General Physics 201
Laboratory Manual

Linn Benton Community College

Revised Winter 2016

Faye Barras, LBCC Faculty

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Physics Laboratory General Information

The Lab Data Book

Welcome to the laboratory section for Physics 201. Through hands-on experiences in the lab, you should become more familiar with the concepts discussed in lecture. You will also gain valuable job skills, such as recording and analyzing data, organizing ideas, and planning methods to achieve goals. You will communicate ideas in written and graphical form, and development teamwork skills.

Each individual will keep a record of activities in the lab, in your Laboratory Notebook. This notebook will be turned in before you leave the lab. Lab books are written in pen not in pencil. If a mistake is made, draw a single line through the error, and then record the correct information. **Do not erase in the data book!** This way, if you later determine the information is valid, you can retrieve it. Remember that the lab book is your record of your activities in the lab - your lab memory. The lab notebook should be neat and legible.

One of the roles scientists fill is the detailed and accurate recording of information and observations obtained through experiment. The scientist also analyzes and draws conclusions based on the results of experiment. In order to better acquaint you with the role of science and scientists in society, you are to put together your data book in a similar order to professional scientists, as listed below. Not all of your labs will require all sections. For instance, some may not ask you to make predictions, and some labs will not require a graph.

Title	The title of the experiment
Lab Members	A list of the people in your lab team
Objective	The purpose or objective of the experiment
Introduction	What should the reader expect, what does the reader need to know?
Experimental Setup	• List the equipment used during the experiment • Include a labeled sketch of the experimental setup.
Procedure	A step by step listing of the procedure you followed to complete the experiment. This should be specific and in your own words. Do not copy from the prep sheets. This listing should be entered in the data book as you are performing the experiment.

Predictions	Do not expect to make all predictions correctly. This is okay. When making predictions, briefly explain your reasoning.
Data	As data is collected in an experiment, record that data in the lab book by hand. Do not wait for a printout of your data, as information can be lost forever if it is mistyped into a computer.
Analysis	• Provide one sample calculation for any computation performed during the experiment. This includes calculations performed by a spreadsheet. You do not need to repeat every computation in your data book, but you should include one to check that everything is going smoothly. Remember to pay attention to significant figures and units in the sample calculations!! • If a handbook value exists for the quantity you are experimentally measuring, compare your experimental value to the handbook value by performing a percent difference calculation. • Determine the uncertainty in your value as a result of the random measurement uncertainties. This is not the same as the % difference compared a handbook or theoretical value.
Graphs	• When asked to provide a graph, tape or glue the graph into your data book. • Remember to title your graphs and label the axes. As always, include units with your axis labels and watch those significant figures on your axes. • Any trend line inserted into a graph should be edited to show the appropriate symbols for plotted values (instead of x and y), and include units to your trend line. • Immediately after the graph, include a one to two paragraph statement in which you describe what information is contained in the specific graph. They say that a picture is worth a thousand words. Show that you understand the words that go with your graph.
Questions	When answering the questions posed in the lab, either rewrite the question, or phrase your answer in such a way that the question is apparent for any reader.
Summary/Conclusion	Conclusions are based on, and supported by, the data you collect. Some things to include in your conclusion: • A short summary of the experiment – yes that is necessary. • To what extent was the objective of the experiment realized? Every experiment has an objective. Given your observations

and the data collected in the lab, did you meet your objective?

- Restate your experimentally determined value (or at least the key result in case you made multiple experiments) and the experimental uncertainty associated in this value based on the experimental uncertainties. You actually always determine a possible range of values **never just one number.** Discuss possible sources leading to the uncertainty in your experimental value. Based on your listed uncertainties, what is the range you determined for the result in your experiment?
- If a handbook value exists, state the handbook value and the percent difference between the experimentally determined value and handbook values.
- Does the handbook value fall within the range of values you determined in your measurement? If not, why not? Make sure you are specific here. Simply putting "human error" will not suffice. There is nothing like a "human error" in a scientific experiment! We never use these words in this class. Come and discuss if you disagree – but do not use the words.
- Tie the experiment back to lecture. What concepts from lecture have you investigated? Does your lab experience support the ideas you had when you came into the lab? If so, state how. If not, state how your understanding now differs from when you entered the lab.

Reflection

What new concepts did you learn?

