APS NEWS

AUGUST/SEPTEMBER 1997 THE AMERICAN PHYSICAL SOCIETY VOLUME 6, NO 8

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Department Chairs Explore Issues in Undergraduate Education

A special conference of physics department chairs, held May 9-11 at the American Center for Physics in College Park, Maryland, focused on the issue of undergraduate education in physics. The conference was sponsored by the APS and the American Association of Physics Teachers, and was intended to help department chairs of physics departments nationwide improve their undergraduate physics programs along the lines of the latest research results on physics education.

The impetus for holding such a conference derives from two recent reports: "Shaping the Future" from the National Science Foundation, and "From Analysis to Action," from the National Academy of Sciences, both of which exhort the higher education community to reform and revitalize undergraduate science education. In addition, the AAPT sponsored a September 1996 conference to discuss possible reform efforts in this area, resulting in a widely distributed report entitled "Physics at the Crossroads" that calls for the development of an infrastructure to support the notion of continuous, nation-wide reform in undergraduate physics.

"Undergraduate physics programs are under increasing pressure from university and college administrations, industry and funding agencies to better educate and train our students at all levels, from introductory courses to advanced senior-level courses," said Jerry Gollub (Haverford College), who co-chaired the conference with Roger Kirby (University of Nebraska, Lincoln). "The expectations for our programs have changed, and evidence is mounting that they need revitalization." Specifically, Gollub noted that most departments have a small number of physics majors with respect to faculty size, and that many faculty and students have expressed dissatisfaction with their experiences, particularly in introductory courses.

According to Robert Hilborn of Amherst College, current statistics indicate a steady decline in the number of physics majors, and a survey of the conceptual understanding of several thousand introductory physics students indicates cause for serious concern. However, he reported that "interactive-engagement" methods seem to improve both conceptual understanding and student attitudes towards physics, which is cause for some optimism for the future. For example, Eric Mazur of Harvard University has found that the use of peer instruction, which actively involves students in the teaching process, makes physics more accessible for students, as well as improving their conceptual learning.

Participants in the conference of Physics department chairs at the light and shadows "classroom" session.

"We are being asked to change the way we teach," said Edward Redish (University of Maryland, College Park). "Instead of only training tabletop research scientists, we are now being held responsible for adding value to all of our students." Lillian McDermott, who heads the Physics Education Group at the University of Washington, has found that the gap between what is taught and what is learned in introductory physics courses is much greater than most instructors realize. In fact, on certain types of qualitative questions, student performance is essentially the same, before and after instruction, in calculus-based and algebra-based physics, with or without standard laboratory or demonstrations, and regardless of the size of the class

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Inside...

APS Selects First Two Mass Media Fellows

The APS has selected two young physicists as the Society's first Mass Media Fellows. Jeffrey Chuang, a physics graduate student at the Massachusetts Institute of Technology (MIT), is spending ten weeks this summer at the Dallas Morning News in Dallas, Texas. David Kestenbaum, a staff scientist at Fermilab, is spending his ten-week summer fellowship tenure as an intern at WOSU-AM radio in Columbus, Ohio.

The APS Mass Media Fellowship Program was established last year as a means of improving public understanding and appreciation of science and technology. Specifically, the fellowship provides physicists with an opportunity to participate in the news process by learning to describe complex technical subjects in a manner comprehensible to non-specialists; and understand editorial decision-making and the ways in which information is effectively disseminated.

Chuang received his BA in chemistry and physics from Harvard University in 1996. He is currently a candidate for a PhD in physics at MIT, where he is engaged in research in quantum computation theory. As a research assistant in Harvard's physics department, he developed computer simulations to study the dynamics of creating an antimatter atom. He spent two summers as a research assistant at the Center for Superconductivity, working on high-temperature superconductors, and as a research assistant at the National Superconducting Cyclotron Laboratory in East Lansing, Michigan.

David Kestenbaum

Jeffrey Chuang

While at Harvard, Chuang was a news reporter for the *Harvard Independent*, a weekly campus newspaper, on the editorial staff of the *Harvard Science Review*, a college magazine designed to explain scientific topics to the general community, and served on the publicity staff of the Harvard-Radcliffe Television Organization, a college TV station. Ultimately he would like to teach college-level physics and work in science policy.

Chuang said. "Science is critical in many areas that the public must consider, including business, the environment and public policy."

Kestenbaum received his B.S. in

(continued on page 3)

All of Physical Review Available Online

The July 1 release of *Physical Review B online* and *Physical Review E online* marked the successful completion of APS' plan to make the entire *Physical Review* available on the World Wide Web. Joining *Physical Review Letters* and the rest of *Physical Review*, *PRB-online* and *PRE-online* offer features such as browsable tables of contents for current and previous issues, advance listing of accepted papers scheduled for upcoming issues, a PDF file of the full article, enabling users to print articles with the same look and feel as the print version, and versatile full-text or bibliographic search capability.

APS members may enter an online-only subscription to *Physical Review Letters* or any of the *Physical Review* for $25 each, and those who have a paper subscription to *Physical Review Letters* or any of the *Physical Review* will get a free subscription to the online version of the corresponding journal.

A paper subscription to either part of *Physical Review B* (B1 or B15) will qualify APS members for a free subscription to the online version of the entire *Physical Review B* (B1 and B15), which includes Rapid Communications. APS members who have a paper subscription to either part of *Physical Review D* (D1 or D15) will get a free subscription to the online version of the entire *Physical Review D* (D1 and D15).

If you have not renewed your membership yet and would like to take advantage of this offer, you may add your online journal selections on your renewal invoice and remit the appropriate amount. Please take the time to print your email address legibly in the space provided on the invoice so that we may notify you by email as to how you may register online and select your personal username and password.

If you have already renewed your membership but would like to add a subscription, you may contact the APS Membership Department at 301-209-3280 (telephone), 301-209-0867 (fax), or membership@aps.org (email).

Physics Departments Explore Innovative Curriculum Approaches

A central theme of the recommendations from the APS Task Force on Careers and Professional Development is that academic programs of physics departments need to try new approaches to better prepare students to take advantage of the breadth of career and employment options available to them. [See report on the APS home page (www.aps.org) under the Career/Employment button].

There are many examples of physics departments around the country that have undergone the necessary self-examination and devised innovative new approaches to the physics degree, and to physics teaching. A sampling of some of these programs is featured below.

Southwest Texas State University

One innovative approach is the Materials Physics Program (MPP) at Southwest Texas State University (SWT), under the leadership of Professors Carlos Gutierrez and Heather Galloway. While still undergoing the approval process that will make it a legitimate degree, MPP is an alternative major to the traditional physics BS that emphasizes courses and hands-on experience designed to prepare students for the local high-tech industry. SWT is located in San Marcos, near Austin, in the Silicon Hills region of Texas. The world's leading semiconductor companies — including Intel, Motorola, AMD, and National Semiconductor — have facilities in the region and SWT has engaged these companies for advice on how to appropriately prepare undergraduate physics majors for the local high-tech workforce.

Gutierrez reports that MPP graduates have a much easier transition into the workforce than SWT's traditional physics majors, with more options, and attractive salaries. Over the last four years, BS students were placed at Motorola, Applied Materials, AMD, and other semiconductor-related industries at salaries ranging from $30K -$51K per year. However, physics has not been sucked out of the MPP physics bachelors degree: five graduates are currently in PhD programs. "By focusing on the needs of local industry and bringing industry into the department as a partner in physics education, the SWT physics department has strengthened itself by providing a more useful degree to its students and a more useful product to its community," said Gutierrez.

