Physics 201: Lab Requirements and Experimental Descriptions

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Winter Term 2010-11

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Lab Requirements

Here are a few guidelines for your lab book:

1. Records and description of what you have done in the lab are to be kept in a hard cover lab book, preferrably one with included graph paper.

2. The *Prelab* questions are not required unless specified. They are meant to be a refresher for some of the questions you will be dealing with.

3. Have a *Purpose*! Yes, you should write down the "Purpose" as a part of the lab but you literally should have a purpose or goal. And I don't just mean "My purpose is to do the lab." You should know prior to taking data just what it is you want to accomplish. In principle you could follow blindly follow a recipe without a title and get the correct final product but I wouldn't recommend it. Likewise without a goal in mind, that you stick to, your lab will not be coherent and unified; it won't have any purpose. You will go back to the clichéd "Our result came/did not come within experimental error" for a Conclusion.

4. Your lab book should look like a working journal. Since it is a journal it is bound to be a little messy. That is a good thing! When is it too messy? If the data should have been in a table and instead it is scrawled all over the place you should clean it up. If it is so messy that one week later you would have no idea what you did it is too messy. Slow down, leave more space, be a bit more organized. Of course the two most common problems aren't messiness. They are *I'll get the data from my partner later.* and *I'll just write it on scrap paper for now.* This year I am going to be stricter on these counts. **I will check your books before you leave the lab to make sure you have complete raw data tables written in ink. If they are not there I will consider the lab incomplete.**

5. The parts of a lab write-up I would usually expect to be included are title, partner's name, date, purpose/hypothesis, answers to prelab questions if necessary, important elements of apparatus (with a sketch/drawing as appropriate), theory, important elements of the procedure (could someone reproduce what you have done based on the lab handout and your lab book? could someone make sense of the data recorded based on what you have written down?), data tables (see above), refined/transformed data if appropriate, graphs (with labelled axes, slope values on graph, generate either by hand or with a computer but not Excel!), data/error analysis, discussion/conclusions. Conclusions should touch on your purpose, limitations, and possibly extensions/improvements of the experiment. Again if it is messy, that's fine. A few rough notes and comments add character. I sometimes use your old lab books to reproduce experiments and use data in illustrations.

6. The figures/graphs need to be of **high quality** and they can be of high quality based on my experience with these experiments. In most cases they say how the successful the experiment was or wasn't.

7. The computers in the lab are set up with "SigmaPlot" which I find easy to use. It does not calculate "max/min" slopes but you really should work on your technique for this error estimation in any case. One thing it does that is extremely handy is "Quick Transform" which allows you to make easy modifications of the raw data all at once (so you aren't doing the same step with your calculator over and over). There is also a laser printer in the lab. Please trim the graphs and paste/tape them into your book.

8. The conclusions/discussions should be there and they should be **thoughtful**. You should definitely compare your result and its uncertainty to the commonly accepted value but this by itself isn't sufficient. This section is usually where I try to determine what you learned from the lab. This is a big challenge for students but it is worth the reward.

   Here are a few additional things that you might think about:

   (a) What is the biggest limitation of the experiment? Are there easy ways to improve the experiment? Again be *thoughtful*. I don't consider another 20 hours of measurements with a reduction in error from 10% to 9% to be that fruitful but a couple of extra trials to reduce error by half is a great idea.

   (b) Don't immediately assume that the "junky" part of the experiment is the biggest source of error. For many experiments the analog meters or metre sticks do a fine job compared to the other elements.

   (c) Don't just say "reading error"! What does that mean? I think of the classic "reading error" as you try to make a measurement of the length of an object and you need to read "between the lines". If you have a rod with that is less than 100 cm in length and you use a metre stick that is marked in cm to try and make measurements to the nearest mm, then yes, there is a reading error. I would estimate 2-3 mm. But suppose the metre stick is marked in mm and you try to estimate tenths of mm. Most students blindly say the error is 0.2 mm (and this is a reading error) *but* is this the total error? Suppose the ends of the rod aren't flat? Is the metre stick really calibrated this accurately? Are you measuring exactly parallel to the rod? All of these things contribute to the error and I can think of situations where they would be bigger than 0.2 mm and reading error would be unimportant. (Using a stop watch and quoting 0.01 s is another example where the reading error is dominated by other uncertainties.)

