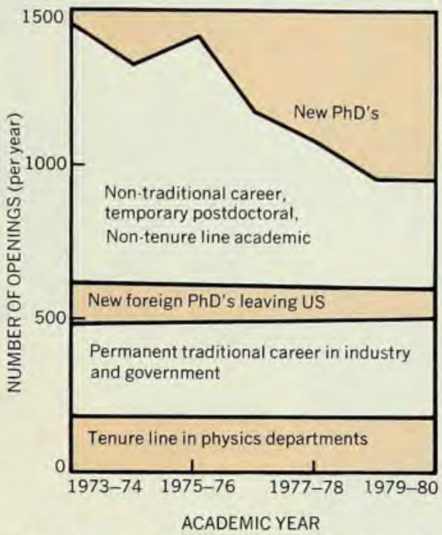
The permanent career problem and some partial solutions

The Conference on Tradition and Change in Physics Graduate Education, held last summer at the Pennsylvania State University, led to some ideas and conclusions that will be of interest to almost everyone in the physics profession.

The original purpose of the conference was to study the relation of physics graduate education to two major changes occurring in the American physics community. One very obvious change is the sudden end to two decades of rapid growth in the size of the profession and in the financial support. Young physicists find difficulty in establishing permanent physics careers; older physicists have problems in maintaining careers. The graduate schools find themselves in the uncomfortable position of being equipped to educate more physicists than society is prepared to employ as physicists. The other major change is the increased interest by physicists in environmental problems, energy problems, the arms race and in improving the methods by which the nation develops its technological policies.

Although the conference was motivated by these two changes, it was dominated by the employment and permanent career problem; the discussions on public-interest physics were mostly limited to public-interest fields as sources of nontraditional physics careers. It is clear that we are all preoccupied by the career problems.

The conference was sponsored by the Forum on Physics and Society of the American Physical Society, by the Committee on Education of the APS, and by the American Association of Physics Teachers. The conference was larger than expected; over 150 attended although the original planning was for 50 or 60. The participants included physicists from industry and government, several score chairpersons or representatives from physics departments, some graduate students and some physicists who have left physics. In spite of the diversity of affiliations, of physics interests, and of ages, a reasonable consensus was reached on the nature and extent of the problems faced by the physics community. Proposed solutions to these problems were examined in detail, a coherent picture of the state of physics graduate education was constructed, and a set of proposals for change in that education and in the physics community was developed. The picture and the proposals were not produced by a system of subcommittees, draft reports, and plenary ratifying sessions. They came about through a close and warm interaction between the conference participants, in the formal sessions, at the communal meals, and on the picnics.



New physics PhD's awarded per year and physics career openings per year for the US. The new PhD projections assume 0.44 of first-year graduate students in PhD granting institutions will obtain their PhD. The postdoctoral and nontenure line openings provide immediate employment, but, of course, they do not provide permanent careers. Figure 1

The Employment Problem. The data were gathered by Lee Grodzins,[1] by Suzanne Ellis,[2] and by others.[3] The Conference began with a discussion of the data and the realization that more than half of all new PhD physicists will not be able to establish *permanent* traditional careers in physics. By "traditional" we mean the things that are accepted, reinforced and relied upon by the generations of physicists coming *after* the Second World War. For example, teaching physics in colleges and universities is a traditional career. (Incidentally about 48% of all employed PhD physicists in the US are in college and university teaching, about 23% are in industry, and the remainder work primarily in government agencies or in federally supported laboratories.) We also use the term "traditional" to identify careers in solid-state physics, nuclear physics, elementary-particle physics, astronomy and astrophysics, atomic and molecular physics. On the other hand, we classify as nontraditional careers in geophysics, biophysics, medical physics, environmental physics and other public-interest physics, engineering, chemistry, computing and mathematics. We do not mean that in the past physicists never went into these nontraditional fields; we only mean that traditionally *most* physicists did *not* go into these fields. However, employment in higher education, the largest of traditional career areas, is no longer growing. Also most employment of physicists in industry involves the traditional high-technology industries—aerospace, nuclear and electronic. These high-technology industries have matured and no longer have an increasing need for physicists.

