Physics 205 - Introduction to Research in Physics

Physics 205 meets Mondays 4-5:45 pm in ISB 231. All first-year Physics grad students must register for Physics 205.

Requirements: Attend every class (at most one will be excused) and turn in a summary of two research topics that interest you, each summary 1 or 2 pages in length, based on Phys 205 lectures and possibly follow-up meetings with the relevant Physics faculty.

Website: [http://physics.ucsc.edu/~joel/Phys205/] Password: Phys205

Instructor: Joel Primack, [joel@ucsc.edu](mailto:joel@ucsc.edu), ISB 318, Office Hours: Wed 2-3 or by appointment

Weekly Schedule

1/6   Joel Primack – Physics as a Profession

1/13  Michael Dine – Interpreting LHC Physics
      Howard Haber – Theory/Phenomenology of the Terascale
      Bruce Schumm & Jason Nielsen – ILC & LHC

1/27  Sriram Shastry – Supercomductors, Magnets, Thermoelectrics
      Sasha Sher – Imaging of Neural Function and Structure
      Sue Carter - Renewable Energy Systems

2/3   David Smith - X-ray Astronomy and Geophysics
      Steve Ritz – Fermi γ-ray Space Telescope & LSST
      David Williams – VHigh Energy Gamma Ray Astrophysics

2/10  Tesla Jeltema – Observational Cosmology and Particle Astro
      Robert Johnson - Proton Computed Tomography Project
      Joshua Deutsch – Biophysics & Condensed Matter Theory

2/24  Bud Bridges – Crystal Structure and Macroscopic Properties
      David Belanger - Phase Transitions & Magnetism in LaCoO₃
      Art Ramirez – Strongly Correlated Matter

3/3   Stefano Profumo – Dark Matter and Baryogenesis
      Tom Banks – Holographic Space-Time
      Anthony Aguirre - Testing Theories of the Super-Early Universe?

3/10  Joel Primack – Physics Ethics

Research Proposals Due
Physics 205 Research Proposals

Each short research proposal should have your name and the title at the top, and then explain

• what physics question you want to answer and why this question is interesting,

• what method(s) you propose to use,

• what information and resources (e.g. experimental apparatus, computational capability, and funding) you expect to need,

• how long you expect this project to take, and

• other relevant information such as which faculty member(s) you discussed this project with, why you are especially interested in this project, and what you might want to do if it succeeds.

Your two research project summaries are due at the last meeting of Physics 205, Monday March 10, 2012. However, if you submit drafts to me in advance, I will try to return them to you quickly with comments that may help you improve them. Please submit your research project summaries by email to joel@physics.ucsc.edu (please also cc a copy to relevant faculty members who would advise you on each project).
Physics as a Profession

Joel Primack - January 6, 2014

Demographics of the Physics Profession

Physics occupations including Public Interest Science

How scientific fields grow and stagnate

Working on the frontier vs. developed fields

The PhD is a research degree

Patterns of physics careers – importance of ~10 yr post-PhD

U.S. and International Science Budgets and Indicators
Of my own UCSC PhD students, about 20% now work in industry, and the rest are at universities or research institutes -- but most of my recent students are now in industry.
Where do Physics Bachelors Go?

Source: www.aip.org/statistics
Physics PhD production in the US has gone through repeated cycles of major increases and declines. Physics PhDs Conferred in the US, 1900 through 2008.

Physics PhD production has again made a dramatic turn, up 38% since a recent low only four years earlier. This sharp upswing is a result of increases in the number of US citizens and non-US citizens earning physics PhDs.

There are a number of influences that affect the cyclical changes in how many PhDs are conferred each year, and for the most part those influences came into play 5-8 years prior to each degree year. Examples of influences are: changes in university budgets and science funding, economic cycles affecting the job market for physicists, issues pertaining to the interests and abilities of international students to enter the US, the number of students receiving undergraduate physics degrees in the US, and the proportion of them choosing to pursue a physics PhD.

The 2008 Survey of Enrollments and Degrees
Degree-granting physics departments are contacted each fall and asked to provide the number of degrees they conferred the previous year.

The 2007 and 2008 Follow-Up Surveys of Master's and PhD Recipients
Degree recipients are contacted in the winter following the academic year in which they received their degree.
Years of Physics Graduate Study to Receive a PhD, Classes of 2007 & 2008 Combined.

