

PREPARING PHYSICISTS FOR LIFE'S WORK

When Yogi Berra uttered his famous quip, "It's déjà vu all over again," he wasn't thinking of physicists—even though he himself was an expert practitioner of physics. The expression aptly describes the up-and-down cycles of the physics job market during the past century, which are shown in figure 1. The ups have resulted from stimuli like war needs, Sputnik, and the invention of the transistor, as well as from the spark of a strong economy. The downs have almost inevitably followed, as the supply of trained specialists has exceeded demand or as the economy has faltered.

During down periods, such as the job crunches of the early 1970s and the 1990s, those hardest hit are the newly minted physicists and students caught in the pipeline. Although, historically, few physicists go unemployed or underemployed for long, they nevertheless experience great angst. Many enter a "holding pattern," taking one postdoctoral position after another; some drop out. As word of the tight job market spreads, physics major enrollments drop, recovering only slowly once conditions improve.

Right now, the demand for physicists in industry is healthy, and more academic openings are available to physicists than have existed in many years. But how long will the boom last? Are we planning ahead for the next rainy day? Many physics departments are listening to students and to a broad range of employers, taking an introspective look at their programs, and instituting measures to increase the robustness and attractiveness of their major.

What will attract students?

Traditionally, students have been drawn to physics because it greatly interests them, challenges them, or stimulates their curiosities. Perhaps they have been led to the discipline by a favorite teacher. Or maybe they see physics as an entryway to another discipline. All are excellent reasons to major in physics. Why then, in an economy that relies increasingly on technology, are the numbers of physics majors rapidly falling? (See the article by Kate Kirby, Roman Czujko, and Patrick Mulvey on page 36 of this issue.) More than one million undergraduate degrees were awarded in 1999 in the US, but fewer than 4000 of those were in physics.

Physics departments are exploring ways to turn out students well matched to today's—and tomorrow's—job opportunities.

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wary of job prospects in physics. The numbers of bachelor's degrees awarded in the US fell sharply after the job crunch of the early 1970s, rose slightly in the late 1980s, and has been dropping since then. But other factors besides the job market influence students' decisions. Many fail to see the relevance of physics; there is no apparent "physics industry." Some of the best and brightest are drawn to appealing alternative disciplines, a number of which, like photonics, materials, nanotechnology, biotechnology, and aspects of computation, are physics in all but name.

We physicists have at times promoted our field with the argument that physics is the technical "liberal arts" degree, which opens up a wide array of career options, as illustrated in figure 2. We argue that, in the long run, physics graduates are better positioned to change directions and will be at least as successful as their more specialized counterparts. But 5–10 years after receiving their degrees, *will* physics majors have fared as well as their engineering or computer science major classmates? We obviously have not convinced students of that. Declines in the number and, arguably, the quality of physics majors will continue unless physics departments make a much more effective case for the relevance and power of a good physics education—and make the necessary changes to ensure that the message is true.

Report card from students

The best way to find how well we are serving our students is to ask them. In late 1997, the American Physical Society (APS) decided to gauge career prospects by surveying its "junior members," that is, those who had earned their final degrees no more than three years earlier.¹ The survey drew responses from 622 junior members; 593 of those respondents had PhDs. At the time, the private sector was on the road to recovery from the recession of the early 1990s. The survey found that very few young physicists were unemployed, and most reported being content with the fields they entered—even those fields with little or no overt physics.

Despite the improving employment picture and the general contentment with their short-term position functions, the survey uncovered a startling level of anxiety among respondents about their long-term career prospects. More than half of respondents with PhDs were in postdoctoral positions, and 80% of those postdocs

Maybe the numbers are down because today's savvy students are good at getting feedback from their predecessors, whose prospects were still bleak when the recent graduates chose their majors. Parents, who may still have an influence on their children's decisions, may also be