Louisiana State University

The Department of Physics and Astronomy and the Department of Computer Science at LSU have developed an interdisciplinary curriculum which offers graduate students the opportunity to obtain a PhD in physics and a MS in computer science. This initiative is an effort to integrate high performance computing and communications (HPCC) with research and education in the physical sciences. The HPCC program was started in 1990 by Professors Rajiv Kalia and Priya Vashishta, who established a Concurrent Computing Laboratory for Materials Simulations (CCLMS) at LSU.

Faculty, postdoctoral researchers, and students at the CCLMS are involved in multidisciplinary research programs in computational materials science, physics and astronomy, chemistry, algorithm design, parallel programming environments, and advanced scientific visualization. The State of Louisiana equiped the CCLMS with a number of parallel machines and visualization platforms. With support from NSF the CCLMS has been connected to other massively parallel machines and visualization platforms in the country via a high-speed network.

Students working toward a dual degree take core courses in physics and preparatory computer science courses, before taking the qualifying examination in physics. Subsequently they take one computer science course per semester over the next three years. In addition, they are required to complete a project in the Department of Computer Science and a PhD thesis in physics.

Encouraged by the success of this initiative, the two departments plan to introduce a three-year program combining a MS in applied physics with a MS from the Department of Computer Science. New interdisciplinary courses in materials physics and chemistry will be designed and a summer internship program will be introduced, allowing students to do research at government laboratories and industry.

Massachusetts Institute of Technology

MIT's Department of Physics has implemented numerous initiatives designed to broaden and strengthen its interactions with industry, under the auspices of its Physics Industry Forum. Specifically, last year the department began helping graduate students to seek summer employment, or "externships," with industries or national laboratories, offering credit towards the department's breadth requirements for the PhD degree. According to Peter Wolff, who serves as department liaison to industry, the program placed six students with major companies in 1996 and doubled that number this year. Wolff said, "Industrial people like to see resumés with industrial experience. It's proof that the student has some of the qualities they are seeking — breadth, flexiblity, collaborative ability — that are not taught as part of the traditional physics training."

To help facilitate direct contacts with industry, the physics department holds a six-week recruiting open house each fall, hosting one to three companies each day and arranging interviews with students when desired. There is also a Visiting Scientist Program for industrial scientists, intended to foster more collaborative research with industry. In addition, the department is trying to broaden its course offerings in physics. For example, there is now a popular course in biophysics. Wolff sees similar opportunities in computational and chemical physics.

Wolff admits that there are still some "cultural" barriers to be overcome. Many faculty members were reluctant to lose their graduate students for the summer and students still feel that going into an industrial position is somehow second-best to an academic appointment. "In subtle ways, academia teaches students that they ought to go into academia," said Wolff. "There are challenging industrial jobs; a lot of great science has come out of industrial projects."

Moorehead State University

Simply walking off campus and into the community can inspire new ideas and opportunities for physics departments. The physics department at Moorehead State University in Moorehead, Minnesota has altered their traditional physics major after consulting with an array of local businesses. Moorehead's goal is to make physics majors more marketable by emphasizing workplace related skills. The most significant modification is the addition of an internship experience as one of the electives available to students. Physics majors may also substitute business courses for some physics courses. Local businesses have been very receptive to this concept, and Moorehead's department chair, Vijendra Agarwal, thinks that this sort of flexibility will lead to many internship and future employment opportunities for physics majors.

Rutgers University

Rutgers University has also seen the future and has introduced four options for the BS in physics: 1) the professional option, designed for the grad-school bound; 2) the five-year engineering option; 3) the general option, which is curricularly flexible and popular with premeds; and 4) the applied option, for those headed for technical jobs. Rutgers' approach has been quite successful. Over the last three years, they have produced 109 bachelors in physics; 45 bachelors will be granted this year, representing more that 1% of the national total; 24% of these are women and 16% are underrepresented minorities. Notably, the applied option is very popular, with 29% of the majors choosing this route. Similar to SWT in designing its applied track, Rutgers has looked to the needs of local industry: optics. Thus, Rutgers' applied concentration is in optics, and the applied graduates have naturally garnered jobs in the local optics industry.

Please send information about other innovative physics programs to: Barrett Ripin, APS Associate Executive Officer, at email address ripin@aps.org.

APS News

Coden: ANWSEN ISSN: 1058-8132
Series II, Vol. 6, No. 8 **August/September 1997**

Editor: **Barrett H. Ripin**
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APS News (ISSN: 1058-8132) is published 11X yearly, monthly, except the August/September issue, by The American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, (301) 209-3200. It contains news of the Society and of its Divisions, Topical Groups, Sections and Forums; advance information on meetings of the Society; and reports to the Society by its committees and task forces, as well as opinions.

Letters to the editor are welcomed from the membership. Letters must be signed and should include an address and daytime telephone number. The APS reserves the right to select and to edit for length or clarity. All correspondence regarding *APS News* should be directed to: Editor, *APS News*, One Physics Ellipse, College Park, MD 20749-3844, email: letters@aps.org.

Subscriptions: *APS News* is an on-membership publication delivered by Periodical Mail. Members residing abroad may receive airfreight delivery for a fee of $20. **Nonmembers:** Subscription rates are: domestic $160; Canada, Mexico, Central and South America, and Caribbean $180; Air Freight Europe, Asia, Africa and Oceania $210.

Subscription orders, renewals and address changes should be addressed as follows: **For APS Members**—Membership Department, The American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, membership@aps.org. **For Nonmembers**—Circulation and Fulfillment Division, American Institute of Physics, 500 Sunnyside Blvd., Woodbury, NY 11797. Allow at least 6 weeks advance notice. For address changes, please send both the old and new addresses, and, if possible, include a mailing label from a recent issue. Requests from subscribers for missing issues will be honored without charge only if received within 6 months of the issue's actual date of publication.

Periodical Postage Paid at College Park, MD and at additional mailing offices. Postmaster: Send address changes to *APS News*, Membership Department, The American Physical Society, One Physics Ellipse, College Park, MD 20740-3844.

NSF Integrative Graduate Education and Research Training Program

The challenges of educating scientists, mathematicians and engineers for the 21st century mandate a new paradigm in graduate training. To meet the need for a cadre of broadly prepared PhDs with multidisciplinary backgrounds and the technical, professional and personal skills essential to addressing the varied career demands of the future, the National Science Foundation (NSF) announces an agency-wide, multidisciplinary graduate training grant program for graduate research institutions.

The goal of the Integrative Graduate Education and Research Training (IGERT) Program is to enable the development of innovative, research-based graduate education and training activities that will produce a diverse group of new scientists and engineers well-prepared for a broad spectrum of career opportunities. Supported projects must be based upon a multidisciplinary research theme and organized around a diverse group of investigators from U.S. PhD-granting institutions with appropriate research and teaching interests and expertise. NSF organizations participating in the IGERT program include the Directorates of Biological Sciences; Computer and Information Science and Engineering; Education and Human Resources; Engineering; Geosciences; Mathematical and Physical Sciences; Social, Behavioral and Economic Sciences; and the Office of Polar Programs.

Awards will be made in amounts up to $500,000 per year (including direct and indirect costs) for a duration not to exceed five years; up to an additional $200,000

(continued on next page)

Rooney is Named Next APS Congressional Fellow

The American Physical Society selected the 1997-1998 Congressional Fellow at its annual spring meeting in Washington, DC in April. Peter Rooney, a program officer for the National Research Council (NRC), will serve one year as a special legislative assistant in a congressional office of his choice, following an intensive, ten-day orientation period and interview process. Rooney applied for the APS fellowship "in order to build on my current science policy experience and gain in-depth exposure to the Congressional policy-making process," he said. "I welcome the opportunity to contribute to the promotion of science and technology policies that promote scientific research and contribute to the strength of our economy."

