# Writing Lab Reports

Lab reports are an important skill used in the work force today. You will be writing reports to your bosses or journal articles to your colleagues. **It is important to know your target audience to know at what level your papers should be written**. These lab reports will give you practice on writing papers to a lay audience. Assume your audience has some familiarity with physics, but needs to have everything explained to them. You will not need to define terms, but you should explain any equations you use with what the variables stand for.

A lab report will be required for 2 experiments and a short write up for the other 8 experiments. Each report must be typed. All graphs and charts must be generated using a computer unless specifically told otherwise. Reports will also be graded for good grammar and writing practices. A lab report will be worth a total of 100 points and should contain:

1. **Abstract** - brief discussion of the main results of your experiment (including what was the expected result).

2. **Theory** - description of the basic physical concepts demonstrated in the experiment. It should include all relevant equations and a drawing of what is happening. Also include a brief discussion of the lab setup and the procedure followed to get your data. This is where you put what results you expect.

3. **Data and Graphs** - All data must be provided in tabular form. Title each table and graph. Each graph must have properly labeled axes along with the appropriate units. **Turn in your original data sheet signed by the instructor along with the lab report.**

**4. Calculations** – Show the first calculation for all calculations (equations) in the lab. Some labs will ask for every calculation you do of a certain type. Watch for this.

5. **Results, Analysis and Conclusions** – summarize the results of your experiment and analyze your data. Compare the results of your experiment with those predicted by theory. Justify any differences. Investigate possible errors and uncertainties in your experiment, which might have affected the accuracy of your results. **Also answer any questions in the lab that have not already been answered. Label all answers to questions with a (Q#) format where # is the question number being answered. This will allow the TA to quickly find your answers to all questions.**

This is a basic rubric that covers how lab reports should be written in general. However, every lab is different, so it is our expectation that you will figure out how these general questions apply to the lab at hand. How much or little is required is at the discretion the TA. I f you are in doubt, ask!!!

**General Notes:**

1. Every lab will not mimic theory exactly. In some cases experimental results are very different than theory due to experimental error. The TA may chose to grade you based on how close your numbers are to theory, however the tolerance is at their discretion. The TA may also choose to disregard the actual result as long as you can explain what should have happened and why your answer is different. Always report on data you get. **Note sometimes discrepancies indicate new science.**
2. You should keep a copy of your lab report for your records both ungraded (in case it gets lost) and graded (in case of a dispute about your grade).

**Abstract-** (At least 3 sentences long, but anything longer is dangerous)

1. State the general purpose of the lab. **For example**:
   1. The purpose of this lab was to test conservation of energy.
   2. The purpose of this lab was to measure the acceleration due to gravity.
2. Lay out the basic setup of equipment used in the lab. This should not be a complete list of equipment but a very short description of what the equipment as a whole is. **For example:**
   1. A ballistic pendulum was used to … by …
   2. A mounted spring system was used to … by …
   3. An airtrack system was used to … by …
3. Make a conclusion in the form of words that answers the purpose. **For example:**
   1. If the purpose is to measure g, then you should list the value (number) of g attained and say if it is accurate or not. If you are after a number include that number here.
   2. If the purpose is to measure conservation of energy, you should say if the experiment was able to show conservation of energy or not.

**Theory-**(As long as it needs to be)

1. A brief descriptionof what is done in the experiment and how the equipment is used to show the physics concept at hand. This should include a short description of the setup and a **diagram** of the setup. You can also include how parts of the setup were used to minimize error. Also include any deviations from the suggested setup and why they were necessary. **For example:**
   1. An airtrack is used to analyze motion by putting it at an incline and analyze the speed the airtrack glider achieves as it moves down the incline. The distance was varied by … for each trial. The speed was measured by … and the time was measured by … The picture is below in Figure … (label it with pertinent information). It was noticed there was not enough air coming through the holes to allow the glider to move smoothly, so the air was turned up.
2. Any knowledge (including but not limited to equations) that you use to do the labs needs to be listed and explained. **Now physics knowledge can be thought of in terms of three main ideas: motion, the forces that cause the motion, and the conservation laws including energy and momentum.** Decide which concepts are appropriate for the lab and discuss them. A good rule of thumb is to include and explain in your theory every basic equation that is used in the lab**.** Some like statistics may be included in every lab, a more extensive explanation is required the first time you use these ideas but a short summary is fine in later labs. Some ideas will take more explaining than just one equation. Take the time to do a thorough job and explain the different parts of an idea. **For example:**
   1. Conservation of energy is best discussed by describing kinetic and potential energy in their own right, then move on to discuss how the total initial energy is equal to the total final energy. Then you would explain how kinetic and potential energy are used in the lab in the calculation of total energy, what quantities are zero (and why) if any, and how to manipulate the equations to get what you want. **Include where the reference zero of potential energy is assumed to be.**
   2. The linearization equations and experimental equations discussed in lab 1 are used in several labs. Describing the procedure in your own words for obtaining these two equations and give the physical quantities each variable represents in both equations and how they relate to the theory equation would be what to include here in theory.
   3. Newton’s laws are also used in many labs. A completely labeled free body diagram with the complete set of Newton’s equations for each body in the lab is required. Some solutions to these equations will be asked for and should be included here in theory. These equations should have explanations of the different forces which are zero and which are equal and why. Any assumptions and simplifications necessary should be included.
3. It is important to explain what the theory says the results of the experiment should be. **For example:**
   1. By looking at the theoretical equation the relationship between the different variables could be determined to be a linear or power relationship.
   2. The slope of a graph should give you a value for gravity if you make the appropriate calculations.
   3. The theoretical equation can be solved for acceleration or kinetic coefficient of friction.
   4. You can determine whether or not a quantity should be conserved in the lab.
4. **Assumptions are used in every lab!!!** You need to make it clear that you understand what the assumptions are, how you are using them, and why you are using them. **For example:**
   1. Many labs ignore fiction or response time and this should be clearly explained why.
   2. Any approximation needs to be clearly explained.
5. Any manipulation of data needs to be acknowledged and justified. This could be done here in theory or in the conclusions part of the report. **For example:**
   1. Reaction time manipulations should be discussed as to what was done and why it was necessary
   2. In a lab, we run the experiment from a set lower value to a set higher value. A discussion of this and why it was done is necessary.

