Physics 905 – Summer 2010

Graduate Research in Condensed Matter and Optical Physics

Instructor: Chih-Wei Lai, cwlai@msu.edu, Office: 4238 BPS.

Guest Instructors:

Prof. John McGuire, Prof. Brage Golding, Prof. Ruby Ghosh,
Tom Palazzolo, Dr. Baokang Bi, Dr. Reza Loloee.

Course Description and Objectives

A 6-week summer course will be offered for graduate students prior to embarking on PhD research. The objective is to provide each student with resources and tools for future research and career development.

Time period: July 12 to August 16

Format: a weekly 3-hr lecture/discussion plus a 3-hr lab

Lecture: 9-12 am Monday

Laboratory: 1:30-5 pm Monday

Location: BPS 4270 (Lecture) and BPS 1245 (Lab)

The analytical and experimental techniques covered in this course are basic to graduate research in condensed matter physics and in atomic, molecular, and optical physics. General topics such as literature searches, laboratory automation, and optical methods (which are applicable to chemistry and biophysics) will also be covered.

Students will keep an individual laboratory notebook, co-author a mini-report, and deliver an individual 10 minute APS-style presentation about an experiment or a specific research topic.
Course Outline

(1) Experimental Techniques for condensed matter physics and biophysics research: basic electronics and circuits, common laboratory electronics and instruments, mechanical design and machining, vacuum techniques, low temperature techniques, optical components and opto-mechanics, opto-electronic devices and instruments, spectroscopy and microscopy, light sources and laser systems, micro- and nano-fabrication facilities, laboratory automation and data acquisition.

(2) Analytical and Communication Skills – tools and resources: numerical simulation and modeling, data analysis and plotting, scientific and technical writing, and technical presentations.

(3) Career development: how to find an advisor and be a good graduate student, online resources and bibliographic tools.

(4) Hands-on experiments, mini-reports, and 10-minute talks: Students will be divided into groups to examine different aspects of a set of experiments related to optical pumping of $^{85}\text{Rb}$ and $^{87}\text{Rb}$ and pulsed nuclear magnetic resonance. Students are required to keep individual laboratory notebook, co-author a mini-report, and deliver an individual 10 minute APS-style presentation about the experiment.

Below is an outline of the content of the course.

**Unit 1: CMP/AMO Research & Groups and Facilities at P-A**

**Unit 2: Mechanical Design and Fabrication**

**Unit 3: Optics – Laser, Microscopy and Spectroscopy**

**Unit 4: Electronics**

**Unit 5: Vacuum Technology and Cryogenics**

**Unit 6: Scientific Writing and Presentation, Computing**

**Unit 7: On Being a Scientist & a Graduate Student**
Your Reading Material

This course does not use a traditional textbook. Instead, you will be reading from different websites and notes. Depending on your chosen field of research, you may consider buying some of the following books.


Computer Software

We will NOT offer training classes for computer software. However, we will give examples based on some of the following programs. You may obtain a student or academic license from MSU computer store (http://cstore.msu.edu/), the official website of the vendors, or online stores such as Academic Superstore (http://www.academicsuperstore.com/).

Data Acquisition and Analysis

LabView (‘free’ MSU site license) (http://www.ni.com/labview/)

Origin Pro (http://www.originlab.com/), or Igor Pro (http://www.wavemetrics.com/), or

KaleidaGraph (http://www.synergy.com/)

Computation

Mathematica (http://www.wolfram.com/) or Maxima (a descendant of Macsyma) (http://maxima.sourceforge.net/)

Matlab (http://www.mathworks.com/) or GNU Octave (free Matlab ‘clone’) (http://www.gnu.org/software/octave/)

MathCAD (http://www.ptc.com/products/mathcad/)

Document Preparation

MS Office, or Open Office, or Star Office

MikTeX + a TeX editor, or proTeXt (http://www.tug.org/protext/), & REVTeX 4.1 https://authors.aps.org/revtex4/

Bibliography

EndNote X3 (http://www.endnote.com/) or any other bibliography manager
Introduction

7/12

Science, Language, and Literacy

Science is about generating and interpreting data. But it is also about communicating facts, ideas, and hypotheses. Scientists write, speak, debate, visualize, listen, and read about their specialties daily. For students unfamiliar with the language or style of science, the deceptively simple act of communication can be a barrier to understanding or becoming involved with the science. [Special Section, Science Vol. 328, 23 April 2010]

Scientific Reasoning

“Critique is not some peripheral feature of science, but rather it is core to its practice, and without it, the construction of reliable knowledge would be impossible.”

