Lab Report Format

Full laboratory reports for this course should include each of the following items in the order described in this document. Make sure that each section and subsection is labeled with the section headings. Do not number the sections. Lab reports are turned in electronically. Most students find that a Google Doc is the most practical way to assemble the report. Any mathematical calculations should be done either with a decent equation editor or by inserting a photo of handwritten calculations.

1. Title of the experiment. The title should be descriptive of the experiment that was (is to be) performed. I like lab titles which describe the lab in a creative or humorous way, but describe it!
2. Name of experimenter/report author. This is YOU! Since you will be including the names of your lab partner(s), make it clear that it is your lab report, not theirs.
3. Date. This should list the date(s) that the experiment was performed.
4. Lab Partners. This should list the names, first and last, of each of the students with whom you performed the experiment.
5. Purpose of experiment. This section is one of the most important sections of the writeup. In the purpose section you should clearly state your objective for the experiment. In general this should tell what you are trying to find, determine, show, verify, etc. Make it clear what you are trying to do and basically how you plan to do it. Sometimes the purpose of the experiment may be stated as a particular problem that you are trying to solve with the experiment. You will specifically address your purpose in the first section of your conclusion. If there are multiple parts to the purpose, you should state each part of the purpose separately.
Example: The purpose of this experiment is to determine how a battery powered car traveling on a level surface moves. We will describe the motion by measuring the position of the car in equal units of time, analyzing the graphs of the data, and by finding a relationship between position and time for the car.
6. Hypotheses. Basically, a hypothesis is your best guess/prediction as to what the results of your experiment might be. This could be stated in an if/then or similar mode. A hypothesis will help guide you as you design and carry out an experiment to fulfill your purpose. These must be generated before performing the experiment. Since lab instructions are available for you in advance of the lab, I will expect that you have generated hypotheses consistent with your purpose prior to beginning the lab. I may check to see that you have done so by asking you to submit your hypotheses or by giving you a quiz in which you have to restate your hypotheses. If there are several major parts to an experiment, you should generate a separate hypothesis for each part of the experiment. Note that there is no pressure on you to have a "correct" prediction in your hypothesis. You should certainly never bias your experiment to try to make your hypothesis "true." In middle school "If A increases, B increases" was sufficient. At the high school, we expect something more like "If A doubles, B ___________."
Examples: As the mass hanging on the end of the pendulum increases, the time required to complete a swing of the pendulum will increase quadradically. OR—I expect the car to move with uniform motion. OR—I expect we will find g to be within 4% of its accepted value. OR—I suspect our value for period will be slightly higher than the actual value because of unavoidable air resistance.
7. Equipment Used (Apparatus). Note that the word is equipment, not equiptment. Make a complete list of the equipment necessary to perform the experiment the way you performed the experiment. If you have a power supply, record the manufacturer. If you use a spring, include its dimensions so you could pick it out of a pile, etc. Properly measured and recorded equipment will save you pain and make you a hero among your peers.
8. Diagram/Description of experimental setup. You should always include a diagram of the physical layout of the apparatus for your experiment. You are not required to be an excellent artist. You are, however, expected to make a neat and properly descriptive diagram. Use a straight edge for straight lines. Label all parts of your diagram. If the diagram does not "stand alone" to describe how to set up the equipment, you should also include a written description of the experimental setup to supplement your diagram. Don't just show a meter stick off to the side – show me how it was used. Often physical variables like length can be indicated and defined from your diagram.

9. Procedure. Write a brief procedure that describes how to perform the experiment you have described in your purpose and hypotheses. This can be a set of steps or a written narrative. Keep it to the point. Including phrases like, "vary the mass on the cart as shown in the table on p. 72," can save you time.
10. Data Table. The data table should be neatly laid out with each variable heading a column including the units of measurement. Data should be displayed in columns (not rows) to the correct number of significant figures for the instruments and techniques used in its collection. Data tables should be titled with some sort of descriptive title making it clear which part of the experiment the data represents. Data tables should have lines (drawn with a straight edge) which separate columns and which offset the title, variable descriptions and unit descriptions from the data (if your data table is from a spreadsheet, make sure the cells are bordered). There is no need to include units on each entry in the data table if the units have been specified in the column heading. Pay attention to standard conventions for the placement of the independent variable (left-most column) and the dependent variable (to the right of the independent variable). Sometimes it will be more convenient to use abbreviations to describe the quantity in some or all of the columns of a data table. If you use abbreviations, be sure to specify exactly what your abbreviations represent. Include, near your data table, a description of the values of quantities which were held constant in the experiment. This will be very important when you attempt to determine the significance of the constant of proportionality of the graphs (slope). If you make a data table using software, all the previous rules apply. Print it out and glue it in your notebook. If you have taken hundreds or thousands of measurements, please just graph the data (exclude that data table). If a data column is not directly measured, it needs a distinct symbol (asterisks, etc.) linking it to…

