



Graduate Education in Physics: Which Way Forward?

**A Conference to Discuss the Status and
Future of Graduate Education in Physics**

January 31–February 2, 2008

American Center for Physics, College Park, Maryland



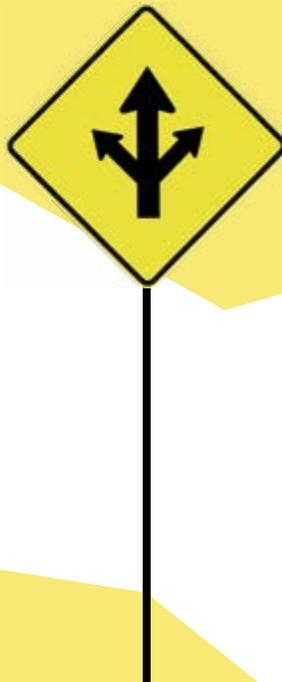
AMERICAN PHYSICAL SOCIETY • AMERICAN ASSOCIATION OF PHYSICS TEACHERS
ONE PHYSICS ELLIPSE • COLLEGE PARK, MD 20740-3844

Graduate Education in Physics: **Which Way Forward?**

A Conference to Discuss the Status and Future of Graduate Education
in Physics January 31-February 2, 2008

American Center for Physics, College Park, MD

www.aps.org/programs/education/conferences/graduate





Executive Summary

The Directors of Graduate Studies (DGS) from 66 of the nation's Ph.D.-granting institutions met for a day and a half at the American Center for Physics in College Park, MD, in February 2008 to discuss trends and practices in physics graduate education. Also represented at the conference were professional societies including the American Association of Physics Teachers (AAPT), the American Physical Society (APS) and its Forum on Graduate Student Affairs (FGSA), the American Institute of Physics (AIP), and the European Physical Society (EPS); National Science Foundation (NSF); and industry representatives were also present. The conference was sponsored by the APS and the AAPT with partial funding from the NSF.

Motivation for this meeting came from the Joint AAPT-APS Task Force on Graduate Education in Physics, whose 2006 report¹ indicated that the physics graduate curriculum has been static for many years, and from the National Academy of Science's *Rising Above the Gathering Storm*² report in 2005, which sounded alarms about the state of science education in general and the implications for U.S. competitiveness. A survey of DGS (see Appendix III) prior to the conference indicated that two-thirds of the responding departments are considering or are implementing significant changes in their graduate programs, and that all were very interested in finding out what does and what doesn't work in other physics programs.

APS Executive Director Judy Franz noted that opportunities for graduate study in physics in Europe and Asia are far more exciting and attractive than in the past, which means that U.S. institutions face far stronger competition than before in attracting high quality students—perhaps the most significant and widespread concern raised by participants.

This document contains the recommendations that emerged from major topics of discussion at the Graduate Education Conference. The recommendations are followed by a section on promising practices that departments and professional societies might adopt to implement the recommendations. These practices emerged from discussion and specific examples presented at the conference, and would obviously be adapted to local conditions. While the conference specifically addressed issues in graduate education, many of the recommendations are also pertinent to undergraduate education. The presentations of the speakers and participants are available at the conference website³.

Recommendations

Several important themes, relating to the curriculum and to the wider graduate experience, emerged from the conference. The recommendations, if adopted, should lead to an improved, more flexible, and more relevant graduate experience for all students.

The perception that a Ph.D. is only for an academic career

Most graduate students receiving a Ph.D. in physics do not enter a career in academia, and it should never be assumed that academia is the only goal. Physics departments should prepare students for other career options. The expectations for careers in academia and industry are very similar: a broad physics background, the proven ability for independent research, and effective communication skills. Thus the programs themselves do not have to be changed, but rather the perception that careers in areas other than academia are less desirable. In addition, career guidance is lacking.

Recommendations

Departments should:

- take pride in and support graduate students who aspire to non-academic professions.
- provide career guidance for graduate students that helps them prepare for a wide range of possible vocational options.

The APS should:

- adopt a statement that articulates the goals and purpose of the doctoral degree to emphasize to students, departments, and potential employers that the Ph.D. represents a sound preparation for diverse careers.

A static curriculum

The core curriculum and the exam structure have been the topic of many recent meetings and discussions. The Joint AAPT-APS Task Force on Graduate Education in Physics summarized the present status of the core courses but did not investigate in detail the content taught in these courses. Anecdotal evidence points to static content and traditional texts that do not reflect the current state and practice of physics. The emergence of many interdisciplinary subfields requires new courses that may conflict with the traditional curriculum.

Recommendations

Departments should:

- consider broadening (not increasing) the core to encourage the interdisciplinary aspirations of students and faculty; and
- regularly examine the currency and relevance of topics taught within the core and in the wider curriculum.

Professional societies should:

- follow up on the AAPT-APS task force findings by gathering information about the content of the core courses.

Exam structure

There is currently no common exam structure followed by departments. Many institutions experiment with various combinations of written, oral, preliminary or comprehensive exams as well as final exams in the core courses. This topic is intensely debated among faculty. Do exams really assess readiness for a research degree?

Recommendations

Departments should:

- critically assess the desirability and efficacy of their comprehensive exams.

Professional Societies should:

- gather information about comprehensive and preliminary exams and make common practices known.

Need for guidance, mentoring, and professional development of graduate students

Graduate students are our young colleagues. Departments and individual advisors have the joint responsibility to guide and mentor the students to develop professionally during their graduate careers and to make a timely transition to the workforce.

Recommendations

Departments should:

- make mentoring and guidance of graduate students a priority that is appropriately rewarded.
- institute methodical tracking of graduate students and their progress towards the degree.
- adopt policies that reduce the time-to-Ph.D. (currently averaging 6.3 years⁴) with particular emphasis on reducing the number of students that take longer than 6 years to graduate.
- encourage graduate students to participate in professional organizations to help them learn networking and other professional skills.
- encourage, though not require, student involvement in outreach activities as a positive aspect of the graduate experience. Professors should lead by example and encourage their students to participate.



Keivan Stassun describes the Fisk-Vanderbilt Masters-Ph.D. Bridge program.

Training for teaching assistants (TA)

All Ph.D.-granting departments rely heavily on graduate students to assist in the delivery of undergraduate courses. Graduate students should be properly trained in pedagogy, content, and class management to enable them to effectively carry out this important role. Departments are also the training grounds for future faculty and must therefore model innovation and excellence in teaching, just as they do in research.

Recommendations

Departments should:

- develop effective TA training programs that pay attention to pedagogy and professional development.
- continue TA training and mentoring throughout the graduate teaching experience.
- provide “shadowing” teaching opportunities for students who aspire to faculty positions.

Ethics training

Departments have a responsibility to teach and uphold the strongest ethical standards. We must respect and acknowledge students’ intellectual contributions and ensure that they are treated fairly, as colleagues. Ethical issues include honesty in the conduct and reporting of research, integrity in the setting and taking of exams and assignments, and in matters relating to fair treatment of our co-workers.

Recommendations

Departments should:

- offer ethics training for students. More than one experience

is needed to ensure that students revisit the topic as more mature researchers. Advisors should continue to model the highest ethical standards.

- ensure that ethics training addresses human and social issues like treatment of colleagues, stewardship of natural resources, integrity of funding sources, as well as the obvious issues of cheating, plagiarism, etc.
- develop a graduate student handbook that specifies the rights and responsibilities of students and faculty members.

Professional Societies should:

- conduct ethics workshops at national meetings and the AAPT/APS/AAS New Faculty Workshop.

Developing communication skills

Skills beyond technical expertise are increasingly important. Departments have a responsibility to teach students how to communicate effectively at all levels, and to develop the writing, speaking, presentation, and negotiating skills that will serve them in a complex work environment. Critical thinking and critical analysis of scientific information have long been the hallmark of the physicist, and the cultivation of these complementary skills must permeate all aspects of the graduate experience.

Recommendations

Departments should:

- require students to present their research orally in a public forum and provide opportunities to help them prepare and also provide them with feedback on their performance.
- require students to submit a written paper describing their research for peer review in an appropriate journal.
- encourage students to present their research at conferences, and provide financial assistance where possible.