Rooney received his BS in physics from Sonoma State University in 1986 and completed his PhD at the University of California, San Diego, in 1995. His research focused on studying the effect of deposition conditions on chemical order in single crystal, thin film binary metal alloys, to determine how the kinetics of film growth and, in particular, the enhanced mobility at the surface relative to the bulk, affect the short and long range order in vapor-deposited thin metal films. From a practical standpoint, the development of advanced materials for a wide variety of applications depends on the ability to control the microstructure of vapor-deposited films, requiring a basic understanding of the kinetics of vapor deposition and growth.

While completing his graduate work, Rooney worked as a research assistant at the University of California, Berkeley's Microfabrication Laboratory as well as at UCSD's Center for Magnetic Recording Research. Both are industry-affiliated technology research centers. It was his experience working in such an environment that stimulated his interest in the issue of U.S. industrial competitiveness, especially as it relates to technology-intensive industries. He also spent seven years as a successful entrepreneur before attending college, co-founding WWC, Inc., a holding company that manages farmland and oil and gas producing properties, as well as a chain of five specialty food stores and affiliated restaurants.

One of Rooney's primary responsibilities at the NRC has been to manage the annual assessment of technical programs for the areas of the National Institute of Standards and Technology (NIST) that are engaged in physical science and information science research and development. He also served as study director for three different NRC panels: the Space Studies Board Task Group on Issues in Sample Return, which examined planetary protection issues surrounding a possible Mars sample return mission; the Space Studies Board Committee on Human Exploration, which reviewed and evaluated the varied approaches NASA has adopted to manage space science human exploration missions; and the Naval Studies Board Committee on Assessment of Fire Suppression Substitutes and Alternatives to Halon, which examined the status of research and engineering directed toward developing alternative fire suppression agents to replace halons on naval platforms.

Rooney also has considerable experience in public service outside the national political arena. From 1980 to 1982 he was a member of the Board of Trustees of Sudbury Valley School, a private, non-profit elementary and secondary school in Framingham, Massachusetts, writing public relations materials and serving as a spokesperson for the school in various public forums. He was also a volunteer board member of the Sonoma County Environmental Forum in Santa Rosa, California, from 1984 to 1986, which lobbied local and regional government bodies in support of environmental issues.

The APS Congressional Fellowship program is intended to provide a public service by making available individuals with scientific knowledge and skills to members of Congress, few of whom have a technical background. In turn, the program enables scientists to broaden their experience through direct involvement with the legislative and political processes. "Fellows gain a perspective which, ideally, will enhance not only their own careers but also the physics community's ability to more effectively communicate with its representatives in Congress," said APS Vice-President Jerome Friedman. "Today's budget climate makes this ability of increasing importance as shrinking resources force hard choices between worthy projects."

Proposed Tax Bill Targets Graduate Assistants

A tax proposal released in June by Rep. Bill Archer (R-TX), Chair of the House Ways and Means Committee, has targeted graduate teaching and research assistants. Graduate students teach up to 40% of the courses on some of the nation's largest university campuses and conduct a large portion of the nation's technological, defense, medical, engineering, chemical and other research. The bill prompted an outcry from the National Association of Graduate-Professional Students (NAGPS), whose members and students held a June 19 Lobby Day in Washington, DC.

"This isn't tax relief that will help make education more accessible," said Bryan Hannegan, a graduate student at the University of California/Irvine and NAGPS President. "The proposed changes in the tax code could push people out of graduate school due to costs, could force universities to dramatically increase teaching and research assistant salaries, could increase tuition for undergraduates throughout the U.S., and could dramatically reduce the value of our nation's research dollars - much of it federal money."

Specifically, the proposed provision would eliminate a subsection 117(d) of the tax code that presently allows universities to waive the tuition of its graduate teaching and research assistants in return for the services provided by the student.

"Eliminating the exclusion from tax of these tuition waivers would have a catastrophic effect on students, as well as the entire education system," said Kevin Boyer, NAGPS Executive Director. For instance, students with a $10K stipend and tuition waiver of $20K per year would force the student to pay taxes on $30K in "income." This is despite the fact that the student would only have $10K in "cash income" from which to pay the tax.

Three other provisions in the tax code also target graduate/professional students: (1) the HOPE scholarships will be curtailed; (2) the deduction for higher education expenses specifically excludes graduate school; and (3) the extension of the Employer Provided Educational Assistance portion of the tax code (Section 127) applies only to undergraduate courses.

Individuals concerned about the tax bill should contact their own members of Congress immediately. This is particularly true for those whose House and Senate representatives are on the Conference Committee. For access information check [http://congress.org].

Shelter Island Conference Celebrates 50 Years

June 1997 marked the 50th anniversary of the first Shelter Island Conference, attended by twenty-five physics luminaries. Held June 2-4, 1947, this meeting was one of the most fruitful of a series of specialized scientific conferences held immediately after the end of World War II, sponsored by the National Academy of Sciences, to counter the feeling that scientific and technical societies had grown so large, or become so narrowly specialized, that no critical discussions were taking place at their meetings. Much like the 1911 Solvay Conference set the stage for developments in quantum theory, the Shelter Island gathering marked the initial stimulus for postwar developments in quantum field theory. These included effective, relativistically invariant computational methods, Feynman diagrams, QED, and renormalization theory, among others. A second Shelter Island conference was held in 1983 at the original Rams Head Inn. [Photo from Niels Bohr Archive]

Shelter Island conference participants, June 1947. From left to right: I.I. Rabi, Linus Pauling, John Van Vleck, Willis Lamb, Gregory Breit, Duncan MacInnes, Karl Darrow, George Uhlenbeck, Julian Schwinger, Edward Teller, Bruno Rossi, Arnold Nordsieck, John von Neumann, John Wheeler, Hans Bethe, Robert Serber, Robert Marshak, Abraham Pais, J. Robert Oppenheimer, David Bohm, Richard Feynman, Victor Weisskopf, Herman Feshbach.

NSF Programs *(continued)*

will be available for appropriate state-of-the-art research instrumentation and special purpose research materials during the first year of the award. The number and size of the awards will depend on the advice of reviewers and on the availability of funds. About 20 awards per year are anticipated during the first three years of the IGERT program.

Applicants compete for support from the IGERT program in a two-stage process. Preproposals outlining the planned IGERT activity must be submitted no later than 5:00 PM EDT, September 8, 1997. These will be reviewed by multidisciplinary advisory panels, after which approximately 60 applications with promising programs will be invited to submit a formal proposal. The formal proposals must be submitted electronically no later than 5:00 PM EDT, December 15, 1997.

Inquiries about the IGERT program in the Directorate of Mathematical and Physical Sciences, can be directed to Henry N. Blount III, 703-306-1946; email: hblount@nsf.gov. Further information, including proposal criteria and application information, can be obtained from the NSF World Wide Web page [http://www.nsf.gov] by accessing "IGERT" under "Crosscutting Activities" in the section entitled "Program Areas."

Mass Media Fellows *(continued from page1)*

physics from Yale University in 1991, where he studied the fractal structure of schizophrenic brain waves and helped develop a detector based on scintillation fibers. He received his PhD in physics from Harvard University in 1996, with a thesis presenting the discovery of the top quark, having worked on the research team that discovered it.

In addition to his scientific work, Kestenbaum worked as a freelance writer for the *Chicago Reader*, and has written articles for both the *CERN Courier* and *FermiNews*, as well as an essay for *Modern Physics*, an undergraduate textbook. Eventually he would like to combine his scientific research career with one in science writing. "I enjoy boiling down a scientific idea and expressing it in a coherent, compact way," he said. "Ideally sentences should have the same distilled beauty that a theory or an equation does."

He added, "Not everyone needs to be science literate, but as scientists it is our responsibility to communicate our endeavors to the taxpayers who fund us and are affected by our work."

OPINION

APS VIEWS

How do you make 40,000 physicists happy?