A quantitative picture of the employment problem is provided in figure 1. The number of permanent career openings, about 500 per year, was projected in the following way. There are about 20 000 employed PhD physicists in the US. If there is no growth in an area, the annual rate of job openings that can lead to a permanent career in that area is 2.2%; 1.2% for death and retirement and 1.0% to replace those who leave the area voluntarily. Assuming no growth in higher education and a (possibly optimistic) 2%-per-year growth in industry and government employment, one finds that the projected number of job openings leading to permanent careers in traditional fields is about 500 per year. Also shown in figure 1 are the number of new physics PhD's awarded per year in the US in 1973 and the projected rate for the next five years. The projection is based on the first-year graduate student classes of the past few years.

It is clear from figure 1 that for the foreseeable future a majority of new PhD physicists will have to establish permanent careers outside the traditional areas of physics. Although there are several thousand temporary postdoctoral research positions and academic positions not in tenure lines, they do not affect this conclusion. They do not provide permanent traditional careers. Thus the problem faced by the young PhD physicist is not a temporary em-

ployment problem; it is the problem of building a *permanent career* that uses his physics graduate education.

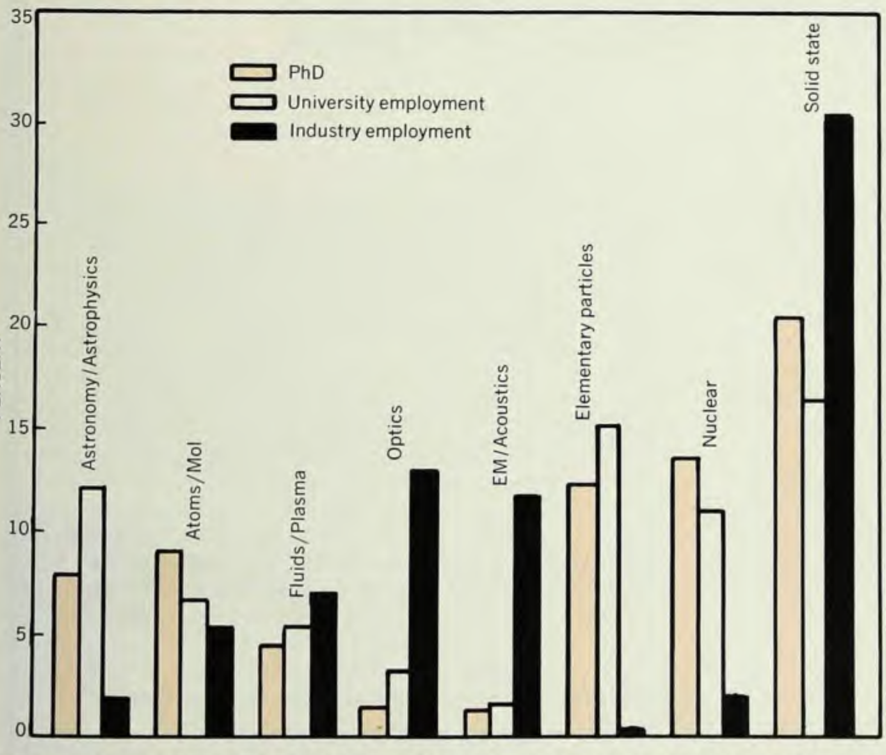
The employment problems of the older physicist were discussed only obliquely at the conference. While the unemployment rate is relatively small (the few percent level) it is still serious, and there is clearly increasing concern about career security.

The origins of the permanent career problem are twofold. First, social attitudes in the US do not permit further growth in the facilities for physics education. The high birth rate after World War II and the "democratization of higher education" led to the growth. The reduced birth rate and a saturation of that democratization ended the growth. The second origin of the problem, applying especially to physics but shared by all sciences and engineering, was the rapid post-war growth of high-technology industry. Of the industries using PhD physicists, aerospace is in decline, and the electronics and nuclear industries have matured so that they often employ new PhD engineers rather than physicists. And, as pointed out by Bruce Rosenblum at the conference, there is no new high-technology industry on the horizon.