Encouraging diversity and a supportive climate

Women and, to an even greater extent, minorities continue to be underrepresented in physics, particularly at the Ph.D. level. It is essential for departments to focus on creating a climate that attracts and retains women and minorities in physics both as students and as faculty. Such a climate improves the environment for all students.

Recommendations

Departments should:

- implement the best practices⁵ developed by the APS Committee on the Status of Women in Physics.



Vincent Rodgers of University of Iowa and a participant discuss summer research programs for undergraduates.

- consider bridge programs to help under-prepared students achieve success in graduate programs.
- develop written departmental plans for addressing issues of climate, image, recruiting, and retention of underrepresented groups.

Recruiting and retention of students

Many departments felt the need to improve recruiting. They cited poor statistics, particularly for women and minority recruitment, increasing competition from programs abroad, and competition from other disciplines.

Recommendations

Departments should:

- project an exciting, welcoming environment on their websites. The Director of Graduate Studies should be visible on the departmental website.
- network and recruit at special events for undergraduates at professional society meetings and other venues.
- work with administrators on campus to expand and improve recruitment.

Professional Societies should:

- explore the possibility of becoming or organizing a national clearinghouse for electronic graduate application materials.

- continue to provide events for undergraduates at its national and regional meetings where they can learn about the advantages of graduate programs in physics and meet with departmental representatives.

Funding agencies should:

- provide more fellowship support for graduate education in physics
- funding agencies were also urged to consider instituting programs that provide support for individual faculty members or teams of faculty members who develop and evaluate new curricula for graduate students.

Next steps

The efforts of physics departments to improve graduate education will benefit greatly from a forum for continued discussions. Professional societies and funding agencies can provide support for such efforts.

Recommendations

Departments should:

- enhance the status of, and rewards for, faculty and staff who devote time and effort to improving the graduate experience.
- communicate their best practices to other departments and adapt the best practices of others to fit the local environment.

Professional Societies should:

- sponsor a conference for DGS every 3-5 years.
- implement a listserv for DGS.
- strengthen the relationship of physics departments with industry by organizing a high-level meeting to promote physics graduate students among industries.
- appoint a task force that examines and reports best practices in successful graduate programs. Such a task force would help disseminate practices presented in this document.

Funding agencies should:

- continue to support conferences, studies, and curriculum development and evaluation programs that enhance graduate education.

Best Practices for Physics Programs

The following pages provide examples illustrating best practices, or at least promising practices, for physics departments to implement the recommendations summarized in the previous section. These emerged from discussion sessions at the conference. It is very important to note that while most departments can point to examples of good practices, it is not always true that they are uniformly applied. The student experience may vary substantially depending on the advisor, and it is incumbent upon departments to provide guidelines that ensure that all students have the opportunity to develop the required skills. This may mean providing department-wide opportunities, or insisting that advisors provide proper mentoring and training in certain areas. Conspicuous by its absence in the following is a discussion of research skills. It was generally agreed that this is one area that is not neglected! It is unlikely that all of the practices described below could be adopted at any one place, even if the resources were available. The local environment will surely suggest adaptations and modifications that retain the spirit of the suggestions.

Where comments are attributed to participants in the Graduate Education Conference, further details may be found in their presentations (posters or talks) on the conference web site³.

Countering the perception that a Ph.D. is only for an academic career

Many conference participants, including the student participants, commented that there is a widespread perception among graduate students and undergraduates that faculty members view non-academic careers as second-class alternatives to faculty positions. This is despite the fact, for example, that industrial positions are often more lucrative and offer considerable opportunity for intellectual challenge. Conference participants felt that departmental leaders must take steps to dispel this notion. They cited ignorance among faculty and students alike about other career prospects such as, for example, science policy or patent law. Faculty must work with physics graduate students to help them augment their deep knowledge of science with skills sought by academic, industrial, government, and other professions.

Departments can support graduate students who aspire to a wide range of careers by encouraging them to form organizations that empower them to seek contacts with industry. One example of this is the Career Development Organization (CDO) at the University of Washington⁶, a student organization of physics and astronomy graduate students. Its mission is to assist physics/astronomy students and postdoctoral fellows in their career advancement by organizing career seminars, compiling relevant employment data and preparatory information, and offering networking opportunities. In particular, CDO annually hosts a Networking Day, which brings representatives from the broader science- and technology-based community to the physics department to interact with students on a one-on-one basis.

Departments and advisors should also help graduate students market themselves and help them find the right job to suit their goals, skills, and temperaments. Such advising about career choices most suited to each student is possible only if there is a culture of advising and mentoring

in the department, and if faculty take the time to discuss graduate students' goals and ambitions. Faculty and students should be made aware of the Forum of Industrial and Applied Physicists⁷ (FIAP) of the American Physical Society. FIAP offers resources to aspiring industrial physicists.

Faculty members should be encouraged by their departments to discuss with their graduate students possible career choices early enough that students can hone skills that may be required to secure a particular type of job. Students interested in careers in the commercial sector should be given opportunities for industrial internships and may benefit from involvement as IGERT Fellows (NSF-Integrative Graduate Education and Research Traineeship), where such an opportunity is often an integral component of the fellowship. The University of Illinois at Urbana-Champaign (UIUC) encourages physics graduate students who may be interested in finance-related careers to take finance courses alongside physics courses towards a Master's degree in finance.

Industrial and other non-academic physicists must be represented at departmental colloquia and other seminars for graduate students and at alumni events. Most physics departments invite such individuals less frequently than they should, thereby perpetrating the perception that only academic positions are valued. Local companies are a useful source of such speakers and FIAP maintains a speaker's list⁸ of industrial and applied physicists who have volunteered to present talks. The APS Committee on Careers and Professional Development also offers a Career Development Speaker Travel Grant program⁹.

Finally, individual departments may consider instituting programs that are directly linked to industrial careers. Ed van Keuren of Georgetown University described that department's Industrial Leadership program¹⁰, which offers both the Ph.D. and the M.S. degree. The Ph.D. degree includes graduate physics classes, business classes, an industrial internship,

and a Ph.D. thesis. Another example is the Professional Science Master's degree program¹¹ that is designed for physics graduate students interested in careers in industry at the interface between science and business. Elements of such programs can be beneficial to Ph.D. students, too. For example, Oregon State University's Professional Science Master's Degree program¹² will package the business component of the course into a Graduate Certificate in 2009. Some departments offer M.S. degrees specifically geared to industrial sector employment. An excellent AIP report describes the characteristics of successful programs of this type¹³.

Professional Societies can help physics graduates find employment and may help influence their career choices. In one wrap-up session, there was a strong consensus that the APS and AAPT websites¹⁴ with career and job information for graduate students should be aggressively updated and expanded, based on feedback from recent job seekers. APS is a natural clearinghouse for information for all physicists, and an effective and highly utilized website would alleviate the necessity for departments to use resources to create independent sites. Such a site should be made attractive to industrial and commercial employers.

The APS can also support department practices that foster broad career choices by adopting a statement that articulates the goals and purpose of the Ph.D. degree to emphasize to students, departments, and potential employers that the Ph.D. represents a sound preparation for diverse careers. This would reaffirm and expand on the APS statement 06.3 Career Options for Physicists¹⁵, which encourages physics departments to consider their educational offerings in the light of the fact that physics degrees have proven to be "an excellent platform for success across a wide range of career options in the private sector, government, academia, and K-12."

Enlivening the curriculum

Departments should encourage interdisciplinary research by graduate students. This stimulates intellectual cross-fertilization and expands research opportunities for students and faculty alike. Working in different but complementary subject areas can be fostered by co-advising by faculty from other departments and physics faculty supervision of research projects of students from outside physics.

Physics Ph.D. students at Oregon State University complete physics doctorates under the guidance of advisors whose academic homes include chemistry, electrical engineering, atmospheric sciences, and biophysics. Students complete the physics academic core and remain integrated in the department. Likewise, physics faculty supervise Ph.D. degrees of students from chemistry, materials science, and science and math education. In many cases, these arrangements have led

to increased research collaboration between departments.

This interdisciplinary focus also requires flexibility in the courses students take. Randy Kamien of the University of Pennsylvania discussed their program that seeks to enhance interdisciplinary research for faculty and graduate students. This department has broadened the core course offerings (and decreased the number from nine semester courses to six, including one elective) to allow students to take advanced graduate courses needed for research, in biology, for example. Other departments also have reduced the number of core courses. Bob Pelcovitz of Brown University described Brown's program, which has reduced the number of core semester courses to six. Margaret Murnane reported a similar move at the University of Colorado, Boulder, where students take five of six designated semester courses to fulfill the core requirement¹⁶.

