How to Write a Lab Report

This document provides general guidelines for how to write a lab report for PHY224. Some parts are adapted from the U of T Writing Advice page on lab reports: https://advice.writing.utoronto.ca/types-of-writing/lab-report/. It is not a strict set of guidelines; there are some experiments where this exact format does not work well. You may want to combine some sections for some labs or split some sections into subsections. There is no single correct way to write a lab report; you will still need to use your own judgment to ensure the information in your report is presented in a clear and logical manner.

Components of a Lab Report

1. **Abstract**
2. **Introduction**
3. **Methods and Procedures**
4. **Results**
5. **Analysis**
6. **Discussion**
7. **Conclusion**
8. **References**
9. **Appendix** (or **Appendices**)

1. The **Abstract** summarizes the entire report in one short paragraph. It states the purpose of the experiment, main results, and conclusion. The abstract often also includes a brief reference to theory or methodology.

2. The **Introduction** is more narrowly focused than the abstract. It states the objective of the experiment and provides the reader with background to the experiment. State the topic of your report clearly and concisely, in one or two sentences.

A good introduction also provides whatever background theory, previous research, or formulas the reader needs to know. The introduction is the primary location for introducing new equations. It's not great style to introduce new physics equations in any of the subsequent sections. Number all your equations so that you can refer to them later.

Usually, an instructor does not want you to repeat the lab manual, but to show your own comprehension of the problem. If the amount of introductory material seems to be a lot, consider adding subheadings such as "Theoretical Principles" or "Background."

Note on verb tense:

Introductions often create difficulties for students who struggle with keeping verb tenses straight. These two points should help you navigate the introduction:

- The experiment is already finished. Use the past tense when talking about the experiment:
  - `The objective of the experiment was...`
- The report, the theory and permanent equipment still exist; therefore, these get the present tense:
  - `The purpose of this report is...`

- `Bragg’s Law for diffraction is ...`
- `The scanning electron microscope produces micrographs ...`

3. **Methods and Procedures** describes the process in chronological order. Using clear paragraph structure, explain all steps in the order they happened, not as they were supposed to happen. Anything that you did specifically to reduce your uncertainties is very valuable information to include here!

Include photos or schematic diagrams if they would help explain the setup.

If you've done it right, another researcher should be able to duplicate your experiment based only on your written procedure.

4. The **Results** section is for presenting your data.

You will want to graph your data (no tables of data, please!) <u>with the line of best fit and error bars</u>. You will want to explicitly describe the line of best fit, probably by referencing one of the equations from your introduction. Axes should be labelled, including units. All figures should have meaningful captions—don't just write “[x variable] vs. [y variable]” as your caption. A graph and its caption should be able to “stand alone” outside the context of the report: if you showed someone just the graph and the caption, they should be able to understand what was measured and the relationship between the variables, even if they don’t know the details of how the experiment was conducted.

Make sure you have written explanation for your data and don’t just put lots of figures with no context. Think of this explanation as commentary walking the reader through your data. It should be clear where all the numbers came from. If you used any equations, reference them by number. You don’t need to show all your calculations here; a sample calculation for each type of calculation can be shown in the Appendix.

5./6. In the **Analysis/Discussion**, you show that you understand the experiment beyond the simple level of completing it. This part of the lab focuses on a question of understanding, “What is the significance or meaning of the results?” All the important results that you included in your Introduction and Conclusion need to be explicitly explained here.

What do the results indicate clearly? What have you found? Explain what you know with certainty based on your results and draw conclusions. What is the significance of the results? What ambiguities exist? What questions might we raise? Find logical explanations for problems in the data. More particularly, focus your discussion with strategies like these:

Compare expected results with those obtained.

> If there were differences, how can you account for them? Saying “human error” implies you’re incompetent. Be specific; for example, the instruments could not measure precisely, the sample was not pure or was contaminated, or calculated values did not take account of friction.

Analyze experimental error.

> What kind of error dominated the experiment? Was it avoidable? Was it a result of equipment? If the flaws result from the experimental design explain how the design might be improved.

Explain your results in terms of theoretical issues.

Often undergraduate labs are intended to illustrate important physical laws, such as Kirchhoff's voltage law. Usually, you will have discussed these in the introduction. In this section move from the results to the theory. How well has the theory been illustrated?

Relate results to your experimental objective(s).

If you set out to identify an unknown metal by finding its lattice parameter and its atomic structure, you'd better know the metal and its attributes.

Analyze the strengths and limitations of your experimental design.

This is particularly useful if you designed the thing you are testing (e.g., a circuit).

7. The **Conclusion** can be very short in most undergraduate laboratories. Simply state what you know now for sure, as a result of the lab.

You should also discuss what the largest uncertainty sources were and mention how they could be decreased in the future.

8. The **References** section lists all the sources that you used. Any style of referencing is fine. You can reference online sources like Wikipedia.

Do not reference the lab manual! That document is not published, so you should not reference it.

You need to include citations. A citation is an in-text reference to one of your references. Basically, any document that you put in your list of references must be cited somewhere in the text, otherwise it was just there for padding.

What should you cite?

- Any images you did not make yourself
- Any equations that are not obvious or common knowledge, unless you derived them from first principles
- Any claims you make that are not directly supported by your evidence and are not common knowledge

9. The **Appendix** (or **Appendices**) is for your raw data tables and calculations. Any number you measure must have an associated uncertainty. The only exceptions are universal constants like π or $e^{-\pi}$, and counted numbers like "five oscillations." Always include units; use SI units. Results should be quoted with error and with the appropriate number of significant figures. In most cases, providing a sample calculation is sufficient in the report.

The Appendix is not just intended as a dumping place for everything that didn't fit elsewhere in the report. Consider whether what you're putting is useful. You should try to reference everything in your Appendix elsewhere in the report. For example, if you used a data table from the Appendix to make a graph in your Results section, mention the specific section of the Appendix where the data can be found in the graph caption so that the reader knows where to go if they have any issues with the graph and want to see the original data. If there's a calculation that wasn't shown in the Results, put it in the Appendix and make it clear in the Results section where it can be found.

Using LaTeX

Using LaTeX to write your reports is optional, but it is very useful to learn how because it is great for typesetting equations and is widely used in physics. If you would like to create and edit LaTeX documents on your own computer, you'll need to download an appropriate TeX compiler, and optionally a front-end (or editor). Alternatively, you can use Overleaf, which is an online TeX editor. Once you have written your .tex document, you can compile it into a PDF.

Consult the Lab_Report_LaTeX_Guide_Template.tex document if you would like to use LaTeX. Compile the .tex file into a PDF and read the PDF for tips on writing reports in LaTeX. Then, you can use the .tex file as a template for your own lab reports.

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