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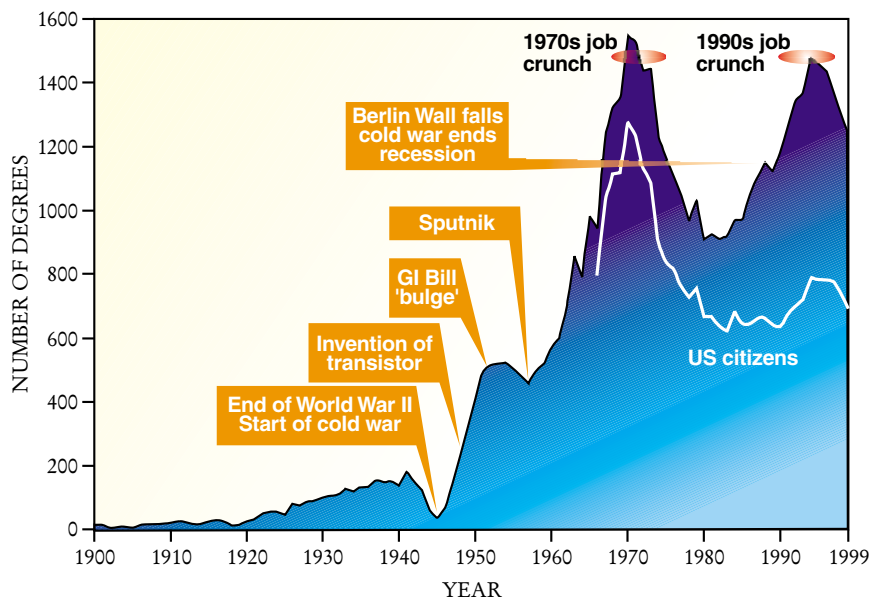


FIGURE 1. NUMBERS OF PHYSICS PhDs conferred in the US over the past century reflects the ups and downs of career opportunities in the field. Pointers highlight times of global events, breakthrough technologies, and economic crises; these correlate with changes in the numbers of degrees, with a roughly five-year lag in response resulting from students already in the academic pipeline. (Data for 1900–19 is from the American Council on Education; for 1920–61, from the National Academy of Sciences; and for 1960–99, from the American Institute of Physics.)

reported being “worried” about finding a suitable permanent job. Half of the postdocs believed they would have to make a major career change within five years because of “lack of opportunities for me in my present career path.” Those employed in industry were much less concerned, as reflected in figure 3. Perhaps the most troubling indicator of the depth of pessimism among the young physicists at the time was their response when asked whether they would advise students to pursue a PhD in physics: 40% of the survey’s respondents said they would not. Certainly, many with long existing visions of themselves as professors or basic researchers were deeply disappointed.

In the three years since the APS junior member survey, the employment situation has improved even more, especially in the private sector. More than half of new PhDs now bypass the postdoc phase: Many take positions in the private sector, including jobs in engineering, computation, and management consulting. Career expectations have obviously taken a pragmatic turn with the increased awareness of the realities of the job market. But would the newly minted retrace the same PhD steps again? It would be instructive to see the opinions from a junior member survey taken today.

Another survey, conducted online in the middle of 1999 by Geoff Davis and Peter Fiske, assessed the attitudes of current and recent PhD graduate students in a variety of scientific and technical disciplines.² (Fiske is a physicist who has written two popular career preparation books.^{3,4}) The survey found that the graduate educational system has much to be proud of. More than 85% of respondents were satisfied with their overall education; most were content with their advisers; and most would recommend their program to others. Physics departments earned a grade of “A–” for preparing students for academic careers. (The survey assigns letter grades based on the number of positive responses.) But their grade fell to a “C” when rated on how well they had prepared students for careers *outside* of academia and how much they had encouraged students to explore a broad range of career options. Physics departments scored lower still, earning only a “D+,” when it came to encouraging students to engage in course work outside the department or to participate in industrial internships, external workshops, and the like. Only half of all respondents reported that their physics department, during the admissions process,

had told them enough about the job market for PhDs to enable them to make a fully informed decision on a career in physics. Merely one-third said their departments had available (or had provided) a list of alumni employers.

These surveys clearly point out that PhD students are concerned about their fate upon graduation (so what’s new?) in good times as well as bad. Furthermore, the students are hungry for better career information and preparation for nonacademic careers.