Reading Materials:

On Being a Scientist


The scientific research enterprise is built on a foundation of trust. Scientists trust that the results reported by others are valid. Society trusts that the results of research reflect an honest attempt by scientists to describe the world accurately and without bias.

➢ Watch On Being a Scientist Video from NAP


"On Facts and Fraud", by David Goodstein (2010)
This is a more lively and interesting book with plenty of anecdotes. You may not appreciate many comments he makes yet.

How to Succeed in Graduate School
Marie des Jardins’s Advice Summary: http://www.cs.umbc.edu/~mariedj/papers/advice-summary.html

Self-education and Self-directed Learning

The inarticulate expertise of not knowing that you know is a dead end from the learning and teaching point of view. The only open position, with potential for development, is that of knowing what you know. (http://www.doceo.co.uk/tools/knowing.htm)

But remember: Some things we can teach, and some we can't.
Example websites for you to begin self-education


Many universities have webcast sites on YouTube, too. Youtube, http://www.youtube.com/.

The Kavli Institute for Theoretical Physics – Online Talks - http://www.itp.ucsb.edu/talks

Nobel Lectures, Lecture Notes, and Interviews: http://nobelprize.org/


Materials on any subjects can be practically found online & library.

Your doctoral research goal is to generate new knowledge.

Online Books (available to MSU students)

- Springer http://www.springerlink.com/

Learning through problems/solutions and catalogues/technical notes

Example Books - Problems and Solutions


Select Catalogues and Trade Magazines (a very incomplete list of companies in optics and photonics)


Buyers’ Guides

Optics – Laser, Microscopy and Spectroscopy
7/12 & 7/19

Optical Components

Reading Materials

[Moore] Ch. 4 Optical Systems

[Hobbs] Ch. 4 Lenses, Prisms, and Mirrors; Ch. 5 Coatings, Filters, and Surface Finishes; Ch. 6 Polarization; Ch. 7 Exotic Optical Components

Presentation Slides by C. H. Lee, Academia Sinica, Taiwan

Optics Handling and Cleaning Tutorial


Light Sources and Illuminators

Reading Materials

[Hobbs] Ch. 2 Sources and Illuminators

Springer Handbook of Lasers and Optics, Part C Coherent and Incoherent Light Sources (Chs. 10-12)

Selected Books on Lasers

Svelto, O. Principles of lasers. (Springer, 2009). (e-book available @ Springerlink)

Werner, A. Ultrafast Optics. (Wiley 2008). (e-book available @ Wiley)


Selected Tutorials and Lecture Notes

Ultrafast laser characterization (by Trebino @ Georgia Tech) http://www.physics.gatech.edu/frog/Tutorial/tutorial.html


Selected Distributors/ Manufacturers

- Oriel (part of Newport)
- Spectra Physics (Newport), http://www.newport.com/
- Spectra Physics (Newport), http://www.newport.com/
Spectroscopy

Reading Materials

Springer Handbook of Lasers and Optics, Ch. 13 Optical and Spectroscopic Techniques

Ultrafast Laser Spectroscopy

- N. Bloembergen, From nanosecond to femtosecond science, RMP (1999) (pdf)
- Th. Elsaesser, Laser Spectroscopy (pdf)
- Li and Cundiff, Ultrafast Spectroscopy in Physics (pdf)

Laser-based precision spectroscopy

- A recent article – The size of the proton, Nature 466, 213 (8 July 2010) (pdf)

Technical Notes

Amplitude and Phase Characterization of Ultrashort Laser Pulses, by Newport (pdf)

Lecture Notes

Optical Spectroscopy: Methods and Instrumentations (link) (ebook)

References/Database


Microscopy

Reading Materials:

*Ch. 16 Microscopy, “At the Bench”, by Barker*

Selected Online Resources:


![Figure 1. Atlas of spatially resolved spectroscopy techniques. They are organized according to their space and energy resolution. The relation between wavelength and energy is represented by dashed curves for photons and electrons.](http://rmp.aps.org/abstract/RMP/v82/i1/p209_1 (2010))
Charge-particle Optics

Reading Materials:

[Moore] Ch. 5 Charge-particle Optics

Selected Online Resource:
The Nobel Prize in Physics 1986 was divided, one half awarded to Ernst Ruska "for his fundamental work in electron optics, and for the design of the first electron microscope", the other half jointly to Gerd Binnig and Heinrich Rohrer "for their design of the scanning tunneling microscope". (click here)

Nobel Lecture

E. Ruska, The developments of the electron microscope and electron microscopy. (pdf)

G. Binning and H. Rohrer, Scanning tunneling microscopy. (pdf)

Selected References


Zewail, A. H. & Thomas, J. M. 4D electron microscopy : imaging in space and time. (Imperial College Press, 2010).

