

By Rachel Ivie  
Kim Nies Ray

AIP Publication Number R-430.02

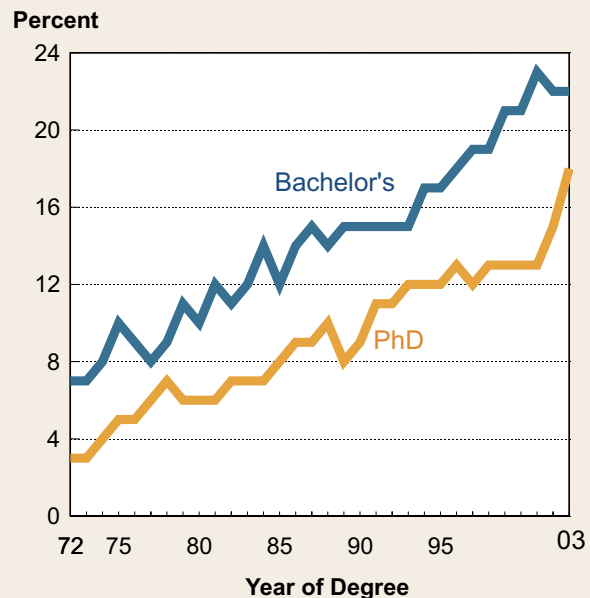
February, 2005

## Women in Physics and Astronomy, 2005

### Highlights

- The representation of women in physics and astronomy at all levels continues to increase. At the high school level, almost half of physics students are girls (**Figure 2**), although fewer girls take AP physics in high school. During 2003, women earned 22% of the bachelor's degrees in physics and 18% of the PhDs in physics—a record high (**Figure 1**). In astronomy in 2003, women earned 46% of bachelor's degrees and 26% of PhDs (**Figure 3**).
- Astronomy has a much higher representation of women than does physics. Although the percentage of degrees awarded to women in physics continues to increase, physics is not attracting women as quickly as other fields (**Figures 7 and 8**).
- There are 18 physics departments that award at least 40% of their bachelor's degrees to women (**Table 2**). There are 10 physics departments that award more than 25% of their PhDs to women (**Table 4**). There are also 19 women's colleges that award at least a bachelor's degree in physics, although these colleges account for only a small percentage of bachelor's degrees in physics earned by women (**Table 3**).
- Women are 10% of the faculty members in degree granting physics departments (**Table 6**). In stand-alone astronomy departments, the percentage of women faculty members is 14% (**Table 5**). In addition, women are better represented at departments that do not grant graduate degrees and in the lower ranks of the faculty.

**Figure 1. Percent of physics bachelor's and PhDs earned by women, 1972 to 2003.**



AIP Statistical Research Center: Enrollments and Degrees Survey.

## Highlights continued

- Examination of the academic “pipeline” reveals that women disproportionately leave physics between taking it in high school and earning a bachelor’s degree. While almost half of high school physics students are girls, less than one-fourth of bachelor’s degrees in physics are earned by women. After this initial “leak” in the pipeline, women are represented at about the levels we would expect based on degree production in the past. There appears to be no leak in the pipeline at the faculty level in either physics or astronomy (**Figures 11 and 12**).
- Estimates of the retention rates for physics graduate students show only small differences in the dropout rate for male and female students.
- African American and Hispanic women earn very few of the physics degrees in the US (**Figures 15 and 16**).
- Internationally, the representation of women in physics is also very low. Most countries award less than 25% of their first-level university physics degrees to women, and most grant less than 20% of their physics PhDs to women (**Tables 11 and 12**).
- Even when working in the same sector for the same number of years, women’s salaries are lower than men’s in physics and related fields.

The authors wish to thank the Alfred P. Sloan Foundation for their support of this report. We also thank our colleagues at the Statistical Research Center of the American Institute of Physics for assisting with this report. Raymond Chu, Mark McFarling, Patrick Mulvey, Michael Neuschatz, and Starr Nicholson provided assistance with some of the analyses in this report. Julius Dollison laid out the report, and Roman Czujko provided valuable insights and comments.

Despite years of continued growth, women's participation in physics remains among the lowest of any scientific field. The issue is of great concern to many in the scientific community, spawning talks at conferences, data collection efforts, and speculation about the causes of women's low participation in physics. Although women's participation in higher education overall has now passed the 50% mark at the bachelor's level and is approaching 50% at the PhD level, women earned just 22% of physics bachelor's degrees and 18% of physics PhDs in 2003 (a record high). Women's participation in physics is increasing, although slowly, and the rate of increase has not kept pace with other fields. One field that is notable for having a much higher representation of women is astronomy, which is closely related to physics. In spite of the relationship between the two fields, women are more highly represented in astronomy than in physics. For example, women earned 46% of bachelor's degrees in astronomy in 2003 and 26% of PhDs in astronomy in 2003.

This report will document the status of women in physics and astronomy. We will examine the participation of women in physics and astronomy at each step up the academic ladder, starting with high school and ending with college and university faculty. We will compare the representation of women earning bachelor's degrees and PhDs in physics and astronomy with the representation of women in other scientific disciplines. We will look at how the representation of women earning degrees in various scientific disciplines has changed over time.

We will also examine the evidence concerning the so-called "leaky pipeline" in physics and astronomy. Instead of moving up the academic ladder, do women disproportionately leave these fields? We will answer this question by comparing the actual percentages of women in physics and astronomy to the expected percentages based on degree production in the past. In doing so, we will be able to describe exactly the points at which women are leaving physics and astronomy.

Although women are very under-represented, especially in physics, there are colleges and universities that award much higher than average percentages of physics degrees to women. We will feature these schools in this report, along with featuring physics departments that have large numbers of women faculty. We will also present estimates of retention rates for male and female graduate students in physics and discuss the future of the physics and astronomy faculty in terms of its representation of women.

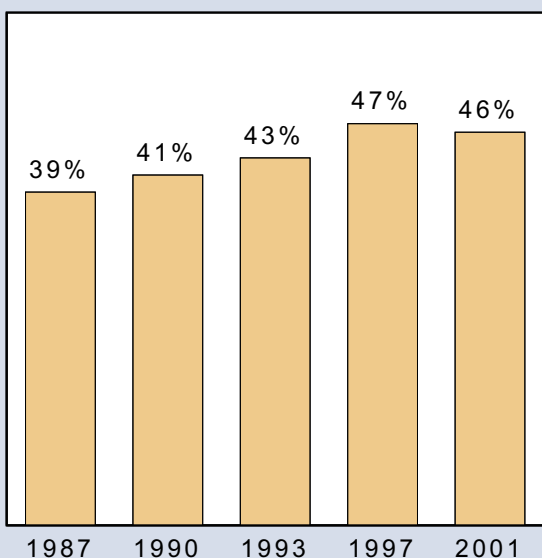
In order to understand how the data on women in physics and astronomy fit into a larger context of diversity, we will present data on minority women in these two fields. We also will present international data on women in physics, so that comparisons can be made between the US and other countries. Finally, salary differences between men and women working in physics and related fields will be documented.

This report draws on physics and astronomy data collected by the Statistical Research Center of the American Institute of Physics. Data from other fields were obtained from either the National Center for Education Statistics or the National Science Foundation, and are available on-line (<http://caspar.nsf.gov>). This report was funded by the Alfred P. Sloan foundation, whose support made possible this expansion and update of the SRC's previous report on women in physics and astronomy, published in 2000. The support of the Sloan Foundation is deeply appreciated.

## STUDENTS AND DEGREES

In 2001, more than 930,000 students took physics in high school. Almost half of these high school physics students were female (**Figure 2**). Physics is a popular subject among students who are college-bound, and as more women attend college, the percentage of high school physics students who

**Figure 2. Girls as a percentage of total enrollment in high school physics over time.**



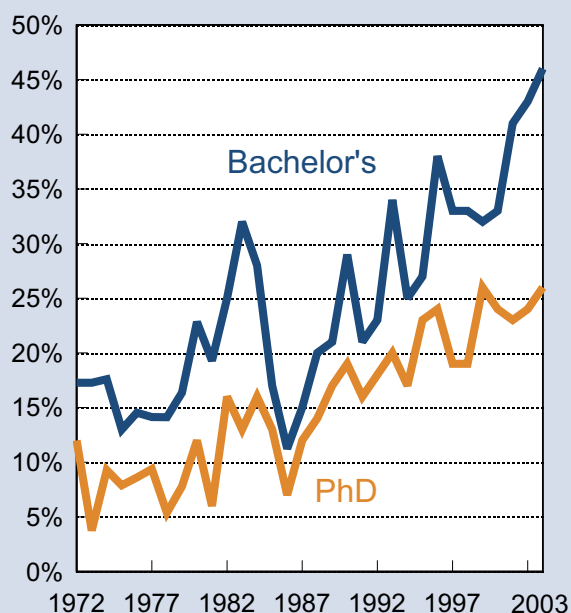
AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97 & 2000-01 High School Teacher Surveys.

are girls has also increased from 39% in 1987 to 46% in 2001 (Neuschatz and McFarling 2003). This means that almost 430,000 young women took high school physics in 2001 alone.

