GENERAL INSTRUCTIONS

“Perfect logic and faultless deduction make a pleasant theoretical structure, but it may be right or wrong: the experimenter is the only one to decide, and he is always right.”
— L. Brillouin, 1964

Course Objectives:

P551 is an advanced laboratory course in which you will carry out experiments that probe various aspects of modern physics, *i.e.*, the quantum-mechanical nature of solid-state, atomic, nuclear, and particle systems. This course has two primary objectives:

1) to acquaint you with some of the experimental methods and equipment used in present-day physics research laboratories, and introduce you to a variety of general techniques (computer-based acquisition, high-vacuum environments, etc.) frequently encountered; and

2) to provide an opportunity for you to deal with “real” data and confront real technical problems (*e.g.*, faulty electronics!), analyzing your results and coming to meaningful conclusions within the context of our current theoretical understanding, mindful of the errors and uncertainties encountered in your measurement.

In this course, I want to strongly encourage student independence and initiative. Rather than performing experiments “cook-book” style, my hope is that you will go beyond the minimum required; once you have identified the main physics issues to be addressed (from your prior reading), you will attack the problem with all of the resources available in the laboratory. Turning on switches and recording a string of numbers is *not* the way physics research is done! It is, by necessity, a slow, often frustrating experience, but one that can lead to great insight, excitement, and a true sense of accomplishment, as seemingly insuperable obstacles are overcome, one by one. With a bit of effort on your part, this course can provide you with a ‘taste’ of what physics research is all about — the good, the bad, and the occasionally ugly.
Course Structure and Requirements:

In keeping with the above goals, the structure of the course will be fairly flexible. There are approximately a dozen experimental stations throughout the lab. During the course of the semester, you will be expected to become familiar with, and carry out some set of measurements on, about 5 or 6 of these. For most experiments, this should take about one to three weeks, depending on the complexity of the apparatus and the difficulty of the analysis you perform. It may also take less time if you work with a partner, rather than alone.

It is possible that at some point in the semester, if the opportunity arises, you may decide to pursue some experimental question which is new to this lab. This might involve an investigation, based on your readings and previous work with the apparatus, into some more subtle aspect of the original measurement, or even an entirely new type of test. This level of exploration is highly encouraged! While any endeavor of this sort must receive my approval before you can proceed, I will usually try to help you along, providing assistance and possibly even buying new equipment (if we can afford it. Ask!)

Whenever you are in the lab, you will be expected, as is common practice, to record all of your activities and measurements (as you do them) in a personal LOG BOOK (see below). At the conclusion of an experiment, you will often write a REPORT (see below). Though you might actually perform 5 or 6 different experiments, you will only need to write up 3 of these in formal reports.

Some general guidelines on lab organization:

- Once you decide which experiment you wish to perform next, sign up on the white board to reserve that equipment at least one week in advance.

- Before starting the lab, read over the appropriate handouts. These will usually provide a brief overview of some of the physics principles involved, a description of the apparatus, and some suggestions for procedures to follow. The handout will also contain some recommended texts for further reading.

- The references mentioned in the handout should be on 24-hour reserve in Swain library. Read these over; if there is a problem, let me know.

- Some experiments will involve equipment which is new to you. Try to read over the appropriate instruction manuals in advance.

- Some experiments will also involve equipment or materials which are expensive or fragile or potentially dangerous! See the section on Safety below. If in doubt, PLEASE do not hesitate to ask the instructor!
Safety:

There are several potential safety hazards in this laboratory, primarily involving high voltages or radioactive sources. You will be instructed on safe handling procedures and the use of monitoring equipment. A copy of the University Radiation Safety Regulations is also kept in the laboratory for your reference. Please look it over.

In brief, the small radioactive sources should be handled in such a way as to minimize exposure. Your level of exposure will be proportional to the time that you handle the source, and will fall like \(1/r^2\) – so don’t put them in your pocket! After use, radioactive sources should be returned to the instructor for storage. Two items are sufficiently ‘hot’ that they can be used only under the direct supervision of the instructor: the Neutron Beam Irradiation Facility, and the \(^{57}\)Co Mössbauer source. Because radioactive sources may be in use, eating and drinking are not allowed in the lab.

The photomultiplier tube power supplies can generate fairly high voltages (~1000–1500 V). Though these supplies are current limited, they can produce a nasty shock if mis-handled. Just to be safe, never work alone around apparatus using high voltage.

Log Books:

One of the most difficult things to learn, yet one of the most important for future success in physics research, is mastering the ‘art’ of maintaining a proper log book. You should keep a detailed log of all your activities in the lab. Because this is so important, I will require that you adhere to the following “Lab Book Rules”:

- Use a bound notebook, not loose sheets of paper. Extra material, such as computer printout, photographs, etc., may be pasted or taped into the book.

- Make sure your logbook has numbered pages.

- Skip the first page or two to use for a Table of Contents.

- Start a new page for each experiment, but otherwise do not leave blank pages. If you have work to add from a previous experiment, just indicate this with a brief note (“Continued on page 57”).

- Date every page, and record the time of the day for each important entry.

- Always write directly into your log; NEVER work on loose scraps of paper, and then copy things into the book. Even ‘mistakes’ often turn out to be important!
• For the same reason, do not use pencil. If you discover that something was wrong, “x” it out so that it is clearly marked as being in error, but is still legible. Never use White-out, paste over, or (worst of all) remove pages!

As far as deciding what should be entered into your log book, this is largely a matter of personal taste. A few general guidelines might be:

• When you start a measurement, state briefly what its goal is – just a few key phrases to remind yourself exactly what you will be trying to do.

• As you go along, jote down enough information to indicate what you are doing at that moment. Remember to note the times.

• Provide diagrams (sketches, electronic schematics) of the apparatus, with complete information on settings of controls and other relevant instrumental data. As a rule of thumb, these should be sufficiently detailed that you (or someone else) would have no trouble reproducing your experimental setup.

• All measurements should be recorded immediately and directly. Any necessary arithmetic (to convert your numbers to other units, to average two numbers, etc.) should be done in a second step, and also recorded. Remember to record the units for dimensioned quantities, and always estimate the uncertainties in any measured quantity.

• Any time your measurements result in a list of numbers (e.g., determining how a quantity $y$ depends on the setting of $x$), you should immediately convert this information into a graph. This will not only often provide some ‘intuition’ about their correlation, but will usually allow you to spot quickly any departure from a smooth dependence, which might indicate a problem with the equipment or an error in that single measurement.

• If possible, as soon as you finish collecting the data, present some preliminary conclusions: what worked, what didn’t, and what else will need to be done to complete the analysis.

Reports:

You will need to convert your lab notes into a final written report for three of the experiments you perform. These will be due approximately 6, 10, and 14 weeks into the semester. Each report should be brief, yet sufficiently detailed that a reader familiar with the physics, but not with your specific measurement, can figure out what you have done, why you did it, and what you have learned from it. See the sample guide on how to write a research paper.