Menlo School

The Lab Report

Science Department
Version 1.0

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I. Introduction

The goal of science is to seek a better understanding of the world (and beyond!). In order to do this, scientists conduct experiments to test their hypotheses, and every time an experiment is conducted, it must be properly documented. The "lab report" is a standardized way in which scientists document their experiments. While there are many variations of the lab report, all lab reports have the same core elements described in this document.

It is important to note that there is a difference between a lab report and a scientific paper. A lab report is what we might call an "internal" document that the scientist uses for himself/herself, or to share with his/her immediate colleagues. A scientific paper is an "external" document that scientists uses to publish their findings to the world. In so doing researchers attempt to persuade others to accept or reject their hypotheses by presenting the data *and* their interpretations. The scientific paper is the vehicle of persuasion; when it is published, it is available to other scientists for review. If the results stand up to criticism, then they become part of the accepted body of scientific knowledge (unless later disproved).

In your core science courses at Menlo (i.e. Physics, Chemistry, and Biology) you will be primarily writing lab reports. If you choose to take more advanced electives (e.g. Biotechnology, ASR), then you may be asked to write scientific papers.

II. The Basic Lab Report

While different teachers have slightly different variations of lab reports, all reports contain the following elements:

Title Page and **Abstract**
Purpose
Procedure or **Methods**
Results
Discussion
Citations

In addition, your instructor may ask you to include an **Appendix** with some, none, or all of the following sections:

A **Sketch** of the setup
The original **Data Table**
Calculations
Additional **Questions**

III. Explanations of Specific Sections

1. Title Page and Abstract

The title page includes your name, the date, lab partners' names, and a title. The title should indicate to an outside reader what the lab investigation is about. It should also be specific and descriptive. For example, "Termite Lab" does not meet these criteria. "Do termites follow a black pen line longer if the line is darker?" provides much more information.

The abstract is 3-4 sentences. The first sentence or two describe the experiment and what you are measuring. The next sentence tells the reader the main result(s) of the experiment. And the final sentence relates your result to the accepted result(s).

2. Purpose

In a paragraph or two, explain the objectives, or purpose, of the lab. Though sometimes you will have to copy the purpose section directly from the lab instructions, you should attempt to rephrase the purpose as a question, rephrase given questions, and/or add questions of your own.

Give enough detail about the purpose of the lab that a random outside reader can understand the point of why you're doing the lab. Give sufficient background information as necessary.

The following generally applies to Biology labs only: In one clear sentence, state your hypothesis. You may wish to include predictions as well.

3. Procedure or Method

In this section, you should provide a visually simple, easy-to-follow representation of the lab procedure. Include a minimal number of words, i.e. only those that are needed (e.g. volumes, times, etc.), but include enough detail such that an outside person would be able to duplicate your experiment. If you were given a handout with lab procedure instructions, DO NOT recopy these instructions, but rather present them in a way that is clear and easy for you to follow, so that (1) you have thought about the lab ahead of time and (2) your instructor can see that you understand what you will be doing. You are also expected to write in any changes that you made as you performed the lab, including how many replications were performed, how variables were controlled, and notes about any unexpected outcomes. [Note that in some instances your instructor may allow you to omit this section completely.]

4. Results

This is a cleaned-up version of the data collection you did in class. Type all data and observations in your data table. Ideally, your data table was designed so well in your pre-lab that you can simply fill in your collected data. Of course, this is not always the case, and you may add rows or columns to your data table as needed. You can also add notes if, for example, a certain measurement is known to be inaccurate or in doubt. You should not interpret your results yet – save that for the discussion section!

CLASS DATA: Since scientific conclusions are never made based on the results of a single experiment, we will often share data. We will usually tabulate these data on a spreadsheet in class and I will make the file available to everyone online. These tabulated data should also be included in your formal report. When we share data, it is the class data that provide the most information: your discussion should analyze these data more so than your personal data. You will be tempted to discuss your data more carefully than the class data – resist the temptation! Include a caption above every data table so you can easily refer to it in your text. This is a sentence or two that briefly states what data are in the table, without interpreting the data yet.

