Physics 335Z
Lab Report Writing Guidance v3.0

No matter what your declared major, the ability to clearly and accurately convey the results of your experiment or research is pivotal to your future success. This is one of the primary reasons that most majors include a scientific lab course in their requirements. In your case it is your good fortune that you have chosen Physics as your discipline.

Like most scientific disciplines, Physics has its own style of conveying information that encompasses papers, reports, and textbooks. In Physics the goal of any paper or report is to convey the most information with the least amount of overhead. We hold the adage "a picture is worth a thousand words" very dear; by using carefully crafted graphs and tables and very short but complete explanations of what they mean we can achieve this goal.

Your task in this class is to embrace this philosophy of austerity and clarity and apply it when writing your reports. It is hoped that in doing so you will apply this same strategy to papers and reports not only during your academic career but in your final occupation as well.

This expectation should not alarm you; it comes with the availability of guidance from both your Professor and the instructors assigned to the class. I implore you to take advantage of these resources when preparing your lab reports so you can produce the highest quality product with the least amount of stress.

To this end, enclosed is an ironically detailed description of how to approach your lab reports. By following this guideline you should be able to produce a quality lab report without wasting a great deal of time or effort.

Good luck.

Lab Writing Guidelines

There are several general concepts to keep in mind when you conduct your experiment and compose your lab report.

1. You should always keep the end goal in mind both when performing the experiment and when you are writing your report. This means that when you write your report try to stick to concepts, information and equations directly pertaining to the experiment. A more general discussion of the subject matter is usually covered in the introduction section of the report, which we will aim to keep brief and to the point.
   A good example of this would be the Statistics and Uncertainty Lab from Physics I. In this lab the standard deviation of a data set is calculated using the equation given. You need only to mention this equation and what it means, and do not have to delve into the broader field of statistics and where this equation may fit into it.

2. Uncertainty analysis is one of the most important components of the experiment and report. You may think that uncertainty analysis is a mundane afterthought in your experiment, but this could not be further from the truth. If we as experimental Physicists want to make the claim that what we measure is the correct value for a given measurement, we must be honest with both ourselves and the reader as to the limitations of our equipment and analysis procedure. This honest assessment of uncertainty is the key to the credibility of experimental physics.

3. Avoid personal pronouns. Terms including we, us, he, she makes the report seem less about the experiment and more about the experimenters. In addition, including personal pronouns tends to lengthen any sentence they are used in which is counter to keeping it short and direct, which is the preferred style

4. Make sure that your sentence structure and spelling is both clear and correct. This is after all a writing class as well as a Physics class. There is no shame in spell and grammar check, they are your friends. Nothing detracts more quickly from the overall quality of a report than sloppy writing.

5. Writing is not so much about writing as it is about re-writing. Proof-read your work critically. Have your lab partner proof-read your work. And when you think you are done, proof-read it again. You will be surprised how much the work improves with each proof-reading. And often it only takes 15-20 minutes.

6. When writing your report you should keep the reader in mind. The report should be “complete”, this means that all equations and concepts used during the experiment or during the analysis are included in the report. You should make the information contained in the report easy to reference by either properly labeling or physically separating it. (more on this later)

7. When in doubt, look up a couple of scientific papers on a topic that interests you and read them. There is nothing wrong with emulating the style of a well-written paper.

In this class, we will use the American Institute of Physics (AIP) format for publication. Please consult the AIP Style Manual (available on our course website) for more details.

You may use your favorite word processor to write the report. However, the final submitted version should be in PDF format. Extra credit will be given to individuals who take the *time and effort to learn* how to use LaTeX or RevTeX to compose their lab reports. Instructions can be found online.

AIP Specifics and Guidelines

Creating the title:

The title should clearly state what you measured and if possible how you measured it. Whether to including how you measured the value depends on how briefly you can describe it.

Examples would be:

Statistical analysis of two cards consecutively drawn from a standard deck being of the same suit.

The validity of the one electron-shielding model tested through the use of X-ray fluorescence.

