PY581: Physics Advanced Laboratory
Syllabus: Fall 2010

Lab meeting time: Mondays, 10:00 to 6:00; initial session in B58

Lab locations: SCI 132 and SCI 128 Monday, 10 am - 6 pm; initial session in B58

Presentations: 10 am SCI B58, first session, for seminar series, and when announced

Lab Director: Steve Ahlen, ahlen@bu.edu
Office: PRB 275
Phone: 353-8940
Office Hours: Monday 10:00 to noon, and 1:30 to 6:00 in SCI 132, and by appointment.

Teaching Assistant: Dave Newby, dhnewby@gmail.com

Lab Technical Coordinator: Mark Badway, makjon1@bu.edu

Prerequisite: PY354, Modern Physics, or equivalent

Course information: Course information will be distributed by email and will appear on the course Blackboard website (http://blackboard.bu.edu/). Please check your email daily to keep informed.

Recommended references:

Course description: Our goal is to emulate a working research lab and to familiarize the students with experimental methods and techniques. We will not teach, but will help you learn to discover physics and to use the tools that are needed to do this. Several experiments are available to give you a broad overview of current technology. PY581 will give you hands-on experience in a typical physics research environment. You will collaborate, working in teams of two. However, your written reports and seminar presentations will be prepared independently. You will quantify results, complete with statistical and systematic error bars. You will refine your skills at setting up and calibrating equipment, taking and recording data, analyzing data, evaluating errors, and preparing professional quality reports on your work.

The labs are generally not “cookbook” recipes. You are expected to learn about the experimental procedure from wherever you can, e.g. previous work in the literature, manuals, materials in the lab, textbooks, the library, and in discussion with your collaborators and colleagues. You must do your
“library” preparation BEFORE you appear in the lab. Your “deliverables” are oral and written presentations of the results.

Safety:
We take safety very seriously in PY581. It is your responsibility to do so too. In our first session, we will meet at B58 for a lecture on lab safety by Ron Slade of the Office of Environmental Health and Safety. While every effort will made to ensure your safety, you are required to know the hazards involved in each experiment that you do, including high voltage, high current, laser light, cryogenic temperatures, ionizing radiation (e.g. x-rays and radioactive sealed sources), etc.

1) No experiment should be undertaken before receiving a safety briefing from one of the instructors regarding possible hazards of the experiment before working with the apparatus.

2) Report any problem, incident, injury, or contamination to the professor immediately.

3) Absolutely no food, drink, cosmetics, gum or evidence thereof are permitted anywhere in SCI 128 or SCI 132.

If you are hungry, take a break and go to the Science Fare or elsewhere, alerting the Lab Director or the Teaching Assistant before leaving. Disregarding safety rules or instructions will result in severe consequences.

Your Experiments:
You and your collaborator will perform 4 experiments from the list below. To hone your data analysis skills, the first assignment will be measuring and fitting data from the decay of a short-lived radioactive source. Then you will write up the analysis and conclusion sections of a report for this work.

You will devote four sessions to each of the subsequent three experiments, i.e. you will focus for a month on each. The last 8 sessions are shortened by your seminar presentations (see below). See the “Calendar for PY581 Researchers” on the course website.

Lab reports will be due the Monday following the completion of each lab.

First Session, rotation of collaborators, choice of experiments:
After the safety lecture, you will team up with a partner for the lifetime experiment. For subsequent experiments, you will have a different collaborator. After the lifetime experiment on day 1, we will tour the equipment in PY581 (see attached list of experiments) and you will determine an ordered list of what you would like to do. The Lab Director will review your lists and will put together a schedule.

Lab Notebook:
Each experiment has a dedicated quad “lab book of record” assigned to it for use by both collaborators for all data and observations taken in common. Entries are in ink. Do not use pencil. Single, clean, strike-throughs for corrections are the appropriate way to “erase.” It is often useful to review what has been “erased” since sometimes these erasures are incorrect. At the end of each experimental session, you should copy whatever might needed from the lab book so that you have complete data for your report and presentation. You should also keep personal notes in your own book.
Lab Reports:
While data are taken and logbook entries made in teams, the data analysis and lab report are to be solely the work of each individual student. Reports must be prepared according to the style manual of the prestigious journal, Physical Review Letters. You will want to go to the web page and download their style manual so that you can follow their guidelines, format, etc. for submission for publication, including page limitations. Copying a paper or two from the journal to mimic is always helpful.