<table>
<thead>
<tr>
<th>Years of Graduate Study</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
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<td>6</td>
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<td>7</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>9+</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: This graph depicts the number of full-time equivalent years of physics graduate study completed in the US. Includes US citizens only.

http://www.aip.org/statistics

**US citizens took an average of 6.2 full-time equivalent years of graduate study to complete their PhDs.**

Initial employment of physics PhDs, 1979 through 2008.

<table>
<thead>
<tr>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>50</td>
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<td>40</td>
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<tr>
<td>30</td>
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<tr>
<td>20</td>
</tr>
<tr>
<td>10</td>
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</table>

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Potentially Permanent Position</th>
<th>Postdoc</th>
<th>Other Temporary Position</th>
<th>Unemployed</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
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</tbody>
</table>

**ATTRITION AND TIME TO DEGREE**

What percentage of entering PhD students complete a PhD in physics?

96 physics departments answered this question

<table>
<thead>
<tr>
<th># of Departments</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0 to 30</td>
</tr>
<tr>
<td>3</td>
<td>30.1 to 40</td>
</tr>
<tr>
<td>12</td>
<td>40.1 to 50</td>
</tr>
<tr>
<td>8</td>
<td>50.1 to 60</td>
</tr>
<tr>
<td>16</td>
<td>60.1 to 70</td>
</tr>
<tr>
<td>28</td>
<td>70.1 to 80</td>
</tr>
<tr>
<td>9</td>
<td>80.1 to 90</td>
</tr>
<tr>
<td>4</td>
<td>&gt;90</td>
</tr>
<tr>
<td>11</td>
<td>Don’t know</td>
</tr>
</tbody>
</table>
There has been a steady but slow decrease in the number of African Americans who received physics PhDs in the US over the years. Of the 1,499 PhDs conferred in the class of 2007, about a quarter of them were conferred at Historically Black Colleges and Universities (HBCUs). This percentage is down compared to 26% in the class of 2004 and 31% in the class of 2008, even though this year saw an all-time high of 25% the year before.

As those students leaving departments that offer PhD degrees, a percentage is down compared to women. Although subject to year to year fluctuations, this decrease is likely linked to non-US women having a primary dissertation research method that was theoretical; this was also true for men. Foreign citizens were more likely to have a primary dissertation research method than their US citizen counterparts (5%).

US women had a primary dissertation research method that was theoretical. This was also true for men. Two exceptions: condensed matter and astrophysics. Of the 1,480 PhDs conferred at US citizens selected condensed matter as their subfield of physics PhDs, with 26% choosing it. The next most popular subfield in the area of physics PhD recipients was statistical physics (15%).

### Percent of Physics Master’s and PhDs Earned by Women, 1979 through 2008.

- **Exiting Master’s**
- **PhDs**

### Number of Physics PhDs Granted by Subfield From Departments that Offer Physics, Classes of 2007 & 2008 Combined.

<table>
<thead>
<tr>
<th>Subfield</th>
<th>Number of PhDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensed Matter</td>
<td>388</td>
</tr>
<tr>
<td>Particles &amp; Fields</td>
<td>208</td>
</tr>
<tr>
<td>Astrophysics</td>
<td>136</td>
</tr>
<tr>
<td>Atomic &amp; Molecular</td>
<td>102</td>
</tr>
<tr>
<td>Biological Physics</td>
<td>96</td>
</tr>
<tr>
<td>Optics &amp; Photonics</td>
<td>83</td>
</tr>
<tr>
<td>Nuclear Physics</td>
<td>81</td>
</tr>
<tr>
<td>Applied Physics</td>
<td>55</td>
</tr>
<tr>
<td>Materials Science</td>
<td>36</td>
</tr>
<tr>
<td>Relativity</td>
<td>32</td>
</tr>
<tr>
<td>Atmospheric &amp; Space</td>
<td>31</td>
</tr>
<tr>
<td>Plasma Fusion</td>
<td>30</td>
</tr>
<tr>
<td>Statistical Physics</td>
<td>26</td>
</tr>
<tr>
<td>Surface Physics</td>
<td>22</td>
</tr>
<tr>
<td>All Other</td>
<td>156</td>
</tr>
</tbody>
</table>

About a quarter of physics PhD recipients had a dissertation subfield in the area of condensed matter.
Initial Employment of Physics PhDs