Writing the abstract

The abstract should be a very condensed version of your conclusion. In fact the first paragraph of your conclusion often contains much of the same information as your abstract. You should write your abstract after you complete your report. It is hard to summarize something that you have not written yet. The abstract should include the following points (if applicable) in the following order:

1. Clearly state the goal of the experiment. For example, what did you measure or what theoretical concept were you testing?
2. Clearly state what procedure you employed to measure or test your objective. This should be as brief as possible, leave the details for the experimental procedure section.
3. If applicable state how many times you performed the experiment. This gives the reader a sense of how thorough the procedure was in determining the final value. This may not always be applicable; for instance, if the experiment you perform requires several years to gather data you cannot conduct multiple trials very easily.
4. State what your final results including the quantification of associated uncertainties. There are times where this would be a number or a physical value and there are times when this would be an overall assessment of a concept or theory.
5. If applicable, briefly discuss how the final result compares with the theoretical or anticipated value in terms of experimental uncertainty.

An example would be:

The experiment performed was to determine the statistical frequency of any two cards drawn consecutively from a well-shuffled desk being of the same suit. The procedure was repeated five hundred times with an average of 2.72 +- .0167 per ten draws. The theoretical value of 2.553 per ten draws is within two experimental standard deviations of the measured value.

Creating the cover page and report.

Each manuscript has a cover page. Below is an example.

Statistical analysis of two cards consecutively drawn from a standard deck being of the same suit.

Joe Student

Department of physics, State University of New York, Albany, New York 12222

(Received ←Not a mistake there should only be one parenthesis

Abstract

The experiment performed was to determine the statistical frequency of any two cards drawn consecutively from a well-shuffled desk being of the same suit. The procedure was repeated five hundred times with an average of 2.72 +- .0167 per ten draws. The theoretical value of 2.553 per ten draws is within two experimental uncertainties of the measured value.

The extra space left above and below is for the reviewer to leave notes

The following describes the various sections (Introduction, Experimental Design, Experimental Results and Conclusion) in the order in which they should appear.

Introduction

The introduction should be used to provide a brief description of the physics problem that is being solved or explored in the manuscript. One to two short paragraphs (approximately) one-half of a page of text should suffice in most cases.

Experimental Design

The experimental design section should cover your experimental setup, any associated theory, equations, and how you handled your uncertainty calculations. The key here is to relay all of the necessary information in the most condensed fashion possible. It should allow the reader to be able to duplicate the experiment without it reading like lab instructions. It should contain a brief but comprehensive description of the equipment used and how it functioned in the experiment. Illustrations often work very well to help with this explanation. You may use illustrations from lab manuals, as long as you properly reference them.

An example of the distinction between a comprehensive description and lab instructions would be as follows:

Assume there are 3 different signals that are monitored during the experiment. There are two different ways of approaching the description.

1) Signal one was monitored on channel one of the oscilloscope at a range of 1-3 volts, signal two was monitored on channel two at a range of 1-3 volts and signal three was monitored on channel 3 at a range of 1-3 volts.
2) The three signals were monitored using an oscilloscope with appropriate ranges.

The first version reads like lab instructions (possibly) with too much specific detail. The second version tells the reader how you monitored the signals without including unnecessary instructions. Always take the time to decide whether the same information be transmitted using fewer words.

You also need to list and describe any equations and concepts that are relevant to the experiment. Some of the equations you use need to be derived, rearranged, or solved for a particular variable. You should include the not-so-obvious aspects of this work in your manuscript. Here are some specifics for including equations:

1. Each equation should appear **centered** on its own line.

2. Each equation is assigned an equation number or label (sequentially increasing) in parentheses justified to the right margin. This allows equations to be easily referenced elsewhere in the text and found by the reader. In MSWord, this is often accomplished by right justifying the line, and inserting tabs and/or spaces between the

equation number and the equation itself to move the equation to the left until it is centered. In LaTeX or RevTeX, one should use the equation environment.

3. In MSWord, the equation editor should be used to type the equation. In LaTeX equations should be included using the equation environment (encapsulated between \begin{equation} and \end{equation} commands. This will automatically center the equation on its own line and give it a proper equation number.