None of this is new and, in fact, it was forecast, especially by A. M. Cartter.[4] There is however one piece of new information: No massive increase in federal support for physics has occurred or will occur in the next few years. In particular, neither the environmental crisis nor the energy crisis will by themselves provide hundreds of *new* jobs *each* year for PhD physicists. These crises are not the equivalent of the launching of Sputnik.

Traditional applied physics in industry and government. With the uncertain economic conditions it is impossible to project a growth rate in the employment of physicists in the traditional applied physics areas in industry and government. One can only guess that *no* substantial growth is to be expected. An overall growth rate as high as 4% per year (300 or more *new* jobs per year *in addition* to replacement) seems grossly optimistic. Even the 2% per year used in figure 1 may be optimistic. The conference examined two possible obstacles to increasing the employment of physicists in traditional applied physics: the *matching* problem, and *attitudinal* questions.

The matching problem results from a substantial difference between the research done for PhD theses and the research done in industry. As seen in figure 2, the distribution of fields of PhD research follows closely the distribution of fields of academic physicists, but the distribution of fields of industrial physicists is very different. The problem is that today's job seeker often finds a potential employer requiring one speciality, the job seeker having been trained in another speciality. In the rosy years, the matching problem was not apparent; job seekers had many offers, and employers could afford to spend several



Distribution in the various fields of PhD thesis research, of university employment, and of industrial employment. The thesis distribution is closer to the university employment distribution. (From L. Grodzins, based on NRC–NSF data.) Figure 2

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years retraining scientists into the desired specialities.

Partial solutions were discussed at the conference by Eugen Merzbacher who discussed the placement services of the American Institute of Physics, and by Sidney Millman who discussed the Visiting Physicists Program of The American Physical Society. In the latter program, industrial physicists visit physics departments and academic physicists and students visit industrial laboratories; the objective is that the students learn what physics skills and specialities are of interest to industry. The placement services in part serve a similar purpose. They cannot create jobs; but they can show the students the kinds of jobs available.

Perhaps industry and government are not employing as many applied physicists as they might because of attitudes—if so, whose attitudes are wrong? The first snap judgment at the conference seemed to be that the attitude of the new PhD's was wrong; the new PhD's were too inflexible, too interested in basic research, too determined to make careers out of their thesis subjects. However a remarkable property of the conference was its high degree of self-examination. Further discussion of attitudes showed that the new PhD was often very flexible, that he often took the lead in looking for ways to use his physics in applied work, that he often led the way into nontraditional fields.

The final judgment of the conference was that attitude problems are closely tied to the hierarchy of values of the physics community. In this value hierarchy, pure research leading to fundamental discoveries is held in highest esteem, with theory honored more than experiment on the average. Interdisciplinary work, applied science, and engineering appear much lower in the hierarchy. If new PhD's are to be encouraged to go into the latter fields, the hierarchy of values must be modified. And it is primarily the physics faculties—the transmitters of physics tradition and values—who must carry out this modification.

Non-traditional fields. Substantial growth has occurred in the nontraditional areas of applied physics. As documented by Grodzins,[1] more than 6000 PhD physicists have found careers in recent years in nontraditional areas. These areas include engineering, primarily electrical, engineering physics, and nuclear; medical and health physics; biophysics, geophysics; oceanography; environmental physics; chemistry; computing; nonscience teaching and serving as legislative aides both in Congress and in state legislatures. Indeed it is the movement of predominantly the young PhD physicists into these fields that has prevented an unemployment catastrophe in the physics community.

Proposed solutions. The conference made no formal recommendations nor did it develop a set of formal solutions. However a consensus developed on the value of quite a few proposed *partial* solutions—which we report here. At the conference these came to be called "5-and-10% solutions," recognizing that there are no 100% solutions to the employment problem. Few of these proposals are new—some have appeared in the "Bromley Report,"[5] others were recommended by the 1971 Battelle Memorial Institute symposium, *The Education of Physicists*.[6] We emphasize that these are not resolutions adopted in an official way at the conference. They are ideas that were fully discussed and that, in our opinion, had the support of most of the participants.

Graduate enrollment. There should be *no* increase in physics graduate enrollment in the foreseeable future. We have no present knowledge of the capacity of nontraditional fields to absorb physicists five or ten years from now. And it is these fields that must already provide 500 new permanent careers each year. The American educational machine has a very quick response, and a sudden need for physicists, if it should develop, could be filled in five or ten years.