Do you have any suggestions for improving or changing the lab? Can you think of anything that would have increased your understanding and enhanced your lab experience?

Certification

Finally, sign and date the lab book. This is your stamp of approval indicating you certify the work in the book.

Prelab/Postlab

If you did a prelab and/or postlab exercise, glue the sheet into your lab book. Always make sure there is no loose paper in the lab book before you hand it to your instructor or any other person to review. Loose leaf notes are most often lost before they are read.

Enhancement

Ask your instructor whether you are required to do this section. If this is required, you need to consider what you have learned and experimented with in lab and do one of the following:

i. Can you think of any experiment that would have increased your understanding and enhanced your lab experience? Briefly but clearly describe and perform this experiment with the equipment available in the lab – you want to get a numerical result.

OR

ii. Can you think of any real life application that provides insight into and enhances your lab experience? Describe this quantitatively - include at least a back-of-the envelope calculation that provides quantitative insight into this application.

Rubric

Your instructor may grade your lab using a rubric. If that is the case, paste a copy of the rubric at the end of each lab.

Significant Figures In The Laboratory

Significant Figures

A *significant figure* is a reliably known digit. In physics lab, you will be making measurements with various tools to collect data. When you record your data, you are indicating how many reliably known digits, or significant figures, that measurement has. We will be paying a great deal of attention to significant figures in the lab, as the result in a lab can be no more precise than the least precise measurement made along the way.

In short you need to be able to bet money on the fact, that you would get the same result, when you repeat the experiment, or when somebody else repeats it.

Number of significant figures in a measurement:

- If a digit is a 1-9, it is always significant;
- If a 0 is used to locate the decimal, it is **not** significant, so leading zeros are never significant
- Trailing zeros are significant if they appear to the right of the decimal.
- Trailing zeros are also significant if they are followed by a **written** decimal point.

Number of significant figures resulting from a mathematical operation:

There are two rules that are used for determining the number of significant figures in the result of a mathematical operation: one for addition and subtraction and one for multiplication and division. These rules are:

The result of the addition/subtraction of two numbers has no significant figures beyond the last decimal place where both of the original numbers had significant figures.

The number of significant figures in the result of a multiplication/division is no greater than the smallest number of significant figures in any of the factors.

When evaluating expressions that have a combination of addition/subtraction and multiplication/division, follow the hierarchy of mathematical operations and keep the correct number of significant figures in the intermediate steps.

Scientific Notation

Scientific Notation is used to avoid the ambiguity of zero as a significant figure and also to more compactly express very large and very small numbers. When a value is expressed in scientific notation, the number of significant figures is determined by simply counting the digits in the number before the power of ten multiplier. By definition, all of these digits are to be significant.

The table below shows some examples.

Value	Value Expressed In Scientific Notation	Number Of Significant Figures in Value
3.14	3.14×10^{0}	3
5.260	5.260×10^{0}	4
3.079	3.079×10^{0}	4
0.813	8.13×10^{-1}	3
2440	2.44×10^{3}	3
0.003140	3.140×10^{-3}	4
103.52	1.0352×10^{2}	5
100	1×10^{2}	1
Not possible	1.0×10^{2}	2
100.	1.00×10^{2}	3
100.0	1.000×10^{2}	4

Examples Involving Significant Figures

Adding and subtracting: the last decimal place in common determines the last significant figure in the result:

$$10.230 + 4.15 - 14.1 = 0.\underline{2}8 = 0.3$$

Last decimal place in common

Look at next decimal place for rounding.

Multiplying and dividing: the least number of significant figures in any factor determines the number of significant figures in the result:

2 sig figs

$$0.45 \times 1391 \div 2.29 = 2\underline{7}3.3406114 = 270$$

Last significant figure

Look at next figure for rounding.

Significant Figures In Intermediate Steps

You never want to use rounded numbers in calculations. Instead, report a value to the correct number of significant figures when you record it in your lab book but use the value to calculator accuracy in subsequent calculations. To keep track of the actual number of significant figures of the value in subsequent calculations, underline the last significant figure when writing the number in the expression for the calculation.