Although a large number of young women have taken high school physics, women are not as well represented among students who take AP (Advanced Placement) physics in high school. For example, in 2004, almost 22,000 students of both sexes took the calculus-based AP physics exam in mechanics. Twenty-five percent of these students were women. The percentage for algebra-based physics is higher; 35% of more than 43,000 test-takers were female in 2004 (College Board 2005). In the last few years, the number of students taking the AP physics exams has increased, but the percentage of women has remained about the same (**Appendix 3**). The majority of physics bachelors did not take AP physics in high school (Mulvey and Nicholson 2002).

The representation of women among college students who have taken physics is lower than among high school physics students. A nationally representative, longitudinal sample (National Education Longitudinal Study 2000 follow-up) shows that among 25-year olds who attended a four-year college and took physics, 37% are female.

**Figure 3. Percent of degrees earned by women in astronomy, 1972-2003.**

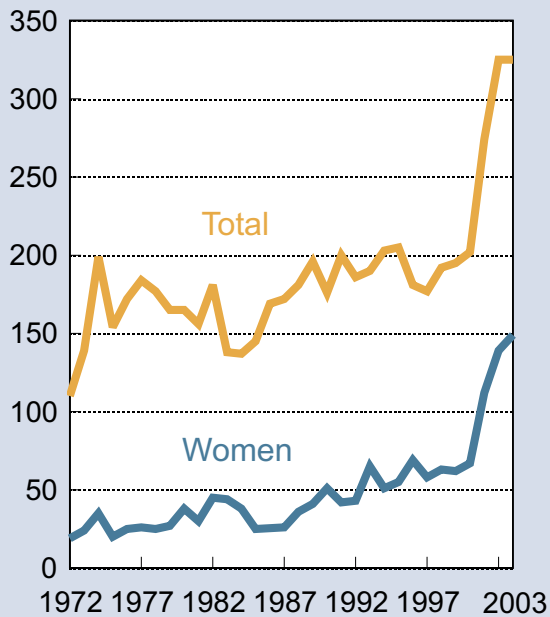


AIP Statistical Research Center: Enrollments and Degrees Survey.

When we look at bachelor's degrees earned by women, the percentages of women are lower still. In 2003, women earned 22% of bachelor's degrees in physics (**Figure 1**). The percentages of astronomy bachelor's degrees earned by women, however, are higher, at 46% in 2003 (**Figure 3**). In addition, the percentages of bachelor's degrees earned by women in both physics and astronomy have increased substantially in the last 35 years. In 1972, women earned seven percent of bachelor's degrees in physics and 17% of bachelor's degrees in astronomy.

The number of bachelor's degrees in astronomy has increased dramatically in the past few years (**Figure 4**). Much of this increase is due to a large increase in the number of women in this field. Between 2000 and 2001, the number of women

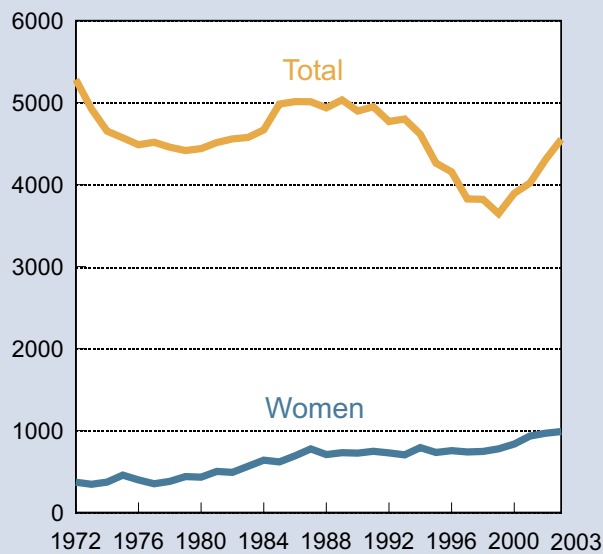
**Figure 4. Number of bachelor's degrees earned in astronomy, 1972-2003.**



AIP Statistical Research Center: Enrollments and Degrees Survey

earning astronomy bachelor's degrees increased by 67%, while the number of men earning bachelor's degrees in astronomy increased by only 20% (Mulvey and Nicholson 2003).

**Figure 5. Number of bachelor's degrees earned in physics, 1972-2003.**



AIP Statistical Research Center, Enrollments and Degrees Survey.

Physics has not shown a similar dramatic increase in the number of overall bachelors. However, in spite of fluctuations in the total number of bachelor's degrees awarded, the number of women earning physics degrees has increased steadily (Figure 5). Even when the number of bachelor's degrees awarded to men in physics decreased, the number awarded to women did not. The same is generally true at the PhD level for both physics and astronomy (Appendices 1 and 2), especially during the 1970s and 1980s.

Just as the percentage of physics bachelor's degrees earned by women has been increasing, so has the percentage of first-year physics graduate students who are women. Among students entering graduate school in the fall of 1994, 16% were female. By the fall of 2003, 21% of entering graduate students were female (Table 1). This is about the same as the percentage of bachelor's degrees earned by women (22%).

Also increasing is the percentage of PhDs earned by women in physics and astronomy. Currently, women earn 18% of the PhDs in physics and 26% of the PhDs in astronomy, up from 3% in physics

**Table 1. Percentage of first-year physics graduate students who are women, 1994-2003.**

	%
1994-95	16
1995-96	17
1996-97	17
1997-98	20
1998-99	18
1999-00	19
2000-01	19
2001-02	21
2002-03	20
2003-04	21

AIP Statistical Research Center, Enrollments and Degrees Survey.

and 8% in astronomy in 1972-73. The percentage of physics PhDs earned by women is at a record high, but this is due to an increase in the percentage of degrees earned by women who are foreign citizens. In 2003, women earned 13% of physics PhDs awarded to U.S. citizens. In contrast, women earned almost 20% of PhDs awarded to foreign citizens. This is a recent phenomenon, because in the past, about the same percentage of foreign and U.S. physics PhDs were earned by women. Future data will reveal whether this becomes a trend.

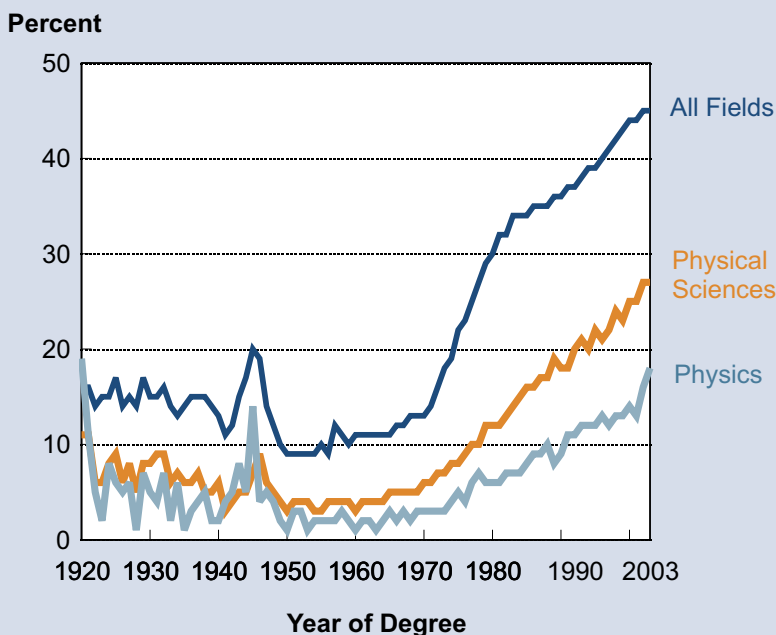
physics. Although more and more women are earning PhDs, the gap between physics and other fields is becoming wider.

**Figures 7 and 8** present further evidence of this widening gap across disciplines. At the PhD level, biological sciences, chemistry, and mathematics all show faster rates of increase for women earning PhDs than physics does (**Figure 7**). The exception is engineering, which has increased at about the same rate as physics.