What the customer wants

Industry wants very bright problem solvers who have a broad technical underpinning. Physics graduates fill this part of the bill and they are frequently hired simply because employers know that the physics major effectively weeds out all but the most talented. As Kirby, Czujko, and Mulvey point out in the companion article, there is currently a high demand for high-tech workers, and, in recent years, more than half of those with new physics PhDs have taken potentially permanent positions in the industrial sector, doing applied physics, engineering, software development, and the like. Those new employees largely report being content with their jobs, although some question whether their PhD program was the most appropriate training.

Aspects of management consulting certainly appeal to a number of physics doctorates, according to Helene Grossman, a PhD candidate in physics at the University of California, Berkeley, who is currently undecided about her career plans. Management consulting involves many of the same skills as physics, such as problem solving and quantitative analysis, but offers rewards on a shorter time scale and allows participation in a greater variety of projects. Plus, she added, the six-figure salaries are nice as well.

Traditionally trained physicists are hired when specialized talent is scarce but, as in the 1970s and 1990s, they are at a competitive disadvantage when demand wanes. Being smart isn’t always enough, as parodied in figure 4. Industry expects new hires to contribute from day one. They are driven by bottom lines, deadlines, and rapidly shifting needs that require teamwork, versatility, and adaptability. Edward Esposito, who has recruited dozens of physicists for Texas Instruments and, now, Alcatel Corp since earning his physics PhD at Harvard Uni-

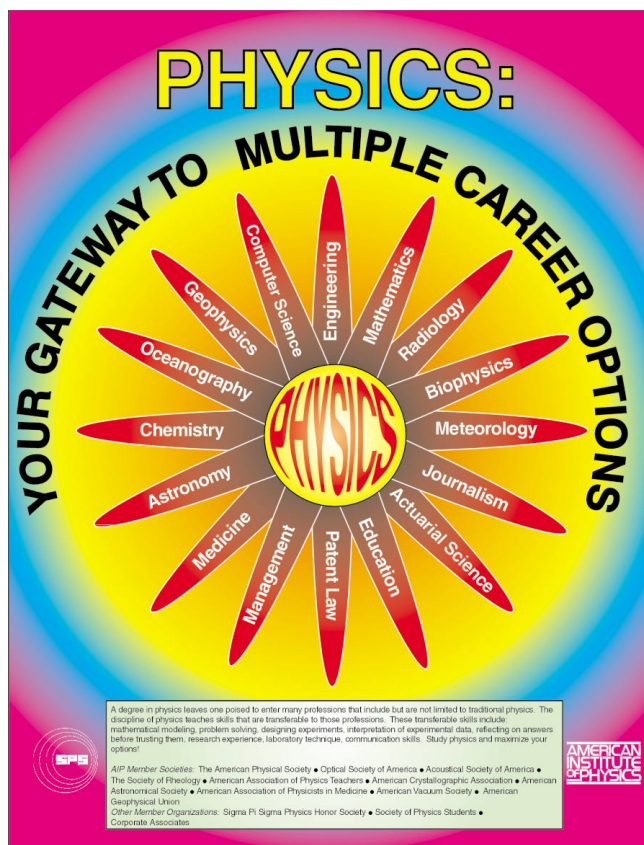


FIGURE 2. CAREERS OPEN TO PHYSICISTS are highlighted in this poster distributed by the Society of Physics Students. It is difficult to find any career in which physicists are not represented.

versity, points out that industrial employers perceive physicists to be on the periphery of the high-tech talent pool; they believe that physicists often lack the social skills needed to work on a team or that physicists are too narrowly focused on a topic and too easily diverted from practical goals by interesting science. Another prominent industrial physicist told me that academic physicists are “utterly clueless about what it takes to survive in the industrial world. . . . They have no idea about customers, on-time, on-target delivery of results without excuses, or participation in teams.” These stereotypical views (both delivered in a tough-love manner) have a grain of truth that needs to be recognized.

Many physics faculty members don’t have the background to prepare students for a career outside the world of academia. Moreover, there persists in academia the remnant of an elitist perception of what proper physics is and what one’s best graduates should do. Although many physicists have in fact been quite successful in business, rising to the highest corporate rungs, their background is less visible to both physics students and corporate colleagues because they no longer bear the “physics” label. These days, elitism is decreasing and is rarely expressed, but students are masters of reading subtle, subconscious signals from their advisers.