Critically evaluating the core and other course offerings on a regular cycle will ensure that the course content remains relevant to problems in modern physics, and that students are learning critical problem solving skills, including modern computational methods. Graduate courses, being more specialized, are more likely to become the province of one faculty member, and the faculty as a whole may be unaware of the specific content, concepts or methods taught in particular courses.

Research in physics education has been largely confined to the undergraduate experience and there was not much evidence at the conference that lessons from that research are widely applied to the graduate curriculum. Faculty who teach at the graduate level should be aware of physics education research, which quantifies how interactive learning in a dynamic environment is far superior to passive listening, and offers particular techniques that may be adapted to graduate instruction. Wider dissemination of successful graduate courses that actively engage students is important.

Examining the exam structure

The examination that admits physics students to Ph.D. candidacy is widely debated and no real consensus exists. This was evident in the discussion on the comprehensive exam at the conference. Some consider a formal written comprehensive exam the ultimate measure of the mettle of a physicist, a rigorous test that maintains a widely recognized standard, and a uniform test necessary to demonstrate research readiness. Others consider the formal exam a constraint on the learning process by restricting core courses to traditional topics, an impediment that delays entry to research without being an indicator of research readiness, and one that offers no information beyond what is already evident from students' course performance. Most take a view somewhere in between, recognizing the value of an objective, rigorous test, but remain uneasy about the rigidity of the content and format.



Conference participants listen to a plenary talk at the Graduate Education Conference held at the American Center for Physics in College Park, MD.

The University of Colorado, Boulder, provides an example¹⁷ of a department that eliminated a written comprehensive exam. Margaret Murnane, former director of graduate programs at CU, reported that the present 2-step candidacy procedure results in a success rate similar to the old exam format, but improves the student experience and productivity by allowing faster entry to research. CU requires a minimum grade on core coursework, followed by a written research paper and an oral examination on that paper and on general physics.

MIT, in a recent reassessment of its curriculum discussed by Tom Greytak, explicitly retained its three formal exams (two written). Students serving on the committee supported the decision (though they are, of course, survivors of the system). MIT requires little formal coursework, only two semesters of courses in the research area and two outside the area. Their two written exams encompass undergraduate topics (year 1) and graduate topics (year 2), and there is an oral exam that follows. Greytak from MIT reported a roughly 4% attrition rate due to the general exam, and a 14% attrition rate due to factors unrelated to the general exam.

Whatever the exam structure, students should be given every opportunity to succeed on the exam. There should be clear expectations, procedures should be crystal clear, and each case handled carefully. Copies of previous exams should be available. Time constraints should be eliminated as far as possible. Exam schedules should be such that candidacy decisions are made in a timely fashion.

Departments should consult the compilation of exam practices adopted by a large number of universities at the Graduate Education conference website¹⁸. This exchange of information about content, procedures, and formats was a useful feature of the discussion at the Graduate Education Conference. Consider adding your department's procedures to the list.

If coursework performance constitutes the entry to Ph.D. candidacy, evaluation of coursework becomes particularly important. Departments must find ways to fairly evaluate students without compromising the peer interaction on homework assignments that is a critical aspect of learning.

Fair and transparent evaluation on oral exams is critical, and there must be no perception that there are “easy” and “hard” faculty examiners. Some departments address this issue by having one examining committee that performs all the oral examinations in a given year.

Professional Societies can support departmental efforts to improve the admission-to-candidacy process by continuing to gather and publicize information about common practices. A study of the effectiveness of the comprehensive exam in determining research readiness or correlating exam scores to success in the research process would also be enlightening.

Improving guidance, mentoring, and professional development of graduate students

Departments should have an explicit reward system for effective advising and mentoring just as for research and teaching, rather than expecting it to be done as an “overload.” Accomplishments in mentoring and advising should be a regular part of evaluation for merit raises and for promotion. Release time for faculty who undertake significant projects in this area should also be considered.

Departments should maintain a highly efficient tracking of graduate student progress throughout the graduate career, and review progress of all students annually. Make expectations and consequences clear to the students. Tom Greytak of MIT described a comprehensive tracking system that MIT implements, with well-defined benchmarks.



Charlie Holbrow leads a break-out session on the interface between the undergraduate and graduate experience.

Minimal requirements include tracking required courses, departmental exams, and yearly meetings with the dissertation committee. Students should summarize their curricular and research progress, including conferences attended, papers written, and talks given. This becomes part of the student's progress record. The dissertation committee should provide feedback to help evaluate each student. There should be discussion each year at these meetings on the student's intellectual growth, technical accomplishments, and what needs to be done to complete the Ph.D. in a timely fashion.

Students should have some exposure to research in the first year of the graduate program. Rotation through a few research groups gives students an idea of work being undertaken and a flavor of the research style. Early formation of the dissertation committee is critical to students' on-time completion of the degree, and experience with the research groups will make this task easier.

Departments should consider ways to reduce the time-to-degree, which presently averages 6.3 years. Common sentiment at the conference was that 5 years should be sufficient to complete a Ph.D. Herman Verlinde of Princeton reported that Princeton's current mean time to degree is 5 years. Princeton students formally change status at the university (to Degree Completion Status) in the sixth and seventh years, and they have no official status thereafter (although the thesis can be submitted and the degree completed). It is not known whether this formal status change contributes to the short time-to-degree, but certainly Princeton has established a culture that expects completion in 5 years. Elimination of the written comprehensive examination at places like the University of Colorado, Penn State, and the University of Pittsburgh, may also reduce time to degree. Aggressive tracking of students as at MIT, where the mean time to degree is 5.6 years, may also help.

Departments should make every effort to track their graduates and invite them periodically to talk to current graduate students. At these events, graduate students should be given the opportunity to personally interact with the speaker, e.g., at lunch or dinner, or a special Q&A session. Alumni with diverse careers in academia, industry, national labs, K-12 education, finance, etc., could be profiled on the departmental webpage or in a newsletter.

Graduate students also need career advice well before they graduate. Steve Carlip from UC Davis described a "Careers in Physics" seminar at UC Davis¹⁹ that includes field trips, speakers and specific job leads.

Conference participants suggested that departments should encourage graduate students to form a graduate student forum that meets regularly. Students learn to organize themselves and develop an agenda to address issues of interest. Students might showcase their research, and obtain feedback in a supportive environment. This forum can also be used to discuss local or national issues important for the graduate students; to invite speakers; or to conduct workshops on technical subjects, communications, ethics, and the like. Departments should consider providing budgetary support for such activities. An example of such a program at the University of Colorado at Boulder is called Preparing Future Physicists²⁰. Students discuss with faculty and others a wide variety of topics related to aspects of being a physicist (job applications, report and grant writing, preparing classes, etc.).

Departments should also encourage students to join a professional organization and take advantage of being part of a professional community. The APS offers reduced rate membership²¹ to students, and the APS Forum on Graduate Student Affairs²² is particularly relevant.

At the local level, graduate student representation on departmental committees that decide issues that affect graduate students will help create a climate of trust, provide valuable input, and give graduate students some exposure to administrative issues.

Departments should recognize that students may wish to participate in appropriate science-related outreach activities. These may be associated with financial support, as for example with the NSF-funded GK-12 program, or with the "broader impact" goals of NSF or other centers with which students are affiliated. In encouraging such participation, departments also have a responsibility to ensure that graduate students' time is appropriately used and that they are not doing work that is expected of faculty.

Training teaching assistants

All Ph.D.-granting departments rely heavily on graduate

students to assist in the delivery of undergraduate courses. Departments must recognize that incoming graduate students are usually not skilled teachers, that they often do not have an expert understanding of introductory physics, and that the students they teach are not skilled learners. It is therefore imperative that a comprehensive training program be in place in the department to educate TAs. This is particularly important early on, but must continue throughout the TA experience.

Ken Heller of the University of Minnesota described the TA training program²³ at UM. This 2-week program is conducted before classes begin. TAs learn about interactive teaching, group learning, educational strategies, what constitutes a “good” problem, and students’ alternative conceptions of physics. TAs also discuss case studies relating to professionalism and diversity issues. TA education continues in the first term; experienced TAs participate in a refresher session early in the year and they function as mentor TAs.

