

Physics 143 Lab Guide

Fall 2009, Duke University, *Prof. Joshua Socolar*

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1 Introduction

Welcome to the Physics 143 labs! These labs are intended to be less cookbook-style than previous labs you have encountered. You will sometimes have to solve challenging, open-ended problems, just as you would in a real-life lab... but you are *not* on your own. **Please do not hesitate to ask for help** if you are puzzled or otherwise stuck. We will meet in Room 005 (the sub-basement on the math side of the building) for all labs.

NOTE WELL: You should approach each lab as if nobody in the world had ever reported a result for it before. Your conclusions should state what your own measurements allow you to conclude about the physics at hand. Only after you have reported your own results (and essentially completed the lab) should you consider whether they are consistent with accepted values. **This is important: we are not interested here in conclusions based on comparisons of your data to measurements made by someone else.** There is a place for that, but in this course it is of secondary (very little) importance.

2 Description of the Labs

There are seven experiments (of which you will get to choose five to complete for your 'regular labs') and two shorter experiments (Lab 0A and 0B) which serve as an introduction to error analysis. Everyone will complete Lab 0 in the first two weeks, but there is no particular order required for the rest of the labs. You will sign up for your top five on the day of Lab 0B. All of the experiments should work, but some will be easier than others. You will be sharing the apparatus with your peers in the other session, so try to be neat and understand that it will most likely be adjusted in between the two

periods you will be working on it. (Good lab notebooks will allow you to put it back the way you had it!)

Lab 0 Data and error analysis of a random process

Part A: coin flipping

Part B: reaction time and the oscilloscope

Lab 1 Measurement of the Speed of Light and Other Waves

Lab 2 The Michelson Interferometer

Lab 3 Two-Slit Interference, One Photon at a Time

Lab 4 The Blackbody Spectrum

Lab 5 The Photoelectric Effect and a Measurement of Planck's Constant

Lab 6 Measurement of e/m and Electron Diffraction

Lab 7 Electron Diffraction

Lab 8 Muon Physics

Each regular lab requires approximately 4-6 hours to complete and so there will be a two week rotation. The first week of a regular lab is called an "A" week, with the following "B" week giving time to complete the lab. The limited time means that you will not be able to get the most out of the lab unless you come prepared to start immediately.

3 Lab Notebooks

It is essential that you bring your lab notebook to each lab session. You need one that will allow you to make a copy of every page, since you will be handing in a copy of your notes to the TA. There are two types available for you to purchase at the Bryan Center: National Brand (100 carbonless sheets and Hayden McNeil (100 carbonless sheets, or you can buy an equivalent somewhere else. In the past students have also used Avery-Dennison #43-649, 'Laboratory Research Notebook,' 200 pages with carbons.

In your future career as a scientist, you will need good lab notebook skills. Your lab notebook is a legally admissible document of the work you've done and when you did it. You can use a good lab book to prove you discovered something first, or to prove to your boss that you weren't just playing Duke Nukem. A good lab notebook should include:

- a rough sketch of the arrangement of your equipment,
- most of your key equations,
- a thorough list of your apparatus and procedure,
- and all* of the data that you collect.

The goal is that you will be able to pick up your lab book after five years have gone by and understand what you were thinking way back in 2009. It is also important that all the data you take is left in even if you later decide it's no good. Any mistakes should be crossed out with a single line (they might not turn out to be mistakes) and no white pages should ever be ripped out for any reason.

What does that mean for this course? You are required to purchase a lab notebook and bring it to each session. Everything you do should go down in the book. That includes your procedure, apparatus, and calculations performed during the session. This doesn't have to be in essay form, but legibility and clarity are essential.

Jotted notes are not good enough – remember, this is for you to look at 5 years from now. 'Wt. Dr' may seem clear to you when you write it down, but we guarantee that you'll have no idea what it means six months from now. Also, if you decide to change your procedure half way through, that's fine! Just write down the change and what made you decide to make the change. At the end of each day (both "A" weeks and "B" weeks, and starting with Lab 0B), the TA will collect your copies of that day's notes and keep them for reference and evaluate them for clarity.

Will you spend all your time writing stuff down? Yes, at first it will seem that way. But careful note-taking is an essential part of all science. Soon it will become routine. Your lab notebook should look more like a comic book or a diary rather than a novel; don't bother making it a work of art, but do show the action and the results clearly.

Since some of the labs require a lot of data taking, it is fine if only one person records the data in his or her lab notebook and/or in a spreadsheet and the rest of the group just references the spreadsheet. In addition, however, you must demonstrate that you participated in the lab by writing down in your notebook which tasks you completed.

4 Pre-Labs

Note: A pre-lab is not required for the very first labs (Lab 0A and Lab 0B).

Every person is expected to hand-in a pre-lab for the five regular labs. Its purpose is to get you thinking about the lab beforehand so that you can use your time in the lab effectively. You should turn this into the TA as you enter the lab. If you choose not to complete a pre-lab then it will be taken as evidence that you didn't come to lab prepared to participate.

The pre-lab write-up should contain:

- the date,
- your name at the top and your partner's name right below it,
- the experiment you are working on
- a brief (4-10 sentences) description of the physical principle that is being tested or measured, and
- a description of the apparatus and how you will use it to take data.

Leave the rest of the page blank. You will continue taking notes at the beginning of the next page. An example of a pre-lab is available on Blackboard. At the beginning of "B" sessions, no pre-lab will be required. However, in order to get timely results, you should probably have some ideas already down in your notebook of what to do next.

