Formal Lab Report Writing Guidelines

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(Dated: August 15, 2021)

This document outlines the nature of an acceptable formal lab report, lists the sections required, and explains the need for each of them. In addition, some general standard conventions for writing lab reports of professional quality are presented.

I. FRONT MATTER

For the most part, this document is designed to mimic the basic formatting desired for a formal lab report. However, everything in this "front matter" section (including the subsections on rationale and structure below) should not appear in your formal lab reports. After the abstract (the paragraph below the title and author name), your lab reports will normally transition directly into an introduction section. For this document, however, additional information may be helpful.

A. Rationale for Formal Lab Reports

Even though we might typically think about writing as being central to the humanities or social sciences, natural scientists, engineers, and medical professionals spend considerable time and effort writing reports. The quality of reports written by professionals is one criterion in performance evaluations, thus the ability to write a polished report is an essential job skill for many of you. For these reasons, training and practice in report writing are important parts of your education.

The format of reports is similar in many fields, and includes sections similar to the ones found in the sections that follow. The report format has evolved over time and – by using it – you can ensure that your report is complete and that readers with different interests or backgrounds can readily find needed information. An advantage for the student is that the use of a standard format reduces the time required to construct a report.

Word processing software incorporates features that produce a professional-quality report. These features include formatting, graphing, drawing, and spell/grammar check tools as well as an equation editor for producing equations. All of your formal lab reports for this course should be prepared with computer-based word processing so that you learn to employ the software features. Personally, I use a professional typesetting tool called $\LaTeX$ which, while awesome and resulting in very clean looking documents, has a rather steep learning curve. For the purposes of this class, it is perfectly acceptable for you to use tools that may be more familiar like Microsoft Word, Google Docs, OpenOffice, etc. If you do not have a computer, PCs and Macs – as well as printers – are available for use throughout the campus.

While report writing requires significant time, that time is well spent providing you the opportunity to develop a skill useful in your career. Several strategies can reduce the time spent. First, plan enough time to write the report. For most of us, it is usually best to work on a report in more than one session. A rough draft is written first and set aside. The rough draft is later edited and polished into the final version. The final version should be proofread carefully before submission. One of the clever things a lab group can do is set up a formatted document in your preferred word processing program that has all the parts and pieces with appropriate format for the text, titles, and tables. It will also include the names of the group members ahead of time. This document can be passed among the members as a starting place for the lab report of the week.

B. Report Structure

The laboratory report is written *for the convenience of the reader!* Thus, each section of the report should be headlined and the sectiosn should be arranged in a logical sequence. The lab report serves to describe what you did during the laboratory session, how you manipulated the raw data, your resulting conclusions, and other observations and commentary that help to contextualize your findings. The sections in a physics lab report should (typically) be arranged in the order listed below:

1. Title and Abstract
2. Introduction/Theory/Background
3. Experimental Setup/Procedure/Method
4. Results
5. Discussion
6. Conclusions
7. Appendices and References (when necessary)

The title and abstract appear at the top of the first page of the report.

Within the title block, expected elements include a brief but informative title, the name(s) of the author(s) of the lab report (with primary author first), and some reference to the date the experiment was performed or the document was written.

Following the title area, you need to present a brief abstract. A scientific abstract can sometimes be a difficult thing to write, but its goal is very simple – an abstract sets out to (briefly) outline what you did, and what you found. Think of it as an extremely abridged version of the whole report; it should be no more than 150 words or so – and sometimes substantially shorter than even that. Someone who reads just your abstract should have a pretty good idea of what happened, but they would not be clear on the details yet. *Note: if the final goal of your report was to identify some specific value/quantity, it is expected that this final value (and its associated uncertainty) is given in your abstract.* Most early science writers try fitting too much into the abstract; try to avoid this pitfall.

II. INTRODUCTION / THEORY / BACKGROUND

A successful introduction section in a science report is able to contextualize what will appear in the paper to follow. Introductions are often quite challenging to write, so keeping the big-picture goal in mind can be quite helpful.

In the context of a lab report, some introduction sections may be quite brief. If the goal of the study is simple and no specialized knowledge is required to understand either the goal or the methods used, it is possible that this section may be a mere statement of the basic objective(s) of the work to follow. *This should not, however, just be a sentence or two copied from the lab manual!*

Unfortunately, many experiments require additional background knowledge to contextualize. For these experiments, an introduction section that merely states the goal of the experiment will not be sufficient. Here, the author needs to provide the reader with enough context/theory/background to understand what is being undertaken.