Finally, to make such a training program successful, departments must foster a culture that values teaching. Awards for teaching excellence by students and faculty, departmental colloquia that address education research, and positive reinforcement of the TA role by research advisors are elements of such a culture.

Addressing ethics

Students should receive formal ethics training as it relates to the conduct of scientific research. It is best if ethics issues are discussed throughout the graduate career, rather than in a “take-care-of-ethics” course during orientation. A graduate forum that meets regularly might be a good venue. The graduate student handbook should also include information on graduate students’ rights and responsibilities, and ethics-related issues such as co-authorship, collaborative research, as well as information that helps them understand what constitutes plagiarism. Myles Boylan of the National Science Foundation commented that agencies might consider making funding contingent upon demonstration of adequate ethics instruction



Participants having a discussion between sessions.

for researchers. It was reported that an APS Task Force on Ethics Education²⁴ developed a set of ethics “case studies” that might be useful for departments to consider. These case studies include research ethics, but deal with many other issues as well including professional relationships, publication practices, and bias.

Marshall Thomsen of Eastern Michigan University (EMU) provided guidelines for the contents of a course addressing ethical issues that are relevant to physicists. Topics should include the obvious ones of honesty in the conduct and reporting of research, cheating, and plagia-

rism, but should also include safety, respectful treatment of colleagues and subordinates, stewardship of natural resources, and integrity of funding sources. Materials relating to ethics come from EMU²⁵ and the Land Grant University Research Ethics (LANGURE) collaboration²⁶. The APS also has available a set of ethics case studies²⁷ that can be used for discussions.

Participants voiced the opinion that faculty should educate themselves on issues in ethics, perhaps in the AAPT/APS New Faculty Workshop²⁸, or at sessions organized at professional meetings. A comment was made that faculty and students should also be aware of the APS statements on professional conduct²⁹ and fair treatment of subordinates³⁰. Faculty should be good role models, and in particular, they should not be lax about plagiarism, for example in showing information from the internet without credit in their presentations.

Improving communication skills

Sherry Yennello of Texas A&M provided a summary of communication skills that students should acquire. Beyond technical talks to peers and general audiences, oral skills such as negotiating, motivating, and selling ideas are important. In addition to writing research papers, students must also learn to write abstracts, reports, and proposals. Explaining complicated concepts to others is the essence of teaching, and this is something physicists do regardless of their job titles.

Departments should provide guidelines that specify the communication goals for students. In the absence of such guidelines, the opportunity for physics graduate students to develop communication skills varies greatly depending upon the research advisor. For example, students must have opportunities to present their research orally in a public forum.



Steve Carlip of UC Davis makes a point during one of the break-out sessions.

Departmental guidelines should require students to make oral presentations at a level commensurate with their seniority and experience at least once a year. These could include group meetings, local seminars, journal clubs, or regional and national meetings. Attending conferences should be encouraged and financial assistance provided to the extent possible. Regional APS and AAPT meetings provide a relatively low-cost option, and attendance should be encouraged. Students should receive prompt feedback from faculty on their presentation.

Participants mentioned that students must also have opportunities to present their research in written form, and departmental guidelines should require students to present written summaries and evaluations of their research to their committees each year. They should also require the submission or publication of a first-author peer-reviewed paper as a condition of graduation.

Departments should offer opportunities for students to develop communication skills of different types. Oregon State University offers a yearly Communication Seminar³¹ in which students critique each other, under the guidance of a faculty member as they practice the 10-minute talk, resume writing, abstract writing, and other skills.

Rewarding faculty who invest significant time in helping students develop communications skills will encourage those mentoring. Such activities are often considered a voluntary overload and go unrewarded. They should be an explicit component of merit and promotion evaluations, and could be assigned in lieu of teaching.

Encouraging diversity and a supportive climate

Policies that help all graduate students are generally also helpful in promoting diversity. Likewise, changes instituted to

improve the climate for minorities and women generally improve the climate for all. Good mentoring and advising related to time-management, career choices, family responsibilities and work balance, and the development of written and oral communications skills are particularly important for fostering positive rapport between graduate students and the faculty and department.

Minorities and women are greatly underrepresented in physics Ph.D. programs nationwide. As such, they represent an untapped resource and a source for growth. Departments should remain informed about issues and developments in these communities. Useful websites are those of the National Society of Black Physicists³² (NSBP), the National Society of Hispanic Physicists³³ (NSHP), the Society for Advancement of Chicanos and Native Americans in Science³⁴ (SACNAS), the APS Committee on Minorities³⁵ (COM), the APS Committee on the Status of Women in Physics³⁶ (CSWP), and the report of the APS Gender Equity Conference³⁷.

These organizations have invested considerable effort in compiling best practice documents for improving the status and numbers of minorities and women in physics. In particular, departments should apply the best practices pertaining to the recruitment and treatment of women physicists³⁸ published by CSWP, and of strategies for recruiting minority physicists³⁹. Some of these are discussed below. The intent is not to duplicate all the information in this document, but to highlight particular aspects that were discussed at the Graduate Education Conference.

Departmental websites should discuss how the department promotes diversity and how that department addresses issues affecting women and minorities. Examples of active programs come from MIT⁴⁰ and UCSB⁴¹. Departments can also advertise



There was plenty of time for discussion between sessions.

their female-friendly practices on the site hosted by the APS⁴².

Departments should encourage faculty to involve more undergraduates, especially women and minorities, in research. Undergraduate research experience is especially critical for making students a part of the research community, and it may be an important factor in a student's decision to apply to graduate school. Vincent Rodgers from the University of Iowa provided evidence for this. He described a program he developed with the help of Jim Gates from the University of Maryland, called the Student Summer Theoretical Physics Research Session. This program provides intensive academic support to prepare students for advanced studies and focuses on inclusion of underrepresented groups into research as opposed to separating them into different programs. Their summer research groups include minorities and Caucasians, men and women, American and international students working alongside each other on various projects. Courses are rigorous, expectations are high, and help is available at all times. Many of the students in their program pursue graduate studies in highly selective physics programs.

Bridging programs are another effective way to improve success rates in graduate physics programs. Keivan Stassun of Vanderbilt University described the Fisk-Vanderbilt Masters-to-Ph.D. Bridge Program⁴³ in which students earn the Master's degree in physics at Fisk, with full funding support. The program includes a paid research experience, and preparation for the GRE. This puts them on the fast-track for admission to the Vanderbilt Ph.D. program, again with full funding support. Fisk provides a smaller, more advising-intensive environment, which is conducive to building skills. Stassun advised the audience to help their departments "recruit" not "compete," by focusing on unrealized potential.

Advising and mentoring are particularly important for women and minorities, who may need extra promotion to draw attention to their work, and extra encouragement to compete successfully.

Departments should make explicit their family-friendly policies to promote diversity. For example, there should be transparent documentation of what is expected in terms of time commitment when a graduate student becomes a mother or father or a graduate student has a family emergency (sick child, spouse or parent). Participants noted that while childcare and family issues are generally raised in the context of women in physics, they are equally relevant to men. In fact, until managing childcare is viewed as equally a male and female responsibility, the climate for women is unlikely to improve.

Recruiting and retaining students

Charles Holbrow, former president of AAPT, provided evidence that only about half of entrants to doctoral programs are awarded the Ph.D. degree. This being the case, retention and recruitment are obviously important priorities.

Competition from other countries and other disciplines can be expected to affect the flow of students into physics. Judy Franz noted that physics programs in Europe and Asia are retaining many of the students who might otherwise have come to the U.S., and certainly physics faces competition from biology as a forefront science that will lure the brightest and the best. The AIP report on enrollments and degrees⁴⁴ (including Fall 2006) indicated that the percentage of entering foreign students is once again less than half, after exceeding 50% between 1996 and 2002.

Departments should devote a section of the departmental website to graduate student issues. The faculty member designated as DGS should be visible, as should others who can assist graduate students. Links to the Ph.D. requirements, funding opportunities, and other useful resources for graduate students should be provided.

