Chapter 10

Student Designed Experiments

The rest of the course (up to the final) consists of student designed experiments. The process for the student designed experiments is as follows:

1. You and your lab group fill out a brainstorming sheet to come up with possible experiments. You and your lab group prioritize the list and hand it in.

2. From that list I will approve an experiment to try.

3. You will have to write a proposal that describes what you plan to do for your experiment.

4. Upon approval, you will perform the experiment, and report on the results in a written paper and a (formal) oral presentation.

We have talked about each of these parts along the way. In this section of the manual, I will describe what I am expecting for each of these assignments. You will have seen some of this before.

10.1 Proposal

You already have produced a proposal. This document was what you used to convince me that your experiment could work and that you should be given the resources and support to perform the experiment. Your proposal has the following parts:

1. Statement of the experimental problem

2. Procedures and anticipated difficulties

3. Proposed analysis and expected results

4. Preliminary List of equipment needed

We will now reuse these parts to perform the experiment and produce your final paper and presentation.

10.2 Performing the experiment

I will provide you with the equipment we have agreed upon from your proposal. You will have three lab days to perform your experimentation. I will be available for advice and to watch for problems or safety issues. But you and your team will perform the experiment. You will want to keep good notes in your lab notebook. You will likely have to change your procedure after you start because of problems. Take careful note of what was actually done, and what your measurements were. Note any unusual things that happen. Carefully record what you do.

10.3 Written report

The written report is designed to match a normal format for an applied physics article in a journal like*Applied Optics* or the *IEEE Transactions* journals.. There should be an introduction, description of the procedure, description of the data and results, a description of the analysis, and a conclusion. These sections are described in detail in the following table.

10.4 Oral report

Your group will have ten to fifteen minutes to explain your experiment and present your results and conclusions. I will grade your presentation on the following areas:

Professionalism in the delivery	25
Clarity of the delivery	25
Quality of Visual Aids	25
Team support and Participation	25
Total	100

The format of the presentation should follow the format of the written report. Don't forget to give proper credit for pictures, or ideas and quotations in your presentation just as you will in your written report.

10.5 Lab Notebook

Hopefully you noticed that a lab notebook is required for this class. The lab notebook is designed to be a record of what you did. If you had to repeat today's experiment five years from now, could you do it based on what you write today?

At most professional labs and major engineering companies your lab notebook is considered the property of the company or organization. It is the proof that you did the experiment that you say you did, and that you got the results you say you got. It has to be readable and understandable to someone who did not participate in the lab with you. This is a pretty tall order.

Of course the evidence that you participated in the group project will all be found in your lab notebook. You have had experience in PH150 and throughout PH250. So you are an expert in keeping lab notebooks. But as usual with a group project not all of what happens will be written in your notebook. Some will be in your coworker's notebooks. That is fine, because you know to refer to that work in your notebook with a reference to the notebook of the person that did the work. Note that the grade for the lab notebook is a large part of your semester grade, this represents the fact that your lab notebook is a large part of what a scientist does. Remember that the lab notebook must be kept *as you go*. It is not OK to try to recreate it after the experiment is over. This takes time away from fiddling with equipment and thinking about procedure, but it IS PART OF PERFORMING THE EXPERIMENT. So recreating something at the end is the same as not doing the assignment. When you are practicing in your field you will find that courts of law feel the same way about lab notebooks. To prove you own the intellectual property you have developed, the lab notebook has to be kept *as you go*.

Here are reminders from PH150 on how to keep a lab notebook:

10.5.1 Designing the Experiment

In PH150 we learned that to design an experiment we needed the following steps. Some evidence of these steps should be found in your lab notebook:

1. Identify the system to be examined. Identify the inputs and outputs. Describe your system in your lab notebook.

2. Identify the model to be tested. Express the model in terms of an equation representing a prediction of the measurement you will make. Record this in your lab notebook. (If you have not solved this problem in your PH121 class yet, call me over and we will go through it together).

3. Plan how you will know if you are successful in your experiment. Plan graphs or other reporting devices. Record this in your lab notebook.

4. Rectify your equation if needed. Record this in your lab notebook.

5. Choose ranges of the variables. Record this in your lab notebook.

6. Plan the experimental procedure. Record this in your lab notebook.
7. Perform the experiment . Record this in your lab notebook (see next section). You will need your uncertainty equations from the proposal.