When writing your introductory sections, your lab manual and/or textbook can often be of significant assistance. Try to remember that all of the experiments you are doing in your introductory classes are designed to illustrate or reinforce a particular idea, and often these ideas build upon other things you've learned.

The introduction/background/theory/context section(s) are there to help the reader understand what they are about to read about, what it was done, and how this fits into the broader scheme of what is known about the world.

The introduction section and/or the theory section will often have references and/or equations. Any statement of fact that is not obvious or explicitly follows from another given fact should be referenced; when in doubt, cite a source. When possible, stick to peer-reviewed sources (textbooks, journal articles, etc.); web sources should be used as infrequently as possible.

The equations that are necessary for understanding the scientific analysis that follows should be introduced and defined in a theory section. Each equation is placed on a line without any other text and is identified by a sequential number in the right margin for ease in referencing the equation elsewhere in the report. You will find examples throughout your lecture textbook and any book presenting equations. The length of the introductory sections can vary greatly depending on the experiment in question.

It is possible that you will need to start from a basic equation found in your text and then "derive" a more applied form of an equation that will be used later in your data analysis. If such a derivation is necessary, it is important to explain what is being done at each step in the process so the reader can understand the steps taken to go from the "reference equation" (out of the textbook) to the "functional equation" actually used in the experiment.

A theory section should not just be a list of equations!!! The theory section is meant to contextualize the steps taken in the experimental procedure within the perspective developed by the introduction. In other words, the introduction tells us what we hope to find out; the theory section identifies how the scientific ideas fit together; and the following sections explain in detail what was done. When it flows better, the introduction and theory sections may be combined.

Note that any variable used in any equation should be identified in the nearby accompanying main text. For example: The Kinetic Energy (K) can be readily computed by utilizing the following relationship:

$$K = \frac{1}{2}mv^2 \tag{1}$$

where m corresponds to the mass of the object (in kg), v the speed of the object (in m/s) and K is measured in Joules.

III. EXPERIMENTAL SETUP / PROCEDURE / METHOD

Once the context and basic understanding of what you will be doing has been established, the next part of the lab report is designed to clearly articulate what you actually did – this is covered in an experimental setup section and/or a procedure or method section.

A. Experimental Setup

To understand many experiments, a pictorial schematic of the set-up is helpful. Include a description of the set-up to accompany the drawing.

When professional scientific products were used to take measurements, the manufacturer and model of the instruments used should be included.

The experimental section should be detailed enough that the reader should be able to duplicate the experimental setup if they had all of the same equipment available to them. Often, this can be done in a few paragraphs.

Note that every figure/drawing/graph/plot/table must be *numbered* and have a stand-alone *caption*. Each figure should also be referenced in the main text. For example:

This experiment inovlved placing a block an an inclined plane (see Figure 1). The block was measured to be 0.513 kg $\pm$ 0.002 kg with an OHAUS TJ611 triple beam balance and the angle of the incline was measured to be $32° \pm 0.5°$ with a standard protractor.

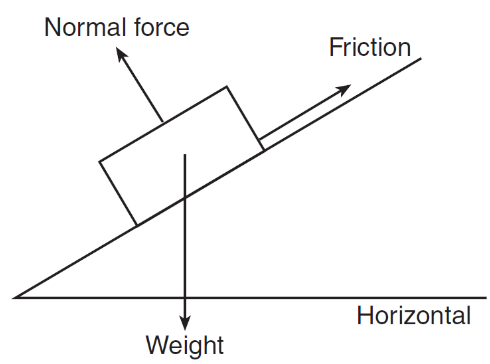

FIG. 1. A cartoon of the experimental setup, with additional indicators showing the associated forces present as the block slides down the inclined plane.

B. Procedure

This section contains a detailed step-by-step procedure for the experiment. After studying the section, a reader should be able to repeat the experiment in an identical manner. Special procedures used to ensure specific experimental conditions, or to maintain a desired accuracy, should be noted. As with all sections of the report, the procedure describes what was done in the lab and should, therefore, be written in the past tense. *While the lab* *manual may be helpful here, copying the procedure from the lab manual would almost certainly provide an inadequate procedure section* (not to mention that copying a previously published document written by someone else is plagiarism – don't do that!).