Departments should implement and advertise their sound academic, advising, and mentoring practices. In particular, current students should be made aware of departmental efforts so that they can be ambassadors for the department during recruiting season. Alaina Levine of the University of Arizona suggested that departments take more advantage of centralized university offices that generally have names like "university advancement". She suggested feeding such university offices specific information about the physics department that they can publicize to raise the department profile, and pointed out that these resources are often underutilized.

When possible, departments should provide travel support to domestic graduate students who are accepted to visit



Representing the APS Forum on Graduate Student affairs were Tracey Wellington and Arlene Ford, grad students at Texas A&M, and Amber Stuver, post doc at LIGO.

the department before they accept the admission offer. The University of Minnesota and UIUC pay for all accepted domestic students to visit on a selected day. Faculty showcase their research and current students meet prospective students. At the University of Pittsburgh, prospective domestic graduate students' travel is also paid for, but students visit at their own convenience. At some universities, prospective students are hosted by current graduate students, who tend to be very influential.

Departments should ensure that there is sufficient funding to support graduate students (tuition and stipend). Stipends provide a reasonable standard of living given the costs of the local area, and prospective students should be informed about the local cost of living. Guaranteed summer support is another powerful draw. Departments should consider dedicating scholarships or significant financial support specifically to minority and women candidates.

APS national meetings have events designed to attract undergraduates, for example undergraduate research sessions. Events like these are places to reach potential physics

graduate students. The University of Minnesota and University of Wisconsin are examples of universities that have set up booths and sent their DGSs to promote their graduate programs at conferences organized by the NSBP, NSHP, and SACNAS. Another example, given by Michael Thoennessen of Michigan State University, is the Conference Experience for Undergraduates⁴⁵ or CEU, an NSF- and DOE-supported program of the Division of Nuclear Physics of the APS. The CEU program awards travel grants for undergraduates to present their research in a poster session at the annual Division meeting, and includes dedicated talks for the students and a graduate school information session. It makes the students feel welcome in the community and is an excellent networking opportunity.

From the perspective of professional society actions, the APS should support departmental efforts to improve recruiting and retention by exploring the possibility of becoming or organizing a national clearinghouse for electronic graduate application materials. This centralized application process is in use by medical schools.



Appendices

- I** Statistics about Ph.D. degrees in physics
- II** Executive Summary of the “Joint AAPT–APS Task Force on Graduate Education in Physics”
- III** Summary of the feedback from the questionnaire sent to Directors of Graduate Studies of physics Ph.D.–granting universities in the United States
- IV** Acknowledgements
- V** Conference Agenda
- VI** Participant List
- VII** References

Appendix I

Statistics about Ph.D. degrees in physics

The motivation for a conference on graduate education in physics came from several sources, which together suggested that business as usual is not the way to continue to be the best in the world. The 2006 APS/AAPT Task Force on Graduate Education in Physics indicated that the curriculum content has been static for many years. There is now strong competition from physics programs outside of the U.S. and there are more restrictions on foreign entry into the U.S., perhaps leading to a diminished supply of foreign students. The Rising Above the Gathering Storm² report is one of several documents to question the scientific literacy of the U.S. workforce. These are all good reasons to assess and discuss the status of graduate education in physics. This appendix presents some relevant statistics that set the stage. Data were taken from the AIP Statistical Research Center⁴⁶, and the NSF Survey of Earned Doctorates.⁷

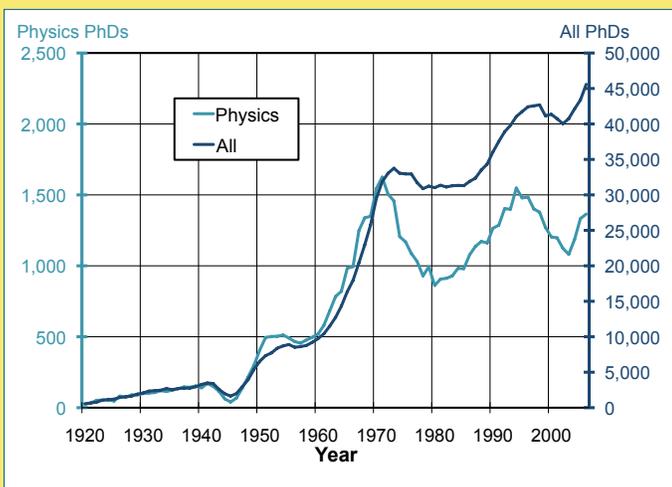


Fig 1. Physics PhDs and all PhDs conferred in the US.
Source: NSF Survey of earned doctorates.

The number of physics Ph.D. degrees awarded in the United States is currently about 1,200 per year, and the trend for the last hundred years is displayed in Fig. 1.

The 1960s coincided with a huge increase in the number of Ph.D. degrees awarded in all fields, including physics. Since the 1970s, the total number of Ph.D. degrees has continued to increase, albeit at a slower rate, but the number of physics Ph.D. degrees has remained, on average, flat.

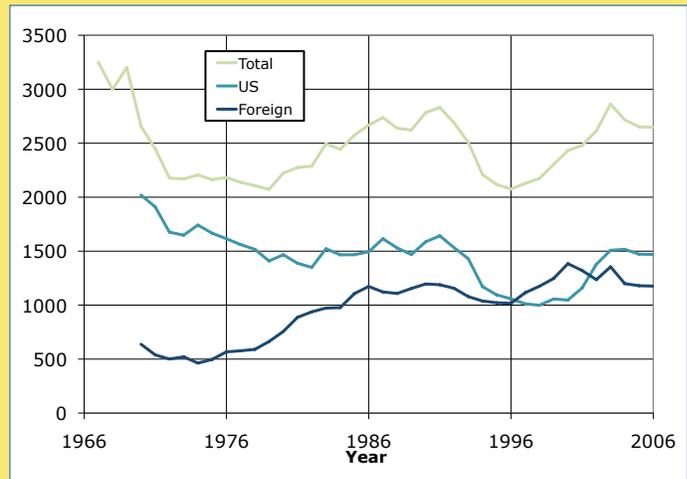


Fig 2a. First year graduate physics student enrollments at PhD-granting physics departments
Source: AIP Statistical Research Center

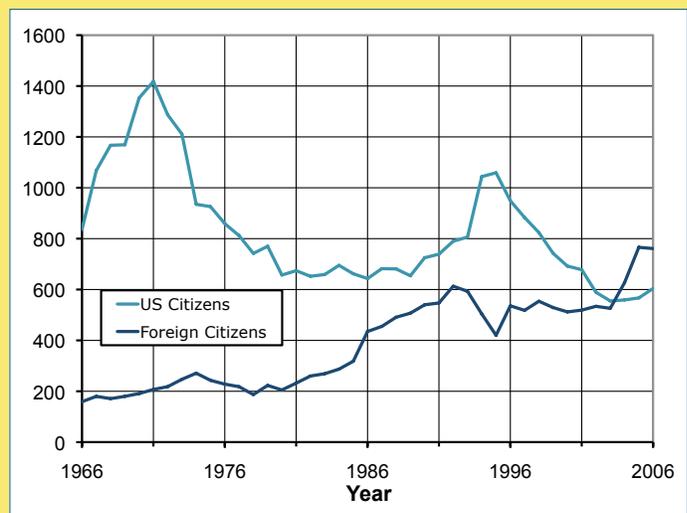


Fig 2b. Citizenship of physics Ph.D.'s, 1967 to 2006
Source: NSF Survey of earned doctorates

Fig. 2(a) shows the number of students entering Ph.D. programs and suggests that the number of foreign students is declining. Fig 2(b) confirms the poor completion rate for all students — the number of Ph.D. degrees awarded falls far short of the number of students entering Ph.D. programs five years earlier.



	Bachelor's		Exiting Master's		Ph.D.s	
	Number	Percent	Number	Percent	Number	Percent
White	4296	86	457	89	509	86
Asian-American	223	4	17	3	39	6
African-American	184	4	14	3	11	2
Hispanic-American	177	4	18	3	16	3
Other	119	2	9	2	19	3
Total US Citizens	4999	100%	515	100%	594	100%

Table I. Number and percent of physics degrees granted to US citizens by minority/ethnic group status, class of 2006.
 Source: AIP Statistical Research Center, *Enrollments and Degrees Report*

Concerning the presence of women and minorities in Ph.D. programs in physics, it is clear that both groups are underrepresented. The underrepresentation of minorities, as indicated in Table I, is severe. Only 11 Ph.D. degrees were awarded to African Americans in 2006, 2% of the total. Hispanic-Americans are similarly poorly represented.

