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. You may write in pencil or black/blue ink. Please do not write using any other color.
2. *Content:* It is important that throughout the report you include **brief** statements describing what you are doing at that point: How did you collect the data in the following table? What instruments, and their settings were used for these measurements? What did you do with your data *next*? What are you calculating? What are you graphing?
3. *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!***

   - Here are some tips for writing a neat and legible report:
     - Follow the graph paper grid lines on which you write your report
     - Write your letters and numbers carefully and distinctly
     - Use a ruler when you need to draw a straight line
     - Write in complete sentences
     - Read and follow the laboratory instructions carefully!

B. The Report:

> **DO NOT** start your report by copying all of the material you see on the blackboard at the beginning of lab. The blackboard material is for the introductory discussion of the experiment. Your report will contain much of this information, but it should be written *as you are performing that part of the experiment!*

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!). **If a sketch appears in the lab instructions, it must appear in your report!**

   > 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.
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. The following excuses are <u>not</u> the result of experimental error:

        - *Human error*: this implies an error by the experimenters that can be reduced by careful technique, or repeating the measurement.
        - *Faulty equipment*: don't blame the apparatus, unless you are positive that is the cause (you should have your lab instructor check any questionable equipment).
        - *Rounding error, calculation error, misreading ruler, etc.*: Again, these are all avoidable errors.

    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*. <u>Don't erase or scribble over mistakes</u>. 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 on the following page; <u>also note that you include units in the column header only</u>:

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 1.53 1.53 1.49	1.51	13.1	8.66
	55.8	2.36 ~~4.57~~ 2.39 2.37	2.37	45.8	19.3

3. *Repetition*. If a number remains constant through the experiment, such as the starting position of a cart on a track, you need not repeat it. Simply leave the rest of the column blank, as shown in the "Initial Position" column above of the previous sample data table. However, if a measured value is the same, you must record it to show the individual number of measurements recorded, as shown in the "Travel Time" column of the table.

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:

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

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.

There are experiments where you will draw a graph by hand, in others they will be created by computer. If you are creating a graph by hand, keep the following in mind:

1. Make the graph large; use a separate sheet of paper, and try to fill the page as much as possible. You don't need to draw your axes away from the edge of the grid.
2. Even though you will create a large graph, choose a scale that makes it easy for you to plot. A scale where each division is 1, 2, 5 or some multiple of 10 units is easy to graph. If each division equals $6.3\overline{3}$ units, you will waste too much time creating the graph. When thinking about the scale of each axis, decide whether it's better to plot the graph in portrait or landscape mode; it may be easier to create the scale for the larger quantity along the long edge of the paper.
3. Plot each data point using a small point to retain the precision of its placement; put a circle around the point so that the point is still visible if a best-fit line is drawn through it $(e.g.\ \odot)$. Use a different symbol (square, triangle) around the point if a second data series is also plotted on the graph.
4. If you will be calculating the slope of linear data, use a small x to indicate slope points; this will distinguish slope points from actual data points. Don't use data points to calculate slope; pick two points on the axis grid that you best-fit line goes through.

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.

Additional details:

- Graphs can be placed in the report at the point where they are created or at the end of the report – <u>be sure the reader knows where they are located</u>.
- If an experiment requires the creation of multiple graphs, *please* attach them to the report in the order they were created!

PLEASE CLEAN UP YOUR BENCH BEFORE YOU LEAVE THE LAB.
IT SHOULD BE IN THE SAME CONDITION AS YOU FOUND IT – *OR BETTER!*