You always make additional choices and procedural decisions above and beyond the actual written procedure in the lab. Including this material in your report is very important. This section may be several paragraphs long, and a common mistake is to omit too much detail in this section. Remember, you are trying to convey enough detail that someone else could adequately replicate your experiment.

IV. RESULTS

Both the raw data obtained during the experiment and the resulting figures/graphs/analysis are presented in this section.

When presenting raw or manipulated data, the units of every reported quantity must be clear to the reader.

The type of data may vary according to the experiment. In addition to raw numbers, data might include sketches, images, or photographs. All numerical data may be initially presented in a standard table, and the reader should be able to identify the measurement error and uncertainty associated with each measurement without having to guess. As discussed in the previous section, *each table, figure, and graph in the report must have a caption or label and a number that is referenced in the written text. For example: Table 1, Table 2, Figure 1, Figure 2, Table 3, etc.* Variables tabulated or plotted should be clearly identified by a symbol or name. Make sure all figures have axes labels, and make sure all quantities have units.

It is important to have some text intermingled with your raw data! It is not acceptable to just write a section heading of "Results", give a table of data and some graphs, and then move on to the discussion section! Even though it might be self-evident to you, a reader should need some sentences putting this data in context. For example:

Table I (below) includes the raw data acquired from Mary's trial of the experiment. The first column indicates the duration of the trial (in seconds) and the second column indicates the speed upon impact (in meters per second).

Duration (s)	Speed (m/s)
0.25 ± 0.10	2.62 ± 0.30
0.40 ± 0.10	4.00 ± 0.30
0.65 ± 0.20	6.22 ± 0.40
0.70 ± 0.20	6.35 ± 0.40

TABLE I. Raw data from Mary's trials. Note the larger uncertainties for the longer trials resulting from having to splice two separate timing gates together.

Note that the information in the narrative part of the results section may not necessarily be detailed, but it must be there.

After presenting the raw data, the results are interpreted. The explanation of what was done to the data should be detailed enough that anyone would be able to perform the same manipulations and obtain the same result. The results of these manipulations are typically presented with graphs and figures and (less often) tables. The goal here is to recast the data in a form that aids in discussing the results and forming a meaningful conclusion.

Much like in the procedure section, a common mistake is to omit too much information here. Your raw data are the facts, the introduction and theory sections give us the context, but the analysis portion of this section needs to naturally lead us to the points of discussion and conclusions in the sections below.

Much like when presenting your raw data, some text is necessary here. Your narrative flow should not rely on graphs/charts and the associated captions to carry the message; they are there to illustrate the point you are making in the raw text.

V. DISCUSSION

In this section you should present your interpretation of the outcome of the experiment. You should describe, analyze, and explain (not just restate) your results. Think in terms of answering the question "What does the analyzed data tell me?" *Quantitatively* compare your results with expected behavior (calculating a percent discrepancy is appropriate here, but we're looking for a lot more nuance than "percent error from expected results"). Comment on any unexpected behavior – giving possible explanations when able.

This section is really the "meat" of your lab report. You have now established all the relevant factual information and presented the basic analysis that leads you to the big-picture answer; now it is time to discuss, argue, speculate, adjust for mitigating factors, consider the effects of error, and basically fully engage in the scientific process. Some of the best science writing has almost half of the text in this section, and speculation here is ok — so long as you are careful to frame the context and limitations of your results, conclusions, and inferences. If your experiment did not go as planned, there should be a discussion as to why. If it did go as planned, what else did you learn? The discussion section is often the difference between a low B and a high A; demonstrate you are actually thinking about this experiment!

VI. CONCLUSIONS

The conclusions section restates the basic key results and succinctly articulates any particularly important ideas that came out of the discussion section.

This section should answer the question "So what?" Seek to make conclusions in a broader context in light of the results. (Try to say things more substantial than "This lab showed that X's law holds using this apparatus.")

Note; if you ended up coming up with any quantitative conclusions about something, those numerical results should be clearly recapitulated here and, as always, any measured or calculated quantitative result should always appear with the associated uncertainty.