**Figure 6** shows the changes in the percentages of PhDs earned by women in all fields, in physical sciences, and in physics since 1920. Women's participation at the PhD level in all fields including physics was actually higher before World War II than it was during the 1950s and 1960s. It was not until the late 1970s that the percentage of PhDs earned by women in all fields began to increase dramatically. It was also at this time that women's participation at the PhD level in fields other than physics began to increase more quickly than in

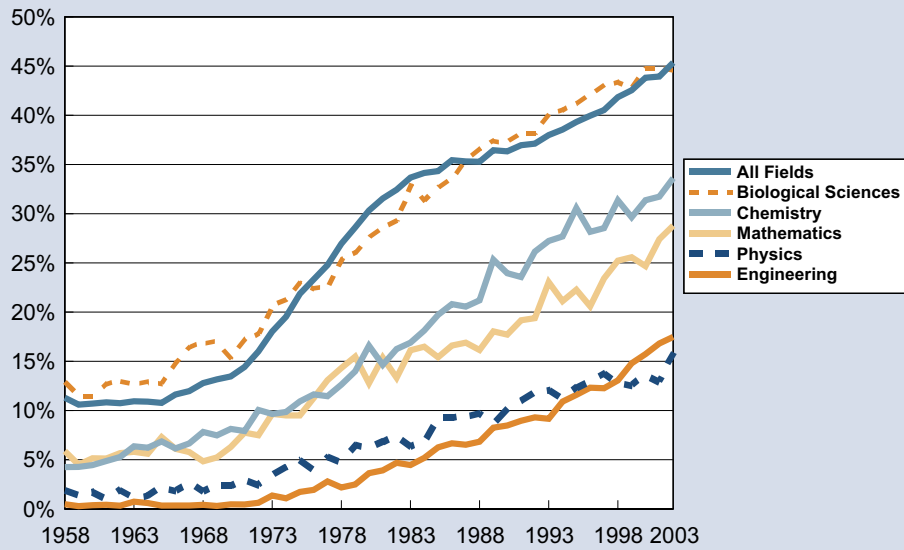
At the bachelor's level, women's participation in the biological sciences and in chemistry has increased more quickly than women's participation in physics (**Figure 8**). The most dramatic increase has occurred in engineering, which before 1970 had a very low percentage of women (even lower than physics), but now awards about the same percentage of bachelor's degrees to women as physics does. Although the percentages are the same, there are more than twenty times the number

**Figure 6. Percent of PhDs awarded to women in selected fields, 1920-2003.**



National Research Council, National Opinion Research Center, and National Science Foundation. Data compiled by AIP Statistical Research Center.

**Figure 7. Percent of PhDs earned by women in selected fields, 1958-2003.**

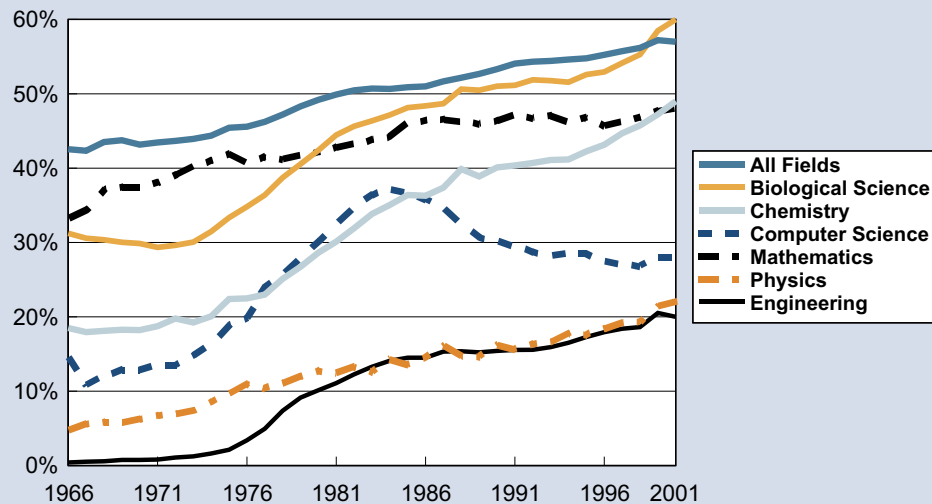


National Science Foundation. Compiled by AIP Statistical Research Center.

of women earning engineering bachelor's degrees as are earning physics bachelor's degrees. Of special note is the percentage of bachelor's degrees earned by women in computer sciences. This percentage actually declined during the late 1980s.

At this time, the total number of women and men earning computer science bachelor's degrees also dropped. This number recently increased, but the percentage of computer science bachelor's degrees earned by women remained about the same.

**Figure 8. Percent of bachelor's degrees earned by women in selected fields, 1966-2001.**



National Center for Education Statistics. Data for academic year 1999 not available. Compiled by AIP Statistical Research Center.

**Table 2. Physics departments awarding at least 40% of bachelor's degrees to women, 1999-2003.**

Alabama A&M University
Alfred University
American University
Bard College
Dallas, University of
Denver, University of
Florida Atlantic University
Grambling State University
Hampton University
Hunter College
Jackson State University
Loyola University - New Orleans
North Carolina A&T
North Carolina Central University
Ramapo College of New Jersey
Roanoke College
San Francisco, University of
Xavier University of Louisiana

Note: To be included on this list, departments had to have at least 5 women graduates during 1999-2000, and had to consistently respond to our annual surveys.

AIP Statistical Research Center, Enrollments and Degrees Survey.

**Table 3. Women's colleges that award at least a bachelor's degree in physics, 2005.**

Agnes Scott College
Barnard College
Bryn Mawr College
Chatham College
Georgian Court College
Hollins University
Mary Baldwin College
Mount Holyoke College
Notre Dame of MD, College of
Randolph-Macon Woman's College
Saint Catherine, College of
Scripps College
Simmons College
Smith College
Spelman College
Sweet Briar College
Wellesley College
Wells College
Wesleyan College

AIP Statistical Research Center, Enrollments and Degrees Survey.

Although the overall percentage of physics degrees earned by women is low, there are some physics departments that award much larger than average percentages of physics degrees to women. **Table 2** shows the physics departments that awarded 40% or more of their bachelor's degrees to women during the five academic years ending in 1999-2003. To be included on the list, these departments had to have awarded at least 5 bachelor's degrees to women during this period. Departments also had to consistently reply to our annual surveys, which have response rates of over 90% each year. This list highlights the importance of Historically Black Colleges and Universities (HBCUs) in awarding physics bachelor's degrees

to women. Of the 35 HBCUs that grant physics bachelor's degrees, seven award more than 40% of their physics bachelors to women. The list also documents the importance of departments that do not grant graduate degrees in physics. Of the 18 departments on the list, only 6 grant graduate degrees in physics. Barbara Whitten and her colleagues (2004) have conducted site visits of female-friendly undergraduate physics departments.

Women's colleges are excluded from this list on **Table 2**, but are included on **Table 3**, which shows women's colleges that award at least a bachelor's degree in physics. Typically, women's colleges



**Table 4. Physics departments that awarded more than 25% of PhD degrees to women, 1999-2003.**

Alaska, University of	
Cincinnati, University of	
Dartmouth College	
Georgia, University of	
Hampton University	
Kent State	
Missouri, University of, at Columbia	
Notre Dame, University of	
Tulane University	
Washington University	
<p>Note: To be included on this list, departments had to have at least 5 women graduates during 1999-2000, and had to consistently respond to our annual surveys.</p> <p>AIP Statistical Research Center, Enrollments and Degrees Survey.</p>	

award almost all of their physics bachelor's degrees to women. However, women's colleges do not account for a large percentage of the physics degrees earned by women in the US. Women's colleges awarded only 5% of the physics bachelor's degrees awarded to women during the period 1999-2003.

**Table 4** documents the PhD-granting physics departments that awarded more than 25% of their PhDs to women during 1999-2003. In order to be included on this list, these ten departments also had to have at least 5 women PhDs in the five-year period and had to consistently respond to our annual surveys. None of the departments produces an especially large number of graduates. In fact, the largest in terms of PhD production (Notre Dame) graduates fewer than 10 PhD students each year. Little is known about what these particular departments are doing to attract and retain women graduate students. These departments could be a starting point for a further study of effective practices concerning the recruitment and retention of women graduate students.

