur and professional astronomers is the Astronomical Society of the Pacific, which was founded in 1889 (*1*) (*26*). In 1946 it had over 800 members.

The Outlook

Although a smaller proportion of the women than of the men astronomers have been engaged primarily in teaching, the postwar shortage of teachers trained in astronomy and in the related subjects

of mathematics and physics provides a better-than-usual chance for women with graduate degrees in astronomy to secure college teaching appointments. However, appointments to teach astronomy exclusively remain fairly limited in number, since only 26 colleges and universities offer graduate work in astronomy (*38*), and courses and enrollments in astronomy are relatively few in the other institutions offering work leading to no higher than the bachelor's degree (*36*). Opportunities for women will continue to be best in women's colleges and in the larger coeducational institutions.

In 1947, 17 women teachers of astronomy were listed in the catalogs of 330 institutions of higher education (comprising a United States Office of Education sample of enrollment in the 1,749 institutions of this type in the United States). Eleven of the women were teaching astronomy only, and 6 were teaching astronomy and an additional subject, such as physics. These 17 women, three-fourths of whom held graduate degrees, were in positions ranging from that of assistant to that of full professor. Of the 4 women serving as professors or assistant professors, 3 held the Ph. D. If this sample of schools is as representative of the employment of women astronomers in all institutions of higher education as it is of enrollment, there were about 86 women in all colleges and universities in the United States who were teaching astronomy exclusively or in combination with another subject. Sixty-four of them were teaching astronomy only, about two-thirds of whom were in schools of liberal arts and science, a classification under which most of the women's colleges are found. The 22 women teaching astronomy and physics or other subjects were found largely in public and privately controlled universities. Obviously, some of these teachers may be primarily physicists or mathematicians rather than astronomers, and some may combine research with teaching. However, this sample study indicates that both the number and the proportion of women astronomers engaged in teaching has risen considerably above those indicated by the distribution of the women members of the American Astronomical Society in 1945.

Research work, mainly in connection with observatories, which employed almost two-thirds of the women astronomers in 1945, will continue, nevertheless, to be the principal type of employment of women astronomers. Only a few outstanding women, however, are likely to reach the full rank of astronomer on observatory staffs. A few observatories have never permitted women to make independent observations, and until World War II women had not been allowed to do night observing with the telescope at the Naval Observatory. This still holds true at some other locations and naturally retards women's opportunities for advancement. In the lower ranks of research associates and assistants, however, women with graduate train-

ing will continue to contribute to astronomical and astrophysical research.

For women with the bachelor's degree in astronomy, there will continue to be a few openings in observatories as computers. In 1946 Harvard employed 18 women, and Mount Wilson employed about 10 women, most of them as computers or research assistants. It is unlikely that such positions for women will increase in number in these or in other observatories.

Normal turn-over of staff will from time to time provide a very few openings for women in the Federal Civil Service. Three women astronomers were employed at the United States Naval Observatory in 1947 out of a total staff of about 40. One outstanding woman astrophysicist is at present on the staff of the National Bureau of Standards. The United States Civil Service Commission in 1947 outlined the requirements for application for examination as junior astronomer. (See p. 6–28f. for requirements for application.)

The already large and expanding popular interest in astronomy will provide a gradually increasing number of jobs for women trained in this field. Of the 20 women members of the American Astronomical Society not engaged in research or teaching in 1945, a number were employed as lecturers, editors, or writers.

In the future there will probably be a few more openings in planetaria for women lecturers, several of whom were employed in 1947 in the five planetaria of the United States, the first one of which was built as recently as 1930. Some training in astronomy and sufficient mechanical ability to operate the projector, combined with poise and a good speaking voice, are required of those who popularize astronomy in planetarium demonstrations. The popularization of astronomy in books and magazines also affords some opportunity to women with training in astronomy and writing facility. A woman astronomer, for example, is part-owner and part-manager of the largest magazine for amateur astronomers, a group already large and constantly growing. Women editorial assistants are also needed from time to time to assist with technical periodicals and reports in the field of astronomy.