Figure 2. 4D electron imaging. The resolution boundaries of ultrafast imaging are compared with those achieved in conventional TEM, limited by the speed of video camera, and, in high-speed microscopy (HSM), defined by the rectangle shown. The spatiotemporal scales of UEM achieved to date are outlined with possible future extensions. The approaches of single-electron and singlepulse imaging are fundamentally different because of the limiting problem of space-charge described in the text. [Zewail, Science (2010) ]
Mechanical Design and Fabrication
7/19, Lecturer: Tom Palazzolo

Reading Materials

[Moore] Ch. 1 Mechanical Design and Fabrication

See also the Lecture Notes prepared by Tom Palazzolo

- Lecture 10:30 am – 11:30 pm, Machine Shop Manager, Tom Palazzolo palazzolo@pa.msu.edu
  Introduction to technical drawings and the machine shop

Distributors

Vacuum Technology and Cryogenics

Reading Materials:

[Moore] Ch. 3 Vacuum Technology

*Practical Cryogenics, by N. H. Balshaw, Oxford Instruments. ([pdf](#))*

*Introduction to Laboratory Cryogenics, by M. N. Jirmanus, Janis Research Company. ([pdf](#))*


Selected Books:

*F. Pobell, Matter and Methods at Low Temperatures, Springer Link ([pdf](#))*


*Ekin, J. W. Experimental techniques for low-temperature measurements: cryostat design, material properties, and superconductor critical-current testing. (Oxford University Press, 2006).*


Selected Distributors/ Manufacturers:

**Vacuum pumps, leak detectors, and components**

- Trinos/Pfeiffer Vacuum, [http://us.trinos.com/vacuum_s/index.html](http://us.trinos.com/vacuum_s/index.html)

**Cryogenic systems and accessories**

Electronics and Optoelectronics
8/2/2010

Electronics

Nearly every measurement made in a physics laboratory comes down to determining a voltage or current, so it is important to have at least a basic understanding of electronic circuits. It is not critical to be able to design circuits, or even to completely understand a circuit given to you, but you do need to know enough to get some idea of how the measuring apparatus affects your results.

Reading Materials

[Moore] Ch. 6 Electronics

[Melissinos] Ch. 3 Electronics and Data Acquisition


It is important to have useful and frequently referenced materials in the form of readily accessible tales, graphs, and diagrams. Textbooks and book chapters should be supplemented with manufacturers’ catalogs, data books, applications texts, handbooks, and more specialized texts that treat the topic of interest in depth.

Handbooks (free)

Keithley (You may request a hard copy from http://www.keithley.com/knowledgecenter.)
- Understanding New Developments in Data Acquisition, Measurement, and Control - A Practical Guide to High Performance Test and Measurement (pdf)

Tektronix (http://www.tek.com/learning/)
- XYZs of Oscilloscopes Primer (pdf), (pocket guide to oscilloscopes)
- XYZs of Signal Generators Primer (pdf), (pocket guide to signal generators)
- Understanding and Characterizing Timing Jitter (pdf)

Online website
- All about circuits: http://www.allaboutcircuits.com/
Selected Distributors and Manufacturers

**Basic Electronic Equipment and Components:**
Newark, Marlin P. Jones, DigiKey, McMasterCarr, Grainger, Fulton Radio, Allied Electric, Mouser, All Electronics, Burr-Brown (now Texas Instruments)

**Connectors and Cables:**
L-Com, Microstock Inc., Times Microwave Systems

**Test & Measurement**
Agilent, Keithley, Tektronix, LeCroy, Anritsu, Rohde & Schwarz, Tabor Electronics, National Instruments (LabView and more)

Case Study I: Cables and Connectors

- Times Microsystems: [http://www.timesmicrowave.com/resources/](http://www.timesmicrowave.com/resources/)
- L-com: [http://www.l-com.com/content/TechnicalResources.html](http://www.l-com.com/content/TechnicalResources.html)

