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/](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

1/7 Michael Dine – Anticipating LHC Physics  
Jason Nielsen & Bruce Schumm – LHC and ILC

1/14 Joel Primack – Physics as a Profession  
Sue Carter – Non-Academic Career Opportunities  
Hee-Sun Lee – Physics Education Research Opportunity

1/28 Sasha Sher – Imaging of Neural Function and Structure  
Sriram Shastry – Supercomductors, Magnets, Thermoelectics  
Gey-Hong Gweon – Spectroscopy on HTSCs and Graphene

2/4 Steve Ritz – Fermi γ-ray Space Telescope  
David Williams – VHigh Energy Gamma Ray Astrophysics  
Tesla Jeltema – Observational Cosmology and Particle Astrophysics

2/11 Tom Banks – Holographic Space-Time  
Anthony Aguirre - Testing Theories of the Super-Early Universe?  
Stefano Profumo – Fundamental Physics with GeV Gamma Rays

2/25 Howard Haber – Theory/Phenomenology of the Terascale  
Robert Johnson - Proton Computed Tomography Project  
Joshua Deutsch – Biophysics & Condensed Matter Theory

3/4 Bud Bridges – Crystal Structure and Macroscopic Properties  
Art Ramirez – Strongly Correlated Matter  
David Belanger - Nanoparticle Magnetism

3/11 Joel Primack – Physics Ethics

Monday, January 14, 13
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 11, 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 205 - Introduction to Research in Physics
January 14, 2012

PHYSICS AS A PROFESSION

4 pm Joel Primack – Physics as a Profession

5:00 pm Sue Carter – Non-Academic Career Opportunities

5:15 pm Hee-Sun Lee – Physics Education Research Opportunity
Physics as a Profession

Joel Primack

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.
Where do Physics Bachelors Go?

Status One Year After Earning a Physics Bachelor’s, Classes of 2009 & 2010 Combined

Graduate Study

Physics & Astronomy: 36%
Other Fields: 24%
Employment: 35%
Unemployment: 5%

Trends in Status One Year After Earning a Physics Bachelor’s, Classes 1995 through 2010

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.

- **Total**
- **US Citizens**
- **Non-US Citizens**

- **Degree Year**
  - 1900
  - 1910
  - 1920
  - 1930
  - 1940
  - 1950
  - 1960
  - 1970
  - 1980
  - 1990
  - 2000
  - 2008

- **Number**
  - 0
  - 200
  - 400
  - 600
  - 800
  - 1,000
  - 1,200
  - 1,400
  - 1,600

- **Degree Recipient Follow-up Surveys**
  - Physics PhDs Conferred in the US, 1900 through 2008.

- **http://www.aip.org/statistics**

- **Physics PhD production has again made a dramatic turn**, up 38% since a recent low only four years earlier.

- This sharp swing 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.
US citizens took an average of 6.2 full-time equivalent years of graduate study to complete their PhDs.
There has been a steady but slow increase in the percentage of women among physics PhDs over the past three decades. As of the class of 2007, women were responsible for conferring about a quarter of all physics PhDs. This percentage is down from a peak of 25% three years earlier. Additionally, there was an average of 1,480 PhDs conferred at US physics departments. Of the 1,499 PhDs conferred in the class of 2007, 136 were in Astrophysics, 96 in Biological Physics, 83 in Optics & Photonics, 81 in Nuclear Physics, 55 in Applied Physics, 36 in Materials Science, 32 in Relativity, 31 in Atmospheric & Space Physics, 30 in Plasma Fusion, 26 in Statistical Physics, 22 in Surface Physics, and 156 in all other subfields.

The majority of graduates were White US citizens, with 41% of all physics PhDs being awarded to those in this category. Asian Americans, Hispanic Americans, African Americans, Other US Citizens, and Non-US Citizens comprised smaller proportions of the PhDs, with 2%, 1%, 1%, 1%, and 54% respectively. The total number of PhDs conferred was 1,480, representing 100% of all physics PhDs awarded.

In the area of condensed matter, US citizens were more likely to have a subfield dissertation than non-US citizens (31% vs. 20%). Two exceptions were condensed matter and astrophysics. The distribution of subfields among US and non-US citizens was similar, with 26% choosing condensed matter as their subfield of physics PhDs.

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

Physics PhDs Starting Salaries, Classes of 2009 & 2010.

Typical Annual Salaries in Thousands of Dollars
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>
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<tr>
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<td>International</td>
<td>foreign students in U.S.</td>
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</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 •
Physics as a Profession

Joel Primack

Demographics of the Physics Profession

* Physics occupations include Public Interest Science

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U.S. and International Science Budgets and Indicators

*See also Joel Primack and Frank von Hippel, Advice and Dissent: Scientists in the Political Arena (Basic Books, 1974; New American Library, 1976).
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.
>150 Science and Public Policy Fellowships per Year

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.