11. Sample Calculations. Many values in your data table may not actually be collected data but may rather be the result of some manipulation or calculation of the data collected in the experiment. You do not have to show each individual manipulation and/or calculation if you will show one example of each manipulation or calculation **with some description of what is being done and with some reference (asterisk) to which column of the data table is being demonstrated by the sample calculation**. Don't forget to show the equation(s) used in calculations (if you used one) and to include units throughout the calculation. Sample calculations are required for every column of your data table that is the result of a calculation, no matter how simple. **Make these calculations on the same page as your data table** so that they are easy to find. Label this section: SAMPLE CALCULATIONS. Each sample calculation should include a written description and or symbolic representation of the calculation to be done. This should be followed by substitution of a specific data point from the raw data (including units) into the symbolic representation (equation). Finally you should calculate the value and show how the units work out (dimensional analysis.)

12. Graph(s). For each relationship that is being investigated in your experiment, you should prepare the appropriate graph. If your graph does not yield a straight line, you will be expected to manipulate one (or more) of the axes of your graph, replot the manipulated data, and continue doing this until a straight line results. Include both non-linear and linearized graphs in your report. In general it should never take more than three graphs to yield a straight line for this course. Graphs will be checked for each of the elements described in class (and in the Student Guide to Graphical Analysis) as essential for good graphing. These include:
a. A title that describes the experiment. For example, if the graph shows the distance moved by a rolling ball as a function of time, and distance is on the Y-axis and time is on the X-axis, a good title might be POSITION vs. TIME FOR A ROLLING BALL. Note that the Y-axis's name always is said first.
b. A graph which fills the space allotted for the graph.
c. The graph must be properly scaled. Scale each axis so as to take up a maximum amount of the space available yet still maintaining divisions which will make plotting the graph as easy as possible. Follow the 1, 2, 5 rule (see Student Guide to Graphical Analysis) when scaling your graphs.
d. Each axis must be labeled with the quantity being measured and the units of measurement. If the graph has time squared on the horizontal axis, the horizontal axis should be labeled: TIME^2 (s^2).
e. Each data point should be plotted in the proper position. You should plot a point as a small dot at the position of the data point and you should circle the data point so that it will not be obscured by your line of best fit. These circles are called point protectors. If they're missing, I'll write PP and be pissed.
f. A line of best fit. This line should show the overall tendency of your data. If the tendency is linear, you should draw a straight line which shows that tendency using a straight edge. If the tendency is a curve, you

should sketch a curve which is your best guess as to the tendency of the data. This line (whether straight or curved) does not have to go through all of the data points and it may, in some cases, not go through any of them. Do not, under any circumstances, connect successive data points with a series of straight lines, dot to dot. This obscures the overall tendency of the data that you are trying to represent, and somewhere, somehow, you have just made a small child cry. I hate you.
g. If you are plotting the graph by hand, you will choose two points for all linear graphs from which to calculate the slope of the line of best fit. These points should not be data points unless a data point happens to fall perfectly on the line of best fit. Pick two points which are directly on your line of best fit and which are easy to read from the graph. Mark the points you have chosen with a +. Do not do other work (such as the mathematical analysis) in the space of your graph. If you graph with a computer, make sure an equation for the line is shown.

13. Mathematical Analysis. In this section you will find an equation which describes the relationship between the variables for each straight line graph that you have plotted. If the relationship is a direct proportion (a straight line graph through the origin) you should follow steps on the left. If the relationship is any straight line which is not a direct proportion you should follow the steps on the right. You'll be surprised how many times the y-intercept can tell you interesting things about your experiment.

Linear Relation—Direct Proportion

1.	Stretch $\rightarrow$ S Mass $\rightarrow$ m	(definition of variable symbols)
2.	$S \propto m$	(relationship stated as a proportion)
3.	$S = km$	(proportion rewritten as an equation)
4.	$k = \frac{\Delta S}{\Delta m}$	(definition of slope)
5.	$k = 0.30\ \frac{\text{cm}}{\text{g}}$	(slope calculated by computer)
6.	$S = 0.30\ \frac{\text{cm}}{\text{g}} \cdot m$	(substitution into general equation)