VII. APPENDICES AND REFERENCES

Using any standard (but self-consistent!) bibliographic format, cite all the published sources you consulted during the conduct of the experiment and preparation of your laboratory report. Sometimes, depending on the experiment, references are not necessary for a student report. If there is any doubt, ask your instructor.

An appendix should include details of analysis, sample computations, etc. that were referenced in the main body of the report but too bulky or lengthy to put in the main body in full without messing with the narrative flow. If the appendix contains more than one type of item, each one is designated by a specific letter (e.g. Appendix A, Appendix B, etc.).

APPENDIX: ADDITIONAL INFORMATION ABOUT LAB REPORT CONSTRUCTION

Laboratory reports are most effective if the language and style are selected to suit the background of the reader. Reports are judged not only on technical content, but also on clarity, ease of understanding, word usage, and grammatical correctness. Some typical trouble-spots are outlined below.

A. Tables, Graphs, Drawings

All tables, graphs, and drawings should be explicitly mentioned in the text and referenced by an appropriate label (Figure 1, Figure 2, Table 1, Table 2, etc). (Note that the label should also accompany the appropriate figure or table in the report as part of its caption). All figures and tables need captions! *Don't expect figures or equations alone to serve where sentences and paragraphs should accompany them. Visual and verbal descriptions should complement each other.*

B. Verb Tense and Usage

Verb tense should be consistent (as past tense) throughout. Examples of usage:

Poor: The TA set up the equipment before the experiment was begun.

Better: The equipment was set up before the experiment was begun.

Poor: We calculate distance using the data from Table 2.

Better: Distance was calculated using the data from Table 2.

The above examples also highlight another important aspect of scientific writing; scientific reports often embrace the passive voice. Although many writing instructors urge you to write in an "active voice", this practice is frequently discouraged in scientific discourse. The reason for this is that the text is intended to be as impersonal as possible. The experiments, observations, and results reported are (hopefully) reflections on aspects of the world we live in and not a consequence of who conducted the experiment. As scientific writers, we embrace this point of view not only in how we conduct our work, but in the word choices we make in reporting our work to others as well. Examples are included below:

Poor: John warmed up and started the death ray.

Better: The death ray was initialized by John.

Poor: We each took 5 paces to determine our average stride length.

Better: Stride length was determined through a procedure of having each group member take 5 steps and using the total travelled distance via equation 2:

$$\text{Average Stride Length} = \frac{\text{Total Distance}}{5n}, \tag{2}$$

where n was the number of people in the group.

C. Text Formatting

The text should be single-spaced in an easy to read font. Include a blank line between paragraphs. Although this document is two column, that is not necessary for your lab report and is often sub-optimal for clear presentation of easy-to-read graphics.

D. Section Heading Formatting

The headings should be in bold type. The format used for the headings should be consistent throughout the report and this document is a model for appropriate heading format.

Use a heading for each section and number the headings. Any sub-sections would be numbered the same as the section followed by a period and then a sequential number. For example, section **8 Results** might be followed by a paragraph introducing the results and then by sections **8.1 Free-Fall Results**, **8.2 Linear Acceleration Results**, and **8.3 Non-Linear Accelerations Results**. Note that subsections are not required but may be appropriate in some cases.

E. Editing

By starting early, writing a rough draft and letting the report sit for a day or two, you can approach it fresh when it is time to edit. As you edit your report, delete unnecessary words, rewrite unclear phrases and clean up grammatical errors. Don't rely only on a spell-checker. Doing so can have unfortunate results. An incorrect word but one spelled correctly will go right past the spell-checker and can turn a simple statement into an embarrassing one. Also beware the current word processing programs that warn you against the use of the passive voice; remember that in scientific writing the use of the passive voice is an asset and not something to be avoided.

F. Final Comments

These guidelines run long and are longer than some of your lab reports might be, but are constructed to try and explicitly point out some common repeated issues. They are intended to make your work easier by giving you a specific plan. The idea behind a scientific report is to say what you did in the clearest, shortest way possible. A lab report should answer questions, not create them in a reader.

Much of the text presented here has been taken almost verbatim from a document created by Dr. Terry Richardson, who constructed this material based on years of teaching at various levels and listening to student needs. The guidelines are also derivative of those used at the Illinois Institute of Technology in their writing lab.