4a. Tables

Let's first make a distinction between "data tables" and "results tables." Data tables are used *during* your lab to record data as your experiment progresses. Often this is done in a lab book with a pen or pencil. While every effort should be made to keep them neat, it is not uncommon them to get a little messy. Results tables are included in your lab report to show your final…well…results. It may include some of your original data, but will almost always include some type of calculated results. Moreover the results tables typically show the *averages* of your trials as opposed to your data table which would depict *all* of your trials. Finally, results tables are presented in the body of your lab report while the data tables are often attached in the Appendix as "backup" material. Please obey the following rules when generating results tables:

- Always provide a descriptive title above your table. "Results Table" is NOT acceptable. Number each data table (e.g. "Table 1") so that you can refer to it in your discussion.

- For each column, include a label with units. If you write the units at the top of a column, then you do not need to write units next to each individual number.

- Rows or columns?…that is the question. Sometimes it's difficult to know whether to put the results in rows or columns. Usually one is more logical than the other, but knowing which is more logical will come with experience.

Sample Table:

Table 1. The Acceleration of Carts of Varying Mass with Constant Pulling Force

	Cart Mass (g)	*Pulling Force (N)*	*Average Acceleration (m/s/s)*	*Predicted Acceleration (m/s/s)*	*Percent Difference (%)*
Cart A	500	4.7	0.185	0.190	2.6
Cart B	990	4.7	0.103	0.110	6.4
Cart C	1490	4.7	0.065	0.060	8.3

4b. Graphs

Graphs are one of the most important ways to present results in a lab report. It is not uncommon for frequent readers of scientific reports to jump immediately to the graphs to ascertain the "nuts and bolts" of the lab. A good graph can tell a story all by itself. Consequently, please take time and care when creating your graphs, and be sure to abide by the following rules:

- Give your graph a descriptive title. NEVER write "A vs. B." When in doubt, use the form, "The Dependence of (your dependent variable) on (your independent variable) for (whatever it is your testing)." For example, instead of writing, "Velocity vs. Time," write, "The Dependence of Velocity on Time for a Frictionless Cart on an Incline." Never start with, "A graph of…"

- If you're told to plot "A vs. B," then A goes on the y axis and B goes on the x axis. If you're not told specific instructions, then always put the independent variable (or the control) on the x axis, and the dependent variable on the y axis.

- ALWAYS label your axes and ALWAYS include units (in parentheses). For example, Volume (mL) or Frequency (Hz)

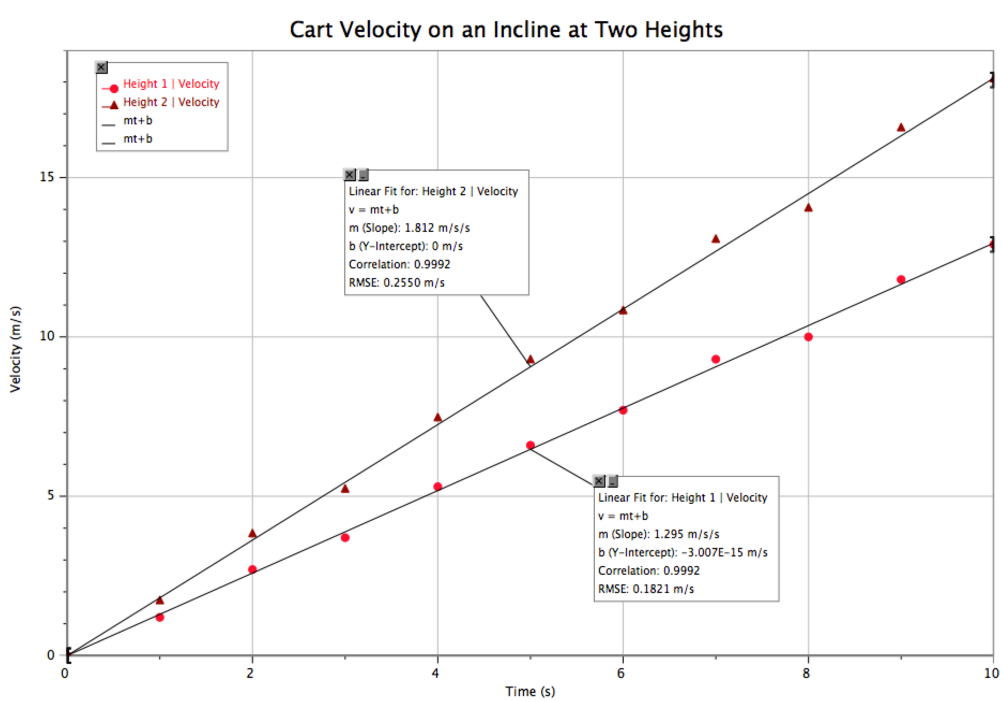
- Make your graphs as large as possible, and use a scale in multiples of 1, 2, 5, or 10.

