THE RESEARCH-GRANTS PROGRAM IN PHYSICS at the NATIONAL SCIENCE FOUNDATION

An account of the first four years of the program giving some of its aims and accomplishments.

By J. Howard McMillen

THE Congress of the United States, in 1950, laid down an unprecedented science policy. For the first time in our history, a special agency—the National Science Foundation [1]—was established to encourage and stimulate basic research in physical, biological, and other sciences. Support of basic research in physics is a dynamic part of the Foundation research-grants program which has now been operating for about four years. The purpose of this report is to highlight this program of research grants in physics.[2]

Physicists have always been deeply concerned with the National Science Foundation even back to the late years of World War II when the idea for a Federal science agency first germinated. Hearings held by the Senate and House between 1945 and 1950 reveal that many physicists were active in giving advice and testimony in support of the bill. A re-reading of these Hearings makes one aware of the fears and hopes shared alike by physicists and congressmen concerning the operation of the agency they were creating. Some of this atmosphere is captured in the House hearings of 1949 where we find The Honorable Joseph P. O'Hara from Minnesota epitomizing certain fears that were then present among scientists when he stated: "There are many scientists, I think I can almost say a majority of scientists and maybe a very large majority, who are very much worried about this science foundation bill, for fear it may strait jacket science, or that it may be misused." Again in the same hearing The Honorable George G. Sadowski of Michigan expressed an ever present fear by the observation: "So when we dish out Federal funds, the important thing is to see that it does not become a grab bag for a few of these specialists in the field of picking up dollars." For scientists who think of the Foundation as an agency for scientists only, the Hearings contain this wise comment by the late K. T. Compton: "At the same time, participation by Government in supporting basic research implies responsibility to the source of that support—namely, the people of the United States. . . ."

In this fifth year of operation it would be interesting to know how effectively the physics grants-program of the Foundation avoids the fears and confirms the hopes of those who sponsored the National Science Foundation Bill. Such analysis is too large an order for this report, but no great insight is required to recognize that the present size of the program, moneywise, falls far short of the hopes of the early sponsors. As near as one can measure, only 6 to 8 percent of all Federal funds used by universities in support of unclassified basic research in physics now comes from the National Science Foundation. This discouragingly low figure is somewhat offset by the rate of growth of the program during its brief history. Research grant funds for physics have about doubled every year, except for the present one. Table I shows funds available for research grants in physics during each year. Whether the physics-grants program will continue its rapid growth is not predictable. Present funds, those for the year ending June 30, 1956, will probably be the same as last year; namely, $1.1 million.

TABLE I. Funds for research grants in physics and the number of grants made are shown for each fiscal year.

Fiscal Years	*Number of Grants*	*Funds in Millions of Dollars*
1951–1952	8	$0.07
1952–1953	22	0.28
1953–1954	42	0.50
1954–1955	67	1.1
1955–1956	67 (Estimated)	1.1 (Estimated)

Limited grant funds are a challenge to carry out the program with extra efficiency. By December 1955 the Foundation had awarded 172 grants in support of basic research in physics. The effectiveness of these grants is just beginning to show itself through the publication of papers. About 5 articles per month now appear with a footnote acknowledging NSF assistance. Most of these articles appear in *The Physical Review*.

Recipients of Research Grants

The Investigators. All investigators receiving physics grants to date have been located in universities and colleges. About 110 different physicists on university staffs have received grants. A fair number of these grants were awarded to physicists whose names are very familiar to all who follow current advances in science. Listing titles of grants would convey very little new information, but the names of physicists to whom grants were awarded give to their project a quality not conveyable by the simple words contained in a project title. To

[1] The National Science Foundation Act of 1950 was signed by President Truman, May 10, 1950, following legislative action of the 81st Congress.

[2] Not included in this article are other activities of the National Science Foundation, such as the Fellowship Program. For a report of the Fellowship Program see B. C. Dees, Am. J. Phys. 22, 559 (1954).

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mention just a few of the hundred recipients of grants, there are Rossi of MIT, Kittel of California Berkeley, Dieke of Johns Hopkins, Kusch of Columbia, Seitz of Illinois, Daunt of Ohio State, Nier of Minnesota, Brillouin of Columbia, Kerst of Illinois, and many others.

Another equally important group of grant holders are physicists on the threshhold of their careers. It is gratifying to note that over one-third of the NSF grants were received by physicists under thirty-six years of age. We are told that for this age group personal support is more difficult to obtain and productivity in original research is high.