Figure 3 shows that the percentage of physics Ph.D. degrees awarded to women has generally increased and is approaching 18%. While these increases are impressive, it is clear we still have a long way to go to reach parity. At our current rate of increase (about 0.4% increase per year), we will not reach parity until 2082. We can do better!

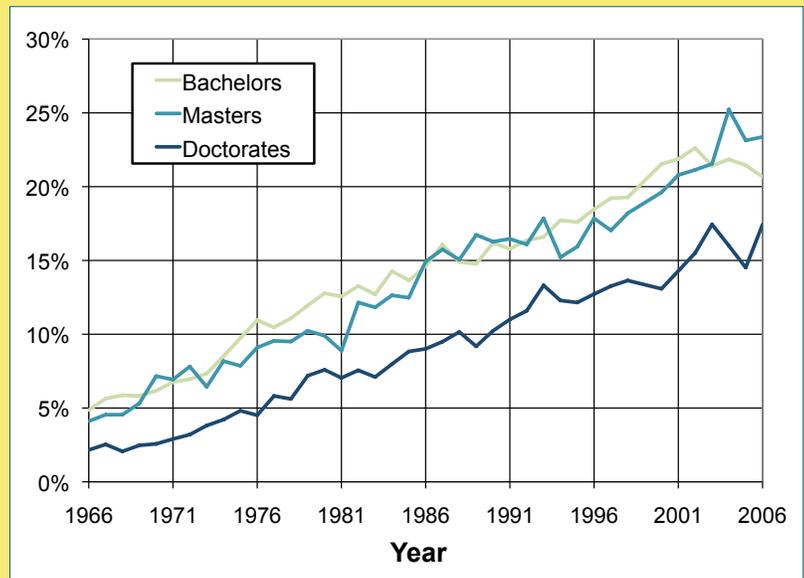


Fig 3. Fraction of bachelors, masters and doctoral degrees in physics earned by women
 Source: Department of Education IPEDS Completions survey

Appendix II

Executive Summary of the “Joint AAPT–APS Task Force on Graduate Education Physics”

www.aps.org/programs/education/upload/2006_Grad_Ed_Report.pdf

The Task Force on Graduate Education in Physics, (TFGE), an ad hoc committee convened jointly by the American Association of Physics Teachers (AAPT) and the American Physical Society (APS), has studied the current status of graduate education in physics Ph.D. programs, and has made recommendations based on what was found. The findings indicate that the majority of Ph.D. programs in physics have a common core curriculum and that students must demonstrate mastery of those subjects by passing either courses or exams. The subjects covered in this core curriculum appear to have remained constant, on average, for some time, and most departments do not plan on wholesale changes to their curricula in the near future. Most departments also require some “breadth” courses in different areas of physics. There appears to be demand from students and potential employers of Ph.D.’s for training in additional skills, such as public speaking, writing, teaching, teamwork, and leadership. The time-to-Ph.D. has been lengthening slowly over the past 30 years, but many departments are making efforts to curtail the increase (which seems to have succeeded to the extent that there is no significant change in time-to-Ph.D. across the past 10 years). Overall, graduate education in physics appears to be healthy, but departments should be aware that as the fields of physics evolve, flexibility may be an increasingly important characteristic of physics Ph.D. programs.

Task Force Recommendations

This report of the TFGE is best summarized by listing our recommendations, in order of their appearance herein:

1. The TFGE recommends that the content of core courses be consistent year-to-year and be supervised closely by the department. Within that context, the TFGE believes that turnover in instructors is a positive occurrence.
2. The TFGE finds it noteworthy that the two texts that appear to be most widely used, Jackson for Electricity and Magnetism and Goldstein for Classical Mechanics, are also among the oldest books, having been first published in 1962 and 1950, respectively, although the latest editions were published in 1998 and 2002, respectively. We note with some amusement that Amazon.com offers a special price for buying the two together, presumably reflecting the fact that marketers have noticed that many departments indeed use both texts.
3. The TFGE recommends that the Ph.D. physics core curriculum should consist of the material generally covered in a
 - one-year course in Classical Electrodynamics,
 - one-year course in Quantum Mechanics,
 - one-semester course in Classical Mechanics, and
 - one-semester course in Statistical Mechanics and Thermodynamics.
4. The TFGE feels that graduate programs benefit by having some breadth requirement in physics, typically taken within the first two years, and recommends that departments require such breadth. The opportunity to take related courses outside physics is also recommended for many students. Departments should provide opportunities for students to develop other skills, such as machine shop, public speaking, and grant writing.
5. TFGE recommends that departments include attendance at the departmental colloquium as a requirement in their graduate programs. The TFGE also recommends that departments consider adding some required computational training to their graduate programs.
6. The TFGE recommends that departments require communication training and information literacy/fluency in their graduate programs.
7. The TFGE concurs with the APS Task Force on Ethics recommendation that the physics community should sponsor and promote development of ethics education programs, and further recommends that this should occur in graduate programs.
8. The TFGE recommends that department chairs review the “best practices” of their peers in the areas of climate and diversity.



9. The TFGE recommends that departments formulate guidelines for graduate student rights and practices and provide these to graduate students.
10. The TFGE recommends that departments take an active role in monitoring students' progress toward Ph.D., in order to ensure, independent of the advisor, that the student is making appropriate progress.
11. The TFGE recommends that departments offer advice and mentoring to their graduate students on the full range of career options available to physics Ph.D.s and in particular increase their students' awareness of, and preparation for, positions in industry.
12. The TFGE recommends that department chairs share best practices on a regular basis, both at the biennial meetings organized by AAPT and APS, and on a website.
13. The TFGE recommends that there be continued close collaboration between AAPT and APS on the subject of graduate physics education. The TFGE further recommends that the AAPT/APS periodically reinvestigate the topics studied here, as well as expanding the scope of the studies to obtain a more extensive view of graduate education in physics.
14. The TFGE makes no recommendation at this time concerning the use of comprehensive exams, except to note that there needs to be some method of evaluating students' knowledge of the core subjects.
15. The TFGE recommends that the physics department chairs engage in discussions of comprehensive examinations and their alternatives.
16. The TFGE makes no explicit recommendations concerning specific courses and their content, but we encourage innovative methods for delivering the graduate curriculum.

Appendix III

Summary of feedback from the questionnaire sent to Directors of Graduate Studies of physics Ph.D.-granting universities in the United States

We contacted the chairs of all Ph.D. granting departments, requesting the email addresses of their directors of graduate studies (DGS). In January 2007, this survey was sent to the DGS of the 141 schools that responded. We received 66 responses to the questionnaire, indicating 60 potential participants from 54 schools. Overall, the responses were very positive and clearly showed a strong interest in such a conference. The replies to the questionnaire were very helpful in preparation for the meeting. Below are short summaries of answers to the questions.

1. Are you contemplating changes or have you recently implemented changes in your graduate curriculum and program? If so, please describe in any detail you see fit.

The main changes were in the curriculum and the exam structure. Twenty-nine departments have made recent changes to the curriculum. The changes to the curriculum covered a broad range, for example modifications to the core curriculum, adding interdisciplinary courses, formal TA training, etc. Fourteen departments have made changes to the exam structure.

Twelve departments are actively considering changes, while 19 departments reported that they are satisfied with their current system.

2. Would you, or a representative, or a team from your department attend such a conference? If so, how many would likely attend?

Fifty-two schools (with 58 participants) responded that they would participate in such a conference.

3. What topics would be of interest or concern to you?

Curriculum (23), Recruiting (21), Funding (18), Exam structure (13), Interdisciplinary aspects (10), Preparation in College (7), Job situation (6), Retention (6), Diversity (6), Foreign student issues (5) were the topics of highest interest.

4. Who would you like to see present at such a conference?

Most responses mentioned the information exchange with other DGSs, and some specifically mentioned that they wanted to hear from top university representatives. Six DGSs responded that they would be interested to hear from representatives from the funding agencies and three were interested to hear about the job market/opportunities. In addition, several individual suggestions for possible topics were made.