By Mary Pat Paris, APS Membership Manager

Although I'd love to offer a snappy comeback, the truth of the matter is, I can't. The reality of it hit home recently as I reviewed the results of the most recent APS membership survey. I should clarify that I tried to find one particular service or benefit that drives physicists to retain APS membership. What I discovered is that "it" just doesn't exist.

Does this mean that I must give up my goal of 100% member satisfaction? Again, my answer is no.

The staff and officers of APS regularly receive calls, letters and e-mail messages from members who ask questions, or offer comments and suggestions on how we are doing. While this gives us some feel for how our efforts are received by the members, it does not necessarily reflect the pulse of the membership as a whole. There are many more members who do not take the time to let us know how we rate in their eyes. In October, 1996 APS solicited a sample of members to complete a grueling 80 page survey (actually 8 pages; it just seemed like 80) in which we asked for the answer to "How are we doing?"

Preliminary results of the survey are in and APS Committees are busy debating what the numbers mean. Some results are open to interpretation, others obviously clear. Demographics top the list of survey results and not surprisingly, report the very diverse nature of APS members. The common bond is physics but the similarities seem to end there. Age, gender, level of education, employment status, and subfield of physics, make a "typical" APS member hard to define. We know that strength is in diversity, however each of these groups has expectations of the role its professional association should fill, and rarely agree on exactly how this should be accomplished. I am referring to specific tangible and intangible benefits offered to members in exchange for their dues.

The survey shows that large groups of members look to APS for its journals. Others value the benefit of presenting papers at APS meetings. Students look to us for career guidance, while some see our insurance programs as critical to maintaining membership. The survey also indicated that some members only belong because of *Physics Today*. Online journal access services are important to some, but not others. Education and outreach rated high on some members' lists while increased resources for public affairs topped others.

I was personally surprised to see how many members rated the paper Membership Directory higher than the online Membership Directory. I expected that since the online directory reflects "up-to-the-minute" changes, members would prefer that to a paper version that is technically out of date when it is printed. I was wrong, and the survey results showed me how important it is to ask you on a regular basis what is important.

The APS Committee on Membership regularly reviews current and proposed benefits of membership. Last year, the Committee approved, and we offered, the opportunity for APS members to subscribe to Internet access through EarthLink™. Some members loved it, others called and wrote about what a waste of resources they thought it was. I have received praise (and just as many complaints) from members about the decision to stop mailing BAPS in advance of meetings, and the increased use of electronic communication with members. Similarly, I have a file of letters from members who wrote in support of a statement APS made several years ago. I also have a file of members who terminated their membership as a result of the same statement.

My goal as Membership Manager is 100% member satisfaction. I always knew this was a tough goal to strive for, however the survey has convinced me that while it is tough, it is possible as long as I change my definition of satisfaction. 100% member satisfaction does not mean that all members will be happy with every benefit or service offered. By putting together a "cafeteria plan" of benefits from which to choose, and by participating in a wide range of education, outreach, international, and public affairs, each member should come away 100% satisfied with their decision to maintain membership in APS.

I invite you to consider your level of satisfaction with APS as a whole. How does your membership benefit you, and how can we make your membership more worthwhile? Call, write, e-mail, and respond to surveys. We need to hear from you!

Study Shows Importance of Publicly-Funded Science to Industry

The value of publicly-funded basic science to industry is extolled in a March 17, 1997 study performed for NSF by CHI Research, Inc., an international consulting firm. Entitled, "The Increasing Linkage Between U.S. Technology and Public Science," the study examines the connection between U.S. industrial patents and their citation of publicly-funded research papers.

Underlying the study's findings is that public science is a driving force behind high technology and economic growth. The report is based on tracing tens of thousands of references from recent United States patents, issued in 1987-88 and 1993-94, to the scientific research papers they cite.

According to the report, 73% of the papers cited by U.S. industry patents are public science, authored at academic, governmental, and other public institutions worldwide. Across all countries and technologies reviewed, the paper finds a steady increase in science linkage for at least two decades. That linkage is growing fastest in the U.S. References from U.S. patents to U.S.-authored research papers have tripled over a six- year period.

The report finds this linkage of patents to science papers to be very subject-specific, being strongest in biological and medical technologies. It is less pronounced in physics, although physics — along with chemistry, engineering, and biomedicine — is one of the four most heavily-cited scientific categories for 1993-94 patents. For research papers in physics, NSF support is cited most often, followed by the U.S. Navy, the DOE, the U.S. Air Force, DARPA, the U.S. Army, NASA, and the DOD in general.

The report concludes that "public science plays an essential role in supporting U.S. industry, across all the science-linked areas of industry, amongst companies large and small, and is a fundamental pillar of the advance of U.S. technology."

zero gravity

If Dr. Seuss were a Technical Writer…

Here's an easy game to play.
Here's an easy thing to say.

If a packet hits a pocket on a socket on a port,
And the bus is interrupted as a very last resort.
And the address of the memory makes your floppy disk abort,
Then the socket packet pocket has an error to report!

If your cursor finds a menu item followed by a dash,
And the double-clicking icon puts your window in the trash,
And your data is corrupted 'cause the index doesn't hash.
Then your siutation's hopeless and your system's gonna crash!

You can't say this?
What a shame, sir!
We'll find you
another game, sir!

If the label on the cable on the table at your house
Says the network is connected to the button on the mouse,
But your packets want to tunnel on another protocol,
That's repeatedly rejected by the printer down the hall,
And your screen is all distorted by the side affects of Gauss,
So your icons in the windows are so wavy as a souse,
Then you may as well reboot and go out with a bang,
'Cause as sure as I'm a poet, the sucker's gonna hang!

When the copy of your floppy's getting sloppy on the disk,
And the microcode instructions cause unnecessary RISC.
Then you have to flash your memory and you'll want to RAM your ROM.
Quickly turn off the computer and be sure to tell your mom!

Author Unknown

George Soros Honored for Aiding FSU Science

On June 4, 1997, leadership from The American Physical Society gathered in New York for a reception and dinner to honor George Soros for his support of science in the former Soviet Union (FSU). At the event APS President, D. Allan Bromley, formally recognized Mr. Soros "for his outstanding efforts in working to preserve the scientific heritage of the nations of the former Soviet Union." In the aftermath of the collapse of the Soviet government, the very existence and future of one of the largest and most important physics communities in the world became endangered. Under the leadership of 1992 APS President Ernest Henley, an APS Task Force on the Crisis in the FSU was appointed to oversee the development of support programs to assist these colleagues. The major contributor to these programs was George Soros, whose network of foundations gave $1.2 million for APS Emergency Small Grants to physicists attempting to continue their work and to provide needed individual travel as well as library journal distribution support which continues today through the Open Society Institute. In addition, Mr. Soros' $100 million endowment of the International Science Foundation brought another $16.57 million to the physics community in the FSU.

Mr. Soros continues to involve himself in APS affairs in a leadership position as a vice chair for The Campaign for Physics, a $5 million fund raising effort to launch and expand science education programs of APS and AAPT (a partner in the Campaign).

D. Allen Bromley presents George Soros with a certificate of appreciation while Judy Franz and Ernie Hanley look on.

OPINION

Take Physics Local

by P. W. "Bo" Hammer, Assistant Manager of Education, American Institute of Physics.

Physicists are fiddling, but not as Einstein once did. As we glory in the centennial of the electron, our profession may be crumbling around us. Consider our operating environment: While the total number of college graduates is at an all-time high, the number of bachelors degrees in physics produced annually is at a 37-year low, approaching 4,000. [See graph and APS Views on page 6 of the July 1997 issue of *APS News*.]