Connector, Coaxial, GPIB IEEE-488, Audio/Video

Computer Interface: USB, Firewire, DIN, SCSI, SATA

Case Study II: High-pass, low-pass, and band-pass filters

- Impedance of a capacitor
- Impedance of an inductor
- LRC circuit

Case Study III: Measuring input and output impedance

- [http://www.zen22142.zen.co.uk/Theory/inzoz.htm](http://www.zen22142.zen.co.uk/Theory/inzoz.htm)

Case Study IV: Noise Reduction

- [Moore] Ch. 6.8 Extraction of signal from noise
- Signal Enhancement, Application Note #6 from SRS (pdf)

Case Study V: Grounding and Ground Loop

- [Moore] Ch. 6.9 Grounds and Grounding
- [Ott] Ch. 3 Grounding (pdf)
Case Study VI: Electronics Simulation for Physicists
Electronics simulation for physicists, Presentation slides and examples, [http://www.physics.berkeley.edu/eshop/Simulating.ppt](http://www.physics.berkeley.edu/eshop/Simulating.ppt)

LT Spice, a SPICE III simulator, free from [http://Linear.com/designtools/software](http://Linear.com/designtools/software)

SPICE: a general-purpose circuit simulation program for nonlinear dc, nonlinear transient, and linear ac analyses - [http://bwrc.eecs.berkeley.edu/classes/icbook/SPICE/](http://bwrc.eecs.berkeley.edu/classes/icbook/SPICE/)

Other Integrated Circuits Design Tool, [http://bwrc.eecs.berkeley.edu/classes/icbook/tools.html](http://bwrc.eecs.berkeley.edu/classes/icbook/tools.html)

FPGA - Field-programmable gate array

*FPGA projects and tutorials, [http://www.fpga4fun.com/](http://www.fpga4fun.com/)*
Optical Detection/Optoelectronics

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Reading Materials

[Moore] Ch. 7 Detectors

[Hobbs]

Selected Distributors and Manufacturers

The following distributors/manufacturers all provide extensive application and technical notes.

**PMTs, Photodetectors, CCDs**
  - PMT Handbook and modules
  - Application Notes

**Sensors and Amplifiers**
- Femto, [http://www.femto.de/](http://www.femto.de/) (current, voltage, & lock-in amplifiers, and photoreceivers)

**Lock-in amplifiers**
Data Acquisition and Computer Interface

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Selected Books on LabVIEW

- LabVIEW for Everyone, by Travis and Kring
- Learning with LabVIEW 2009, by Robert H. Bishop
Computing

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P-A Computing Services
Computer support: George Perkins perkins@pa.msu.ed & Ehren Benson bensoneh@pa.msu.edu

Web site: http://support.pa.msu.edu/

➤ Search P-A Computer Support Knowledgebase
Case Study I: BPS Printer Database ➤ http://thing.pa.msu.edu/printer/

Case Study II: Connecting to network drives & P-A VPN (virtual private network)
http://support.pa.msu.edu/howto.php?s=vpn

Case Study III: SSH and XMing
Installing and Using XMing, http://support.pa.msu.edu/howto.php?id=125
Installing SSH, http://support.pa.msu.edu/howto.php?id=66

Scientific Computing

  o E-book can be viewed (partially) at http://www.nrbook.com/nr3/

Data and Error Analysis

Reading Materials

Experimental Data Analysis Documentation, by Wolfram Research,
http://reference.wolfram.com/applications/eda/

Introduction to Error Analysis (significant figure, error classification, and error propagation)
http://teacher.pas.rochester.edu/PHY_LABS/AppendixB/AppendixB.html


References


[Melissinos] Ch. 10 Elements from the Theory of Statistics
Information Graphics Software

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A list of information graphics software can be found at Wikipedia (click [here](#)).

*Use the tutorials, guides, and file exchange service to user communities.*

Computer Algebra Systems


- Library (Demo, Book, Technical Notes, and more: [http://library.wolfram.com/infocenter/BySubject/](http://library.wolfram.com/infocenter/BySubject/)


Numerical Software


- Extending Matlab with Numerical Recipes, [http://www.nr.com/nr3_matlab.html](http://www.nr.com/nr3_matlab.html).
- Example:


Plotting Programs (Graphing Programs)


*IDL, [http://www.ittvis.com/ProductServices/IDL.aspx](http://www.ittvis.com/ProductServices/IDL.aspx)*

Statistical Software

(most experimental physicists do not need such a program)


Spreadsheets

Check Office Software Package
Good communication skills are as important as a specific technical competency.