Since the job crunch of the early 1990s, there has been a healthy trend for physics departments to take a broader view of the preparation of their charges and to embark on long-term improvements (see the article by Sol Gruner, James Langer, Phil Nelson, and Viola Vogel,

PHYSICS TODAY, December 1995, page 25). Faculty members realize their departments must change if they are to attract good students and serve them well. Professors increasingly take pride in seeing many of their best progenies successfully go on to very different, but nonetheless challenging and important, fields.

Losers and gainers

With declining enrollments, physics departments are challenged either to excel at providing a traditional academic physics program or to adapt their programs to prepare graduates better for the broader employment market. A recent survey provides insight into what some departments have done to attract and retain physics students. The survey, conducted by Robert Ehrlich, assessed undergraduate enrollment trends of 750 US physics programs over the years 1990–97.⁵ Ehrlich identified 7 “big gainers” and 28 “big losers,” in terms of changes in the numbers of physics majors. The losers tended to be large departments in PhD-granting institutions (granting an average of 23 physics BS degrees each in 1991), and the gainers were relatively small departments (granting 1–7 physics BS degrees in 1991). The losers cited a number of reasons for the drop in student numbers, including increased competition from other programs, notably computer science and engineering; poor employment prospects for graduates in the geographic region; declining preparation of incoming students; or changing student demographics. The gainers had all taken some action to change their enrollments. Their efforts included instituting a double major with a department like electrical engineering or a 3-2 program in which students transfer to an engineering school after three years; increasing opportunities for student research; doing more student mentoring; and offering practical career skills. Although the gainers did not have a single silver bullet, all remedies involved visible and improved preparation for careers other than research professorships. (Other educational activities of physics departments were surveyed by Werner Wolf in an article in PHYSICS TODAY, October 1994, page 48.)

Another source of information about departmental innovations is the APS career and professional development liaison program. Under this program, started in 1998 by Diandra Leslie-Pelecky, Arlene Modeste, Allen Goland, and me, about 200 undergraduate and graduate physics departments have selected faculty members to serve as career liaisons. The program provides a means to

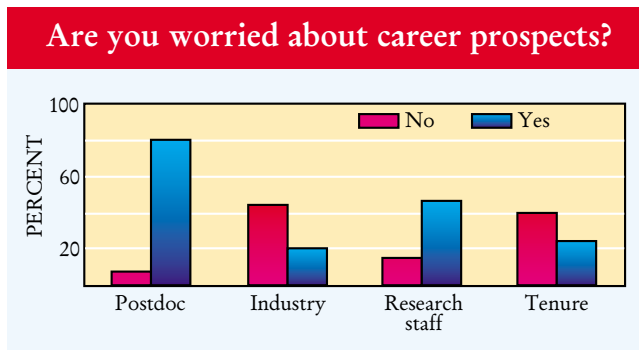


FIGURE 3. CONCERN OVER FUTURE CAREER PROSPECTS, as ascertained by a survey of junior members conducted by the American Physical Society in 1997–98. Concern was considerably lower among those working in industry and other potentially permanent positions. (Adapted from ref. 1.)