4. Equations are part of a sentence and, as such, proper punctuation and capitalization should be utilized. Note that each of the examples below constitutes a single sentence. Note that “where” in the first example, and “with” and “to obtain” in the second, are not capitalized and do not start a new sentence or paragraph (despite what MSWord tries to do). Example 1 is all one sentence, and Example 2 is comprised of three sentences.

5. All the variables in the equation need to be explained in that sentence (or immediately thereafter) if they have not appeared previously in the text.

6. Each variable is defined by a specific font and typeface. In this case, Equation Editor used Cambria Math Italicized to write the variables in the equation. The same variables elsewhere in the text MUST have the same font and typeface. A letter in a different font or typeface could, in some cases, be interpreted as a different variable!

7. If numbers or numeric quantities are used in an equation or expression, then the units MUST be expressed.

Example 1

The equation for the rest mass energy of a particle is given by

$$E = mc^2 \tag{1}$$

where E is the rest mass energy, m is the mass and c is the speed of light.

Example 2

The work required to pull a mass on a spring can be easily found by first noting that the force F on the mass m is proportional, while opposite in direction, to the displacement x, which can be expressed as

$$F = -kx \tag{2}$$

with the proportionality constant being the spring constant k, which has units of force over distance. One can then use the force equation given in (2) above and integrate it using the definition of work

$$W = \int \boldsymbol{F} \cdot d\boldsymbol{x} \tag{3}$$

to obtain the work done, which in this case is

$$W = \int_{x_i}^{x_f} F\, dx$$

$$= \int_{x_i}^{x_f} -kx\, dx$$

$$= -k\left({x_f}^2 - {x_i}^2\right) \tag{4}$$

where x_i is the initial position of the mass m and x_f is the final position. The internal energy stored in the spring is then given by $U = -W$, which is

$$U = k\left({x_f}^2 - {x_i}^2\right). \tag{5}$$

Note how the equations are part of the text and flow right along with it. Equations (3) and (4) are both part of the same sentence along with (5), which ends it.

With equations clearly expressed and labeled a reader can easily follow the flow of ideas and refer back to earlier results to understand a complicated study. This ability to easily scan your manuscript for pertinent information is a feature you should think about in each section as you write.

This section would also include any theoretical values or equations that are needed for the experiment as well as an explanation as to how uncertainty was handled with the associated equations.

Experimental Results

This section includes the results and analysis of the aforementioned procedure. This section can be the most challenging to accomplish. You need to include the necessary information to back up your results without overloading the reader with unnecessary clutter. The use of tables and graphs is invaluable in representing large data sets in a fashion that is digestible to the reader.

A good example would be the Statistics and Uncertainty lab from Physics I. In this lab we only repeated the experiment nine times, this allowed us to include a table with individual values for each toss. However if we repeated the experiment five hundred times including the data for each toss would be cumbersome at best. You could instead graph the data and make a visual representation of the values in a small space or you could create a summary table with just the important information needed to make your case. Either of these approaches would minimize the footprint the data would have in the report.

Your tables need to be clear and include labels with units. All quantities in table headings, or contents, or figure axes, or legends, need to be properly labeled with units. Every table or figure is labeled, such as Table 1, or Figure 2, and referenced as such, consistently in the text. In addition every table and figure needs a caption. The caption should be succinct, but descriptive and relatively complete, highlighting any important details (even if they appear elsewhere in the text). Keep in mind that some readers focus on the abstract, the figures and tables and the conclusions. Summarizing important results displayed in a figure in the figure caption is encouraged. If there is a way of consolidating tables without confusing what is being presented you should work towards that end. Never bury your results within the text, always find a way to separate the results from the text. This follows the rule of making the information easy to reference.

After presenting you data, either in table or graphical form you need to discuss what it all means. Just spilling the data onto a piece of paper does not constitute a report. The purpose of the report is to give the reader some insight into the subject matter you are exploring. This would be the appropriate section to discuss your findings and the associated uncertainty involved.

Conclusion

As mentioned above, the conclusion section usually starts with much of the same information as your abstract. After this you may want to expand on the information included in the abstract. Typically this is where the in depth discussion and analysis is summarized from the report. This includes a discussion of what can be concluded from your analysis, and what the greater implications are, if any.