**Calculations:**

1. **Example calculations must be in the form of:**

**Formula with labeled variable**

**= formula with numbers plugged in for variable (with no simplifying or rearranging)**

**= a number…**

1. Calculations may be done by hand if they are legible, but using Equation Editor is better. That way you will be able to keep an electronic copy of your lab report.
2. All instances of finding the linearization equation and experimental equation must be shown in detail. Also all instances of using the propagation of error must be shown in detail. Once is not enough and show all work.
3. Only one set of example calculations is necessary for each table. This would consist of one row or one column of each table. If the same formula is needed for each cell, you still need to include work for one row/column, because knowing what value to plug into the formula shows understanding.
4. Some students show all of their work in the chart by letting the first row/column be the label (with units), the second row/column be the formula with variables, the third row/column be the formula with the numbers plugged = number, then the fourth row start the cells of numbers (repeating the final answers from row/column three).
5. One example calculation for the average, standard deviation, SEOM, percent difference/error, or any other required statistical information needs to be included with every lab.

**Data and Graphs**

1. Often students reproduce the tables from the lab manual and place them in the lab report for reference. This is required either as a Xerox copy or by retyping the data tables. Also, the **sheet that you manually recorded data on during the lab must be attached (with TA’s initials) to the end of the lab report.**
2. All graphs are expected to be done in excel. NOT BY HAND, unless specifically otherwise stated. Please put more than one graph to a page. 3 graphs per page is a good suggestion.
3. If a graph of data is required it needs to be fully labeled with an appropriate graph name, axis labels, and unit labels for all axes. The equation of the trendline and the R2 value must both be on the graph.
4. **IMPORTANT NOTE: In working with graphs to find the experimental equation, if theory says your data should be linear use the linearization equation from your linear graph to find the experimental equation**. You may find another graph has a larger R2 value but you should use the graph theory predicts to find the appropriate experimental equation not the one with the highest R2 value. Just note in the conclusion which graph had the highest R2 value and discuss what error in the lab might have caused the discrepancy.

**Results, Analysis and Conclusions**

1. A list or reproduction of your final results is necessary. **For example:**
   1. The value of g was determined in several ways, list all of your final values for g in one place (a table would be better) in the conclusion. Include which method produced which value.
   2. Several graphs were analyzed; list the final experimental equation for each set of data and the comparison of it to the theoretical equation.
2. Be specific about the results and conclusion for each experiment or section. What did each experiment contribute to the overall conclusion/result? What errors where inherent in each experiment? (See below)
3. **How to deal with bad data:** Grading of data is at the discretion of the TA. However, if your data does not agree with theory, do not say that the experiment showed/proved the principle of physics at hand. The TA will be looking to make sure you made the appropriate conclusion from the data that you measured. Often, if you make the right conclusion, know what theory says should have happened, and can clearly identify where the error came from, you will lose little or no credit.
4. **Any and every error in the lab needs to be fully discussed** here. What the error was is not enough. You must include where the error came from and an estimate of its effect on the results. **For example:**
   1. We disregarded friction” is not good enough. You need to discuss where the friction is coming from in the device set up and estimate the magnitude of its effect, such as did it cause you to over or under estimate a variable or keep you from reaching the expected conclusion. A numerical estimate of the effect is not necessary unless asked for, just the trend.
   2. A discussion of which graph had the highest R2 value and what error in the lab might have caused the discrepancy between expected results and actual results
   3. A short list of possible example errors that need further explanation: sources of friction, assumptions, reaction time, insensitive measuring devices, calibration errors, environmental effects, flaws with the experimental setup, and/or devices that are not working properly (ie warped, etc. ).
5. Where appropriate, quantify error with percent error or percent difference. Include an explanation of what happened and why your results are not what you expect. **For example:**
   1. If g = 9.79 m/s2 and you get an experimental value of g = 8.95 m/s2. A percent error of –8.58% is calculated. Reasons for the discrepancy should be given.
6. One more thing to consider is whether or not the theoretical value is in the range of your experimental value and its uncertainty. **For example:**
   1. The theoretical value of a is .45 m/s2 and you get an experimental value of .512 ± .005 m/s2. The range of your experimental value is .507 < a < .517 m/s2. The theoretical value of .45 m/s2 is not in this range. Reasons for the discrepancy should be given.
7. This is also a good section to describe how to improve the experimental setup. Anything touched by human hands is a good place to start when describing the error inherent in the lab.

**Questions**

1. Most questions will be answered in the body of the lab report. You do not need to repeat the answers in a separate section if you label the question sufficiently well in the lab:
   1. Labeled the answers to questions with a **(Q#) format** where # is the question number being answered.
   2. **This should be in bold to make it stand out from the rest of the lab report.**
   3. This could be dangerous because it is more difficult for the TA to find the answers. Also some of the questions have parts to be answered in different sections of the lab report. You might think you completely answered the question but you didn’t or the TA couldn’t find the rest of your answer.
2. It is best to have a separate section of the lab report at the end for questions. If you answered the question somewhere else. Give the question number and copy/paste your answer as it appears in the body of the lab. Still use the **(Q#) format.**
3. It is helpful to copy the question with the answer. That way you actually read the entire question and are more likely to answer it fully.