- NEVER connect the dots on your graph. Careful, some graphing programs do this by default so you will need to manually remove them.

- If your data suggests a mathematical trend, then include a best-fit line (or curve), however, if your data does <u>not</u> suggest a trend, then don't include a best-fit line.

- Use different data markers (e.g. circles, squares, triangles, etc.) to delineate different series of data, and include a legend.

Sample Graph:



5. Discussion

Every discussion should start with a short paragraph that summarizes the goal, method, and overall finding of the lab. For example:

> "In order to determine the effect of ink color on the line-following behavior of termites, we placed termites on lines of three different colors, in randomized order, using black pen as our positive control and pencil as our negative control. We measured how long each termite stayed within 1 cm of the line. We found that black was the only color that termites followed for more than three seconds."

After this paragraph, analysis of the findings and critique of the strengths and limitations of the experimental design are expected. Answers to lab-specific conclusion questions may also be included within the text of the discussion.

5a. Error and Uncertainty

Analyzing the error and uncertainty in your lab is both of the most important aspects of your discussion, and also the most frequently misunderstood. First of all, error is not the same as a mistake. When scientists talk about error, they are referring to *experimental error*.

- Don't talk about the *possible*, talk about the *probable*. Of course it's *possible* that your speed gun was broken, but was it? After all, if it was broken, then why did you continue to use it? Focus on the things that had a likely and probable cause of error.

- Don't just make a laundry list of sources of error; analyze the *significance* of each. If you were off by one degree in your measurement, how would that affect your final result? Would it cause a 10% difference? 1%? 0.1%? As you can see it matters because if it only caused a 0.1% difference, then you might not even cite it as a source of error, but if it caused a 10% difference, then you certainly would.

- NEVER cite "human error." All experiments are conducted by humans so there is no need to account for that.

- Don't list mistakes. "I could have entered the numbers incorrectly into my calculator" is not a source of experimental error.

For more on discussion, go to the Writing Center at University of North Carolina at Chapel Hill (http://writingcenter.unc.edu/handouts/scientific-reports/)

6. Citations

When using information in your lab write-up taken from other forms of literature, include proper citation of sources. You may use either MLA or Chicago.

7. Optional Appendix Items

7a. Sketch of Setup

Some instructors will ask you to provide a sketch of your setup. The sketch can be hand-drawn but care should be taken to make it as neat as possible. The sketch should provide enough information so that the reader can replicate the experiment.

7b. Original Data Table

Your instructor may ask you to attach your original data table to your lab report. This is the "raw" table that was used during the actual lab. This table should not be edited.

7c. Calculations

If your lab involves any kind of calculation, then you need to show one sample calculation for each type of calculation (you don't need to show sample calculations for incredibly simple calculations such as averages). If you were measuring the density of rocks in the lab, you would have measured the mass of a sample directly and the volume by measuring initial and final volumes in a graduated cylinder before and after adding the rock. Even if you did these calculations for 10 different rocks, all you need to show is how you did one of them (see below).

Calculation of volume of rock

$V_{rock} = V_f - V_i$
$V_{rock} = 24.77\text{ mL} - 12.08\text{ mL}$
$V_{rock} = 12.69\text{ mL}$

Calculation of density of rock

$\rho = m_{rock}/V_{rock}$
$\rho = (36.55\text{ g})/(12.69\text{mL})$
$\rho = 2.880\text{ g/mL}$

To Type or To Write? Simple equations like those shown above can be typed using a word processor, however when equations get more involved, then using a word processor becomes inadequate. Microsoft Word has a built-in equation editor which makes equations look great, but it is rather difficult to use. If you don't know how to use the equation editor, then leave a blank space in your report and write out your equations neatly by hand.