Employment in physics means an individual’s primary or secondary employment field was in physics or astronomy. Data only include U.S.-educated physics PhDs who remained in the U.S. after earning their degrees.

http://www.aip.org/statistics
The Statistical Research Center is your source for data on education and employment in physics, astronomy and allied fields. The links below lead to listings of full reports and highlighted tables and graphs for each general topic:

<table>
<thead>
<tr>
<th>Full Reports by topic</th>
<th>Essential data (click on keywords to jump to detailed tables and graphs on the topic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school &amp; two-year college physics</td>
<td>enrollments</td>
</tr>
<tr>
<td>Undergraduate education</td>
<td>2-year college</td>
</tr>
<tr>
<td>Graduate education</td>
<td>enrollments</td>
</tr>
<tr>
<td>Faculty</td>
<td>number</td>
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<tr>
<td>Employment</td>
<td>bachelors</td>
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<tr>
<td>Women</td>
<td>degrees</td>
</tr>
<tr>
<td>Minorities</td>
<td>bachelors</td>
</tr>
<tr>
<td>International</td>
<td>foreign students in U.S.</td>
</tr>
</tbody>
</table>
National Center for Science and Engineering Statistics (NCSES)

(formerly the Division of Science Resources Statistics (SRS))

A new name. A broader mission.

Science and Engineering State Profiles

Education
- Degrees
- Disabilities
- Elementary and Secondary
- Graduate Students
- International
- Minorities
- Postdoctorates
- Universities and Colleges
- Women

Federal Government
- Budget Function
- Demographics
- Expenditures
- Facilities
- Funding
- Research and Development
- Workforce

Business and Industry
- Funding
- Geographic
- Innovation
- Research and Development
- Trends
- Workforce

International
- Education
- Graduate Students
- Research and Development
- Workforce

Research and Development (R&D)
- Academic
- Budget Function
- Business and Industry
- Cyberinfrastructure
- Expenditures
- Facilities
- Federal Government
- Funding
- Geographic
- International
- Workforce
Physics as a Profession

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AAAS Science & Public Policy Fellowships

Q: What is the deadline for AAAS Fellowship applications? 
The annual deadline is 5 December, without exception. All required
information, including three letters of recommendation, must be submitted
by 11:59 p.m. U.S. Pacific Standard Time on that date. Applications are
being accepted this year from early September to 5 December, for the
fellowship class that begins the following September.

Q: Who is the ideal candidate for a AAAS fellowship? 
There is no "ideal" candidate for a fellowship. Fellows come from many
different disciplines in science and engineering; they arrive from academia,
industry and the non-profit sectors; and they represent a broad range of
career stages, from recently graduated postdocs to mid-career
professionals and faculty on sabbatical, to retired individuals.

Q: Is previous experience in public policy necessary to be a strong
candidate? 
No, the fellowships are designed to help scientists and engineers learn
about the policymaking process by participating in it. However, it is
important to convey an understanding of the societal impacts of science in
your application materials and during an interview. You should also be
prepared to speak about how your specific scientific specialty relates to
policy issues and how it can be applied in government decision-making.
Q: How many persons apply each year and how many are selected? The ratio of applicants to fellowships awarded is different in each of the fellowship program areas. We urge you not to consider "the odds," but to apply to the fellowships that fit best with your interests and area of expertise. It is in those areas that you will be most competitive. Overall, AAAS awards more than 150 fellowships each year, including second year renewal fellowships. In addition, approximately 30 congressional and 10 executive branch fellowships are selected and awarded by other science and engineering societies that partner with AAAS to provide the Science & Technology Policy Fellowships.

Q: Does AAAS have any fellowship programs for undergraduate or graduate students? Yes. AAAS also administers the Mass Media Fellowship Program, which places undergraduate and graduate students at various media sites throughout the U.S. during the summer, to work as science journalists. For more information about this program, contact Stacey Pasco at spasco@aaas.org.
I recruited the first class of Congressional Science Fellows in 1973. They were physicists Ben Cooper and Michael Telson and biologist Jessica Tuchman [Mathews]. Ben Cooper, one of the first two APS Fellows, gave up tenure at Iowa State after his Fellowship year to join the staff of the Senate Interior Committee, subsequently renamed Energy and Natural Resources, where he remained for more than twenty years. Michael Telson had received his M.I.T. PhD just before becoming a AAAS Fellow. After his Fellowship year, he had offers from three universities and several Federal agencies, but he instead joined the staff of the newly formed House Budget Committee working on energy and environment, where he stayed for twenty years. He subsequently worked as Chief Financial Officer of the DoE for several years, and now works for the University of California. Jessica Mathews helped lead Mo Udall’s Presidential campaign, served on the National Security Council staff in the Carter administration, was an editor at the Washington Post, and is now President of the Carnegie Endowment for International Peace.