## TEACHERS AND FACULTY

Not only are the percentages of physics degrees earned by women very low, the percentages of physics teachers and faculty who are women are even lower. In 2001, just 29% of high school physics teachers were women (Neuschatz and McFarling 2003). At the college and university level, degree-granting physics departments had just 10% female faculty members in 2002 (Ivie, Stowe, and Nies 2003). Degree-granting astronomy departments that are separate from physics departments also have a very low percentage of female faculty members, with just 14% in 2003 (**Table 5**).

However, there are differences by rank and by type of institution, with larger percentages of women in the lower ranks and at departments that do not grant graduate degrees (**Table 6**). While only 5% of full professors of physics are female, 16% of assistant professors are female. Similarly, 16% of adjuncts and instructors are women. This is largely a function of age, because among younger physicists, there are more women than among physicists experienced enough to be full professors. The age distributions of physics and astronomy professors will be discussed in more detail in the section entitled "The Pipeline."

**Table 5. Percent of faculty positions in astronomy held by women, 2003.**

Academic Rank	Percent
Full professor	10
Associate professor	23
Assistant professor	23
Instructor / Adjunct	15
Other ranks	15
Overall	14
<p>AIP Statistical Research Center.</p>	

**Table 6. Percent of faculty positions in physics held by women, 1994, 1998 and 2002.**

	1994 %	1998 %	2002 %
<b>Academic Rank</b>			
Full professor	3	3	5
Associate professor	8	10	11
Assistant professor	12	17	16
Instructor / Adjunct	N/A	N/A	16
Other ranks	8	13	15
<b>Type of Department</b>			
PhD	5	6	7
Master's	7	9	13
Bachelor's	7	11	14
Overall	6	8	10

AIP Statistical Research Center: 2002 Academic Workforce Survey.

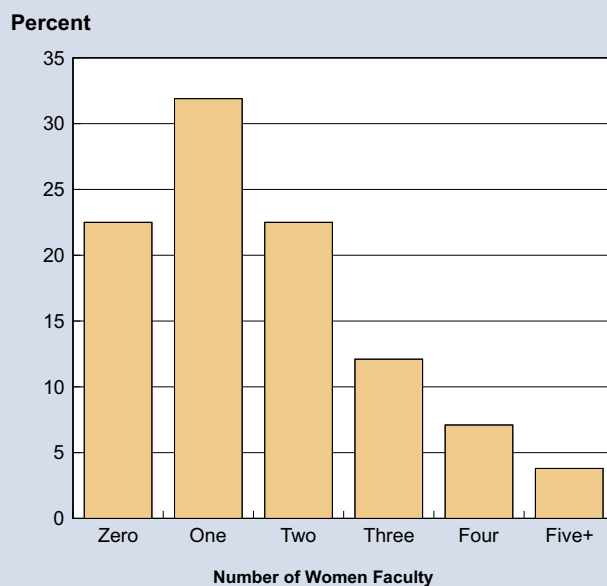
Although the percentage of women faculty in physics is low, it has been increasing. In fact, the percentage of female professors of physics has been steadily increasing from 6% overall in 1994 to 10% overall in 2002. **Table 6** shows increases since 1994 within ranks and by type of department.

Many observers of women in physics claim that the climate for women in physics will improve when more women are represented on physics faculties. Indeed, there has been much progress in this area. For example, in 1985, more than 50% of PhD physics departments had no women at all on their faculty. By 2002, the percentage of PhD departments with no women in the professorial ranks dropped to less than one-fourth (**Figure 9**). And, in 2002, a few PhD physics departments had four or more women in the professorial ranks of full, associate, and assistant professor. **Table 7** shows the PhD departments that had 4 or more women in ranked positions in 2002. In order to be

Women are also more highly represented at physics departments that grant only bachelor's degrees. Fourteen percent of faculty at these departments are women. At departments that grant PhDs in physics, just 7% of faculty members are women. This is partly a function of the distribution of ranked professors in each type of department. Almost 60% of faculty members at PhD departments are full professors, while only 34% of professors at bachelor's departments are full professors. Professors in the lower ranks tend to be younger, and there are more women among young physicists than there are in the older cohorts. Therefore, we see more women at physics departments that grant only bachelor's degrees.

The differences by rank are similar for stand-alone astronomy departments, although we have data only for 2003 and not for previous years in astronomy (**Table 5**). In these departments, 10% of full professors are women, and 23% of assistant professors are women.

**Figure 9. Percent of PhD physics departments by number of women faculty in professorial ranks, 2002.**



AIP Statistical Research Center: 2002 Academic Workforce Survey.

**Table 7. PhD-granting physics departments with four or more women in professorial ranks, 2002.**

Boston University
California Institute of Technology
California, University of (Los Angeles)
California, University of (San Diego)
California, University of (Santa Barbara)
Harvard University
Illinois, University of (Urbana-Champaign)
Kansas, University of
Maryland, University of (College Park)
Massachusetts Institute of Technology
Michigan, University of (Ann Arbor)
New Hampshire, University of
North Carolina State University
Northwestern University
Notre Dame, University of
Oklahoma, University of
Pittsburgh, University of
Rutgers University (New Brunswick)
Washington, University of
Wisconsin, University of (Madison)

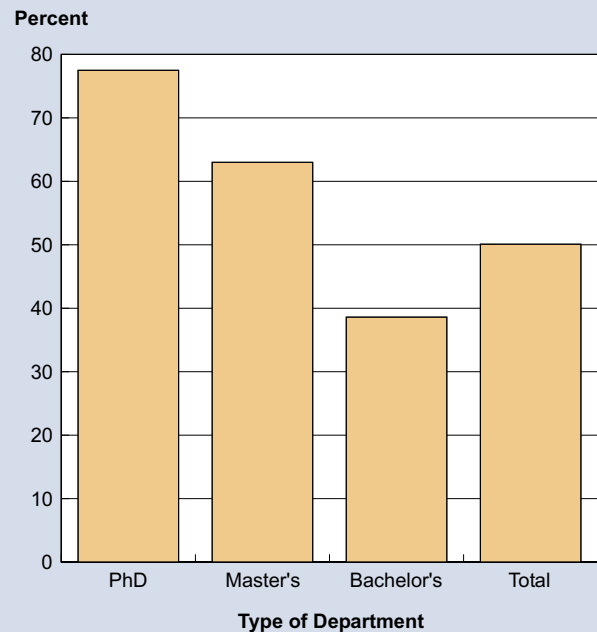
Note: To be included on this list, departments had to have responded to our 2002 Academic Workforce Survey

AIP Statistical Research Center, 2002 Academic Workforce Survey.

included on this list, departments had to have responded to our 2002 survey (which had a 94% response rate).

The percentage of departments that have women on the faculty is higher among PhD departments than it is among departments that only grant bachelor's degrees in physics (**Figure 10**). Indeed, less than 40% of bachelor's-granting physics departments have any women in their professorial

**Figure 10. Percent of physics departments with women faculty in professorial ranks, 2002.**



AIP Statistical Research Center: 2002 Academic Workforce Survey.

ranks. The fact that more PhD departments have women is probably because PhD departments have larger faculties, and therefore have a greater likelihood of having at least one woman.

Physics departments hired just fewer than 650 new faculty members to start in the academic year 2003-2004. Of these, 18% were women. The 37 stand-alone astronomy departments hired 30 faculty members to start in the 2003-04 academic year. Five of these were women. The number of new hires for both physics and astronomy include faculty members at all ranks, including non-tenure track.

## THE PIPELINE

Women's participation in physics decreases with each step up the academic ladder. To review, we have shown that almost half of all high school physics students are girls. However, women earn

just 22% of bachelor's degrees in physics and just 18% of physics PhDs. At the faculty level, women's level of participation is even smaller. Just 10% of physics faculty are women, and only 5% of full professors of physics are women.

Some might look at these numbers and conclude that the pipeline is indeed leaking for women. There are fewer women at the upper levels of academic physics than at the lower levels. However, before we can determine if and where the pipeline is disproportionately losing women, we must look at the pool of available women, or at the lag time between earning a physics degree and advancing to the next level. For example, we cannot expect 20% of the physics faculty to be women if, in the past, women earned a much smaller percentage of physics PhDs.

In this section, we will compare the current percentages of women at various levels of physics to percentages of degrees earned by women at appropriate points in the past. All of these comparisons overlook the multiple pathways that people can take to move from one level to the next. For example, we use either the average time to degree or the time that the middle 50% of the professoriate took to complete a PhD in physics, but clearly these measures exclude some people. So our conclusions should be taken with a degree of caution. Nevertheless, looking at the pipeline in terms of lag time is an important part of the picture for women in science. Without considering lag time, we are left with erroneous conclusions about what the distribution of women faculty members "should" be without enough information about what the available pool of women is. To have a complete picture of how the pipeline for women in science works, we would need data collected from multiple cohorts of individual degree recipients, who would then be periodically contacted to see how many of them have advanced to the next level, and how many of them have left the pipeline altogether. Collecting such data is, of course, extraordinarily expensive, and therefore we do not currently have this part of the story.