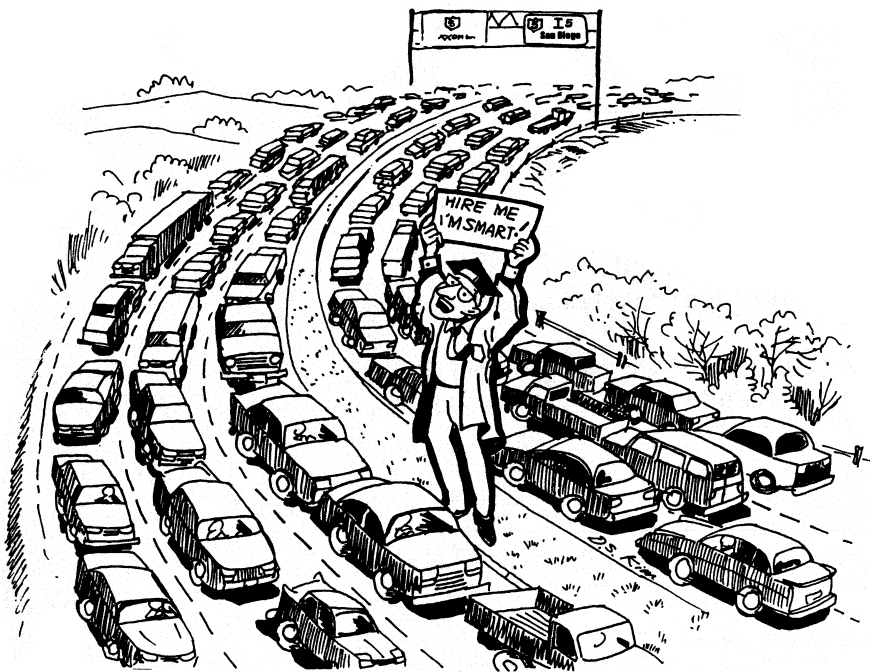


FIGURE 4. BEING SMART isn't always enough to land a job. (Reprinted with permission from ref. 3.)

funnel career information to the departments and acts as a forum for the departments to share initiatives or “best practices” with each other. From these liaisons and other sources, I have learned that physics departments are responding to the need for broader curricula and more extensive career preparation in a variety of ways. Depending on the degree of change, I loosely group them into three categories: business-as-usual, evolutionary changes, and revolutionary changes.

▷ **Business-as-usual.** Virtually all departments provide advice to students on a one-on-one basis and through postings on departmental bulletin boards or a local Web page. The extent, accuracy, and timeliness of this advice vary widely with the knowledge, interest level, and mentoring skills of the faculty in charge.

In some departments, students are assigned to handle career-related activities, or they do it by default; in others, a benevolent faculty member takes the initiative. Sadly, the number of faculty attending these events is often paltry, with faculty members typically pleading: “I’m too busy doing research”; “I help students when they come to me”; “Students do a better job of sorting out careers than I could”; “All our students seem to get good jobs on their own”; “All my students have gotten good postdocs (or research positions, or . . .)”; or “Many get good jobs in Wall Street or management consulting companies.”

Even when faculty members are willing to help, a number of them have privately commented to me that they know how to advise students seeking graduate school admission or postdoctoral and academic appointments, but that they are at a loss when it comes to jobs in the private sector. That’s especially true for jobs on the periphery of a technical area, such as management consulting or product development. In my opinion, it is a professor’s responsibility to become more knowledgeable about the physics marketplace, even if it takes a little time from research. Faculty members might start by learning about the jobs held by alumni from their own departments. Or they might invite as prime-time colloquium speakers various alumni and other researchers who are doing research in areas far from the department’s interests.

Physics is fortunate to have an excellent pulse on employment and enrollment trends from statistics compiled by the American Institute of Physics. *PHYSICS TODAY* and newsletters of various professional organizations report on current career issues. Also helpful to students are employment listing services and career workshops, such as those run by AIP’s Career Services Division. Some useful resources are listed on page 34 of this issue.

Information about the health and appropriateness of specific career paths, particularly outside of the traditional sectors of academia and industrial and government research laboratories, is more difficult to extract. Various careers are explored in a recently released CD-ROM, *Careers for Physicists*, which was produced by AIP under the sponsorship of the Sloan Foundation. Periodically, certain fields suddenly become hot, as photonics and information technologies are today. Physicists have their best shot at entering such fields if they can react quickly, before the field is widely publicized. For instance, one new field that emerged a few years ago was bioinformatics, the computer-based methods of piecing together gene sequencing and analysis. A few physicists recognized the relevance of the math they used in physics and got in on the ground floor.⁶ Now, however, degree programs devoted to the discipline provide most of the talent needed. The story is the same for many high-tech entrepreneurial ventures today: You must keep your ear to the ground to learn about them in time.

▷ **Evolutionary changes.** Many departments broaden students’ horizons by supplementing the physics curriculum. Increasingly, departments are inviting physicists who work in diverse areas to give departmental seminars or talks at chapter meetings of the Society of Physics Students (SPS). Speakers can be drawn from industry, alumni, or from speaker lists, such as the one maintained by the APS Forum on Industrial and Applied Physics. Some SPS chapters organize tours of local industries and research laboratories, or go on “road trips” to section meetings of the APS or the American Association of Physics Teachers.