As emphasized by Brian Schwartz, the *tragedy-of-the-commons*[7] concept applies and provides valuable understanding here. Any single physics department or physics speciality can benefit itself by increasing the number of graduate students it trains. But if all or even many do this, the community of physics suffers.

Annual manpower reports. Physics manpower reports with projections of the type made here should be issued annually. Every physics department should have a faculty member expert in manpower statistics and projections, so that the student has an immediate source of information.

Program variations. It is obvious that physics departments should continue to experiment with different variations of the traditional graduate program to help prepare the students for careers in nontraditional fields. The core graduate curriculum now consists of quantum mechanics, advanced electricity and magnetism, mathematical physics, perhaps advanced classical mechanics, perhaps statistical mechanics. In many universities some pruning of the core has occurred, permitting more courses in applied physics, environmental problems, science and society, biophysics, energy and so on. However, economic constraints prevent a department from trying out too many variations. Perhaps more differentiation between the

curricula of different physics departments should occur.

Faculty attitude. The attitude of physics faculties toward careers in applied physics, engineering physics, and public-interest physics should change toward a greater acceptance of these careers. They should be accepted as equal to the traditional careers in the heirarchy of values of the physics community. A change in the reward structure of physics to reinforce the change in attitude should be considered.

Applied physics. Physics departments should establish ties with applied research laboratories in industry, government and other institutions. These ties may influence the selection of research areas at the university departments, may lead to greater awareness by the faculty of emerging technologies, and bring about a greater involvement by faculty and students in cross-disciplinary contacts.

Nontraditional fields. It should be made clear to each student early in graduate school that there is at least a 50% probability that he will have to build a permanent career in a nontraditional field of physics or in a field completely out of physics. The student should design his graduate program accordingly.

Teaching in non-PhD granting institutions. Although there is no total growth in the physics faculties of masters-granting or bachelors-granting institutions, there are some career opportunities in these institutions for physicists who know and can teach nontraditional fields such as oceanography or atmospheric physics. There are also teaching career opportunities in junior colleges and high schools. But a PhD will often be too expensive for the school district. Physicists heading for those careers might better stop at the bachelor, master or doctor of arts level.

Career mobility among older physicists. Career changes are highly desirable and could benefit everyone. For example, during his sabbatical a professor might be encouraged by his institution to work in an area outside his speciality. He might end up liking the new area, leave his old career, and make a job for a young physicist. Department policies might, through the offer of seed money or reduced course load, encourage faculty members to try nontraditional fields, thus producing openings for young physicists in a traditional field.

The entire conference was greatly indebted for much of its financial support to the Ford Motor Company Fund, Esso Research and Engineering Company, E. I. du Pont de Nemours and Company, and Corning Glass Works.

An account of the conference with short versions of many of the papers will be published in an issue of the *Newsletter* of the Forum on Physics and Society [Vol. 4, No. 1 (1975)]. The abstracts of the conference appeared in the July 1974 issue of the *Bulletin of the American Physical Society.*

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Ode to charm

The world of nuclear power
is full of sinister "charm."
They make the electrons glower
at a three-billion electron-volt arm.

This "charm" seems only forthcoming
in the wake of an unheard of smack—
A gentler approach is producing
a mere bit of "strangeness"—alack.

Oh man, were you made of that matter!
Would you too exude charm on attack!!
But, alas, you react to the latter
with nothing but counter-attack.

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Extending the interferometer

In his excellent article "Michelson and his interferometer," Robert S. Shankland retraced the history, indeed most fascinating, of Michelson and his work (April, page 37). This account, however, omitted almost entirely a recent extension of the interferometer, namely the Fourier Interferometer Polarimeter (FIP).

In recounting the narrow-slit experiment, Shankland stresses Michelson's "remarkable observational ability as he describes precisely the . . . polarization . . ." He also suggests that the optical phenomena observed in this experiment were precursors to the invention of the interferometer. It does not appear, however, (and Shankland never hinted even at the possibility) that Michelson ever thought of using his interferometer for measuring the polarization of light within spectral lines.

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