For example, suppose we want to know the density of the material that a right circular cylinder is made of. The cylinder has a mass of 27 g, radius of 0.73 cm, and a height of 1.26 cm. We would first calculate the volume:

$$V = \pi r^2 h = \pi (0.73\,\text{cm})^2 (1.26\,\text{cm})$$

$$V = 2.\underline{1}09434954\,\text{cm}^3$$

$$V = 2.1\,\text{cm}^3$$

Now, the volume of the cylinder is used to calculate the density. You do not want to use a rounded or truncated value as this can have a profound effect on the results.

$$\rho = \frac{m}{V} = \frac{27\,\text{g}}{2.\underline{1}09434954\,\text{cm}^3}$$

$$\rho = 1\underline{2}.7996362\,\frac{\text{g}}{\text{cm}^3}$$

$$\rho = 13\,\frac{\text{g}}{\text{cm}^3}$$

The ability to correctly apply the rules regarding significant figures is an important part of your laboratory experience in this course. You should review this document periodically.

Physics Laboratory Information

Graphs and Data Tables

Introduction

The ability to produce and interpret graphical information is essential in any science and engineering discipline. A graph is a method of communicating information much like a written statement or mathematical formula. However, a graph is much more than that -- a graph is an analytical tool from which the written statement and the mathematical equation can be obtained. A graph is a powerful analytical tool you will use often in the physics lab.

The Data Table

For any graph you make, you will need a data table. What goes into a data table depends upon the particular experiment. Suppose you are planning an experiment to measure the acceleration of a freely falling body. You intend to calculate the acceleration of the object from the slope of a graph that has speed plotted on the y-axis and elapsed time on the x-axis. This sounds direct enough, except that the object you are using doesn't come equipped with a speedometer that will allow you to conveniently observe the object's speed. What must be done is to measure incremental displacements of the object over successive time intervals, calculate the average speed of the object during those time intervals, and plot those speeds as a function of elapsed time. The acceleration of the object will then be given by the slope of the graph.

In your data table, you need columns in which to record elapsed time in seconds, and incremental displacement in centimeters. You also need a column for the calculated speed in centimeters per second. Give each table a title and include a number in the title if there will be more than one table for an experiment. Rule off the table in rectangular columnar form. Columns need not be the same width. You can make some columns narrow and others as wide as needed by the data. Head the columns with labels. Column labels should include powers of ten (if appropriate) and units. A single data table may have several columns – extra columns may be added in which to list data that have been derived, or calculated, from initial measurements. In this example, speed is a derived quantity.

When you prepare a data table, you have to decide what experimentally measured and calculated quantities you will record. The data table should be prepared before you take measurements. Then, record your original observed readings directly into the table. Don't waste your time recording values on scratch paper with the intention of copying information more neatly later into your notebook. The scratch paper may be lost more easily than an entire lab notebook. The observed readings are of extreme importance to you. Do not try to short cut work by recording only those calculated values that may be needed for graphs and subsequent analysis. The reason for this is that if you make a mistake in your calculation, there is no way to recover the original data when the mistake is discovered.

While calculated quantities are of obvious importance, all of the conclusions that you draw are ultimately the result of the observed quantities, not the calculated ones, as calculations rely on the validity of the data supplied. Put another way, how would you like to make recommendations to an employer based on your conclusions from data which is questionable at best? If your recommendation causes sufficient expense or embarrassment to your employer because of poor laboratory technique, you will most likely find yourself hunting another job. The point of science is the detailed and accurate recording of experimental observations. This is the reason that data should be recorded directly into the data book. Likewise, never erase any of your original measurements because the entry could be correct after all. Once erased, the data is gone forever. If you are lucky, this will only mean more time in the lab repeating an experiment.

If you do not discover the error in judgment early enough, you may be unable to complete your analysis. The only accepted method for making a correction in previously entered experimental data is: **draw one line** through the incorrect entry. Then, write the correct entry beside or above the incorrect entry. In this way, you have saved the original entry as a backup in case it is needed.

If you perform any mathematical operation on the original data to produce derived data, (in the example above, average speed is derived data) record the derived data in a separate column of the data table, or make a new table for derived data.

Drawing the graph

When plotting a graph, you are indicating a dependence of one variable, called the dependent variable, on another, called the independent variable. The independent variable is a parameter which you as the experimenter control, and is always plotted on the x-axis. The dependent variable is then plotted on the y-axis. Label the axes from the information at the top of the data columns in your data table. Always include powers of ten (if appropriate) and units in the axis label. Numerical scales along graph axes do not always have to begin at zero.