The Institutions. The legislative history of the National Science Foundation Act shows clearly that both scientists and legislators wished to avoid the concentration of grants in few places. Reassuringly, grants have become quite well dispersed among institutions as the Foundation's program has grown. Grants in physics have been awarded to 73 different universities and colleges—by no means all that are eligible, but enough to demonstrate clearly a wide distribution of grants.

Grants have been awarded to staff members of almost all of what we might call *the larger departments of physics.* Of the 37 larger physics departments, only 3 have not submitted proposals, and all that have applied received at least one grant. (For statistical purposes we define as "large" those departments granting at least 3 PhDs per year on the average.)

The smaller departments of physics include a large number of graduate departments established since the war. (For statistical purposes we define as "small" those departments granting less than three and more than one PhD per year on the average—about 23 in number.) They account for part of the increase in physics PhDs that occurred when the number jumped from about 150 per year in the late thirties to about 500 at the present time. Because of their unique environment and the personnel of their present staffs, many of these growing departments possess the potential for further expansion. In spite of their brief history of accomplishments, they have received a fairly large number of grants. For example, in the year ending June 30, 1955, 16% of the grants went to this group of smaller departments, although they graduated only 9% of the PhDs. In the preceding year, about one-third of the grants were received by staff members of universities in this category. Along with the usual benefits derived from these research grants, they may, hopefully, result in an increase throughout the country in those types of teaching positions which include uncommitted research as part of the job.

Physicists on the staff of 24 colleges and universities having no PhD program also received grants. (For statistical purposes, this "no PhD" group is defined as one that does not average one PhD per year. Most grant none.) Naturally, the number of applicants in this group to whom grants were awarded is not so high as the number from large universities where research is a major activity. Of institutions submitting proposals, only about half were awarded grants. On the whole, however, physicists in educational institutions where teaching is emphasized did well in competition with those in larger institutions where research is emphasized. In the year ending June 30, 1955, about one-fourth the grants went to this group; in the preceding year, about 30%. (Percentage of funds is, of course, much less.) Institutions receiving these grants include liberal arts colleges such as Reed, Amherst, DePauw, etc., state universities such as Michigan State, Maine, Florida State, University of New Mexico, etc., and private universities such as the University of Denver, Western Reserve University, Marquette University, etc.

Developing Future Research Leaders

The research-grants program would be shortsighted if it did not concern itself with the development of future leaders for physics research. A review of the grants program shows that it has been active during the three important stages in the training of a physicist; namely, the undergraduate stage, the graduate level and the postdoctoral training period.

At *the undergraduate level* the research-grants program of the Foundation has attempted to insure inspired teaching by making grants in support of good physics research carried out by teachers of undergraduate physicists. Such grants not only lead to more inspired teaching, but also make it possible for universities and colleges where teaching is emphasized to do better staffing jobs. A large percent of the grants discussed above under the "no PhD" institution category are of this type. They are expected to yield not only good research, but also an increase in the number of well trained undergraduates interested in research as a career. A significant factor in evaluating some requests for grants of this type is the institution's record as an undergraduate source of physics PhDs. Benefits of research-by-teachers grants are not easy to measure and reliable assessment may have to await an evaluation of records collected over a number of years. Clearly, a list of publications does not tell the whole story here.

The research-by-teachers program derived its endorsement and guidance from the NSF-sponsored conference on this subject held at Amherst College in May, 1953. (See *Physics Today,* Vol. 7, No. 3, p. 14, 1954.) Additional impetus came from a second conference, held at DePauw University in March, 1955, which dealt with one particular field of research. At the DePauw Conference cooperative research between colleges and universities in the field of nuclear physics using emulsions was critically reviewed. Encouragement of cooperative programs and special summer research institutes on the subject were recommended by participants at the conference from small colleges, large universities, and some of the national laboratories doing nuclear research.

At *the graduate level,* training is indirectly supported through grants to senior investigators who employ research assistants. Research assistant positions have been set up by these investigators during both the academic year and the summer months. Grants for the year end-

ing June 30, 1955, enabled investigators to maintain 74 of these positions, many for more than one year.

At *the post-PhD level*, positions of a training nature have also been established by investigators using NSF grants. These positions, commonly called Research Associate positions, give young PhDs an opportunity to obtain more research experience and acquire further specialized knowledge. In the year ending June 30, 1955, sixteen such positions were made possible through regular NSF grants to senior physicists, some for more than one year. Interestingly enough, about one-fifth of the Research Associate positions are filled by physicists from foreign countries.