Career-skill courses. A number of departments have



FIGURE 5. UNDERGRADUATE PHYSICS majors at Southwest Texas State University are operating an atomic force microscope under the supervision of a master's degree student (center). Undergraduates receive hands-on experience on equipment used in developing silicon chips, the dominant local industry. (Photo courtesy of Heather Galloway and James Crawford.)

instituted seminar series or courses in career-expanding areas. These range from interdisciplinary courses such as biophysics and skill enhancements such as computation and electronics, to the practical and nontechnical, such as business, scientific writing, and the like. Some allow or require students to take courses in other departments; others hold seminars on pragmatic topics like how to search for jobs and prepare for interviews; still others integrate career-oriented course offerings into their formal program. For example, the University of Wisconsin at River Falls requires a one-credit course for students planning to take an internship. The featured speakers are industrial physicists, who describe what physicists do in the "real world." The Wisconsin students get a taste of the environment in industry by working in teams to complete a required project, according to the department's career liaison, Lowell McCann.

Brian Schwartz, who has been active in physics career issues since the job crunch of the 1970s, developed a series of graduate-level courses at the Graduate Center of the City University of New York, with such titles as "Strategies for Enhancing Job Prospects," "Scientific Career Management, Communication, and Multimedia Skills," and "Business and Economic Aspects of High-Technology Business." Courses are team-taught by experts in each area. Schwartz notes that these were deliberately set as zero-credit offerings to encourage enrollment.

MIT has a faculty member dedicated to expanding career opportunities for its students. Peter Wolff, an MIT professor with prior experience in industry, has built up an active physics/industry forum at MIT to serve as an interface with physics-oriented industries and US national laboratories. The forum invites distinguished physicists from such institutions to visit MIT for two to three days to give talks and meet with students and faculty. The forum hosts career fairs and open houses for potential industrial and government employers and recruits companies and students for internships (the MIT term is "externships"). To help students find jobs, the forum maintains a database of industrial firms, especially those where alumni work. MIT has also instituted a breadth requirement for PhD students that includes interdisciplinary courses such

as biological physics; fluid physics; and entropy, information, and the brain.

Internships. Programs that involve students working with professional physicists, either in an industrial setting or in a university laboratory, work well for undergraduates, especially when done under the mentorship of a caring adviser. NSF's Research Experience for Undergraduates program provides funding for this purpose. Such internships or research positions give students a realistic sense of what a physicist does. They also offer students the opportunity to work in a team or group environment, make decisions that have impact on the success or failure of the project, and feel the responsibility and satisfaction of being creative. Employers and graduate schools like to see this kind of experience in applicants.

Internships at the graduate level, on the other hand, are a more complex matter. MIT has placed only 3–10 students in its externships each year (out of about 200 students per year), despite concerted efforts by Wolff. He cites as hindering factors the reluctance of advisers or students to interrupt progress on thesis projects and the hesitancy of students to broach the issue with their advisers, fearing their disapproval. On the part of industry, Wolff finds administrative red tape, fears that the task of bringing in a "green" student will be a drain on staff time, and concerns about intellectual property and proprietary information. Once an internship match is made, however, students and their industrial and academic advisers tend to rate the venture highly. In addition to the real-world experience, participants frequently gain new ideas and connections useful in their thesis work.

▷ **Revolutionary changes.** Some departments have made significant structural changes to reinvigorate their undergraduate or graduate programs. As found in Ehrlich's losers-and-gainers survey, the addition of a dual-track undergraduate curriculum seems to have been a factor in enabling departments to maintain their size or even to grow. In addition to some joint engineering programs and 3-2 plans, another example is the BS in computational physics instituted in 1999 at SUNY Buffalo; the school plans to expand it to the master's level this year.

Southwest Texas State University has created a flourishing undergraduate and master's degree physics

program that builds on the strengths and labor needs of its predominant local industry, silicon chips. The SWT physics and technology departments have entered into an effective collaboration with local industry. Under the program, those graduating with BS and MS degrees in physics have a strong background in materials and hands-on experience with modern semiconductor processing equipment, as seen in figure 5. Although some BS graduates go on to graduate school, most are snapped up by regional employers, who praise SWT graduates as being immediately productive. Many SWT physics majors have switched to this program from another field, attracted by the knowledge of good job prospects as well as by a nurturing faculty.