So in looking at the pipeline in terms of lag time, we can begin by looking at the transition between taking high school physics and earning a bachelor's degree in physics. In 1997, 47% of high school physics students were girls. Four years later, in 2001, women earned 23% of bachelor's degrees in physics. We can see that there is, in fact, a significant drop-off in women's participation between taking high school physics and earning a bachelor's degree in physics. Women are half of all high school physics students, but at some point, more women than men decide not to major in physics during college.

The next transition occurs between earning a bachelor's degree in physics and entering graduate school in physics. If there is no disproportionately leaky pipeline for women, then we should expect about the same percentage of entering graduate students to be women as the percentage of bachelor's degrees earned by women. In the academic year ending in 2003, women earned 22% of bachelor's degrees in physics. The next academic year, the entering class of US citizen graduate students in physics was 19% female. In physics, the percentage of first year US graduate students who are women has closely followed the percentage of bachelor's degrees earned by women for the past ten years.

Next, we can consider the step between entering graduate school in physics and earning a PhD. If women do not drop out of graduate school at disproportionately higher rates than men, then we would expect to see the same percentage of PhDs earned by women as entered graduate school, on average, seven years earlier. In 2003, women earned 18% of physics PhDs. Seven years earlier, in 1996, 17% of entering graduate students were women. So about the same percentage of women received PhDs as entered graduate school a few years earlier.

What about the faculty? Many observers have speculated that there are fewer women at the top of the academic ladder than we would expect given degree production in the past. However, this is not the case in physics. To see this, we must first

<b>Table 8. Representation of women physics faculty compared to percentage earning PhDs.</b>			
	<b>Dates of PhD</b>	<b>Average % PhDs to Women</b>	<b>% Women Faculty, 2002</b>
Full professor	1967-1980	4	5
Associate professor	1984-1991	9	11
Assistant professor	1991-1997	12	16

Dates of PhD are for middle 50% of faculty respondents to the 2002 AIP Membership Survey.

AIP Statistical Research Center.

examine the data concerning how long ago physics professors earned their degrees. Every two years, AIP surveys members of our ten Member Societies. Of those who responded to the survey and are full professors, the middle 50% earned their PhDs between 1967 and 1980 (**Table 8**). During those years, women earned 4% of physics PhDs. Currently, 5% of full professors of physics are women, which means that women are represented at about the rate we would expect given the available pool of full professors. Since so many professors of physics are full professors who earned their degrees many years ago, this has a huge effect on the overall percentage of physics professors who are women.

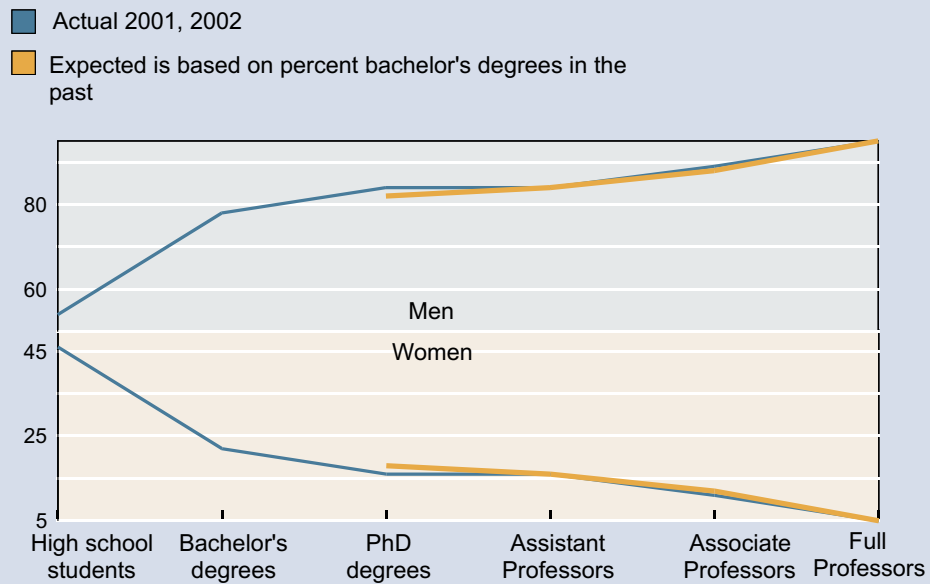
We can see similar trends for associate and assistant professors. There are fewer associate professors and assistant professors than full professors. The middle 50% of our respondents who are associate professors earned their PhDs between 1984-1991, when women earned 9% of physics PhDs. Currently, 11% of associate professors are women, which is a little higher than we would expect given degree production in the mid- to late 1980s. The middle 50% of assistant professors earned their PhDs between 1991-1997. During that time, women earned 12% of PhDs in physics. However, currently, 16% of assistant professors of physics are women, meaning that women are more highly represented on physics faculties at the assistant professor level than we would expect.

Examining the lag time data for physics shows us that women are represented in graduate school, on the faculty, and among PhD recipients at about the proportions that we would expect. Indeed, the data show that there is only one significant leak in the physics pipeline, and that is between taking high school physics and earning a bachelor's degree in physics. Although many girls take physics in high school, women earn very few of the bachelor's degrees in physics. It is likely that women take physics in high school in order to go to college, but have already made decisions about their career paths that steer them away from physics. These decisions are most likely the result of a lifetime of exposure to our culture that still portrays science, especially physical science, as a primarily male pursuit.

The lag time data can also be displayed graphically on the scissors diagram, (**Figure 11**), which shows the actual percentages of men and women at each level of physics. This diagram also shows the expected percentages of women and men at each level based on bachelor's degree production in the past. Again, representation at the upper levels of academic physics is almost exactly where we would expect it to be.

The percentage of women professors at stand-alone astronomy departments is actually higher than we would expect given degree production in the past (**Table 9 and Figure 12**). However, there may be a leak in the pipeline between earning a bachelor's degree in astronomy and earning a PhD in

**Figure 11. Actual and expected percentage of women and men in physics in the US.**



AIP Statistical Research Center.

astronomy. For example, in the academic years ending in 2002 and 2003, women earned an average of 24% of astronomy PhDs. The corresponding pool of astronomy bachelor's degree recipients from 1995 and 1996 had 32% women. Of course, these data should also be interpreted with caution, since about 60% of incoming astronomy PhD students actually have physics bachelor's degrees (McFarling, Neuschatz and Mulvey 2004). The percentage of bachelor's degrees earned by women in physics is lower than in astronomy, so the fact that so many astronomy graduate students have physics bachelor's lowers the percentage of women among astronomy PhD

recipients. Nevertheless, the percentage of astronomy PhDs earned by women continues to increase, as does the percentage of astronomy bachelor's degrees earned by women.

The discussion above and the scissors diagrams both use the overall dates of PhD for all faculty. It is possible that women do not advance at the same rate as men, and thus we should use different dates of PhD for women faculty. These data are shown in **Table 10**, and although the women's time since degree is slightly shorter for some ranks, the differences between male and female faculty (using

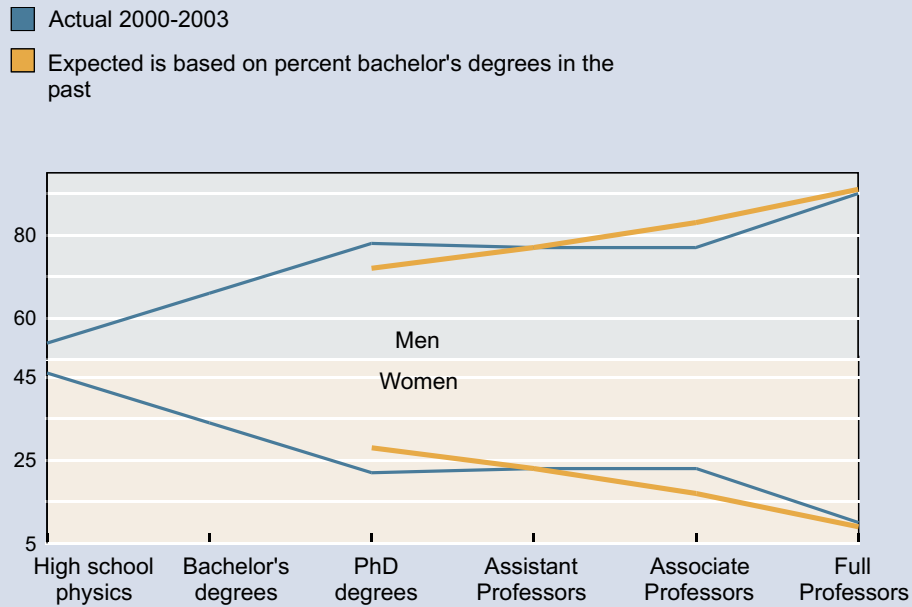
**Table 9. Representation of women astronomy faculty compared to percentage earning PhDs.**

	Dates of PhD	Average % PhDs to Women	% Women Faculty, 2003
Full professor	1969-1981	7	10
Associate professor	1982-1990	13	23
Assistant professor	1993-1998	19	23

Dates of PhD are for middle 50% of faculty respondents to the 2002 AIP Membership Survey.