Divide the vertical and horizontal scales of your graph so that your graph takes a large portion of the sheet of graph paper when plotting graphs by hand. The reason for this is that uncertainty is reduced when computing the slopes of lines that extend over a large portion of the page as compared to when the area of the page covered is small. When you get to the point that you are using computers to graph information, choose scales for your horizontal and vertical axes that are easy for the reader to interpret. Remember that the graph is a powerful communication tool. Make sure the reader can interpret the information that you are trying to convey as quickly and efficiently as possible.

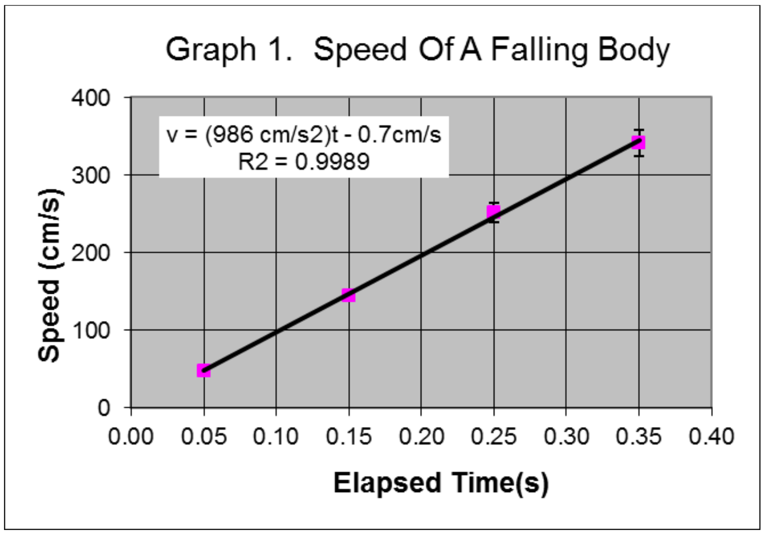
Once you have plotted the data pairs of interest, the next thing to be done is to determine the accuracy to which you know each value. That is, you need to determine the size of the error bars for each data point. While there is obviously uncertainty in both the independent and the dependent variable, usually only the uncertainty in the dependent variable is depicted. That is, only vertical error bars are usually included on a graph. Next, provided your graph justifies fitting a straight line to the data, draw a single straight line that represents all of the data points. Do this by using a transparent ruler over the data points and adjust the ruler until the edge of the ruler appears to represent the data well. This line is referred to as the line of best fit. If you determine the line of best fit in the manner just described, the result is obviously subjective. Once you are familiar with this type of line of best fit, you will be presented with more analytical methods for determining this line of best fit. In any event, do not ever draw a stock-market chart line from point to point. That type of line is completely inappropriate for the physical quantities you will be investigating.

After you have fitted a straight line through the data points, you can draw a slope triangle and from it determine the slope of the line. The slope of the line is given according to

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x}$$

Always remember that the slope of the line you determine from a graph in the physics lab has units, and you should report those units along with your numerical value for the slope of the line. The y-intercept has units as well, and can usually be read directly from the graph, provided the number scale on the x-axis includes zero. If this is not the case, the y-intercept must be calculated by solving the equation of a straight line ($y = m x + b$) for the y-intercept which gives $b = y - mx$. Here m is the slope of the line, and (x,y) form a data pair included on the line of best fit.

You want to include the equation of the line of best fit on any graph that you produce. If the graph is computer generated, you will usually use a numerical technique for determining the line of best fit. You want to make sure that you edit the equation that the computer gives you to include the appropriate symbols for the plotted quantities, as well as inserting units on the numerical constants which are reported. Finally, graphs (like tables) should be titled, with a number in the title if there is more than one graph produced in your analysis of an experiment. Your completed graph for the case of the free falling object mentioned above might look something like Graph 1.



NAME ________________________ Peer Reviewed by: ______________________

Lab 1 Warmup: Significant Figure Worksheet

(This worksheet will not be accepted/corrected if not reviewed/corrected by another student. You both will receive the average grade of the two of you).

