Formal Lab Report Writing Guidelines

Introduction

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

Rationale for Formal Lab Reports

Even though we might typically think about writing as being central to the humanities or social sciences, natural scientists 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 here. This format has evolved over time and – by using it – you can ensure that the final 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. 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 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 Word (or another 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.

Report Structure

The laboratory report is written *for the convenience of the reader!* Thus, each section of the report should be headlined and the sections 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, and what you conclude as a result. Think of the report as a document communicating these ideas to your reader. The sections in a physics lab report should be arranged in the order listed below:

1. Title and Abstract
2. Introduction
3. Theory/Background
4. Experimental Setup
5. Procedure
6. Data
7. Data Analysis
8. Results/Discussion
9. Conclusions
10. Appendix and References (if necessary)

The content of each section is described below. Most of the descriptions are general enough to be useful for reports in other classes, though some details will almost certainly vary by discipline.

1. Title / Abstract

The following information should begin the document:

A brief but informative title.

The name(s) of the author(s) of the lab report (with primary author first)

Date the experiment was performed.

Course name and section.

Your instructor's name.

Following this information, you should 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 shouldn't 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.

2. Introduction

A successful introduction to a science report is able to contextualize what will be presented 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, the "introduction" can be a mere statement of the basic objective(s) of the work to follow. Note that, if you use this method, the objective is seldom "to familiarize students with the use of equipment" or "to learn how to perform some task". Rather, the objective should identify some critical idea that your procedure, data, and analysis attempt to address. Some key verbs that may appear in the objective include "to investigate," "to measure," or "to compare". The section should inform the reader precisely why the project was undertaken (other than trying to pass a class and graduate). This often can be done in a few sentences. ***This should not, however, just be a sentence copied from the lab manual.***

3. Theory/Background

This section is a concise description of the relevant background information necessary for the reader to have in order to understand the rest of the paper. Sometimes, this section can be combined together with the introduction.

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 this 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 this section 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.

This 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.

Note that any variable used in an equation should be identified in the 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.

4. Experimental Setup

If appropriate, provide a clear schematic drawing of the experimental set-up, along with explanatory text. Include a description of the set-up to accompany the drawing. Where there is no need for a drawing, this section would have a full description of the instruments used. The reader should find all the information needed to duplicate the experimental setup. This can usually 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 directly in the main text. For example:

This experiment involved placing a block on an inclined plane (see Figure 1). The block was measured to be 5.13 kg +/- 0.02 kg with a triple beam balance and the angle of the incline was measured to be 32° +/- 0.5° with a protractor.

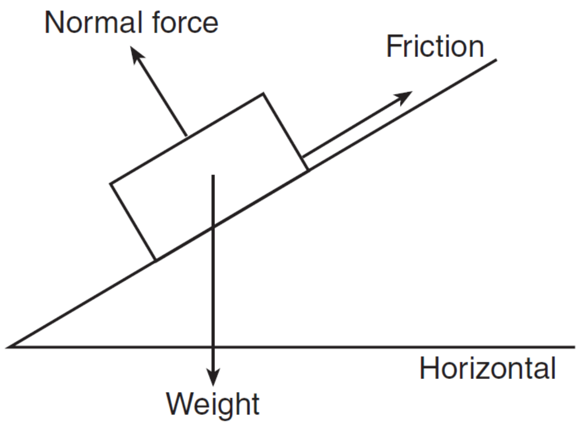

Figure 1: A cartoon of the experimental setup, with additional indicators showing the associated forces present as the block slides down the inclined plane.

5. 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).

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.

6. Data

The raw data obtained during the experiment are presented in this section. Usually this section contains only measured information, not results from manipulation of data. If the results beg to be included in the same table as the raw data in the interests of space or presentation style, the raw data should be identified clearly as such. The units of every number should be made obvious to the reader.

The type of data may vary according to the experiment. In addition to numbers, data might include sketches, images, or photographs. All numerical data should be presented in a standard table, and the reader should be able to identify the measurement error/uncertainty associated with each measurement without having to guess. As discussed above, **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, etc.)** Variables tabulated or plotted should be clearly identified by a symbol or name. Make sure all figures have axes, and make sure all quantities have units.

<u>It is important to include text in this section</u>! It is not acceptable to just write a section heading of "Data", give a chart, and then move on to analysis!!! Even though it might be self-evident to you, a reader would need some sentences putting this data in context. For example:

> Table 1 (below) includes the raw data acquired from Mary's trial of the experiment. The first column indicates the time of the trial, the second column indicates the duration of the fall (in seconds), and the third column displays any comments associated with the trial.

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

7. Analysis of Data

Here the data is manipulated and interpreted. The information presented should allow anyone to perform the same manipulations and obtain the same result. The results of the data analysis are reported in this section, using (most often) graphs, figures, tables, or other convenient forms. The end result should be information, usually in the form of tables, charts, or graphs that can help facilitate discussion in the next section.

Much like 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 this section needs to naturally lead us to the conclusions and discussions in the sections below. As in the data section, some text is necessary here – the section should not be graphs/charts and captions alone.

8. Results/Discussion

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?" Compare your results with expected behavior (calculating a percent discrepancy – remember that in the physics laboratory error is the same as uncertainty of the measured or calculated number), if such a comparison is useful or necessary. 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 factual information relevant; 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 results/discussion section is often the difference between a low B and a high A; demonstrate you are actually thinking about this experiment!

9. Conclusions

Often in introductory labs the conclusions section is combined with the previous one. In any case they are closely related. Base all conclusions on your actual results. Explain the meaning of the experiment and the implications of your results. Examine the outcome in light of the stated objectives. 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.

10. Appendix and References (when necessary)

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. 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.).

General Formatting and Language Information

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! <u>Don't expect figures or equations alone to serve where sentences and paragraphs should accompany them. Visual and verbal descriptions should complement each other.</u>

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 calculated 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

$$\text{Average Stride Length} = \text{Total Distance} / (5\ n), \qquad (2)$$

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.

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.

These guidelines run long and are longer than some of your lab reports might be. 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.