I: Science and Technical Writing

References (provided by Dr. Ruby Ghosh)

*AIP Style Manual: http://www.aip.org/pubservs/style/4thed/toc.html*
Prepared by the American Institute of Physics this manual offers a concise guide to all aspects of publishing a paper in a physics journal. It is brief with references on every topic. Free download.

*Merriam-Webster's Collegiate Dictionary Merriam-Webster; 11th edition (July 2003)*

A classic book that will guide you through writing a scientific paper, writing your thesis, writing a conference proceedings…, with a special section for non-native speakers. I recommend purchasing a personal copy.

A masterpiece on the graphical representation of data, read it for instruction and come away inspired.

Selected Online Resources:

- MSU Writing Center, [http://writing.msu.edu/](http://writing.msu.edu/)
- Common Errors in English Usage, [http://www.wsu.edu/~brians/errors/index.html](http://www.wsu.edu/~brians/errors/index.html)
- Technical Writing, by R. Standler, [http://www.rbs0.com/tw.htm](http://www.rbs0.com/tw.htm)

Selected Books:

- *The Art of Scientific Writing, by Ebel, Bliefert, & Russey (Wiley-VCH)*
- *Science & Technical Writing – A Manual of Style, by P. Rubens*
- *How to Write and Publish a Scientific Paper, by R. Day & B. Gastel*
- *The Craft of Scientific Writing, by M Alley*
- *(For non-native speakers)*
- *Introduction to Technical Writing – Process & Practice, by L. J. Rew*
- *Technical Writing and Professional Communication for Nonnative Speakers of English, by Huckin & Olsen*
- *The Random House Hanbook, by F. Crews*
- *Grammatically Correct, by A. Stilman*
II: Presentation

Online Resources

Advice to Beginning Physics Speakers, by J. Garland, (Physics Today 1991) (pdf)


Selected Books

- The Craft of Scientific Presentations, by M. Alley
- The Art of Lecturing, by P. Aarabi
- Loud and Clear, by Morrisey, Sechrest, & W. Warman
- Communicating Effectively, by L. Arredondo
CMP Research Groups and Facilities at P-A MSU

Facilities
ERC Cleanroom, http://www.egr.msu.edu/erc-cleanroom/
P-A Electronic Shop, 1230 BSP, http://www.pa.msu.edu/services/elec-shop/
Glassblowing Facility, 39 Chemistry, http://www2.chemistry.msu.edu/Facilities/GlassBlowing/glass.shtml

CMP Research Groups at MSU

Wanted – website manager for a new cmp Wikipedia site http://cmp.pa.msu.edu/

Gases, Chemicals, and Utilities

See presentation slides by Reza Loloee.
Searching and Managing Scientific Literature

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Keeping Current with Scholarly Literature

*Selected online guides*

*Email Subscriptions*
Sign up at the websites of journals. You will need a good email filtering and reading habit to keep track of the emails.

*RSS Feeds*

**What is RSS?** RSS (Really Simple Syndication) is an XML-based format for sharing and distributing content. The Virtual Journals' feeds are refreshed upon publication of new issues, with the latest additions appearing at the top of the list.

**Where do I get a reader?** There are a number of different news readers available, many of which are freely available. A list of the most popular RSS readers is available for various OS platforms at [http://feeds.aps.org/readers.html](http://feeds.aps.org/readers.html). Note also that Thunderbird and MS Outlook can both serve as an RSS reader. Google also provides a good reader - [http://www.google.com/reader/](http://www.google.com/reader/).

*Example Physics Journals*


- **Physical Review Series**
  Physics, PRL Editors’ Suggestions, PRB Editors’ Suggestions, Topical Cross-journal Feeds (eg. grapheme, magnetic semiconductors, metamaterials, spintronics, topological insulators, ultracold bose and Fermi gases, and many others), and Journal Feeds of Physical Review series

- **AIP Journals**, [http://journals.aip.org/](http://journals.aip.org/)

  Email Alerts for Virtual Journals, [http://vjs.aip.org/vjs/notification](http://vjs.aip.org/vjs/notification)

  RSS Feeds for Virtual Journals, [http://vjs.aip.org/vjs/rss](http://vjs.aip.org/vjs/rss)

- **Virtual Journal of Applications of Superconductivity**
- **Virtual Journal of Atomic Quantum Fluids**
- **Virtual Journal of Biological Physics Research**
- **Virtual Journal of Nanoscale Science & Technology**
- **Virtual Journal of Quantum Information**
- **Virtual Journal of Ultrafast Science**

Reference/Bibliography Management

Databases of Scientific Literature


- Example: How to Customize “Scholar Preference”

Set Bibliography Manager to “Show links to import citations into” Endnote or BibTeX.