Appendix IV

Acknowledgements

This report describes the results of the conference “Graduate Education: Which Way Forward?” organized by the American Physical Society and the American Association of Physics Teachers. The conference received substantial support from the National Science Foundation under Award PHY-0701352. We would like to thank Kathleen McCloud, the NSF funding agency representative, for her advice and support. Support for this project came from a number of different divisions within the NSF including Physics (PHY), Graduate Education (DGE), Materials Research (DMR), and the Office of Multidisciplinary Activities within the Directorate for Mathematical and Physical Sciences (OMA).

In addition, we wish to express our appreciation to the following American Physical Society staff members: Judy Franz, Executive Officer; Theodore Hodapp, Director of Education and Diversity; Kerry G. Johnson, Manager of Special Publications; Krystal Ferguson, Graphic Designer; and Sue Otwell, Women and Education Programs Administrator, who contributed generously of their time and skills. Their assistance was invaluable.

Organizing Committee

Janet Tate (chair)
Oregon State University
tate@physics.oregonstate.edu

Theodore Hodapp
American Physical Society
hodapp@aps.org

Michael Thoennessen
Michigan State University
thoennessen@nscl.msu.edu

Chandralekha Singh
University of Pittsburgh
clsingh@pitt.edu

Advisory Committee

Renee D. Diehl
Pennsylvania State University
rdiehl@psu.edu

Steven M. Girvin
Yale University
steven.girvin@yale.edu

Kenneth J. Heller
University of Minnesota
heller@physics.umn.edu

John T. Markert
University of Texas
markert@physics.utexas.edu

Margaret M. Murnane
JILA/University of Colorado-Boulder
murnane@jila.colorado.edu

Horst Stormer
Columbia University
horst@lucent.com

Appendix V

Conference Agenda

Thursday, January 31 (Marriott Greenbelt Hotel)	
5:30 pm – 7:00 pm	Registration
7:00 pm – 10:00 pm	Dinner, keynote address and poster session following dinner Renee Diehl , Penn State University, APS/AAPT Task Force on Graduate Education
Friday, February 1 (American Center for Physics)	
6:45 am	Buses depart for ACP
7:15 am – 8:00 am	Breakfast
8:00 am – 9:00 am	Plenary addresses Michael Neuschatz , American Institute of Physics Statistical Research Division Ken Heller , University of Minnesota, Past AAPT President
9:00 am – 10:15 am	Panel session 1: What's wrong (or right) with the status quo in graduate education? Robert Pelcovits , Brown University Thomas Greytak , Massachusetts Institute of Technology
10:15 am – 10:45 am	Break
10:45 am – 12:00 pm	Breakout sessions (parallel) Recruiting, Retention and Funding Keivan Stassun , Vanderbilt and Fisk Universities Does the Undergraduate Curriculum Prepare for Graduate School? Charlie Holbrow , Colgate University Mentoring and Career Advising Steve Carlip , University of California Davis



12:00 pm – 1:00 pm	Lunch
1:00 pm – 2:15 pm	Panel session 2: Preparation for Non-Academic Careers Shirley Chiang , University of California at Davis Bijoy Chatterjee , National Semiconductor Venky Venkatesan , Neocera (presented by Janet Tate)
2:15 pm – 2:45 pm	Break
2:45 pm – 4:00 pm	Breakout Sessions (parallel) Interdisciplinary Courses Randall Kamien , University of Pennsylvania Communication Skills, Professional Development Sherry Yennello , Texas A&M University Internships, GK-12 Programs Naomi Halas , Rice University Edward van Keuren , Georgetown University
4:00 pm – 4:15 pm	Break
4:15 pm – 5:30 pm	Report back
5:30 pm – 6:30 pm	Light reception
6:30 pm – 7:30 pm	Dinner
7:30 pm – 9:30 pm	Panel discussion and continued poster session: Where to next? Judy Franz , American Physical Society Michael Neuschatz , American Institute of Physics Statistical Research Division Michael Thoennessen , American Association of Physics Teachers Myles Boylan , Division of Graduate Education, National Science Foundation
9:30 pm	Buses return to hotel



Appendix V: Conference Agenda

Saturday, February 2 (American Center for Physics)	
6:45 am	Buses depart for ACP
7:15 am – 8:00 am	Breakfast
8:00 am – 9:15 am	Panel Session 3: Climate and Diversity Margaret Murnane , University of Colorado Boulder Vincent Rodgers , University of Iowa
9:15 am – 9:45 am	Break
9:45 am – 11:00 am	Breakout sessions (parallel) TA Training Ken Heller , University of Minnesota Ethics Awareness Marshall Thomsen , Eastern Michigan University Comprehensive Exam, Time to Degree Hermann Verlinde , Princeton University
11:00 am – 12:30 pm	Report and wrap up
12:30 pm – 1:30 pm	Lunch
1:30 pm	Adjourn