Professional master's degree programs. Sheila Tobias, Daryl Chubin, and Kevin Aylesworth have argued that a PhD in physics is not the appropriate training for many technical jobs in industry.⁷ (Aylesworth was the creator of the Young Scientists' Network in the early 1990s.) Instead of the PhD, these authors promote the notion of professional master's degrees that are designed to bring graduates to high levels of proficiency in specific applied or industrial physics areas. It is quite different from the usual "terminal" master's degree, which is typically earned these days by a PhD student who opts out early or as a pro forma award to a student continuing his or her education (see PHYSICS TODAY, June 1999, page 54).

About 50 US physics departments have instituted master's degree programs tailored to employment in such industries as semiconductors, medical physics, electronics, optics and photonics, instrumentation, computation, and environmental monitoring. A few programs are unabashedly oriented toward business. For example, Case Western Reserve University offers "Entrepreneurial Physics," and the University of Southern California has "Physics for Business Applications." Professional master's degree programs include courses and projects that lay a good foundation in physical principles and teach problem-solving skills pertinent to their focus disciplines. The programs also provide practical, hands-on training and experience, often in an industrial setting. Departments usually choose program specializations consistent with the strengths of their faculty and the needs of local industry. To be successful, they must gain the cooperation, participation, and oversight advice of the local industry.

The Sloan Foundation has taken an active interest in promoting and evaluating the professional master's option and provides funding to several fledgling programs. With Sloan sponsorship, AIP recently surveyed existing and developing professional or employment-oriented master's programs in the US and identified features of successful programs.⁸

Accreditation. Considerable discussion has centered around expanding the Accreditation Board for Engineering and Technology (ABET), to which most engineering departments subscribe, into the applied sciences, such as materials programs. The argument is that accreditation would put students on an equal footing with engineers in the eyes of industry. A major downside is the hassle of gaining and maintaining accreditation. ABET currently accredits about 20 engineering physics programs, the majority of them in engineering schools. The Health Physics Society and the Materials Research Society are two nonengineering members of ABET. Other accreditation models exist. For example, the American Chemical Society will approve a chemistry program that adheres to its guidelines. And the Canadian Association of Physicists has plans to establish a trademarked "Professional

Physicist," modeled after the "Professional Engineer" certification.

Most physics department liaisons cringe at the thought of going through an accreditation process. One responded, "I'm concerned that it will entail considerable effort for little payoff. I'm not sure what its purpose would be for most physics programs." On the other hand, Michael Cobb of Southeast Missouri State University, whose department is in the process of gaining ABET accreditation for its engineering physics program, believed the department needed it, "so that we have a viable BS program."

A full toolbox

No matter whether our graduates become university professors, national laboratory researchers, Wall Street analysts, or product managers, they are all physicists. That's true whether they do physics, or use physics, or simply think like physicists. We owe all our students—undergraduates through postdocs—a full toolbox to forge a successful career. I don't advocate turning physics programs into engineering departments, which can narrow choices. Rather we should make physics truly the "liberal arts" of technology we claim it to be by offering even greater breadth to graduates. Even those who opt for the traditional, academic path are well served by exposure to the same skills required by those headed to jobs in industry: an awareness of rudiments of other disciplines, the ability to write and speak effectively, experience in teamwork, a working knowledge of instruments, an ability to focus on an objective, and an understanding of budgets and the bottom line.

No magic formula will immunize us against the job crunch that may come with the next economic downturn. It behooves physicists to be agile enough to make the best of whatever the future brings. One industrial physicist called this strategy "survival of the adaptable." Each department must choose its own path to train students, while considering the department's strengths. There is no one-size-fits-all "best-practice." But I urge each department to engage in honest introspection—a probing and probably painful questioning of how it might do better by its faculty and its students. If we cannot present a true and convincing case that studying physics does indeed provide superior preparation for life's work, then majors and departments will invariably shrink to a fraction of today's level.

Of course, students are ultimately responsible for their own futures. Independent of what a department may or may not offer, students need to dig for their own information and take measures throughout their academic tenure to strengthen their position for both the career path of their dreams and alternatives if need be. As Peter Fiske said in his most recent career guide, "It's about creating options and recognizing opportunities."⁴

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