Subject Matter of Research Grants

Inasmuch as the support of basic research in *all* branches of physics is the Foundation's mission, there is little incentive for cataloging grants of the ordinary type according to subject matter. In awarding grants, preference is given to those current proposals that have the best rating and as a consequence of this procedure some subject fields receive more grants than others. In general, the subject distribution pattern points up what subject matter physicists want to investigate, and, as well, the fields not emphasized by other research-supporting agencies. For example, the percentage of NSF grants in nuclear physics is less than would be expected from the total university research activity in this field, primarily because of the support given it by the AEC and ONR. An interesting comparison was made between published articles and last year's Foundation grants. The accompanying table shows that the number of grants made in nuclear physics, percentage-wise, was less than the number of published articles by university physicists on the same subject. Grants referred to in this table are for the year ending June 30, 1955; the articles appeared in the AIP journals under university staff authorships. The large percentage of grants in low-temperature physics shows a compensatory response of the Foundation to an action taken several years ago by ONR when it announced a reduction of its support in this subject area.

Among Foundation grants listed under "other" in the table are subjects which convey the breadth of the NSF research support. They include such subjects as theory of gravitation, freezing of terrestial waters, phase contrast methods, information theory, polarized light studies, etc. In the list of grants for former years, this category contained subjects such as the physical characteristics of musical tones, the definitions and laws in the physical science, ultracentrifuge study of molecular weights, etc.

TABLE II. Comparison of FY '55 grants with 1954 university articles in THE AMERICAN INSTITUTE OF PHYSICS journals, according to subject matter.

Subject	*National Published Articles*	*NSF Grants*
Nuclear	45%	34%
Atomic	15%	18%
Solid State	16%	20%
Low Temperature	3%	9%
Cosmic Rays	3%	9%
Other	18%	10%
	100%	100%

Facility Projects and Cooperative Research

Among many ways that the Foundation can be of assistance in supporting research, two are rather unique with foundations. One is the support of costly facilities; the other is the support of projects that call for cooperation between institutions. Grants for facilities (not their operation) are usually single-shot affairs which do not tie up grant funds that will become available in the future. So far the Foundation has been able to assist several physicists with good-sized apparatus projects. A grant of $70 000 to R. W. Thompson of the University of Indiana is enabling him to construct a pair of cloud chambers about a square meter in size, equipped with a magnet weighing about one-hundred tons. With this instrument, precision momenta measurements are anticipated on very energetic cosmic-ray particles. A grant of $34 500 was made to California Institute of Technology for the use of J. R. Pellam to set up a laboratory to investigate properties of liquid helium II. Typical of smaller grants for equipment is one to I. L. Kofsky of Smith College, to help him buy about $2700 worth of equipment to carry on studies of cosmic-ray air showers.

Foundations and large research supporting agencies can also serve research in a very special way by making grants or contracts in support of cooperative enterprises. The largest cooperative program in physics that the Foundation has supported to date is the Midwestern Universities Research Association. This group of physicists banded together (at first without the formality of corporation) to investigate the best methods for accelerating nuclear particles in the Bev range. Meeting first at one university and then at another, the MURA scientists from eight universities have carried on intensive investigation of a very complex problem. The MURA group has made an outstanding contribution to our knowledge of accelerators. Their success in exploiting the fixed field alternating gradient has won acclaim from all who work in this very important field.

Examples of cooperation on a smaller scale are the grants to DePauw University for the use of A. D. Sprague, to Marquette University for the use of A. G. Barkow, and to the University of Chicago for the use of M. Schein. These grants support cooperative research on emulsions activated by nuclear or cosmic-ray events. Another example is a grant to R. L. Leonard of Principia College which makes it possible for him to carry on nuclear research on tridents in cooperation with the staff of the University of California, Berkeley.

Conferences and Exchange of Information

Physicists recognize the value of small conferences dealing with subjects of limited scope where discussions

are quite extensive and the subject matter fully exploited. A number of these conferences have been helped through Foundation grants, including the Rochester Conference on High-Energy Nuclear Physics, the Duke Conference on Cosmic Rays, the Rice and Louisiana State University Conferences on Low-Temperature Phenomena, the University of Texas Conference on Molecular Quantum Mechanics, the Brown University Conference on The Structure of Liquids, and others. About six to eight conferences in physics have been sponsored by the Foundation each year.

Interest in improved physics teaching for engineers led the Foundation to support a series of conferences and a study on the role of physics in engineering education. Conferences were held at Illinois and Carnegie on the teaching of solid-state science, at Columbia and Northwestern on nuclear science, at New York University on mechanics, at Purdue and Pennsylvania State on thermodynamics, and at Lehigh on electricity-magnetism. The study was conducted by an AIP committee under the chairmanship of Elmer Hutchisson.