Appendix VI

Participant List

Eric Abraham
University of Oklahoma
abe@nhn.ou.edu

Marcus Alfred
Howard University
maralfred@Howard.edu

George Alverson
Northeastern University
g.alverson@neu.edu

Robert Beichner
North Carolina State University
beichner@ncsu.edu

Myles Boylan
National Science Foundation
mboylan@nsf.gov

Joseph Brill
University of Kentucky
jwbrill@uky.edu

Steve Carlip
University of California Davis
carlip@physics.ucdavis.edu

Duncan Carlsmith
University of Wisconsin-Madison
duncan@hep.wisc.edu

Shailesh Chandrasekharan
Duke University
sch@phy.duke.edu

Bijoy Chatterjee
National Semiconductor
Bijoy.G.Chatterjee@nsc.com

Shirley Chiang
University of California Davis
chiang@physics.ucdavis.edu

Joshua Cohn
University of Miami
cohn@server.physics.miami.edu

Aaron Covington
University of Nevada Reno
acovington@unr.edu

Ricardo Decca
Indiana University-Purdue University Indianapolis
rdecca@iupui.edu

Renee Diehl
Penn State University
rdiehl@psu.edu

Keith Dienes
University of Arizona
dienes@physics.arizona.edu

Hume Feldman
University of Kansas
feldman@ku.edu

Hendrik Ferdinande
European Physical Society
hendrik.ferdinande@UGent.be

Arlene Ford
Texas A&M University/FGSA
aford@tamu.edu

Judy Franz
American Physical Society
franz@aps.org

Appendix VI: Participant List

Huaxiang Fu
University of Arkansas
hfu@uark.edu

Madalina Furis
University of Vermont
madalina.furis@uvm.edu

Yuri Gershtein
Florida State University
gershtein@hep.fsu.edu

William Graham
Texas Christian University
w.graham@tcu.edu

Thomas Greytak
Massachusetts Institute of Technology
greytak@mit.edu

Harald W. Griesshammer
George Washington University
hgrie@gwu.edu

Naomi Halas
Rice University
halas@rice.edu

Ken Heller
University of Minnesota
heller@physics.umn.edu

Robert Hengehold
Air Force Institute of Technology
robert.hengehold@afit.edu

Stephen Hill
University of Florida
hill@phys.ufl.edu

John Ho
SUNY Buffalo
proho@buffalo.edu

Theodore Hodapp
American Physical Society
hodapp@aps.org

Charlie Holbrow
Colgate University
cholbrow@mail.colgate.edu

Tom Humanic
The Ohio State University
humanic.1@osu.edu

Edson Justiniano
East Carolina University
justinianoe@ecu.edu

Randy Kamien
University of Pennsylvania
kamien@physics.upenn.edu

Steven Kevan
University of Oregon
kevan@uoregon.edu

Peter Koehler
University of Pittsburgh
koehler@pitt.edu

Rajeswari Kolagani
Towson University
rkolagani@towson.edu

Yuichi Kubota
University of Minnesota
yk@physics.umn.edu



Cagliyan Kurdak
University of Michigan Ann Arbor
kurdak@umich.edu

Don Langenberg
University of Maryland
dnl@usmd.edu

Frank Lee
George Washington University
fxlee@gwu.edu

Alaina Levine
University of Arizona
alaina@u.arizona.edu

Ramon Lopez
University of Texas Arlington
relopez@uta.edu

James MacDonald
University of Delaware
jimmacd@udel.edu

S.D. Mahanti
Michigan State University
mahanti@pa.msu.edu

John Markert
University of Texas
markert@physics.utexas.edu

Jim McClymer
University of Maine
mcclymer@maine.edu

Laszlo Mihaly
SUNY Stony Brook
laszlo.mihaly@sunysb.edu

Prabhakar Misra
Howard University
pmisra@howard.edu

Joseph Moody
Brigham Young University
jmoody@byu.edu

Kieran Mullen
University of Oklahoma
mullen@nhn.ou.edu

Patrick Mulvey
American Institute of Physics
pmulvey@aip.org

Margaret Murnane
JILA/University of Colorado Boulder
murnane@jila.colorado.edu

Hisao Nakanishi
Purdue University
hisao@purdue.edu

Michael Neuschatz
American Institute of Physics
mneuscha@aip.org

Kathie Newman
University of Notre Dame
newman@nd.edu

Ed Nowak
University of Delaware
nowak@udel.edu

Michael O'Shea
Kansas State University
mjoshea@phys.ksu.edu



Appendix VI: Participant List

Richard Palmer
Duke University
palmer@phy.duke.edu

Robert Pelcovits
Brown University
pelcovits@physics.brown.edu

John Philip
Catholic University of America
philip@cua.edu

Talat Rahman
University of Central Florida
talat@physics.ucf.edu

Ronald Ransome
Rutgers University
ransome@physics.rutgers.edu

David Reid
University of Chicago
dreid@uchicago.edu

Vincent Rodgers
University of Iowa
vincent-rodgers@uiowa.edu

William Saam
Ohio State University
saam@mps.ohio-state.edu

Cass Sackett
University of Virginia
sackett@virginia.edu

Joseph Scanio
University of Cincinnati
joseph.scanio@uc.edu

Sally Seidel
University of New Mexico
seidel@phys.unm.edu

Steve Sharp
University of Washington
sharpe@phys.washington.edu

William Simpson
University of Delaware Library
wsimpson@udel.edu

Chandralekha Singh
University of Pittsburgh
clsingh@pitt.edu

Paul So
George Mason University
passo@gmu.edu

Jan Sojka
Utah State University
sojka@cc.usu.edu

John Stack
University of Illinois Urbana Champaign
j-stack@uiuc.edu

Keivan Stassun
Vanderbilt/Fisk Universities
keivan.stassun@vanderbilt.edu



James Stone
Boston University
stone@bu.edu

Amber Stuver
LIGO/Caltech/FGSA
stuver@gmail.com

Greg Sullivan
University of Maryland
gws@umd.edu

Janet Tate
Oregon State University
tate@physics.orst.edu

David Tedeschi
University of South Carolina
tedeschi@sc.edu

Michael Thoennessen
Michigan State University
thoennessen@nscl.msu.edu

Marshall Thomsen
Eastern Michigan University
jthomsen@emich.edu

Sheila Tobias
PSM Consulting, Sloan Foundation
sheilat@sheilatobias.com

Charles Torre
Utah State University
torre@cc.usu.edu

Edward van Keuren
Georgetown University
vankeu@physics.georgetown.edu

Hermann Verlinde
Princeton University
verlinde@princeton.edu

Patricia Viele
Cornell University
ptv1@cornell.edu

Joyce Ward
National Inventors Hall of Fame
jward@invent.org

Tracey Wellington
Texas A&M University/FGSA
twellington@tamu.edu

Paul Wolf
Air Force Institute of Technology
paul.wolf@afit.edu

Sherry Yennello
Texas A&M University
yennello@comp.tamu.edu

Appendix VII

References

- 1 The report of the Joint AAPT-APS Task Force on Graduate Education in Physics, www.aps.org/programs/education/upload/2006_Grad_Ed_Report.pdf. See Appendix I for the executive summary.
- 2 Rising Above the Gathering Storm, www.nap.edu/catalog.php?record_id=11463
- 3 Graduate Education in Physics: Which Way Forward? Conference website, www.aps.org/programs/education/conferences/graduate/
- 4 AIP Statistical Research Center, www.aip.org/statistics/trends/highlite/emp/figure14.htm
- 5 Best practices for female graduate students, www.aps.org/programs/women/reports/bestpractices/graduate-students.cfm
- 6 Career Development Organization (CDO) at the University of Washington, students.washington.edu/cdophys/
- 7 APS Forum on Industrial and Applied Physics, units.aps.org/units/fiap/
- 8 APS Forum on Industrial and Applied Physics speaker list, www.aps.org/units/fiap/speakers
- 9 APS Career Development Speaker Travel Grant program, www.aps.org/careers/educator/travelgrant/
- 10 Georgetown University Industrial Leadership in Physics, www.physics.georgetown.edu/grad_ilp.htm
- 11 Professional Science Masters, www.sciencemasters.com
- 12 Professional Science Masters at Oregon State University, psm.science.oregonstate.edu/professional-training
- 13 APS report on Professional Masters programs, aip.org/professionalmasters/msreport.html
- 14 APS careers, www.aps.org/careers and AAPT careers, careers.aapt.org/search/
- 15 APS Statement on Career Options for Physicists, www.aps.org/policy/statements/06_3.cfm
- 16 University of Colorado Physics graduate program requirements, www.colorado.edu/physics/Web/education/grad/requirements/PhDcourses.html
- 17 University of Colorado Physics “comps” requirements, www.colorado.edu/physics/Web/education/grad/comps
- 18 Ph.D. candidacy requirement survey, www.aps.org/programs/education/conferences/graduate
- 19 University of California Davis physics career advising, www.physics.ucdavis.edu/grad/grad_careers.html
- 20 University of Colorado Physics Preparing Future Physicists, www.colorado.edu/physics/EducationIssues/pfpf
- 21 APS student membership, www.aps.org/membership/student.cfm
- 22 APS Forum on Graduate Student Affairs, www.aps.org/units/fgsa

- 
- 23** University of Minnesota TA training program, groups.physics.umn.edu/physed
 - 24** APS Task Force on Ethics Education, www.aps.org/programs/education/ethics
 - 25** Eastern Michigan University ethics course, www.rcr.emich.edu
 - 26** Land Grant University Research Ethics, www.chass.ncsu.edu/langure/
 - 27** APS ethics case studies, www.aps.org/programs/education/ethics
 - 28** AAPT New Faculty Workshop, www.aapt.org/Events/newfaculty.cfm
 - 29** APS guidelines for professional conduct, www.aps.org/policy/statements/02_2.cfm
 - 30** APS statement on treatment of subordinates, www.aps.org/policy/statements/04_1.cfm
 - 31** OSU Communications Seminar, www.physics.oregon-state.edu/~wwarren/COURSES/ph607/
 - 32** National Society of Black Physicists, www.nsbp.org
 - 33** National Society of Hispanic Physicists, www.hispanicphysicists.org
 - 34** Society for Advancement of Chicanos and Native Americans in Science, www.sacnas.org
 - 35** APS Minorities in Physics, www.MinoritiesInPhysics.org
 - 36** APS Committee on the Status of Women in Physics, www.aps.org/programs/women
 - 37** Gender Equity Report, www.aps.org/programs/women/workshops/gender-equity/upload/genderequity.pdf
 - 38** Best practices pertaining to the recruitment and treatment of women physicists, <http://www.aps.org/programs/women/reports/bestpractices/>
 - 39** Strategies for recruiting minority physicists, www.aps.org/programs/minorities/recruitment/upload/Tips_for_recruiting_and_hiring_minorities.pdf
 - 40** MIT Women in Physics, web.mit.edu/physics/wphys
 - 41** University of California at Santa Barbara Women in Physics, www.physics.ucsb.edu/~Women
 - 42** APS listing of female-friendly departments, www.aps.org/programs/women/female-friendly
 - 43** Fisk-Vanderbilt Bridge Program, www.vanderbilt.edu/gradschool/bridge
 - 44** AIP Statistical Research Center, Report on Enrollments and Degrees www.aip.org/statistics/trends/gradtrends.html
 - 45** Conference Experience for Undergraduates Program of the APS DNP, www.aps.org/publications/apsnews/200602/undergraduate.cfm
 - 46** AIP Statistical Research Center, www.aip.org/statistics
 - 47** NSF 2006 Survey of Earned Doctorates, www.nsf.gov/statistics/srvydoctorates



AMERICAN PHYSICAL SOCIETY
AMERICAN ASSOCIATION OF PHYSICS TEACHERS
ONE PHYSICS ELLIPSE
COLLEGE PARK, MD 20740-3844