The career paths of the 58 APS Congressional Fellows (as of 2004) have been diverse. One, Rush Holt, is now the Representative for the New Jersey district that includes Princeton University, where he had earlier worked at the Forrestal Research Center. Five others are presently on Congressional staffs. Twelve have positions in the Executive Branch, ten are at universities or laboratories, eleven work in industry, five are on professional society staffs, and seven work for public interest groups.
Benjamin Franklin is America’s earliest model of the “civic scientist”. Science was his passion and expertise, but society was his concern. As scientists in a much more complex world than Franklin’s – we face a society and momentum that, in many ways, we as scientists have created. Just as many in our ranks have taken on the task of insuring a better informed public on scientific matters, and many have moved into policy positions in government and academic institutions, it is clearly a moment in history when more of us should actively seek that role and responsibility that was so clear to Franklin – the larger public arena.


• A civic scientist should be a credentialed scientist with sufficient professional standing to have credibility among colleagues, policy-makers, students, and the public.

 • A civic scientist must possess the wisdom and judgment to understand the boundaries of scientific authority and when it is appropriate to apply scientific authority to policy issues.

• A civic scientist should be able to communicate effectively with a variety of audiences in order to convey his or her message most effectively.

• A civic scientist must not expect to persuade solely by virtue of his or her scientific authority; rather, he or she should understand the nature of political discourse and decision-making and realize that progress is made incrementally through a process of compromise and consensus building.

• A civic scientist is committed to applying scientific knowledge and experience to the benefit of the public.

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U.S. and International Science Budgets and Indicators
Growth of Knowledge in One Area

Schematic Picture

Figure 6. Inverse relationship between the accumulation of application and the interest in a basic-research field.

Figure 1.6. Growth in Length of a Beanstalk as a Function of Age

Figure 7. The escalation of discovery lines.

From Gerald Holton, “Models for Understanding the Growth of Research”
Figure 1.11 in Derek J. de Solla Price, *Little Science, Big Science* (1963).
How exponential growth can continue via repeating sigmoid growth curves...

As an old technology saturates, a new one takes off.
MOORE'S LAW - THE FIFTH PARADIGM

Electro-Mechanical | Relay | Vacuum Tube | Transistor | Integrated Circuit

Calculations per Second per $1000


Source: Ray Kurzweil, each dot is a computing machine
Big Challenges of AstroComputing

Big Data

Sloan Digital Sky Survey (SDSS) 2008
- 2.5 Terapixels of images
- 40 Tb raw data ➔ 120 Tb processed
- 35 Tb catalogs

Mikulski Archive for Space Telescopes (MAST)
- 185 Tb of images
- 25 Tb/year ingest rate
- >100 Tb/year retrieval rate

Large Synoptic Survey Telescope (LSST)
- 15 Tb per night for 10 years 2014
- 100 Pb image archive
- 20 Pb final database catalog

Square Kilometer Array (SKA) ~2024
- 1 Eb per day (> internet traffic today)
- 100 PFlop/s processing power
- ~1 Eb processed data/year

Changing Computers

Response: Multicore & GPUs

Shortfall 100x

Year of Introduction

Clock Frequency (Mhz)

Processor Clock Speed

Clock Speed (Ghz)

10,000

1,000

100

10


1995

2000

2005

2010

2015

2020

100,000

10,000

1,000

100

10

1,000,000

100,000

10,000

100

10


A.4 Microprocessor power dissipation (watts) over time (1985-2010).
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Who Are the Scientists? A Representative Case

The element of discontinuity in the general experience of our time merely reinforces the discontinuities in the experiences of contemporary science. The rate at which events happen is again the important variable. For, when a field changes more and more rapidly, it reaches at some point a critical rate of activity beyond which one has to learn by oneself, not merely the important new ideas, but even the basic elements of one’s daily work. This is now true of many parts of physics and of some other fields of science, not only for the most productive and ingenious persons, but for anyone who wishes to continue contributing. The recent past, the work of one or two generations ago, is not a guide to the future, but is prehistory.