You must learn to write succinctly, keeping no more than the details necessary for another scientist to verify and to build upon your results. You should make every effort to make your paper acceptable for publication. It must be coherent and well organized. The choice of word processor is up to you. The senior lab officials refuse to read any paper that is not spell-checked or that does not conform to Phy. Rev. Lett. style.

Except for Report 1 (which is limited to analysis and conclusions) each paper will generally contain the following sections (see the samples of previous years’ work on the bulletin board outside the lab).

1) The top of the Title page: includes the name of the lab, author (first in order) and collaborator, an abstract, the beginning of the paper, and a date at the bottom of the page. Your signature certifies that the writing and analysis is yours alone.

2) Abstract on the title page: a few sentences that describe the objectives of the lab and the results. It should say all that is necessary to entice a reader to peruse the entire text. Continue to fill up the first page.

3) Introduction and Motivation on the title page: state what you intended to measure and why. Provide adequate motivation with a short discussion of the physics explored. A short presentation of the theory with relevant equations and references is appropriate. Trace the origin of equations you are using to well known physics, and reference them. Detailed derivations are not appropriate since this is an experimental paper; we are interested in the line of reasoning, not details of derivations.

4) Experimental Setup: describe the apparatus, instrumentation, and data taking procedures. A drawing or two is absolutely essential.

5) Data and Error Analysis: present your data in tabular (with errors) and/or graphical form (with error bars). Usually both are helpful, but graphics usually get the point across better. Perform statistical error analysis. Quote chi-squared goodness of fit and number of degrees of freedom for any fits. Quote statistical errors and identify and quantify the main systematic error sources.

6) Discussion: compare your results with those expected from theory. If your numbers disagree with expectations beyond the errors, suggest possible sources of problems with the measurements. If your numbers agree with expectations, suggest possible ways to improve the precision of the measurements in future work.

7) Conclusions: a brief summary of the results and what you learn from the experiment. This will be very similar to the abstract.

8) References and acknowledgements: Thank your collaborator and anybody else who provided assistance.
Seminar Presentations:
You must convince your thesis advisor, lab director, boss, peers at the annual meeting of your professional society, the venture capitalist or the funding agent, that the results you obtained are valid. Otherwise it is all for naught. Generally, before reading your paper, they will judge your work by your oral presentation. Starting at our ~6th session, we will have two 25-minute no-frills power point or overhead presentations at 10 am in B58. Each will distill the essence of one of your Reports. Part of your grade will come from the questions and helpful critique you provide to the speaker after each presentation.

Data Analysis Tools:
You should use what you are most familiar and comfortable with. If your expertise with the various programs available is not sufficient, it is your job to learn what you need. In the old days, one would write Fortran (or now C++) programs to do their own analysis. This is generally not necessary now since there are many free and commercial options available. These include, but are not limited to:

MATLAB
Mathematica
Excel
Root (freely available at CERN’s website, and it can be installed on all platforms, including PCs

Grading:
1) Completion of four experiments, including logbook and Reports.
   Lab 1 Radioactive data fit: 10%
   Labs 2-4 at 20% each 60%
2) Oral presentation: 20%
3) Class participation, attendance, independence, innovations, etc. 10%

Missing Class and Late Penalties:
Late/incomplete report: 1/4 grade step per day
Missing Class without prior agreement by the Director: 1/2 grade step
   (One grade step = A to A–, A– to B+, etc.)

Initial, Easy Experiment
• Ba-137 Radioactivity Decay – each student will measure and fit a lifetime

Straightforward experiments that are not difficult
• Optical Pumping of Rubidium
• Pulsed Nuclear Magnetic Resonance
• Bifurcation and chaos in water droplet flow
• Double Slit Diffraction with Single Photons
• X-ray Diffraction Crystallography
• Compton Scattering
• Faraday Rotation
• High Tc Superconductivity
Experiments that take the most time to do

- Planck's Law for Black Body Radiation
- Mossbauer Spectroscopy
- Quantum Hall Effect and Superfluid Helium
- Lifetime of the Muon
- Zeeman Effect