10.5.2 Performing the Experiment

Step 8 is really many individual steps recording the actual performance of the experiment. You learned this in PH150, but here is a review of the criteria I will use to grade your lab book:

- Describing the goal for the work
  - Usually this takes the form of a physical law we will test.
- Give predictive equations and uncertainties for the predictions based on the physical law.
  - This usually involves forming a mathematical model. You should record any assumptions that went into the model (e.g. no air resistance, point sources, massless ropes, etc.).
- Give your procedure
  - Recording what you really did (not the lab instructions), tell what changes you make in your procedure as you make them.
  - Record as you do the work.
  - Record the equipment used and settings, values, etc. for that equipment (see next item).
  - Did you learn how to use any new equipment? What did you learn that you want to recall later (say, when taking the final, or when you are a professional and need to use a similar piece of equipment five years from now).
- Record the data you used. . The data are all the measurements you took plus your best estimate of the uncertainties in the measurements. Record any values you got from tables or published sources (or from your professor) and state where you got these values. You don't always want to write down all the data you use. If you have a large set of values, you can place them in a file, and then record the file name and location in your lab notebook. Make sure this is a file location that does not change (emailing the data to yourself is not a good plan).
- Give a record of the analysis you performed. You should have given some idea of how you got your predictive equation. Now, what did you do to get the data through the equation? Were there any extra calculations? Did you obtain a set of "truth data" (data from tables or published sources, or from an alternate experiment) for your experiment? If so, did you do any calculations, have any uncertainty, etc. associated with the truth values?

- Give a brief statement of your results and their associated uncertainties.
- Draw conclusions
  - Do your results support the theory? Why or why not? What else did you learn along the way that you want to record.
  - This is where we may compare the percent error to our relative uncertainty.

This may seem like a lot of work (that is because it IS a lot of work). It takes practice to be able to do this professionally, which is why we do it here.

Section/Value	50-40pts	40-30 pts	30-20 pts	20-0 pts
Introduction: **Answers the question "what is this lab about?"**	• Answers the question "what is this lab about?" sufficiently that a person who did not perform the lab would understand • Gives enough background so that the lab report makes sense as a stand-alone document • Tells the reader what your expected outcome is based on theory.	• Answers the question "what is this lab about?" sufficiently that a person who was part of your lab group would understand • Gives enough background so that the lab report makes sense to someone who knows the lab topic well	• Mentions what the lab is about • Gives some background	• It is difficult to tell from the introduction what the lab is about • Little or no background provided
Procedure: **Answers the question "what did you do?"**	• This section answers the question "what did you do?" sufficiently so a non-expert can understand what was done. • Describe the entire procedure, especially indicate any deviations from your plan and explain why those deviations were necessary.	• This section answers the question "what did you do?" sufficiently so your lab partner could understand what was done. • Tells where you deviated from the plan	• Major points of the procedure are listed	• It is difficult to tell what you did from your description
Data: **Answers the question "what did you measure?"**	• Each measured value is given with units • Each value is given with a good estimate of uncertainty • Only measured values that are needed are given • The data is presented in a way that is easy for the reader to find and read. (e.g. label graphs and table columns)	• Each measured value is given with units • Each value is given with an estimate of uncertainty • Extra values that were not needed are given	• measured values are given	• It is not clear what you measured
Analysis: **Answers the question "how did I get from my data to my results?"**	• It is clear how you got from your measured values to your results • Major equations are given and discussed. • The method of determining uncertainties is discussed	• It is possible to tell how you got from your measured values to your results • Major equations are given • The method of determining uncertainties is discussed	• It is possible to tell how you got from your measured values to your results • Major equations are given • Method of determining uncertainty is not discussed	• It is not possible to tell how you got from your measured values to your results • Major equations are missing • Method of determining uncertainty is not discussed
Results: **Gives the results of your analysis**	• There is a clear, understandable answer to the question the lab asks. For example, if I ask you how fast a car is going, the result would be a calculated speed, with its calculated uncertainty and units. • Report percent error or percent difference • Report fractional uncertainty	• There is a an answer to the question the lab asks with uncertainty and units • Report percent error • Report fractional uncertainty	• There is a an answer to the question the lab asks • uncertainty and units are missing • Percent error or fractional uncertainty is missing	• There is no clear answer to the question the lab asks • Percent error or fractional uncertainty is missing
Conclusion: **Answers the question "did the experiment show what was intended?"**	• There is a clear discussion of whether the experiment was supported or falsified the theory. • This discussion includes a comparison of the percent error and fractional uncertainty • If there were difficulties, they are discussed here • There is a statement of what you learned from this experiment. Note any problems and how you would resolve them if you were to redo this experiment.	• There is a general discussion of accuracy (often with percent errors quoted) • There is some mention of whether the predictive theory is supported • Problems are noted and how you would resolve them if you were to redo this experiment is discussed.	• There is no comparison of the percent error and fractional uncertainty • There is a statement of what you learned from this experiment.	• There is no outcome of the accuracy of the experiment • There is no comparison of fractional uncertainty and percent error • There is no clear conclusion about the predictive theory • There is little mention of what was learned