Linear Relation—Not Direct Proportion

1.	Stretch $\rightarrow$ S Mass $\rightarrow$ m	(definition of variable symbols)
2.	$y = mx + b$	(slope - intercept form of line)
3.	$S = km + b$	(defined variables substituted)
4.	$k = \frac{\Delta S}{\Delta m}$	(definition of slope)
5.	$k = \frac{S_2 - S_1}{m_2 - m_1}$	
6.	$k = \frac{18.0\text{ cm} - 6.0\text{ cm}}{50.0\ g - 10.0\ g}$	(substitution of marked slope points from graph)
7.	$k = 0.30\frac{\text{cm}}{\text{g}}$	(result of slope calculation)
8.	$b = 3.2\text{ cm}$	(read from graph)
9.	$S = 0.30\frac{\text{cm}}{\text{g}} \cdot m + 3.2\text{ cm}$	(substitution into general equation)

14. Sources of Error. This section should discuss any factors which could have affected the results of your experiment. Be specific. NEVER list "human error" as a source of error. It would be reasonable, on the other hand, to list the reaction time associated with starting and stopping the stopwatch as a source of error. Sometimes the error will be unavoidable because it is systematic. In other words, it is a direct result of the method or equipment used for collecting data in the experiment. If the method could be replaced with one which gives as good or better results without the built-in error, you should suggest such an improvement in the procedure of the experiment (and maybe even do it). Sometimes the error is avoidable because it is the result of poor measuring on the part of the experimenter. While you should avoid the latter type of error, you should report all possible sources of error in an experiment. "It's late and I'm tired" is not a source of error. It's a reminder that you should do your labs right after performing the experiment.

15. Error Calculations. If your lab has a linear graph, your error calculation should be based on its slope rather than presenting me error for each of the data points. Where there is an accepted value for a quantity which have determined in an experiment, you should include a calculation of the absolute error and the relative error in the experiment. Also where you have measured something and also used experimental data to determine it. This will happen in almost every lab, multiple times. Sometimes it's tricky to find something to analyze for error, but be persistent. For a simple example, let's say the slope of a velocity vs. time graph represents the acceleration due to gravity, and the accepted value for this quantity is 9.80 m/s^2. The slope of your velocity vs. time graph yields an experimental value of 9.92 m/s^2. Make sure that you describe how you determined the experimental and accepted values. The calculation of the absolute error and relative error would be as follows

Error analysis on the acceleration due to gravity:
Experimental Value of acceleration due to gravity = slope of velocity vs. time graph
Experimental Value = 9.92 m/s^2

Accepted Value of acceleration due to gravity = acceleration due to gravity on earth
Accepted Value = 9.80 m/s^2

ABSOLUTE ERROR
Absolute Error= |accepted value-experimental value|
Absolute Error= |9.80 m/s^2 – 9.92 m/s^2|
Absolute Error= |-0.12 m/s^2|
Absolute Error = 0.12 m/s^2

RELATIVE ERROR
Relative Error = (Absolute Error)/(Accepted Value)
Relative Error = (0.12 m/s^2)/(9.80 m/s^2)
Relative Error = 0.012
Relative Error = 1.2%

16. Conclusion This is the most important part of your lab report. It will be worth a major portion of the credit on the lab. You should devote considerable thought and effort to this section of every lab report. This section should summarize the results of the experiment, discuss thoroughly the relationships found, and support any statements made with direct evidence from the experiment. The conclusion should be written in paragraph form and include the following (not bulleted, without a bold section heading):

- **Restate your purpose.** Your conclusions should begin by addressing the purpose you originally stated in the introduction. If there are multiple parts to the purpose or multiple purposes, be sure to address each of them.
- **Restate your hypotheses.** Make sure that you have as many hypotheses are there are parts to the purpose.
- **Briefly describe the experiment.** This does not require the same level of detail you provided in the procedure described in the introduction to the experiment.
- **Make a claim.** Address your purpose. Answer the question posed by the experiment.
- **Provide evidence.** What do you see in your data or graph that supports your claim
- **Tie the claim and evidence together with reasoning.** Explain how the evidence supports the claim. This section might include things like explaining the physical significance of the slope or y-intercept of your graph. After that, you can provide any general mathematical models that you know because to ht lab. You might state any laws of physics that are supported by your data. You should include any new vocabulary learned through the lab.
- **Repeat the C, E, R process for each hypothesis.**

Plagiarism

Do not use anyone else's words at all. Discuss extensively with others, but choose your own words for your writeup. The single exception is that you may share a verbatim hypothesis and procedure with your partner.

If you are working on graphs together during class, you may use the same copy for you reports. If, however, you run out of time in lab and must finish the rest of your graphing outside of class, you should make a copy of the spreadsheet and then work on your own individual copies outside of class.