Thus the representative physicist is far more his own constantly changing creation than ordinary persons have ever been. His sense of balance and direction cannot come from the traditional past. It has to come from a natural sure-footedness of his own—and from the organism of contemporary science of which he strongly feels himself a part. None of the novels or the representations in the mass media which I have seen have portrayed him with success, perhaps because they missed the fact that this is the component that really counts.

The Parable of the Talents from the Gospel of Matthew 25:14-30

14"Again, it will be like a man going on a journey, who called his servants and entrusted his property to them. 15To one he gave five talents of money, to another two talents, and to another one talent, each according to his ability. Then he went on his journey. 16The man who had received the five talents went at once and put his money to work and gained five more. 17So also, the one with the two talents gained two more. 18But the man who had received the one talent went off, dug a hole in the ground and hid his master's money. 
19"After a long time the master of those servants returned and settled accounts with them.
20The man who had received the five talents brought the other five. 'Master,' he said, 'you entrusted me with five talents. See, I have gained five more.'
21"His master replied, 'Well done, good and faithful servant! You have been faithful with a few things; I will put you in charge of many things. Come and share your master's happiness!'
22"The man with the two talents also came. 'Master,' he said, 'you entrusted me with two talents; see, I have gained two more.'
23"His master replied, 'Well done, good and faithful servant! You have been faithful with a few things; I will put you in charge of many things. Come and share your master's happiness!'
24"Then the man who had received the one talent came. 'Master,' he said, 'I knew that you are a hard man, harvesting where you have not sown and gathering where you have not scattered seed. 25So I was afraid and went out and hid your talent in the ground. See, here is what belongs to you.'
26"His master replied, 'You wicked, lazy servant! So you knew that I harvest where I have not sown and gather where I have not scattered seed? 27Well then, you should have put my money on deposit with the bankers, so that when I returned I would have received it back with interest. 28" 'Take the talent from him and give it to the one who has the ten talents. 29For everyone who has will be given more, and he will have an abundance. Whoever does not have, even what he has will be taken from him. 30And throw that worthless servant outside, into the darkness, where there will be weeping and gnashing of teeth.'

[Note: 1 talent ≈ $1000 today.]
Lotka’s Law

The number $N$ of authors publishing $>n$ papers is roughly proportional to $n^{-2}$.


According to the article in Wikipedia on Lotka’s Law, the $\sim 2$ power law index slightly differs in different fields. It has been found that Lotka’s Law does not apply when papers with $>100$ authors are included.

Figure 2.2 in Derek J. de Solla Price, *Little Science, Big Science* (1963).
UCSC ranked first in nation for research impact in Physics

In a 2007 analysis of research publications from top U.S. universities, the University of California, Santa Cruz, ranked first for the impact of its faculty in the field of physics and fifth in the field of space sciences. These rankings were reported in Science Watch, a newsletter published by Thompson Scientific.

Citation impact is based on the number of times a published paper is cited by other researchers. These rankings are based on the citation impact of research papers published by the top 100 federally funded universities between 2001 and 2005.

UCSC has been highly ranked in similar surveys for many years. Past rankings for the campus, all based on citation impact data, include first among U.S. universities in space sciences (2003), second worldwide in physical sciences (2001), and first among U.S. universities in physics (2000). In 2008, Science Watch reported that UC Santa Cruz achieved the highest score for the number of citations per high-impact paper in molecular biology and genetics.
**Table 1**: Impact Index of US Universities: Based on affiliation with University PhD Granting Departments for Astronomy PhD’s.

<table>
<thead>
<tr>
<th>Rank</th>
<th>University</th>
<th>N</th>
<th>h-index</th>
<th>h(m)</th>
<th>NRC Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Caltech</td>
<td>347</td>
<td>67</td>
<td>6.46</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>UC Santa Cruz</td>
<td>1096</td>
<td>106</td>
<td>6.45</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Princeton University</td>
<td>194</td>
<td>51</td>
<td>6.20</td>
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<tr>
<td>4</td>
<td>Harvard University</td>
<td>757</td>
<td>87</td>
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<td>Colorado</td>
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<td>8</td>
<td>Penn State Univ</td>
<td>647</td>
<td>78</td>
<td>5.86</td>
<td>21</td>
</tr>
<tr>
<td>9</td>
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**Table 2**: Impact Index based on University affiliation (includes Physics, Earth & Planetary Sciences, and Applied Mathematics).