Furthermore, for every 1000 bachelors degrees awarded each year, only 3.6 are in physics, compared to an historical level of about 5 per 1000. Over half of all college graduates are women, but in physics we are hovering just below 20%. Similarly, with Blacks and Hispanics, our numbers are in the single digits and out of proportion to the total number of minorities graduating from college. A visit to physics departments is likely to reveal malaise and anxiety among students concerned about their professional future. And why not? Funding for R&D is in decline. Our own publications lament the job situation for physics graduates, and physicists entering the workforce face an unreceptive audience of employers. Taken together, these conditions indicate a profession in distress, yet what we observe are symptoms, not the disease.

After World War II, physics departments and the federal government entered into an agreement whereby physicists would perform federally funded basic research in exchange for training PhDs and providing the technological advances that strengthened the U.S. military and industry. The outcome of this bargain was a research and training enterprise that drove the emerging US high-tech economy. What ails us today is that federal budget pressures, the end of the Cold War, and global competition have chipped away at the tenets of this contract. The pact between physics and society has eroded and our vision of the future is blurred as we cling to the Cold War bargain that sustained our academic and industrial research enterprise.

The bachelors degree was a necessary station on the PhD assembly line, but was never really viewed as a worthy end product, even though fewer than 8% of all physics bachelors have become PhD physicists doing research or teaching. Yet, despite their neglect by the physics community, physics bachelors and masters students have gone on to productive professional lives because of the utility of the physics degree.

Our professional base — the physics bachelors degree — is disappearing in response to a perception among students and many employers that physics is no longer a viable professional option. If this base erodes much further, the damage could take years to correct, putting the U.S. years behind its competitors in the interim.

The problem with rebuilding this base is that we cannot rely as we once did on the federal government to provide the bricks and mortar. There is intense pressure to bring government spending into balance. The structure of the federal budget and its off-limits entitlements mean that even in the rosiest of fiscal scenarios, funding for science is not going to grow much above inflation. The key to our long-term professional survival, therefore, is to re-establish physics' pact with society. We must do this by reaching out to our local communities and building symbiotic relations whereby physics and the communities we serve become mutually dependent partners. In other words, physicists and physics departments need to take physics local.

The opportunities to take physics local are particularly rich in urban and regional centers that usually have affordable higher education at public two- or four-year colleges.

Yet, many of these departments do not have PhD programs and cannot compete for federal funding against the big research universities in their states. As state budgets for higher education become tighter, pressures are building to phase out the physics major in departments which produce few undergraduate majors. With a national average of less than six majors per department, many urban and regional departments are already feeling the heat. The solution is for physics departments to take physics local, becoming such visible and valuable resources to their local communities that no sane university or state administrator would dream of even nicking them with the budget axe.

This concept is not so far-fetched. Consider the aggressive outreach and utility that engineering, business, and education schools provide to their communities. Engineering schools are particularly good models because they and physics draw from a similar pool of potential majors. Yet while physics struggles to keep its annual number of majors above 4,000, the engineers have been turning out around 100,000 graduates per year. Why such a discrepancy?

One explanation is the natural link, made in the minds of students and employers, between the value of an engineering degree and the types of jobs in the technical workplace. Engineering, business, and teaching programs provide students with a vision of their professional futures in ways that physics does not because there is no explicit physics industry. Engineering and business schools are intimately cognizant of the needs of their customers, typically local industry. When asked, companies will tell you that they need skilled workers, problem-solvers, and people with bachelors and masters degrees who can think on their feet and learn new tasks quickly.

But engineering schools don't just produce a hot employable commodity by churning students through the curriculum. Engineering schools often provide a lot more bang for students' tuition buck than physics by adding meaningful value to the degree through extracurricular benefits such as internships, co-op positions, connections to companies that have a history of hiring their graduates, and professional certification.

Furthermore, engineering and business schools aggressively track their alumni. Workforce-bound graduates from regional and urban commuter schools are especially valuable because they tend to stay local. Maintaining good alumni contact and relations is key because alumni who get jobs eventually progress into positions of influence and may be able to provide internships, jobs, contracts, and advice. These are the types of interactions which are necessary if a department is going to be an important community resource.

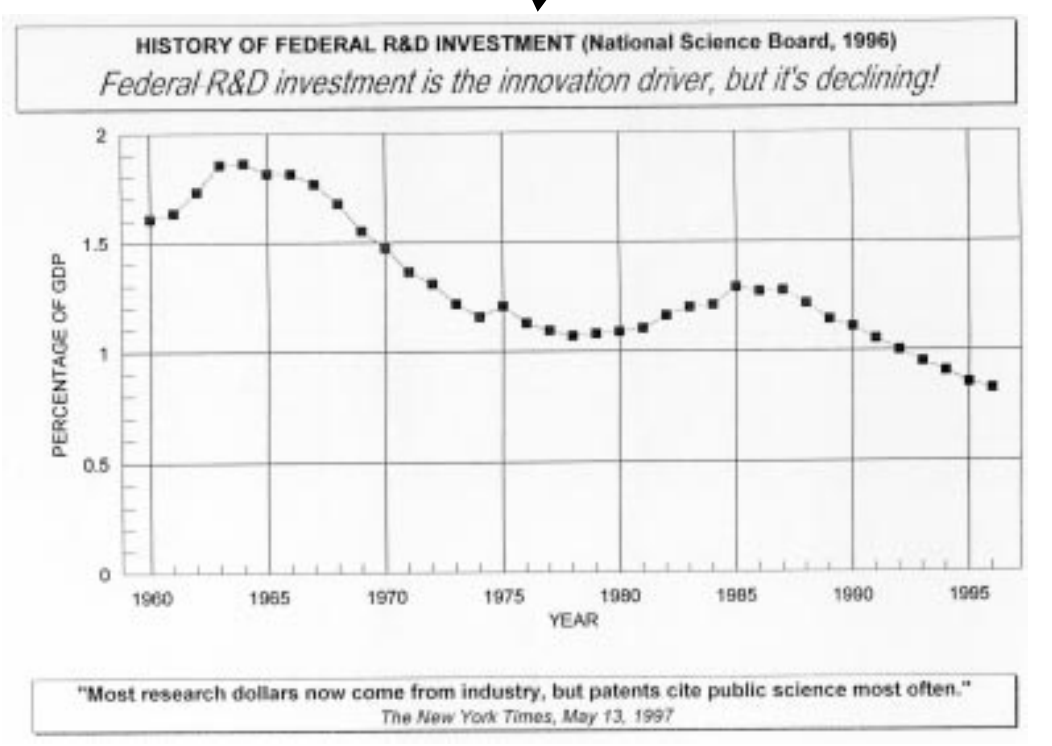
The physics community can rebuild its pact with society, not by mimicking engineering, but by maintaining the curricular, innovative, and complex problem solving strengths of physics. Furthermore, if physics students are our customers, then many physics departments are struggling because of poor marketing and inadequate attention to the needs of these customers. We must assess and act on the needs and goals of our students, and on how physics can be put to service for the good of the local community. Engineering and business schools thrive in this environment because of the continuous ebb and flow of people between campus and the private sector. The secret is to build symbiotic relations through human interaction and human resources. Another area where physics departments can take leadership is in the training of K-12 science teachers. Quality pre-college education is arguably the single greatest need within urban areas and one in which physics departments now play a very small role. Physics departments must become proactive in the training of teachers for the simple reason that better K-12 science education results in better prepared college students, a larger and higher quality pool of potential majors, and a population of high school and college graduates who are more at ease with science and technology and ready for work in our technical economy.

Reestablishing the pact between physics and society by taking physics local is not a blue-sky concept. There are many examples of physics departments around the country that have devised innovative approaches to the physics degree and to physics teaching, some of which are highlighted in this issue of *APS News*. These departments are quite varied in nature, but they all have made the operational connection between society, the communities their universities serve, and their departments' long-term survival.