- Get the most out of Google Scholar
  - A tutorial video, [http://www.youtube.com/watch?v=9-GfFI2TCQ4](http://www.youtube.com/watch?v=9-GfFI2TCQ4)


- Require subscription, use VPN if you need to access it off-campus
  How to setup VPN via PA at MSU? [http://support.pa.msu.edu/howto.php?s=vpn](http://support.pa.msu.edu/howto.php?s=vpn)


Reference Management Software


- ~$100 through the MSU computer store

- Free classes on EndNote X4 and EndNote Web provided by LCTTP at MSU
  EndNote X4, [http://lcttp.msu.edu/classinfo/detail.asp?course=82364](http://lcttp.msu.edu/classinfo/detail.asp?course=82364)


Comparison of Reference Management Software
On Being a Scientist and a Graduate Student

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On Being a Graduate Student

Selected Resources at Michigan State University
Graduate School at MSU, http://grad.msu.edu/
Graduate Wellness, http://grad.msu.edu/wellness/
Physics Graduate Program at MSU, http://www.pa.msu.edu/grad/

Reading Materials
✓ Guides developed by S. A. Koblinsky, University of Maryland:
  1. “Mentoring - Advice for Doctoral Students”
  2. “Completing Your Dissertation: Strategies for Success”
✓ “How to do research at the MIT AI lab”, http://www.cs.indiana.edu/mit.research.how.to.html

Beyond Academy
Ken Robinson’s Talk on

Selected Books
✓ A Ph.D. is not Enough! A Guide to Survival in Science, by Peter Feibelman

Teaching (not covered in this workshop)
✓ comPADRE – Physics and Astronomy Education Communities, http://www.compadre.org/
The ComPADRE Digital Library is a network of free online resource collections supporting faculty, students, and teachers in Physics and Astronomy Education.

The PhysTEC project is led by the American Physical Society, in partnership with the American Association of Physics Teachers and with continued support from the American Institute of Physics.
Networking – Professional Societies

- Professional societies you should consider join:
    
    Membership: [http://www.aps.org/membership/join.cfm](http://www.aps.org/membership/join.cfm)
    
    Membership is free for the first year for students in physics, related science, and engineering graduate and undergraduate programs.
  
    
    Membership: [http://www.osa.org/membership/default.aspx](http://www.osa.org/membership/default.aspx)
  

Selected online resources

*Berkeley Career Center,*
Academic Job Search & Career beyond the Academy: [https://career.berkeley.edu/PhDs/PhDs.stm](https://career.berkeley.edu/PhDs/PhDs.stm)

Online workshops: [https://career.berkeley.edu/MM/Workshops.stm](https://career.berkeley.edu/MM/Workshops.stm)

*Stanford Career Development Center,*
Resources for PhD/post docs [http://studentaffairs.stanford.edu/cdc/phd-post-doc](http://studentaffairs.stanford.edu/cdc/phd-post-doc)

Wisc: Graduate Student Professional Development Career Planning, [http://www.grad.wisc.edu/education/gspd/careerplanning.html](http://www.grad.wisc.edu/education/gspd/careerplanning.html)

Physics Today jobs, [http://www.physicstoday.org/jobs/seek/resources.html](http://www.physicstoday.org/jobs/seek/resources.html)

Nature Career Toolkit, [http://www.nature.com/naturejobs/career-toolkit/index.html](http://www.nature.com/naturejobs/career-toolkit/index.html)

Science Careers (from the journal Science), [http://sciencecareers.sciencemag.org/](http://sciencecareers.sciencemag.org/)
Appendix A – Handbooks and Database

Fundamental Physics, Chemistry, and Mathematics


Laser and Light Sources


Materials


**Semiconductor Properties**, [http://cleanroom.byu.edu/semiconductor_properties.phtml](http://cleanroom.byu.edu/semiconductor_properties.phtml)
Appendix B – Laboratory & Research Notebook/Journal