The college woman who takes undergraduate work in astronomy will find that it contributes to her understanding of the universe more than does any one of the other sciences. But the woman interested in making astronomy her life's work should realize at the outset that the Ph. D. is virtually a prerequisite for full recognition as an astronomer. (See p. 6–29 for list of institutions awarding the Ph. D. in astronomy.) For teaching and research in astronomy and astrophysics, she will need excellent ability as well as thorough training in mathematics and physics, in addition to a reading knowledge of French and German. According to one outstanding woman astrophysicist, the

prospective astronomer must also acquire a respect for scientific instruments, habitual accuracy in handling figures as well as observations, and the ability to do sustained routine work whenever necessary.

A deep interest in astronomical phenomena must be combined with long years of exacting study to achieve success in this field. In astronomy and astrophysics the satisfaction of contributing to the knowledge of the universe must be relied upon to supply an even greater proportion of the compensation to those who engage in it than it does in other scientific fields. But the enthusiasm characteristic of the women in this field is evidence that such satisfaction is to be found in astronomy.

APPENDIX

Minimum Education and Experience Requirements for Application for Beginning Federal Civil Service Position as Junior Professional Assistant With Option as Physicist ($2,644 a year)

(As taken from Civil Service Announcement No. 75, issued October 14, 1947, closed November 4, 1947)[1]

Applicants must have successfully completed one of the following:

A. A full 4-year course in a college or university of recognized standing, leading to a bachelor's degree in physics. This study must have included courses in physics consisting of lectures, recitations, and appropriate practical laboratory work totaling at least 24 semester hours; or

B. Courses in physics in a college or university of recognized standing, consisting of lectures, recitations, and appropriate practical laboratory work totaling at least 24 semester hours; plus additional practical laboratory experience or education which when combined with the 24 semester hours in physics will total 4 years of education and experience and give the applicant the substantial equivalent of the 4-year college course.

In either A or B above the courses must have included a fundamental course in general physics and in addition any two of the following: (*a*) Electricity and magnetism, (*b*) heat, (*c*) light, (*d*) mechanics, (*e*) modern physics, (*f*) sound.

Minimum Education and Experience Requirements for Application for Beginning Federal Civil Service Position as Junior Professional Assistant With Option as Astronomer ($2,644 a year)

(As taken from Civil Service Announcement No. 75, issued October 14, 1947, closed November 4, 1947)[1]

Applicants must have successfully completed one of the following:

A. A full 4-year course in a college or university of recognized standing, leading to a bachelor's degree in astronomy. This study must have included courses in astronomy consisting of lectures, recitations, and appropriate practical laboratory work totaling at least 12 semester hours, and courses in mathematics totaling at least 18 semester hours, including differential and integral calculus; or

B. Four years of successful and progressive technical astronomical experience of such a nature as to enable them to perform successfully

[1] For more complete and later information, consult latest announcements of the Civil Service Commission posted in first- and second-class post offices.

at the professional level. This experience must have demonstrated that the applicant has acquired a thorough knowledge of the scientific principles of astronomy and their application and a good understanding of mathematics including differential and integral calculus. The experience must also show that the applicant possesses an understanding of the field of astronomy equivalent to that which would have been acquired through the successful completion of a full 4-year course in a college or university of recognized standing, including at least 12 semester hours in astronomy and 18 semester hours in mathematics; or

C. Any time-equivalent combination of A and B. In combining education and experience, the applicant must show for each year of education for which credit is claimed an average of at least 3 semester hours in astronomy and 4.5 semester hours of study in mathematics.

Minimum Requirements for Membership in the American Association of Physics Teachers (*3*)

Membership is open to teachers of physics in institutions of collegiate grade and to secondary-school teachers having professional qualifications equivalent to those required of teachers of college physics. College and university students with a major in physics may be elected to junior membership. Application for membership or junior membership must have the endorsement in writing of two members of the association.

Minimum Requirements for Membership in the American Astronomical Society

"Any person deemed capable of preparing an acceptable paper upon some subject of astronomy or related branch of science may be elected by the council to membership in the society upon nomination by two or more members of the society."

List of Colleges and Universities Offering the Ph. D. in Astronomy (*38*)

Columbia University	University of California
Cornell University	University of Chicago
Harvard University [1]	University of Michigan
Princeton University [1]	University of Minnesota
Radcliffe College	University of Pennsylvania
Washington University	University of Virginia
Yale University	University of Wisconsin

[1] Does not grant the Ph. D. in astronomy to women.

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