AIP Statistical Research Center.

**Figure 12. Actual and expected percentage of women and men in astronomy in the US.**



AIP Statistical Research Center.

a t-test) are not statistically significant. Therefore, we have used the overall dates of PhD in discussing possible leaks in the physics and astronomy pipelines.

Further evidence of the fact that women are hired into professorial positions at their availability rates or better is shown by examining the gender of newly hired physics professors. In the academic

year 2003-2004, women were hired into tenure-track and tenured positions in physics departments at respectable rates—13% of new tenured professors and 17% of new tenure-track professors were women. However, 20% of new temporary faculty and 22% of new part-time faculty were women (Figure 13). We can see a similar pattern when looking at the ranks of new hires in physics departments. Women were 15% of newly hired full professors, 11% of new associate professors, and 18% of new assistant professors. However, the percentages of newly hired instructors / adjuncts and visiting professors who were women were higher than the percentages hired into professorial ranks. Twenty-three percent of new instructors / adjuncts and 21% of new visiting professors were women in 2004 (Figure 14). Although women are hired into ranked positions in the tenure system at better than their availability rates, the percentages of women going into the less desirable non-tenure-track positions are higher still.

**Table 10. Mean years since PhD for physics and astronomy faculty, 2002.**

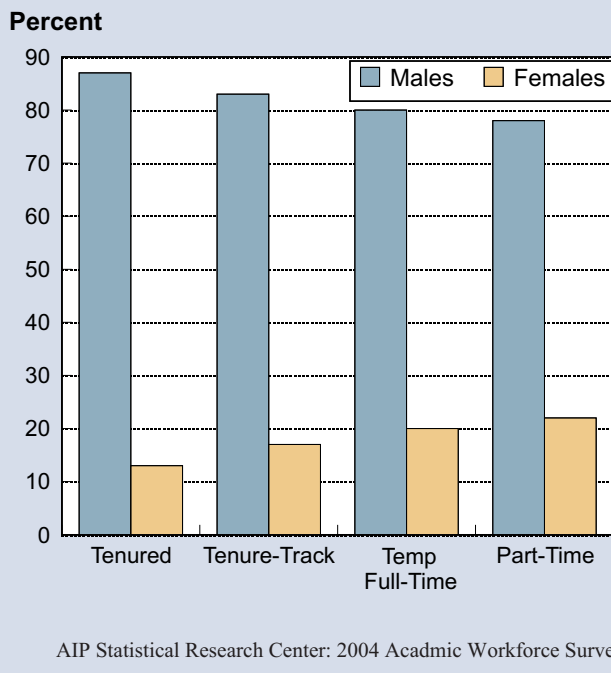
	Physics	Astronomy
Full Professor		
Male	29	28
Female	22	20
Associate Professor		
Male	17	18
Female	13	16
Assistant Professor		
Male	8	7
Female	8	6

Differences between men and women are NOT statistically significant.

AIP Statistical Research Center, 2002 Membership Survey.

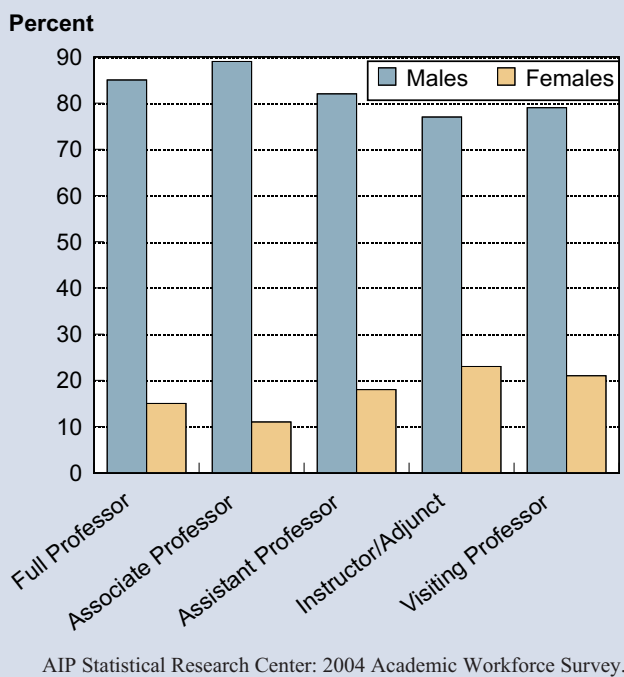
In sum, the data show that the percentage of women among astronomy and physics faculty will continue to increase because the percentage of bachelor's degrees earned by women in these fields

**Figure 13. Employment status of new physics faculty by gender, 2004.**



continues to increase. With the possible exception of a leak between undergraduate and graduate degrees in astronomy, once women earn

**Figure 14. Current positions of new physics faculty by gender, 2004.**



bachelor's degrees, they seem to be able to advance at the rate similar to men in physics and astronomy. In other words, there are very few disproportional leaks at the upper levels of physics and astronomy. This is particularly true at the faculty level, where we see at least the percentages of women that we would expect on physics and astronomy faculty, if not more.

## RETENTION

Just as the scissors diagram shows virtually no leaks in the pipeline between earning a bachelor's degree in physics and earning a PhD in physics, estimates of the retention rate for physics graduate students show little differences in the dropout rates for US women and men. We estimated retention rates using our data on the number of first year graduate students in PhD programs. From the number of first year graduate students, we subtracted the number who left after earning master's degrees and the number who earned PhDs in 7 years for US citizens and 6 years for foreign citizens (the average time taken to earn a PhD in physics). Our estimated average dropout rate for US males is 29% and for US females is 26% (classes entering fall of 1981-1997 and excluding those who left after earning master's degrees). Although our estimate for women is lower than our estimate for men, the difference is certainly within the margin of error and probably is not significant. The estimated average dropout rate for foreign males is 24%, but it is much higher for foreign females at 36% (classes entering fall of 1981-1998, again excluding those who left after earning master's degrees). More first year foreign students are female (estimated average of 17% for classes entering 1981-2003) than are US students (estimated average is 15% for the same years). However, among those who received physics PhDs, 12% of both US degree recipients and foreign degree recipients were female (averages of classes of 1987-2003). These data indicate that although US women persist in graduate school at about the same rates as US men, foreign women are



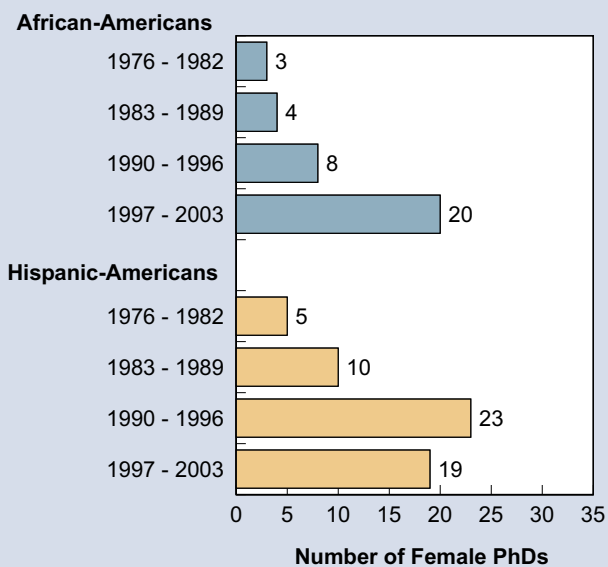
more likely to drop out than foreign men. However, the percentage of PhDs earned by foreign women has recently increased, so this difference between foreign women and men may be ending.