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Physics as a Profession

Joel Primack

Physics occupations include Public Interest Science

How scientific fields grow and stagnate

Working on frontier vs. developed fields

The PhD is a research degree

Patterns of physics careers
  – importance of ~10 yr post-PhD

U.S. and International Science Budgets and Indicators
The PhD is a research degree

Graduate students should start research as soon as possible. Ask faculty members about research opportunities both now and starting in summer 2014. Start thinking about affiliating with a research group. Finish a research project and Advance to Candidacy for the PhD by the end of your 3rd year, if possible. Finish your PhD within 3 years after that.

Patterns of physics careers
– importance of ~10 yr post-PhD

In science, medicine, law, and even business, during the first decade or so after finishing your advanced degree you are expected to make major progress rapidly. These are also the prime child-bearing years. You can relax somewhat during your graduate studies, but to succeed in a scientific career you must hit the ground running when you get your PhD. You should also finish at least one major paper that’s not a continuation of your dissertation during the first year after the PhD.
The AP (12/7/09) reports that Elizabeth H. Blackburn and Carol W. Greider, the two female winners of the 2009 Nobel Prize in medicine urged scientific institutions to change their career structures to help more women reach top positions. Blackburn said, "The career structure is very much a career structure that has worked for men," and "many women, at the stage when they have done their training really want to think about family ... and they just are very daunted by the career structure. Not by the science, in which they are doing really well." Blackburn added that "a more flexible approach to part-time research and career breaks would help women continue to advance their careers during their childbearing years," while Greider said "she especially wants to see measures to get more women onto committees and decision-making positions."

UCSC hosted the 2010 Undergraduate Women in Physics Conference on the UCSC campus. About 100 undergraduate women from western states visited.
Physics as a Profession

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Patterns of physics careers – importance of ~10 yr post-PhD

U.S. and International Science Budgets and Indicators
Per Capita GDP by Country/Region

Per Capita Employee Productivity

EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

NSB Science and Engineering Indicators 2008 and 2010
The number of research articles published in a set of international, peer-reviewed journals has grown from about 460,200 in 1988 to an estimated 788,300 in 2009. The geographical distribution of the authors provides an indication of the size of a country's or region's research enterprise and its production of research results (figure O-13). Researchers in the EU and the United States have long dominated world article production, but their combined share of published articles decreased steadily from 69% in 1995 to 58% in 2009. In little more than a decade, Asia's world article share expanded from 14% to 24%, driven by China's 16% average annual growth. By 2007, China surpassed Japan's article output and moved into second place behind the United States—up from 14th place in 1995. By 2009, China accounted for about 9% of world article output. India's output of scientific and technical articles, stagnating through the late 1990s, began to rise after 2000, but India's ranking hardly changed from 12th to 11th place in 2009. Japan's output declined in volume and global share. Russia's article output flattened after 2005, following a decade-long decline that resulted in a drop from 7th to 13th place in global output ranking.

The distribution of a country's research publications across different fields is a broad reflection of its research priorities. A large portion of U.S. articles focused on the biomedical and other life sciences; scientists in Asia and some major European countries published a preponderance of articles in the physical sciences and engineering. Recent shifts in emphasis include China's growing focus on chemistry R&D and South Korea's growing output in biological and medical sciences. These changes reflect government policy choices as China is building up its chemicals industry, and South Korea is trying to develop a world-class reputation in health sciences.

Worldwide, the number of engineering research articles have increased substantially faster than total S&E article production, particularly in Asia outside Japan (figure O-14). Growth in the United States and Japan averaged less than 2%; in the EU, about 4.4%. China's engineering article output grew by close to 16% annually, and the Asia-8 economies expanded their combined output by 10% a year. Consequently, the production of engineering research articles has shifted away from established S&T nations. In 1995, the U.S. share of engineering articles was 25%, by 2009, 13%. Japan's share declined from 10% to 5% during the same period. The EU's share dipped from 25% to 19%. Asia's share, excluding Japan, increased from 9% to 23%, with China producing nearly half of these articles by 2009. The relative preponderance of engineering articles in developing Asian economies reflects the region's emphasis on innovation and technology.
World High-Tech Exports

U.S. High-Tech Balance of Trade

World GDP Shares

EU = European Union; GDP = gross domestic product
NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