Another activity of the research grants program has been grants to individuals for travel to foreign countries for purposes of exchanging information on an international scale. Most international travel grants have been for large international congresses and meetings endorsed by international unions. For the two-year period ending June 30, 1955, twenty-five grants for foreign travel were awarded to physicists. However, the lack of funds for this particular activity in the present year will prevent such grants being awarded during the year ending June 30, 1956.

Another example of Foundation assistance in exchanging scientific information is the two Russian translation activities of the Foundation's Office of Scientific Information. One is a grant to AIP for the translation of the Russian *Journal of Experimental and Theoretical Physics* (see *Physics Today*, Vol. 8, No. 8, p. 20, 1955). The other supported the *Doklady* translation carried out for the year 1953 by Columbia University.

Procedures in Awarding Research Grants

Procedures for awarding grants have many unique features. First, experienced research physicists are called upon extensively for evaluation and advice. Written reviews of all applicant-prepared proposals are made by at least one member of the NSF Advisory Panel for Physics. In addition, special reviews are obtained from scientists who know the applicant, the institution, and the subject of the proposal. Last year alone over 380 different reviewers cooperated in reviewing the 90 applications received in the physics program.

Second, the grants themselves are simple and flexible. Changes in the current rate at which research is done and changes in the detailed plans for using funds are left to the investigator working in the framework of his institution. In fact, midstream changes in the direction of a research program are advocated when the investigator feels they are for the best interest of science.

Third, NSF grants in physics are made for 2, 3, or even 5 years. Although difficult because present funds are limited, 5-year grants are still considered available.

For those interested in applying for a grant, the Foundation has prepared a guide which can be obtained by writing the National Science Foundation, 1520 H Street, N.W., Washington, D. C. Grants are awarded 5 or 6 times a year. An average of 4 to 5 months is required from the time a proposal is received to the time a grant is awarded.

Physics-Grants Program Advisors

Advisory panels help the Foundation on matters of policy and on individual grants. The principal panel in physics is known as the Advisory Panel for Physics. It has given much thought and study to questions of how grant funds for physics can best be utilized. The Foundation is deeply indebted to members of this panel for the service they have rendered the program. Those that have served on the panel (from one to three years) are: *S. K. Allison,* C. D. Anderson, R. M. Bozorth, *R. B. Brode,* W. L. Elmore, H. Fletcher, *G. P. Harnwell,* G. R. Harrison, *K. F. Herzfeld,* J. O. Hirschfelder, W. V. Houston, J. Kaplan, *C. T. Lane,* H. W. Liepmann, H. F. Mark, *R. E. Marshak,* E. M. McMillan, R. S. Mulliken, A. O. Nier, *W. K. H. Panofsky,* E. M. Purcell, B. Rossi, F. Seitz, *J. C. Slater,* J. A. Wheeler, *E. P. Wigner,* W. H. Zachariasen. (Italics indicate members of this year's panel.)

In addition to the regular Advisory Panel for Physics special panels have been assembled from time to time to deal with such subjects as low-temperature research, ultrahigh-energy nuclear accelerators, etc. Members of these panels and other individuals that have assisted us in a consultant's capacity are: W. P. Allis, R. F. Bacher, J. R. Bardeen, H. A. Bethe, F. G. Brickwedde, S. C. Collins, J. G. Daunt, P. G. Frank, L. J. Haworth, C. Herring, C. T. Lane, E. A. Long, R. J. Maurer, P. M. Morse, J. R. Platt, I. I. Rabi, C. F. Squire, W. E. Stephens, E. Teller, M. A. Tuve, M. G. White, J. H. Williams, and J. R. Zacharias.

Present and past members of the National Science Board, appointed by the President, include: L. A. DuBridge, *W. V. Houston,* and *L. W. Morris.* Also under the Act a Divisional Committee was set up to advise the Director of the Foundation and the National Science Board on matters relating to the Mathematical, Physical and Engineering Sciences Division in which the physics program operates. Physicists who are or have been members of that Committee are: J. W. Beams, *A. O. Nier,* G. B. Pegram, and *J. H. Van Vleck.* (The names in italics are members now.)

Physicists on the staff are A. T. Waterman, Director; P. E. Klopsteg, former Associate Director and now a consultant; R. J. Seeger, Assistant Director for Mathematical Physics and Engineering Sciences (Acting); H. C. Kelly, Assistant Director for Scientific Personnel and Education; Bowen C. Dees, Program Director for Fellowships; and the author.