

Introduction to Laboratory Practices

Lab Report

Your report is a record of your lab experience, containing both your observations and your analysis of these observations.

A. Overall:

1. *Reports:* Lab reports will be hand-written on graph paper, which will be provided for you. You will be working in groups, but each person will be writing their own lab report.
2. *Neatness:* A reasonable neatness and orderliness will help you to communicate your results to the reader. However, the lab report is a **working** journal and **should not** look as if it is a copy of material recorded elsewhere. ***Don't waste time recopying data!***

B. The Report:

1. *Title, date, names.* Write the following at the top of the first page of each report: the name of the experiment, the date, your name and your partner's name.
2. *Statement of purpose.* In a sentence or two, briefly state the purpose of the experiment.
3. *Sketch of experiment.* This shows the apparatus used in your experiment, and the points where measurements were taken. Quantities that are referred to in your report should be labeled on your sketch. *Be sure that labels in sketches and tables are consistent* (e.g., if you use 'x' for distance in your table, don't use 'd' in your sketch to describe the same measurement!).

Note that there are times when you may have several sketches in your report, e.g. when the configuration of the apparatus changes. In those cases, it is more appropriate to keep the sketch with the relevant data and calculations.

4. *Data Section.* Record your original measurements in your report as you collect them. Use tables to keep data neat and organized. Details are described in the next section below.

It is important that throughout your report you include simple statements describing what you are doing at that point: "Measuring the distance the projectile travels", "Calculating the slope so that we may determine the velocity", etc.

5. *Sample Calculation.* Show *one sample of each calculation* in sufficient detail to demonstrate how your results were obtained.
6. *Graphs.* These include hand-drawn and computer graphs, and will be discussed below.
7. *Discussion.* This is a **brief** summation of your results and conclusions drawn from them. In general, you will be answering several questions at the end of the experiment, but there are some items you will always have in common:
 - a. Always begin your discussion by restating your final results; use a summary table to present your results in a way that is easy to read.
 - b. Evaluate your results: did anything, not accounted for in the theory, affect your results? Were there any difficulties taking measurements? Be specific with your responses.
 - Don't use "human error" as an excuse; this implies an error by the experimenters which can be reduced by careful technique, or repeating the measurement. And don't blame the apparatus, unless you are positive that is the cause (you should have your lab instructor check any questionable equipment).
 - c. Did your experiment behave as predicted by the theory? If not, what may have caused the discrepancy? Note that you will not be "proving" a theory; rather, you will determine if your experiment behaved *as predicted* by the theory.

Data

A. Overall:

1. *Promptness.* Your measurements must be **written down at once in your report**. Don't collect data on scratch paper, and then recopy. You waste time and increase the chance of introducing transcription errors when you recopy data.
2. *Mistakes.* Don't erase or scribble over mistakes. If you decide a measurement or result is wrong, draw a single line through it that leaves it readable. It makes your report neater, and allows you to see the original value if you later decide it's usable.
3. *Tables.* Create tables (details below) to organize your data. Use a ruler to draw straight lines, and follow the grid lines that appear on the graph paper. This makes your table neat and easy to read.

B. Numerical Data:

1. *Definition.* Only the numbers you actually read are data. If measure the length of a rod, and one end is near the 10.0 cm mark on a meter stick and the other end near 45.8 cm, the data are 10.0 cm and 45.8 cm. The length of the rod is not itself a datum but a calculation made by subtracting one datum from another. **Do not introduce errors into your work by doing mental arithmetic before you write the numbers down.**
2. *Tables.* Sets of similar data are easier to read if they are put into tables.
 - a. Let your table grow as you collect data; don't draw lines to determine the length of your table before you begin the experiment!
 - b. Enter multiple measurements of a quantity on individual rows. Use a single horizontal line to separate *groups* of measured quantities. Don't bother underlining each data point; it wastes time, and makes your table more crowded.
 - c. Use a *single line* to cross out obviously erroneous data, and include an explanation for its exclusion below the table. *Do not* erase, rewrite, or scribble vigorously over erroneous data!