Our profession is threatened, not by the priorities of Congress, the President, or an ill-informed public, but by our own complacency about our changing role in society. The federal government will continue to fund a broad-based program of basic research in physics. However, funding will decline over the next five or more years and will not sustain today's population of PhD-granting physics departments and the doctorates they produce. Yet, our departments live in communities that have real needs, representing the new universe of opportunities for physics. Just as the business, engineering, and education schools on many campuses operate symbiotically with the local environment, so can physics. The secret is to get out there and meet the managers, scientists, and engineers in the community and ask them how physics can help. Then do it.

This is a challenge to the physics community to assess itself as our profession makes this transition into the post-Cold War, globally competitive world. The APS and AIP want to help physics departments make this transition proactively and successfully so that physics' foundation in society is built to last. The AIP Education Division is collecting success stories with the goal of identifying models for change, establishing a network of community-focussed physics departments, and disseminating this information to the physics community. We welcome your stories and your comments on this challenge.

Factoid



APS Awards Twenty-six Scholarships to Minority Undergrads

The APS has awarded corporate-sponsored scholarships for the 1997-1998 academic year to 26 minority students who are majoring, or plan to major, in physics. Since its inception in 1980, the scholarship program has helped approximately 200 minority students pursue physics degrees. Each scholarship consists of $2,000, which may be renewed once, and which may be used for tuition, room and board.

"We are extremely impressed by these young scholars and look forward to watching them evolve into productive scientists as well as outstanding models for the next generation of minority scientists." said Judy Franz, APS Executive Officer. "We are proud to have them take part in our APS scholarship program."

Out of 90 applicants, 15 new scholarships and 11 renewal applicants were selected. The Committee on Minorities in Physics noted that the quality of the applications was extremely high, so much so that the number of scholarships was increased from 24 to 26. The committee also noted that this year's batch of students are extremely well-rounded, excelling in sports, languages, community volunteer activities and music. Fifteen of the scholarship recipients have engaged in some form of research.

The APS scholarship program operates under the auspices of the APS Committee on Minorities, and is supported by funds allocated from the APS Campaign for Physics. Scholarships are awarded to African-American, Hispanic American or Native American students who are high school seniors, college freshmen, or sophomores. Roughly half are awarded to students enrolled in institutions with historically or predominantly Black, Hispanic, or Native American enrollment. After being selected, each scholar is matched with an available scholarship, as well as an accomplished physicist to act as a mentor.

David Anjelly is one of the newly selected scholarship recipients, and will be starting his freshman year at Yale University this fall. Despite being born partial blind, he has been involved in varsity track and field, varsity cross-country, math tutoring and community service programs. He was selected as one of 20 students to attend the Summer Research Institute at SUNY at Stony Brook in 1996. There he began an independent research project with the Department of Materials Science earned him semifinalist status at the Westinghouse science competition. Anjelly has scientific publications pending, was an invited speaker at SUNY Stony Brook's student research symposium, and presented a poster paper at the 1997 APS March Meeting while still in high school.

Another scholarship recipient is Joanne Byars, who will be entering the University of Chicago this fall. Byars received perfect (800) scores on the verbal and math sections of SAT, and also on the writing, chemistry, literature, biology, and American history SAT subtests! In high school, she was the founder and president of the science honor society, and president of Mu Alpha Theta, as well as a volunteer in other community programs. In addition, she found time to engage in two independent study courses in physics at her high school and to take an elementary abstract algebra course at the University of South Florida.

Minority scholar Seth Guinals will begin his freshman year at MIT this fall. He is a graduate of Bronx High School of Science. He became involved in a Syracuse University summer research program allowing high school students to participate in research with a faculty member. His project was to mathematically model the micromechanical behavior of cavities formed in composite materials, such as steel. In addition, Guinals was a member in the Bronx Science Center for Holocaust Studies, Unidad (a Hispanic culture club), the math team, and the Arista National Honor Society. He has also participated in Books for Bosnia, Hands on New York, and the Julliard School Music Advancement Program.

The other new scholars for and their institutions, are: Danon Price (Emory), Charlesly Joseph (Brown), Juan Nieto (Harvard), Robert Villareal (Southwest Texas State University), Mark Hill (MIT), Jean Morrow (Harvard), Edward Little (Cal Tech), Andrew Mercado (U.S. Air Force Academy), Elvis Dieguez (University of Miami), Taran Villoch (Ball State University), Michael Boss (Case Western University), and Tasha Oswald (UC, San Diego).

Students whose scholarships were renewed are Gregory Baeza (Emory), Terance Barkus (Morehouse College), Martha-Elizabeth Baylor (Kenyon College), Carina Curto (Harvard), Adetokunbo Lukan (University of Toledo), Jaime Morales (University of Texas, El Paso), Lisa Morton (California State University, Chico), Melinda Nickelson (Bryn Mawr College), Ann Margaret Orthuber (UC, Santa Cruz), Eugenio Ortiz (Princeton) and Conan Viernes (University of Washington).

New Facilities, FELs, Accelerator Applications Highlight PAC'97

Plans for the next generation of high-energy and nuclear facilities, as well as recent advances in control software, free electron lasers, and accelerator applications, were among the highlights of the 1997 Particle Accelerator Conference (PAC'97), held 12-16 May in Vancouver, British Columbia. The 17th in this series, the conference covered new developments in all aspects of the science, technology and use of accelerators. PAC'97 was held under the joint auspices of APS Division of Physics of Beams and the Institute of Electrical and Electronics Engineers , and was sponsored by the U.S. DOE, the NSF, and the ONR.

Opening Plenary Session

The opening plenary session on Monday morning focused on the current status of various projects deemed vital to the future of particle physics, including the second operational run of the LEP collider at CERN and the first commissioning of the super photon ring-8GeV in Japan, a third-generation synchrotron radiation source for X rays. In addition, C. Joshi of UCLA reported on the proposed use of lasers to accelerate particles to high energies in short acceleration lengths, using the very high electric fields associated with laser beams. Speakers at a Monday afternoon session provided status reports on upgrades to Fermilab's Main Injector and Recycler, construction of Brookhaven's Relativistic Heavy Ion Collider, and the Large Hadron Collider project scheduled for completion at CERN by 2005.

Free Electron Lasers

Free electron laser (FEL)research has proceeded during the last 25 years from marginal proof of principle experiments to the construction and operation of user-oriented devices. Among the major milestones are the first experimental results from the FEL facility at the Thomas Jefferson National Accelerator Facility (see *APS News*, July 1997), as well as the development of user facility at Duke University to explore the capability and application of high power, synchronized multiwavelength infrared, ultraviolet, and gamma ray FEL light sources.

John Madey of Duke University, believes the size, cost and capabilities of such facilities are well-suited to the resources and interests of multi-disciplinary research universities.

The TESLA FEL at DESY in Germany makes use of the high quality electron beam that can be provided by the superconducting linac to drive a single-pass FEL at wavelengths far below the visible region. In order to reach wavelengths of 6 nanometers, the TESLA Test Facility currently under construction is being extended to 1 GeV beam energy, using the principle of self-amplified spontaneous emission. According to DESY's Jorge Rossbach, the key prerequisite for such single-pass, high-gain FELs is a high intensity, diffraction limited electron beam to be generated and accelerated without degradation. Once proven in the micrometer to nanometer regime, this scheme should be applicable down to Angstrom wavelengths

The study of the Inverse Free Electron Laser (IFEL) as a potential mode of electron acceleration has been pursued at Brookhaven National Laboratory for a number of years, according to Arie van Steenbergen. The studies focus on the development of a low energy, high gradient multistage linear accelerato. The BNL team recently completed a successful proof-of-principle experiment with a single module accelerator unit.