In order to complete the pre-lab, written materials describing the labs will be available to you in the lab room beforehand and on the web. You may look around the lab or ask other students about the experiments you will be doing in the future. The instructor and TA will be available during office hours to discuss labs. We are also available at other times; schedule a meeting with us whenever you need help or just want to chat.

5 Lab Reports

In writing your lab reports, you should pretend that you have been asked to prove some new bizarre kind of physics that some wild-eyed genius has just invented. The acceptance or rejection of these heretical theories hinges on your experimental results, which you have rushed into publication to resolve the controversy. Don't be pompous, but do be precise.

Your report should be:

- roughly 4 to 8 double-spaced pages,
- typed or neatly hand written.

Things you will want to include are:

- the name(s) of the author(s);
- an abstract (more on this below);

- the major results or effect and what physical principle it demonstrates;
- a summary of your results and how you got them (a brief reprisal of your procedure);
- the answers to all of the questions asked in the lab description;
- error analysis;
- a conclusion discussing reasons for systematic error and statistical error, with suggestions on how to improve the experiment;
- and (if necessary) derivations of equations and other calculations (maybe in an appendix if you think it will clutter the main part of the report).

What I expect is that if someone with a basic understanding of modern physics picks up your report someday they should be able to understand what you did, why you did what you did, and what your results mean. As long as this comes across you will have done your job, and (hopefully) learned a great deal in the process. That said, one can think of many ways to accomplish this task. For those who are interested, there is an example of a made-up lab report from last year that follows a traditional style: Sample Lab Report (on Blackboard).

While you are free to choose any style you wish for the main body of the report, your abstract must adhere to some specific guidelines. This is because writing an abstract is a difficult and important skill to master and, like anything, takes some practice. So what is an abstract, you ask? In a nutshell, an abstract is your report in a nutshell. That is, it is a super-condensed version of your report (about 3-5 sentences) where everything but the bare essentials necessary to briefly describe your objectives, methods, results, and conclusions has been stripped away. With this in mind it may be easiest to write your abstract last.

Keep in mind that reports will not be graded on results. Of course, if your apparatus did not give you the answers you might have expected, it would be nice to see in your report the reasons you think caused the trouble. We have done each of these experiments recently. This only guarantees that they worked once; as you will learn, sometimes machines develop personalities. That's when experimental physics starts to get fun ...

Note: The very first labs (Lab 0A and Lab 0B) do not need to be written up in the same format as the others. You just need to answer the questions, but do include your data.

6 Due Dates and Grading Policy

Your grade for lab will be based on your pre-labs (roughly 10%), your lab notebook (roughly 10%). While you do not gain 'points' for your participation, if you hope to learn anything from the labs then it is vital that you are present and engaged in what your group is doing. If you are absent for an extended period of time (without a dean's excuse), are noticeably uninvolved while your group is working, or fail to turn in a pre-lab, then it will be noted on your lab report and can impact your grade. I sincerely hope that I never have to enforce this.

Pre-labs will be due at the beginning of each "A" period (i.e. before you start each of the regular labs). Your lab notebook pages are due as you leave each lab period. Finally, the lab reports will be due one week after the "B" period in which the lab was completed. As with the pre-labs and lab notebooks, you can turn your report into me (Kristine) directly or put it in my mailbox in the front office before it closes (at approximately 5 pm).

You must come to lab prepared to contribute to your group's experiment, and for this reason pre-labs will not be accepted late. If for some reason, however, you are not finished with your lab report by the due date you should request an extension from me before the due date has passed. As I am sure you are aware, it is to your advantage to finish your lab report before starting the next lab, but I do understand that things don't always go according to plan. If something comes up and you would like an extension there is a chance you could get one, but you should not plan on it. If you are granted an extension you must turn it in by the agreed date, and if your request is refused or if you do not make a request you must turn it in by the original due date. I reserve the right to give you zero credit if you fail to adhere to this policy. You are all adults and so it is your responsibility to initiate any necessary communication and to submit your work at the appropriate time.

Your grade for each lab will depend on the quality of your pre-lab, copies of your lab notebook pages, lab report, and participation. The labs will not be graded on a curve, which means that all of you could potentially get 'A's on everything. In the last two weeks of the semester you will have no new labs assigned and you may use this time (if you want) to improve upon one of the regular labs that you completed during the semester.

Keep in mind that your classmates are your greatest asset during this course, just as your colleagues will be in your career in the sciences. You may work with your lab partner(s) or other students in the preparatory research, but every student should write his or her own pre-labs and notebook entries.

(It is reasonable for one person to record the data while the other is reading the numbers from the measurement instrument. The person who did not write down the data should then take the time to record the data in his/her notebook before you leave and the original data logger should double check the entries.)

Each group should turn in a single lab report. In doing so, **both authors are certifying that they worked together and stand by the results and conclusions.** If one author cannot certify that the other made substantial contributions in both data gathering and the crafting of the report, he or she should turn in an individual report and ask the other member of the group to do the same.

7 Lab 0

The first lab, Lab 0 (Part A one week, Part B the second week) is required by everyone and serves as an introduction to data and error analysis. There is no pre-lab assignment for Lab 0, but you are expected to come prepared by reading the Lab 0A and Lab 0B labs and the handouts given in class and/or in the labs and/or on the web site. We will meet in the lab room (Room 005).

8 Closing Comments

This will be a lot of work, but you will be rewarded in the end. Like all of the hard courses in college, you will get out as much as you put in to this class. It will not seem easy; learning is never easy. (Anything that feels like learning but isn't difficult is probably only entertainment.) Don't kill yourself or the TA. Try not to maim your professor or your roommate.

Remember, we sincerely want to help you over whatever difficulties you will have in this class. We like teaching and we like students. Come see us anytime.