NSB Science and Engineering Indicators 2008
Composition of the Proposed FY 2012 Budget
Total Outlays = $3.7 trillion

outlays in billions of dollars

- Net Interest $242
- Defense Discretionary $647
- Other Mandatory $625
- [Defense R&D] $83
- Nondefense Discretionary $542
- [Nondefense R&D] $69
- Medicaid $269
- Medicare $485
- Social Security $761

Source: Budget of the United States Government FY 2012.
Projected unified deficit is $1.1 trillion.
© 2011 AAAS
Federal Nondefense R&D Under BCA Caps With and Without Sequestration
in billions of constant FY 2012 dollars

1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017

ARRA
Nondefense
Under BCA Caps
Under Sequestration
Under NDD Cuts Only

Source: Based on AAAS estimates of R&D funding and the FY 2013 budget, and CBO analyses of the Budget Control Act.
© 2012 AAAS
Total R&D by Agency, FY 2013
budget authority in billions of dollars

- DOD, $72.6
- HHS (NIH), $31.3
- DOE, $11.9
- NASA, $9.6
- NSF, $5.9
- USDA, $2.3
- Commerce, $2.7
- All Other, $6.1

Total R&D = $142.2 billion

Source: OMB R&D data, agency budget justifications, and other agency documents. R&D includes conduct of R&D and R&D facilities. © 2012 AAAS
The United States leads the world in R&D investment
$369b PPP, 35.7% of world R&D investment
But, others are quickly increasing their investment

In the decade from 1997 to 2007,
South Korea, +0.99% of GDP to 3.47%
China, +0.85% of GDP to 1.49%
Taiwan, +0.81% of GDP to 2.63%
Japan, +0.57% of GDP to 3.44%
United States, +0.10% of GDP to 2.68%

President Obama set goal of 3.0% of GDP investment in R&D

http://www.aaas.org/spp/rd/
Physics as a Profession?

It’s a great time to be a physicist!

There are now terrific research opportunities in many areas of physics, including astrophysics, condensed matter physics, and particle physics.

Solving many of the world’s biggest problems -- energy, climate, environment, defense -- will involve physics.

There will be good employment opportunities as the need for physicists grows and as the current generation of senior physicists retires.

The Obama administration has had two superb physicists at Cabinet meetings: Science Advisor John Holdren and Energy Secretary Steve Chu (now back at Stanford).
On Being a Scientist: Third Edition

Committee on Science, Engineering, and Public Policy, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine


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- Purchase printed books
- Purchase PDFs
- Explore with our innovative research tools
Freshmen, sophomores, and first-year graduate students: start now to plan your job search.

Landing Your First Job
A Guide for Physics Students
by John S. Rigden

Available for loan in Physics Office

American Institute of Physics
Career Services Division
Additional highly recommended books for young scientists

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1 Do You See Yourself in This Picture? 1
A set of nonfiction vignettes illustrating some of the ways that young scientists make their lives more unpleasant than they need to or fail entirely to establish themselves in a research career.

2 Important Choices:
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A discussion of what to consider: young adviser versus an older one, a superstar versus a journeyman, a small group versus a "factory." Understanding and attending to your interests as a postdoc.

3 Giving Talks 27
Preparing talks that will make people want to hire and keep you, and that will make the information you present easy to assimilate.

4 Writing Papers:
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5 From Here to Tenure:
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6 Job Interviews 71
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7 Getting Funded 83
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8 Establishing a Research Program 95
Tuning your research efforts to your own capabilities and your situation in life, e.g., why not to start a five-year project when you have a two-year postdoctoral appointment.

Basic Choices

Sections of this Chapter
1.1 “Know thyself” so you can set realizable goals
1.2 Match your goals to your character and talents
1.3 Work style choices: Lone wolf, collaborator, team player, team leader?
1.4 Choices in work climate
1.5 A basic style choice: Experimentalist or theoretician?

1.1 “Know thyself” so you can set realizable goals

Make the effort to “Know thyself” so that your goals are realistic and will indeed satisfy you when you attain them. What should be your career goals as a scientist? This should include not just what you would like to achieve as a scientist, but how to advance in your career so as to have the means to do what you want. Asking yourself this question openly, critically and realistically at each stage of your career (preferably well before the next stage is to begin) is extremely important. It may save you a lot of trouble and frustration, later on. Of course you should not forget to ask yourself this basic question from time to time later in your development as a scientist (say every few months at least), and not