Accelerator Applications

Historically, particle accelerators were developed initially for nuclear, then for particle physics research, eventually resulting in accelerator applications in medicine and industry. This includes the production of radioisotopes for medical diagnostics and the production of electrons, protons or fast neutron beams for cancer therapy. According to Y. Jongen of Ion Beam Applications, research-oriented accelerators tend to be complex and expensive. In contrast, most accelerator applications are done with low to moderate energy protons or electrons, but with large average beam power, and tend to be simple and inexpensive to operate.

TRIUMF and Northrup Grumman have developed a new system for the detection of explosives and drugs, called the Contraband Detection System (CDS), based on the resonant absorption of gamma rays by nitrogen-14. According to TRIUMF's Bruce Milton, the collaboration has produced 3D images of the nitrogen regions which may be used to determine if small amounts of nitrogen-based explosives, heroin, or cocaine are present in scanned containers.

Bernhard Ludewigt of Lawrence Berkeley National Laboratory reported that accelerator-driven epithermal neutron sources are becoming an attractive alternative to nuclear reactors for Boron Neutron Capture Therapy (BNCT), designed to deliver a localized dose to tumors.

Closing Plenary Session

The focus was on the future of high energy and nuclear physics at Friday afternoon's closing plenary session, which included an overview of the recommendations of the 1996 Long Range Plan for nuclear science developed by the DOE/NSF Nuclear Science Advisory Committee. Brookhaven's W.T. Weng, who is chair of the next PAC meeting, CAP99 in New York City, reported that the three to four orders of magnitude increase in both peak intensity and average flux gained in the last 30 years have made it possible to construct high intensity proton accelerators. Herman Winick of SLAC said that concepts and designs being developed for fourth-generation light sources that will increase the brightness and coherence of the radiation using storage rings.

Lynda Williams, the Physics Chanteuse, gives the PAC banquet attendees an easy way to remember Maxwell's equations.

Andrew Sessler (left) being presented the APS Wilson Prize by John Peoples.

Announcements

AWARD NOMINATIONS SOUGHT

Please refer to the APS Membership Directory, pages xxi-xxxvi, or the APS home page for complete information regarding rules and eligibility requirements.

AWARD FOR OUTSTANDING DOCTORAL THESIS RESEARCH IN ATOMIC, MOLECULAR OR OPTICAL PHYSICS

Sponsored by members and friends of the APS Division of Atomic, Molecular and Optical Physics.

Purpose: To recognize doctoral thesis research of outstanding quality and achievement in atomic, molecular or optical physics, and to encourage effective written and oral presentation of research results.

Nature: The award, which is given annually, consists of $1,000 and a certificate citing the contributions made by the recipient. The award will be presented at the APS April Meeting in Columbus, Ohio, in April 1998. Nominees must submit an abstract for presentation at the meeting. The selection committee will choose finalists who will be required to present their work orally in a special invited paper session devoted solely to such presentations. The selection committee will choose the winner from among the finalists based on both oral presentation and the written material described below. All finalists will receive a travel stipend of $500.

Rules and Eligibility: Doctoral students at any university in the U.S. or abroad who passed their thesis defense for the PhD in the disciplines of atomic, molecular or optical physics after 5 December 1995 are eligible for the award, except for those whose thesis advisors serve on the current selection committee. Any APS member may submit a nomination for this award.

The complete nomination package must be submitted by 5 December 1997 to the chair of the selection committee: Carol Tanner, Department of Physics, University of Notre Dame, Notre Dame, IN 46556, Phone: (219) 631-8369, Fax: (219) 631-5952, email: carol.e.tanner.1@nd.edu.

Department Chairs Explore *(continued from page1)*

and proficiency of the instructor. To address this shortcoming, her group is developing a set of instructional tutorials in introductory physics that supplement, but do not replace, traditional lectures and textbooks.

The conference featured two "classroom" sessions to illustrate how instructional tutorials can promote the intellectual engagement of students. In each, the participants worked through a set of research-based instructional materials developed by McDermott's group to supplement the lectures and textbook of a standard introductory physics course. The tutorial on electric circuits guides students through the process of constructing a conceptual model for electric current from direct experience with simple circuits consisting of batteries, bulbs and wires. Participant observations form the basis for a scientific model that can be used to predict and explain the behavior of simple electric circuits. The tutorial on light and shadow requires students to make observations using bulbs, masks and screens to account for various phenomena, such as the formation of images and shadows due to extended sources.

Conference participants separated into two breakout groups to discuss the development of flexible curricula. "We viewed it as a broadening of educational and career options, implemented by increasing elective courses and lowering the number of required courses," said George Skadron of Illinois State University, who headed one breakout group. The other group's recommendations included surveying employers to learn what skills they seek in potential employees, introducing topical courses to capture the interest of more students, developing multiple tracks to encourage diversity of career goals, and improving the student advisory process. Many institutions have already begun to implement some form of these suggestions (see related article, page 2).

For example, Louis Bloomfield of the University of Virginia has developed a course for non-science students entitled "How Things Work," introducing them to physics in the context of everyday objects. Each segment of the course covers about 25 familiar objects, ranging from bicycles to clocks, and from microwave ovens to nuclear reactors.

The conference also featured numerous other breakout sessions, exploring such issues as the reward systems for faculty, courses for non-physics majors, recruitment and retention of women and minorities in physics, improving the mentoring process, and discovering more accurate ways to measure learning. Saturday evening the participants reconvened to share summaries from each breakout session, and to hear keynote speaker Robert Eisenstein of the NSF provide a view on the future of physics from Washington, DC.

Thesis Award in Computational Physics Established by APS Council

The purpose of the newly established Nicholas Metropolis Award for Outstanding Doctoral Thesis Work in Computational Physics is to recognize doctoral thesis research of outstanding quality and achievement in computational physics and to encourage effective written and oral presentation of research results.

The Award was named to honor Nicholas Metropolis for his outstanding contributions and numerous accomplishments in area of computational physics.

Support for the Award is from the *Journal of Computational Physics,* a publication of Academic Press. The award consists of $1,500, a certificate to be presented at an awards ceremony of the Division of Computational Physics and a travel allowance of up to $500.

Announcements soliciting nominations will appear in the *APS News*, the APS Prize and Awards webpage and other venues in early 1998.

CAUGHT IN THE WEB

Notable additions to the APS Web Server. The APS Web Server can be found at http://www.aps.org

APS News Online latest edition

APS Committees and Governance
- Speaker Lists for Minorities & Women in Physics (with online updates) and Industrial and Applied Speakers

Units
- DBP, FIAP, FHP, TGMA, STX: pages updated

Meetings
- DCMP: Online Invited Symposium Nominations for March '98
- DFD: Meetings information updated

Membership:
- New Guide to Member Services
- Pay APS invoices online
- Membership home page updated

GRANT OPPORTUNITIES FOR ACADEMIC LIAISON WITH INDUSTRY (GOALI)

The National Science Foundation provides funding to encourage and support innovative interactions between universities and industry. The program has particular interest in providing opportunities for

1) faculty, postdoctoral, and student research on and experience with production processes in an industrial setting;
2) industrial scientists and engineers to bring industry's perspective and integrate skills to academe; and
3) interdisciplinary university-industry teams to conduct long-term projects.

For full program details and contact information, refer to:
http://www.nsf.gov/home/crssprgm/goali/start.htm

PHYSICAL REVIEW CD-ROMS AVAILABLE

CD-ROMs for the 1996 volumes of *Physical Review Letters, Physical Review C,* and *Physical Review D* are available to APS members for $25 each. All three CD-ROMs contain the same contents and functionality as the online version of the respective journal. The CD-ROMs can be used in Windows, Apple Macintosh, and Unix Sun SPARC Solaris and HP environments. All CD-ROMs include a booklet providing basic information on installation and use, and technical support is available.