   (d) Are there systematic errors? Usually this manifests itself as approximations you made in the theory. In a well designed experiment these effects are small compared to the other errors but they can creep in. Data that doesn't fit straight lines when it should is a sure indication of a prominent systematic error. That is one of the reasons we make plots rather than just plug a few numbers into a formula.

   (e) Just plain old mistakes. Yup, they happen. You hope to catch them before you leave the lab but if you don't try and figure out what happened and how this affects your conclusions.

9. Another thing I want you to develop is your experimental technique. These experiments usually involve several components working in concert. What do you expect from each of these sub-units? Can you test their function? Jim and I are happy to help but it doesn't

hurt for you and your partner to take a couple of minutes to think things over. It is almost always easiest to do this one piece at a time rather than just say "it doesn't work". There are handheld voltmeters available for testing.

Lab Handouts

The lab handouts are also on-line www.stfx.ca/people/cadams and follow the links.

Lab Schedule

We will spend the first week on the uncertainties/pendulum lab. After that let's consider two groups of labs: Experiments 2,3,4,and 8 will form one group and then Experiments 1, 5, 6, and 7 will form the 2nd group. We will take 3 weeks to do the first two "Modern Physics"labs. I may ask you to extend measurements or ask questions beyond the lab handout. After that it is probably easiest to cycle through the labs in the 1st group and then we will switch to the second group. That will give you the chance to change partners.

Marking

Lab collection days are in the course description. I will mark the first lab out of 10. Out of the remaining 8 labs I will formally mark 3 labs (you can pick two, I will decide the other). Each one I will mark out of 10. Four others I will give a quick look over to make sure everything is complete, assigning a mark out of 5. They will be worth half as much as the ones marked out of 10. One lab, which you pick, will not be marked. (even if I don't mark the lab you will still be responsible for its content as it relates to the course). I will expect to see your records but I won't look at the analysis. Indicate which ones you want marked and for how much in the Table of Contents. I will be a bit more forgiving with late lab books compared to assignments but YOU MUST ASK ME. I won't consider not handing the book in reason to grant an extension. Late work will be penalized as an assignment.

Experiments

Here is a list of experiments along with an estimate of the relative uncertainty. I also mention Nobel Prizes associated with these experiments (Yes, at the time these were groundbreaking experiments. We are greatly aided by hindsight and modern equipment.)

1. Franck-Hertz Experiment: prove the existence of quanitized energy levels in mercury without using light. Instead use the inelastic scattering of electrons. Uses a computer and Labview to assist in the data collection. 1% error (Nobel Prize 1925)

2. Photoelectric Effect: show that the amount of energy that can transferred from light to an electron in metal is quantized. Show that the photon energy is proportional to frequency and obtain a value for Planck's constant. 15% error (Einstein 1921, Millikan 1923)

3. e/m of an Electron: confirm the existence of the electron and show that it has a definite charge to mass ratio. 5% (von Lenard 1905 ,J.J. Thomson 1906)

4. Millikan Oil Drop: confirm the existance of quantized charge and measure its value e in the classic experiment. 1% (Millikan 1923)

5. Electron Diffraction: confirm the existance of matter waves and the correctness of the de-Broglie relation. 5% (de Broglie 1929, Davisson and G.P. Thomson 1937)

6. Balmer series: investigate the spectrum of atomic hydrogen and show that the spectral lines agree with the Bohr model. Find a value for the Rydberg constant. 5% (Bohr 1922, work of Rydberg, Ritz, and Balmer predates the Nobel Prize)

7. Radioactivity: look at different types of ionizing radiation and see how they are affected by shielding. Also verify the inverse square law. (I am considering a modification of this lab to allow for measuring the energies of β particles and important key to the discovery of the neutrino and the weak force.) (Bequerel, Curie, and Curie 1903)

8. Speed of Light: with a rotating mirror. Quite a bit of error (20%) but an interesting experiment that requires some experimental skill. (predates Nobel Prize but was work done by Fizeau, Focault, and Wheatstone in the mid to late 1800's.)

Demo Experiments

I also show various demonstrations through the term of different experiments.

(a) Kater's Pendulum: accurate measurement of g.

(b) Michelson Interferometer: look at the student version of the device used to look for motion through the ether.

(c) Zeeman Effect: splitting of spectral lines in the presence of a magnetic field.

(d) Sonoluminesence: conversion of sound into light. The "star in a jar"! More of an observation lab.