How many significant figures does each of these numbers have?

a. 4.73 __________

b. 47.3 __________

c. 4730 __________

d. 4730.0 __________

e. 0.0473 __________

f. 0.470 __________

g. 0.47 __________

h. .47 __________

i. 1.0473 __________

j. 4.73×10^{3} __________

k. 4.73×10^{-3} __________

l. 47.3×10^{3} __________

Write each of these numbers using floating point notation (the notation you are used to).

a. 4.73×10^{3} __________

b. 4.73×10^{-3} __________

d. 47.3×10^{3} __________

e. 47.3×10^{-3} __________

Write each of these numbers using scientific notation.

a. 4730 __________

b. 4730.0 __________

d. 0.047 __________

e. 0.470 __________

Calculate each answer and write it with the proper number of significant figures.

a. 62.2×21.6 __________

b. 62.2 – 21.6 __________

c. 62.2 / 84.5 __________

d. 3.254×2.3662 __________

e. 62.2^{2} __________

f. $(4.73 \times 2.32) - 5.1$ __________

Physics 201 Laboratory Experiment

Uniform Motion

Objective

To investigate uniform motion.
To use graphing techniques to understand and interpret data

Introduction

Uniform motion is the motion of objects in a straight line at a constant speed. In this experiment, you will produce uniform motion using a low friction cart on a track, record the amount of time it takes the cart to reach checkpoints along the track, and interpret your results. **As you complete this lab, pay attention to safe lab procedures and proper recording of data.**

Predictions

Before performing the experiment, graph what you predict for the position of the cart as a function of time, for uniform motion.

Compare predictions with your lab partners. After discussion, make a second graph of the group's prediction for position vs. time.

Procedure

Using the cart on the track, produce the most steady motion you can. As part of your recorded data, explain how you produced this motion and why you consider it uniform.

Assign a starting point and 4 checkpoints along the track. Explain why you have chosen these positions.

Set the cart in motion and record the time of travel from a starting point to each checkpoint. Record how you measure the time. (eg. Will you stop the timer when the front of the cart passes the checkpoint?)

HINT: Practice a few times until you can repeat the experiment consistently.

Procedure (continued)

Record your results in a table, like this one:

Checkpoint	Position on track	Distance from Start	Time
1			
2			
3			
4			

Analysis

Plot your data on graph paper. Draw a line through your data that shows the trend. The points should approximately line up to form a straight line. (We will often work with linear relationships, or you will try to find linear relationships through your thoughtful analysis. Linear relationships are easier to verify.)

How does the graph compare to your prediction? Tell the ways in which they differ and why this occurred. If the graphs are the same, tell what assumptions you made when making the prediction.

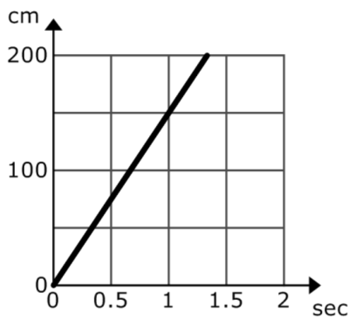
Compute the slope of your line. What is the meaning of this slope? Verify that your result is reasonable.

Questions

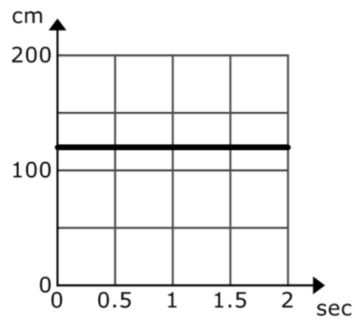
Look at the time you recorded at checkpoint 4. If the cart traveled for twice as long, how far will the cart be from the start?

Consider the graphs of position vs. time below. How does the slope of each of these graphs compare to your original graph? What can you say about the motion (compared to your cart) in each case?

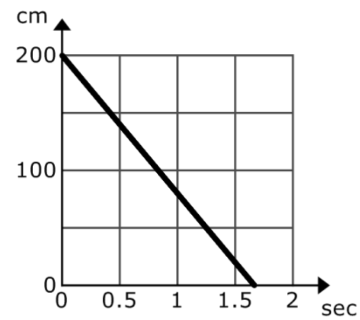
GRAPH A:



GRAPH B:



GRAPH C:



Use the knowledge you gained in this lab to graph this situation in your lab notebook:

A dog is walking down the street, pulling its owner with a leash. The dog spies a squirrel straight ahead, stops for a few seconds and stares, then runs as fast as it can toward the squirrel. Make sure you present your graph with a title and labels on the axes.