If you have not renewed your membership and would like to order a CD-ROM, you may add the selection on your renewal invoice and remit the appropriate amount. If you have already renewed your membership but would like to order a CD-ROM, please contact the APS Membership Department at 301-209-3280 (telephone), 301-209-0867 (fax), or membership@aps.org (email).

THE BACK PAGE

Reforming Graduate Education in the Sciences

by Congressman George E. Brown, Jr.

For a number of years, I have been advocating a two track agenda for the science and engineering community. I have repeatedly urged scientists and engineers to become more involved in the political and policy process and I have stressed the need for a reassessment of our national research and development (R&D) enterprise in light of the major changes that it faces. The first element of this agenda is well underway amidst numerous signs of a heightened political presence by the science and engineering community. Unfortunately, progress on the second agenda item is not as visible. And nowhere is this reassessment needed more than in the area of academic research and graduate education.

The need for a reexamination of our National R&D efforts has been well discussed. With the end of the Cold War, the clear and simple justifications for much of our R&D efforts, found in our competition with the Soviets and the need to contain global Communism, have disappeared. No clear mission has emerged to take the place of that previous, easily communicated goal. Pressures to balance the budget have eroded funding for R&D programs, clearly displayed in the recent budget agreement that outlines about a 14% decline in civilian R&D over the next five years.

All of these changes will force us to reassess our past policies and goals for academic R&D and graduate education, where such policies and goals exist at all. This new funding reality means that we can no longer accommodate the limitless aspirations of every institution and discipline in the science, engineering, and academic community. The stress of this change is already becoming apparent and is producing a higher education system that is financially strapped while the public is treated to news stories of excessive tuition increases. And the worst is due to come in the next decade when the children of the "Baby Boomers" begin to enter college in large numbers and further complicate the situation.

Our science and engineering (S&E) graduate education efforts are already a mess and will suffer further disruption unless we openly address the problems we face. The direct and simple motivation for our national science and technology efforts during the Cold War obviated the need to develop a sophisticated set of goals and justifications for the linkage between academic research and graduate education. What passes for policy in this area is really a set of simple assumptions that we have accepted as truths for forty years, assumptions that are being challenged by the complexities we face today.

For nearly twenty years, we have linked academic R&D grants and graduate education, assuming that some portion of our R&D funding will go to support graduate students. But we never clearly spelled out our higher education goals separate from the performance of R&D. This unthinking linkage of R&D to graduate education means that the number of Ph.D.'s produced reflects the availability of academic R&D funding, rather than having a relationship to a set of national goals for S&E graduate education. And, we do an inadequate job of monitoring conditions in the graduate education system and do not conduct sophisticated national analyses of the ongoing situation with S&E advanced education. The predictable result of this haphazard system is a series of surprises such as the current "overproduction" of S&E Ph.D.'s.

When federal R&D spending rose through the 1980's, this prompted a rise in the numbers of graduate students. But the full nature of this relationship is not understood and there is no government source able to document how much of the $12 billion in federal R&D funding for academic research (1995 figures) went to support graduate student education. Without this information it is impossible to tell if our current levels of S&E graduate education support are too high, too low, or about right. And, there is no way of knowing what we will do to S&E graduate education as we cut federal R&D programs in order to balance the budget.

"But in an odd and ironic twist, it may be that the availability of resources is to blame for some of the problem we face."

But being able to measure levels of support tells us little without some idea of our goals for S&E education. We have seen some discussion of these goals in recent studies citing the need to diversify and broaden graduate education to prepare S&E graduates for jobs outside of academia. These discussions reveal the consequences of our past simple linkage of graduate education to academic R&D: the creation of a system of training and rewards that is myopically focused on academic R&D as a career choice. It is no wonder that this system resulted in an "overproduction" of Ph.D.'s seeking academic appointments as federal R&D increased and then fell. But this revelation is a very superficial one and begs further discussion of national S&E education goals.

This revelation also prompts an examination of the role of academic institutions in contributing to our current graduate education problems, for if there is an "overproduction" of Ph.D.'s one is lead naturally to an examination of "overcapacity" within the academic R&D system. While there has been growing discussion of the narrow career focus of S&E graduate students there has been little discussion of the reward system of academic institutions that is just as narrow.

With the federal government's steady funding of R&D through the 1980's, we rewarded higher education institutions that were able to capture some of that R&D funding. This encouraged schools to work their way up the Carnegie Classification of Academic Institutions ranking system "ladder," to Research II status (receiving between $15.5 million and $40 million annually in federal support) and then to the top category of Research I status (at least $40 million in annual federal support and awarding at least 50 doctoral degrees). Receiving more R&D money meant expanding the size and prestige of the institution and allowed more graduate students to be supported off of those grants. The results are predictable.

Between 1988 and 1993, the number of Carnegie I research universities jumped 30%, from 68 to 88. Given that these schools graduate 65% of the science and engineering PhD's, the structural capacity of the system to produce PhD's may have expanded as well. But while this fact gets passing mention in the NSF 1996 *Science and Engineering Indicators*, the reasons for and details on this expansion are not fully understood or analyzed. But it seems evident that the federal government's linkage of R&D and graduate education sent clear signals to higher education institutions that they should move into research and expand their research and graduate education capacity.

We do not understand how this dynamic plays out in individual disciplines, because neither the federal government nor the National Academy of Sciences collects and analyzes relevant data by discipline or profession on an ongoing basis. For that information you have to go to the various scientific societies, such as the American Institute of Physics, which does have good statistics and can provide analysis. But this ad hoc process does not meet our current need for a more sophisticated review of graduate education. Again, we are so used to the old, simple paradigm that evolved during times of plenty that we are flying blind into a time of limited resources.

But in an odd and ironic twist, it may be that the availability of resources is to blame for some of the problem we face. In a study submitted for publication by two researchers at the University of California, San Francisco, there emerges what seems to be a direct relationship between increases in extramural funding at the National Institutes of Health and numbers of doctorates awarded in the biological sciences. Other trends include an flattening grant size, lower success rates for extramural R&D applications, advancing aging at the point of first grant and first position, and lengthening time spent in postdoctoral positions. In short, it may be that high funding for biomedical R&D, combined with our simplistic model for R&D and graduate education from the Cold War, is creating the same stress in the biological sciences that we have seen in physics, chemistry, and mathematics. If true, this means that restoring funding for federal R&D will not only *not* fix the problems in graduate education, but may make them worse. If true, this data indicates that broad S&E graduate education reform is needed before we can discuss levels of funding.

But this reform requires the active involvement of the higher education community, a group that has not provided much public information and analysis on these issues. This reform will also require the candid participation of the scientific and engineering professional societies and focused discussion, such as we see in this publication. And we will need open and painful discussions by leading scientific institutions, involving not only the esteemed Ph.D.'s from the 1960's and before, but some people who have recently minted doctorates and are living through the current situation.

"...restoring funding for federal R&D will not only *not* fix the problems in graduate education, but may make them worse."

The time is long past when we can placate taxpayers and parents with reassuring anecdotes about physics Ph.D.'s who were lucky enough to get jobs modeling stock prices on Wall Street. Serendipity is an inadequate public policy, even in times of plenty. There is a need for more sophisticated answers than, "Trust in market forces to rectify the situation." The federal government, institutions of higher education, directors of research labs, and scientific societies have all passively conspired to create the current market forces that are producing a dysfunctional situation. We must all work together to change the market forces.

George E. Brown, Jr. is serving his 17th term as Representative of the 42nd district of California. He is the ranking Democrat on the House Science Committee.

The Back Page is intended as a forum to foster discussion on topics of interest to the scientific community. Opinions expressed are not necessarily those of the APS, its elected officers, or staff. APS News *welcomes and encourages letters and submissions from its members responding to these and other issues.*