Using the Equation Editor - YES

$$d = \sqrt{\frac{Gm_1m_2}{F}}$$

Using a Word Processor - NO

d = square root (G x m1 x m2) / F

7d. Additional Questions

Some teachers may ask you to answer additional questions related to the lab.

IV. Other Stuff

1. What's a PreLab?

A *prelab* is essentially a homework assignment given prior to the lab to help you properly prepare for the lab. Since class periods are only 55 minutes long, it is essential that you complete the prelab to maximize your efficiency during class time. Prelabs vary from teacher-to-teacher but may consist of reading the procedure, creating data tables, doing sample calculations, and/or answering questions.

2. Lab Report Template

Some instructors provide a soft copy of a lab report to use as a template. Check with your individual instructor.

3. Lab Report Checklist

Some instructors provide checklists (an example is shown right). Check with your individual instructor.

MENLO PHYSICS — FORMAL LAB CHECKLIST

This is a general checklist that is applicable to most formal labs.

Name:

Lab Report Basics
- ❐ Name (in bold)
- ❐ Partners' names
- ❐ Date of write-up
- ❐ Title
- ❐ Date of lab
- ❐ Lab typed
- ❐ Lab stapled
- ❐ Lab well organized and neat

Purpose
- ❐ Purpose is on front page

Equipment
- ❐ Brief listing of apparatus used to conduct this experiment
- ❐ Or, equipment section is referenced and attached

Procedure
- ❐ Brief but accurate procedure. Sufficient for physics student to replicate the experiment.
- ❐ Or, procedure section is referenced and attached

Data Table
- ❐ Original raw data table is attached
- ❐ Data table has proper title and date
- ❐ Correct units on data table
- ❐ Data table calculations are correct

Graphs
- ❐ Graphs are complete and attached
- ❐ Graphs have <u>descriptive</u> titles (not "Density vs. Mass")
- ❐ Axes are labeled with proper units
- ❐ Graphs use full page and are neat
- ❐ Each data run has unique marker with legend
- ❐ No dot-to-dot lines
- ❐ Best fit line where appropriate with slope highlighted

Calculations
- ❐ Calculations are present for <u>each</u> type of calculation
- ❐ All calculations have units
- ❐ Calculations are correct
- ❐ Calculations are neat and legible

Results
- ❐ Results table included in body of lab
- ❐ Table has descriptive title
- ❐ Columns and rows have headers with units where applicable

Discussion and/or Questions
- ❐ Double-spaced typed
- ❐ Addresses purpose of lab
- ❐ Contains intro, body, and conclusion
- ❐ Briefly explains methodology
- ❐ Answers to all questions are incorporated into body
- ❐ Thoughtful commentary on error. Consider which sources of error WILL have an impact on your results and which will not.
- ❐ Discussion is thoughtful
- ❐ Discussion is well-written with proper use of English grammar

4. DO's and DON'Ts

- Maintain a scientific tone throughout your lab report.
- Lab reports are to be submitted as professional documents.
- Neatness counts!
- Avoid contractions (e.g. "doesn't") and colloquial language.
- All data must be clearly labeled. Put a descriptive title on every data table and graph, and include units on the column/row labels in data tables.
- All figures and tables must be referenced parenthetically in the discussion section. Example: "The mean temperature for Trial 4 was found to be 33°C (Table 2)."
- All lab reports must be typed unless otherwise stated.
- Plagiarism will not be tolerated. Include a bibliography section if you consulted any outside sources.

V. Resources

Engineering Report Writing, by the Electrical and Computer Engineering Department of the University of Connecticut, September 2003.

Scientific Reports, The Writing Center at The University of North Carolina at Chapel Hill, http://writingcenter.unc.edu/handouts/scientific-reports/, accessed June 6, 2012.