We can also look at the differences in the rates at which men and women enter PhD programs but leave with master's degrees. Before examining the numbers, it is important to note that some of those leaving with such a "terminal" master's degree may have intended all along to get only a master's degree, and therefore should be counted as successful in terms of achieving their goal. Again, the difference between US men and US women is small. Of US students, 23% of men and 27% of women leave PhD programs with terminal master's degrees (classes entering fall of 1981-2001). Although there is some difference in the rates of terminal master's for male and female US citizens, this difference is likely within the margin of error and is probably not significant. There is a similar small difference in the rates of terminal master's for foreign men and foreign women. For the classes entering fall of 1981-2001, 20% of foreign men and 24% of foreign women left PhD programs with terminal master's degrees. Again, these differences between male and female graduate students may not be significant, and should not be interpreted as women dropping out more frequently than men. This is because the extent to which people who received terminal masters intended to do so before entering graduate school is not known.

## MINORITY WOMEN

In spite of women's continued progress in physics and astronomy, the representation of minorities in these fields continues to be very low (Mulvey and Nicholson 2003). The numbers of minority female US citizens earning degrees in physics and astronomy are correspondingly low. For example, during the twenty-eight year period 1976-2003, just 35 African-American women earned PhDs in

**Figure 15. Number of Hispanic and African-American female PhDs in physics, 1976-2003.**



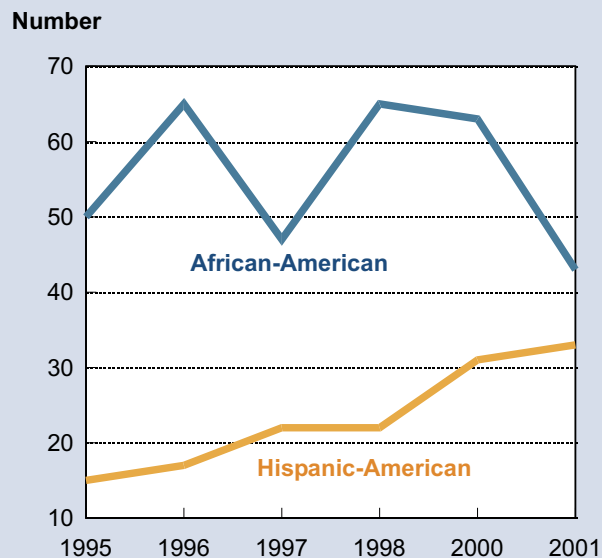
National Science Foundation. Data compiled by AIP Statistical Research Center.

physics (**Figure 15**). The number of Hispanic women earning PhDs in physics is higher, at 57 between 1976-2003. The number of minority women earning PhDs in physics has begun to increase in recent years. However, between 1997 and 2003, there was an average of fewer than three Hispanic women and fewer than three African-American women earning PhDs in physics in the US *each year*. Currently, there are more than 1100 PhDs awarded in physics each year.

The numbers are also quite low for minority female US citizens in astronomy. Between 1979 and 2003, only 7 African-American women and only 12 Hispanic women earned PhDs in astronomy. This is far less than one per year. Currently, there are about 100 astronomy PhDs and an additional 60-70 PhDs in astrophysics awarded each year.

For bachelor's degrees, data are only available from 1995-2001, and are missing from 1999. From 1995-2001, 333 African-American women and 140 Hispanic women received bachelor's degrees in physics. This is an average of 56 African-American women and 23 Hispanic women

**Figure 16. African-American and Hispanic-American women receiving physics bachelor's degrees, 1995-2001.**



National Center for Education Statistics. Data for academic year 1999 not available. Compiled by AIP Statistical Research Center.

each year. During this same time period, however, a total of about 3800 bachelor's degrees in physics were awarded *each year*. As **Figure 16** shows, the number of Hispanic women earning physics bachelors has increased from about 15 per year to just over 30 per year.

From 1995-2001 (and excluding 1999), Hispanic women earned 20 bachelor's degrees in astronomy. However, during this six-year period, only *two* African American women earned a bachelor's degree in astronomy. This is not an average of two, but two total during the entire period 1995-2001. In 2001 alone, about 260 astronomy bachelor's degrees were awarded in the US. None was earned by an African-American woman.

Numbers like these are of great concern for many policy makers and observers of the scientific community, who would like to see more women

and minorities earning science degrees and working in science. Minority women especially represent a great, untapped resource that could be drawn on to increase the size of the scientific workforce in the U.S.

## INTERNATIONAL WOMEN

In 2002, an international conference on women in physics was held in Paris. In preparation for the conference, a survey was conducted of more than 1000 women physicists in 55 countries (Ivie, Czujko, and Stowe 2002). In addition, representatives to the conference from various countries prepared reports on the status of women in physics in their countries. The reports are available in the conference proceedings and provide a wealth of information about women in physics across the world (Hartline and Li 2002).

A few countries keep reliable statistical data on the number of physics degrees awarded to women and men. The representation of women in physics is extremely low worldwide. Most of the countries for which we were able to find reliable data grant less than one-fourth of their first-level degrees in physics to women (**Table 11**), and most grant less than one-fifth of their PhDs in physics to women (**Table 12**). Some of the countries that award a large number of physics degrees and also have higher percentages of women graduates are Turkey, South Korea (which each award more than 2000 bachelor's degrees each year in physics), and France (which awards more than 3000 bachelor's degrees annually in physics). Women earn almost 40% of Turkey's bachelor's degrees in physics, 33% in France, and 30% in South Korea. The reasons for these differences are unknown. However, in France, the wide availability of low-cost childcare may be a factor. Overall, however, the evidence shows that the low representation of women in physics is a worldwide problem.

## SALARY

In spite of the increased representation of women in both physics and astronomy, women still earn less than men, even when they have the same years of experience and work in the same sector. We surveyed members of AIP's Member Societies and collected data on more than 4000 full-time

employed scientists' employment sector, years since degree, and salary (post docs were excluded from the analysis). Controlling for employment sector and years since degree, women make significantly less than men. Across all sectors, women with comparable years of experience

**Table 11. Percent of physics bachelor's degrees awarded to women in selected countries: 2-year averages.**

	<b>% Bachelor's to women</b>	<b>Avg # of Bachelor's per year, both sexes</b>
Turkey	39	2,219
Greece	34	588
France	33	3,256
South Korea	30	2,189
Sweden	29	55
Latvia	26	12
Australia	21	182
United Kingdom	21	1,755
Norway	21	72
USA	21	3,770
Taiwan	20	825
Slovenia	19	26
Estonia	18	20
Mexico	18	162
Denmark	17	95
Japan	13	3,314
The Netherlands	12	206
Germany	9	2,173
Switzerland	9	206
19 Countries	24	21,125

1998-99 data are presented for countries in blue. For all other countries, 1999-2000 data represented. To be included, countries had to provide appropriate data from reliable statistical agencies.

Compiled by AIP Statistical Research Center.

**Table 12. Percent of physics PhDs awarded to women in selected countries: 2-year averages.**

	<b>% PhDs to women</b>	<b>Avg # of PhDs per year, both sexes</b>
Turkey	28	50
France	26	898
Greece	25	39
Australia*	20	100
Latvia	20	3
Denmark	20	51
Norway	20	28
United Kingdom	18	415
Sweden	17	60
Slovenia	15	17
Poland	13	182
USA	13	1,237
The Netherlands	12	68
South Korea	10	125
Taiwan	10	24
Japan	10	374
Estonia	10	5
Germany	10	1,570
Switzerland	9	109
19 Countries	15	5,355

\* Includes Master's degrees.

1998-99 data are presented for countries in blue. For all other countries, 1999-2000 data represented. To be included, countries had to provide appropriate data from reliable statistical agencies.

Compiled by AIP Statistical Research Center.

working in the same sector as men make \$3050 less annually. This is equal to almost 5% of the base annual starting salary for men in academe, although the difference applies to all sectors. We do not have data on job title, so this analysis does not include it. If it were included, it would probably have some effect on the size of the salary difference.

## CONCLUSION

Women have made substantial progress in the fields of physics and astronomy. The percentage of physics PhDs earned by women, for example, reached a record high in 2003 at 18%. There also has been a dramatic increase in the number of

people receiving bachelor's degrees in astronomy. This increase is driven largely by the increasing number of women earning bachelor's degrees in astronomy. On the other hand, despite years of effort and concern on the part of many in the scientific community, women still earn just 18% of physics PhDs. In 2003, women earned just 22% of the bachelor's degrees in physics. There are fewer women in physics than in almost every other scientific field. So while there has been progress, it is occurring much more slowly in physics than in other fields.