A sample data table appears below; also note that you include units in the column header only:

Sample Data Table

Initial Position, X_i (cm)	Final Position, X_f (cm)	Travel Time, t (sec)	Average Time, $\langle t \rangle$ (sec)	Total Distance, $X = X_f - X_i$ (cm)	Velocity, $v = X/\langle t \rangle$ (cm/s)
10.0	23.1	1.52	1.51	13.1	8.66
		1.53			
		1.49			
	55.8	2.36	2.37	45.8	19.3
		4.57			
		2.39			
		2.37			

3. *Repetition.* If a number remains constant through the experiment, you need not repeat it. Simply leave the rest of the column blank, as shown in the "Initial Position" column above.
4. *Include a leading zero!* If you collect a measurement of two tenths of a centimeter, record it as "0.2 cm", not ".2 cm". Omitting the leading zero makes the datum difficult to read, and can lead to calculation errors.

Calculation

A. Significant Figures:

1. *Single observation.* The number of significant figures (sig. figs.) you get from a measurement will depend upon the measuring instrument used. You should record a measurement so that it is clear how many sig. figs. are represented. For example, if you use a ruler to measure the length of a rod, it might be recorded as 3.4 cm (two sig. figs.). Measuring the same rod with a vernier caliper may give you 3.412 cm (four sig. figs). Remember that leading zeros are not significant, so 0.00238 cm has three significant figures.
2. *Combined result.* When two measurements are combined in a calculation, you should use the memory function of your calculator to retain all sig. figs., especially when several subsequent calculations are performed. Do not round a result, and then use it in a calculation; this will introduce significant rounding error. Only round the final result that you write in your report. *The final result should not have any more significant figures than the least accurate measurement.* If you combine one value with three sig. figs, and another with four, your final result should only have three sig. figs.

B. Percent Difference:

Frequently you will perform calculations of a quantity derived from two different methods. You can compare two numbers by calculating the percent difference between them. Do this by subtracting the two numbers and dividing by the average of the two. *Note: One or two significant figures are sufficient in percent difference calculations.*

Example: Two measurements of the same object give the length as 4.7 cm and as 5.1 cm. The percent difference is calculated as:

$$\% \text{ Difference} = \frac{\text{Difference}}{\text{Average}} \times 100 = \frac{(5.1 - 4.7) \text{ cm}}{\frac{1}{2}(5.1 + 4.7) \text{ cm}} = 0.08163265 \dots \times 100 \approx 8\%$$

Graphs

During many experiments, you will be graphing your data *as it is collected*. The theory will be discussed before the experiment begins, so you will have an idea of what the graph should look like (linear, polynomial, etc.). The graph lets you see this theory develop, and check for any radical deviations, possibly due to a calculation or measurement error. This allows you to check your calculations or repeat a measurement before the configuration of your apparatus changes.

Your graph will also indicate how many points you need to measure. For example, if you are measuring a cart falling along a 2-m long track, do you need to take a measurement at 1-cm intervals? Can you increase the distance interval to 10 cm, or 20? In order to see where you need to make measurements, and to see the function develop, the first data points collected should reflect the extremes of the experiment when possible (shortest time, longest time; shortest distance, longest distance; etc.). After these two points are plotted, continue to collect data to fill in the space between them so that there are no significant gaps in the graph.

All graphs, whether created by hand or on the computer, *must* contain the following elements:

1. *Title:* Every graph must have a title describing what quantities are being plotted. The title should be sufficiently descriptive to be understood without reading the rest of the report.
2. *Names:* Include your name, and your lab partner's, as well as the date.
3. *Axis labels:* Each axis must be labeled, giving both the *quantity* and the *units* in which it is measured. If the axis represents velocity, you might label it 'v (cm/s)'.
4. *Function:* When analyzing your data with a computer plot, you will be adding a function that best fits the data. Be sure that the equation for that function appears on the graph; you'll need it to complete your analysis.