Q: What impact has the fellowship had on the career path of former Fellows?

In the year immediately following their fellowship, approximately 40-50% of the Fellows continue working in the policy realm; 20-25% return to the sector in which they worked previously; and another 20-25% use the experience as a stepping stone to a new opportunity. To read about AAAS Fellows' perspectives on their experiences click here.
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.


Monday, January 14, 13
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Monday, January 14, 13
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 in Derek J. de Solla Price, *Little Science, Big Science* (1963).

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).
As an old technology saturates, a new one takes off.

How exponential growth can continue via repeating sigmoid growth curves...

Figure 2. The increase of operating energy in particle accelerators. (Courtesy of M. S. Livingston.)
MOORE'S LAW - THE FIFTH PARADIGM

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

Calculations per Second per $1000


EXPONENTIAL SCALE

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

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**Changing Computers**

- Shortfall
- 100x
- Response: Multicore & GPUs

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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 Matthew Effect in Science

1968


The workings of this process at the expense of the young scientist and to the benefit of the famous one is remarkably summarized in the life history of a laureate in physics, who has experienced both phases at different times in his career. “When you’re not recognized,” he recalls, it’s a little bit irritating to have somebody come along and figure out the obvious which you’ve also figured out, and everybody gives him credit just because he’s a famous physicist or a famous man in his field.

Here he is viewing the case he reports from the perspective of one who had this happen to him before he had become famous. The conversation takes a new turn as he notes that his own position has greatly changed. Shifting from the perspective of his earlier days, when he felt victimized by the pattern, to the perspective of his present high status, he goes on to say:

This often happens, and I’m probably getting credit now, if I don’t watch myself, for things other people figured out. Because I’m notorious and when I say it, people say: “Well, he’s the one that thought this out.” Well, I may just be saying things that other people have thought out before.

In the end, then, a sort of rough-hewn justice has been done by the compounding of two compensating injustices. His earlier accomplishments have been underestimated; his later ones, overestimated.17

This complex pattern of the misallocation of credit for scientific work must quite evidently be described as “the Matthew effect,” for, as will be remembered, the Gospel According to St. Matthew puts it this way:

For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath.

Put in less stately language, the Matthew effect consists of the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark. Nobel laureates provide presumptive evidence of the effect, since they testify to its occurrence, not as victims—which might make their testimony suspect—but as unwitting beneficiaries.
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.

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<thead>
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<th>Rank</th>
<th>University</th>
<th>N</th>
<th>h-index</th>
<th>h(m)</th>
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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 2013. 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.
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U.S. and International Science Budgets and Indicators
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...
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.
Composition of the Proposed FY 2012 Budget
Total Outlays = $3.7 trillion
outlays in billions of dollars

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

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

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

Total R&D = $142.2 billion

- 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

Source: OMB R&D data, agency budget justifications, and other agency documents.
R&D includes conduct of R&D and R&D facilities.
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Monday, January 14, 13
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
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 two superb physicists at Cabinet meetings: Science Advisor John Holdren and Energy Secretary Steve Chu.
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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Non-Academic Career Opportunities

Bruce Rosenblum

Preface

Where do physics students go for help and advice when they anticipate starting a job hunt? Most likely, you would go to your physics professor. However, most academic physicists begin their employment on a campus and they end it on a campus; therefore, they may have little or no experience in industry or government which is where the great majority of physicists work. So your physics professors may be unable to provide the detailed advice and the focused guidance that students need as they plan their job search. You could go to your campus career center. And you should. The career center staff can be very helpful. In addition, read this short book. This book, Landing Your First Job, was written to guide students who are looking ahead to seek employment. It is a practical book that identifies the important steps to the first job.
Freshmen, sophomores, and first-year graduate students: start now to plan your job search.

Available for loan. in Physics Office

Landing Your First Job
A Guide for Physics Students
by John S. Rigden
American Institute of Physics Career Services Division
Additional highly recommended books for young scientists

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A discussion of what to consider: young adviser versus an older one, a scientist 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: Publishing Without Perishing 39
Why it is important to write good papers. When to write up your work, how to draw the reader in, how to draw attention to your results.

5 From Here to Tenure: Choosing a Career Path 53
An unsentimental comparison of the merits of jobs in academia, industry, and in government laboratories.

6 Job Interviews 71
What will happen on your interview trip, the questions you had better be prepared to answer.

7 Getting Funded 83
What goes into an effective grant proposal, how and when to start writing one.

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**Basic Choices**

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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 from 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...