The news in astronomy is much more encouraging, as the percentage of degrees earned by women has reached respectable levels. In 2003, women earned almost half of bachelor's degrees and more than one-fourth of the PhDs in astronomy. Nevertheless, the representation of women on astronomy faculties remains low, just as it does in physics. However, we have seen that the low representation of women on physics and astronomy faculties is just an artifact of the low representation of women PhDs in the past, especially among those old enough to be full professors, who form the bulk of the physics and astronomy professors.

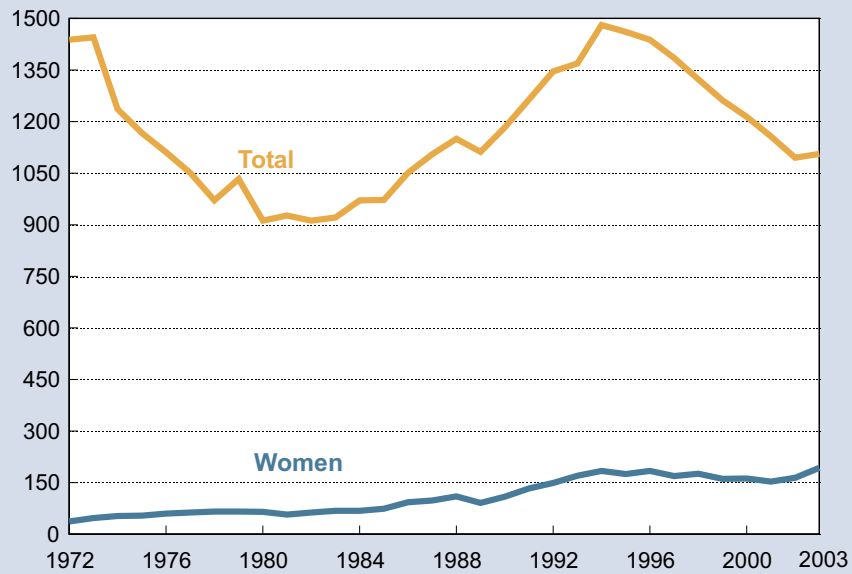
In fact, the leak in the pipeline for physics seems to occur at one point only, and that is between taking physics in high school and earning a bachelor's degree in physics. To determine if there is a leak during graduate school in astronomy, better data are needed because so many astronomy graduate students have physics bachelor's degrees, and there are fewer women among physics bachelor's

degree recipients than among astronomy bachelor's degree recipients. Once women have earned a bachelor's degree in physics, they advance through the levels of the academy at about the rates we would expect. Although their journeys are most likely difficult, women do persevere. From these data, and from the fact that the number of women earning bachelor's degrees in physics and astronomy continues to increase, we can conclude that with time, physics and astronomy faculties will more closely resemble today's graduating classes.

There are problems that exist and may be difficult to remedy. For example, even when working in the same employment sector with the same years of experience, women in physics and related fields on average earn less than men. The number of minorities earning physics and astronomy degrees continues to be very low, and the number of female minorities is dismally small. Women are being hired into the professorial ranks at better than their availability rate, but the proportion of women in temporary faculty positions is even higher. Another issue of concern (about which we have no data in this report) is the effect of the climate for women in physics, which in some departments is very chilly. The climate speaks to the everyday work life of female physicists, who are often still told, through actions if not through words, that physics is a man's world. Although many departments do not have chilly climates and are working to improve the conditions for faculty and students, better data are needed to document the conditions so that effective practices may be established to correct unwelcoming climates where they exist. As women continue to progress up the academic ladder in physics and astronomy, we will no doubt see many corrective actions and much progress in this area.

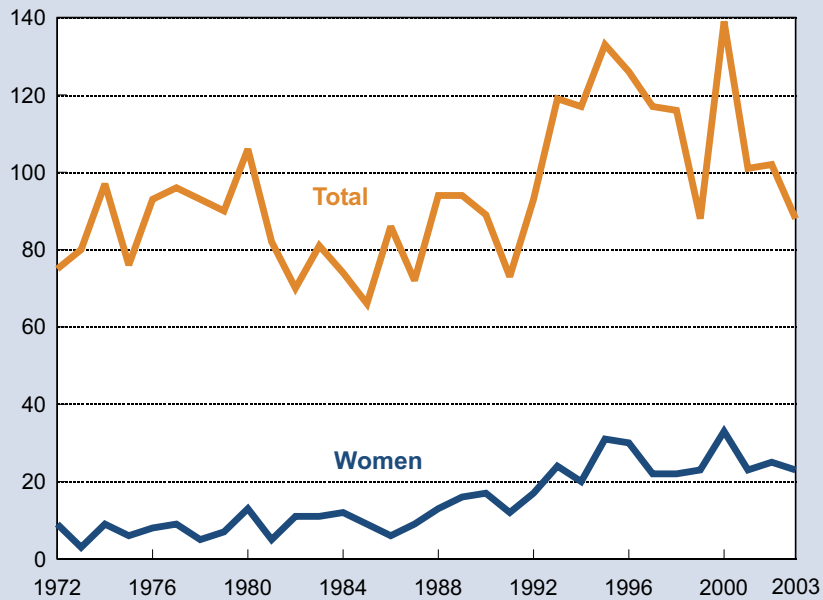
## APPENDIX

**Appendix 1. Number of PhD degrees earned in physics, 1972-2003.**



AIP statistical Research Center: Enrollments and Degrees Survey.

**Appendix 2. Number of PhD degrees earned in astronomy, 1958 - 2003.**



Data do not include astrophysics PhDs awarded by physics departments.

AIP Statistical Research Center: Enrollments and Degrees Survey.

**Appendix 3. High school students taking AP physics exams.**

	2000		2004	
	Number	% Female	Number	% Female
Physics B (algebra-based)	30,967	35	43,295	35
Physics C (calculus-based)	15,634	26	21,903	25

Physics C exam includes those taking the Mechanics exam only, because almost all of those taking the Electricity & Magnetism exam also take the Mechanics exam..

Source: College Board 2005.

## REFERENCES

- College Board. 2005. *Advanced Placement Summary Information*. New York: The College Board.
- Hartline, Beverly K. and Dongqi Li, editors. 2002. *Women in Physics: The IUPAP International Conference on Women in Physics*. AIP Conference Proceedings Volume 628. Melville, NY: American Institute of Physics.
- Ivie, Rachel, Roman Czujko, and Katie Stowe. 2002. *Women Physicists Speak: The 2001 International Study of Women in Physics*. College Park, MD: American Institute of Physics.
- Ivie, Rachel, and Katie Stowe. 2000. *Women in Physics, 2000*. College Park, MD: American Institute of Physics.
- Ivie, Rachel, Katie Stowe, and Kimberley Nies. 2003. *2002 Physics Academic Workforce Report*. College Park, MD: American Institute of Physics.
- McFarling, Mark, Michael Neuschatz, and Patrick J. Mulvey. 2004. *Graduate Student Report: First-Year Physics and Astronomy Students in 2002 and 2003*. College Park, MD: American Institute of Physics.
- Mulvey, Patrick J., and Starr Nicholson. 2002. *Physics and Astronomy Senior Report: Classes of 1999 and 2000*. College Park, MD: American Institute of Physics.
- Mulvey, Patrick J., and Starr Nicholson. 2003. *Enrollments and Degrees Report*. College Park, MD: American Institute of Physics.
- National Education Longitudinal Study of 1988 (2000 follow-up). National Center for Education Statistics. <http://nces.ed.gov/surveys/nels88/>.
- National Opinion Research Center (personal communication). Data from Survey of Earned Doctorates, 1962-1966.
- National Research Council. 1963. *Doctorate Production in United States Universities: 1920-1962*. Washington, DC.
- National Science Foundation WebCASPAR: Integrated Science and Engineering Resources Data System. <http://caspar.nsf.gov>.
- Neuschatz, Michael, and Mark McFarling. 2003. *Broadening the Base: High School Physics at the Turn of New Century*. College Park, MD: American Institute of Physics.
- Whitten, Barbara L., Suzanne R. Foster, Margaret L. Duncombe, Patricia E. Allen, Paula Heron, Laura McCullough, Kimberly A. Shaw, Beverley A. P. Taylor, and Heather M. Zorn. 2004. "Like a Family": What Works to Create Friendly and Respectful Student-Faculty Interactions." *Journal of Women and Minorities in Science and Engineering* 10:229-242.