References or Bibliography

Any works cited in the manuscript (citations) must be listed in the References section or Bibliography. This includes any relevant research papers mentioned, lab equipment manuals used, etc. There are three styles that are commonly used. The first involves references denoted by superscripts, so that when referencing Einstein's paper on special relativity[1] one uses a numeric superscript such that the first reference in the paper is #1, the second is #2 and so on. Another style uses consecutive numbers as well, but puts them in square brackets, such as in this example referencing Bohr [2]. However, these methods pose challenges to papers written in MSWord since if you insert a new reference early on, you will have to change ALL the subsequent numbers. Another style is to use numbers, but the numbers refer to the citations as they are listed in alphabetical order (according to the author's last name, the second author's last name, …, and year). Yet another style makes it a bit easier by citing the reference according to the author's last name and/or the year of the paper, such as the electromagnetism text by Griffiths (1981), or (Jackson, 1988), or the papers by Dirac (1928) and Higgs (1964).

Choose the method you like best and stick with it. Different journals have different requirements. (I prefer name and year myself.)

References (in Numeric Format in order of Appearance)

1. Einstein, A. (1905). "Zur Elektrodynamik bewegter Körper" [On the Electrodynamics of Moving Bodies]. Annalen der Physik (in German) 17 (10): 891–921.

2. Bohr, Niels (1913). "On the Constitution of Atoms and Molecules, Part I". Philosophical Magazine 26 (151): 1–24.

References (Name and Year in Alphabetic Order)

Dirac, P. A. M. (1928). "The Quantum Theory of the Electron". Proceedings of the Royal Society A 117 (778): 610.

Griffiths, David J. (1981). Introduction to electrodynamics (1st ed.). Englewood Cliffs, N.J.: Prentice-Hall. ISBN 0-13-481374-X.

P.W. Higgs (1964). "Broken Symmetries and the Masses of Gauge Bosons". Physical Review Letters 13 (16): 508–509.

Jackson, J. D. (1998). Classical Electrodynamics (3rd ed.). Wiley. ISBN 0-471-30932-X.

Google Scholar is an excellent resource for finding papers online. It can also be used to generate the citation (usually if you are careful). Note that sometimes it messes it up, so you have to check it over carefully.

Wikipedia may be helpful for quickly learning some basic details, but it is not acceptable to reference Wikipedia unless you use a figure from Wikipedia, in with case you must cite it. For technical material, scroll down to the bottom of the Wikipedia page and look at the references. Often you can find a reference that you can use for further information.

EXAMPLE EXPERIMENT REPORT

At this point we can walk through a fictitious experiment to help illustrate the different components of the lab report. When in doubt, do not hesitate to look up some physics papers or texts to see how the authors handled the issue in question.

Imagine that we are conducting an experiment that involves analyzing motion information (velocity, acceleration etc…) for a drive around town.

The Abstract is a very brief description of what was done and what was learned from the experiment

The Introduction section would go into a brief description of the problem. In professional manuscripts, the introduction also describes other experiments done in the past that are along these same lines and the knowledge learned from them. We will not worry too much about this in this course. However, you should then go on to motivate the experiment by explaining why this experiment is important and what theory or theories it aims to test.

The Experimental Design section is where you would include the information necessary to understand the science involved in the experiment including concepts and equations such as the distance equation and its derivatives. You would then detail the design of the experiment and the equipment used to carry it out. For our fictitious experiment it may read as follows.

> A drive through town was conducted and the motion of the vehicle was analyzed. The equipment used to conduct the experiment is as follows.
>
> A car with the ability to convert fossil fuel into linear motion, equipped with devices to both accelerate and decelerate the vehicle by means of foot pedals. The car is also equipped with a device that can change the direction of the linear motion by turning a control wheel. In addition, a suite of sensors are imbedded in the car to allow the motion of the vehicle to be recorded for later analysis.
>
> In addition to the car, a computer with analytical software capable of producing graphs and tables that will be used to analyze the motion recorded.
>
> The uncertainty analysis for the experiment will be handled in the following manner:
>
> Blah Blah Blah.. You know what to put here.

The Experimental Procedure / Results and analysis section is where you describe to the reader the details of what was done in the experiment and what it means. For our fictitious experiment it may read as follows.

> The car started from a stationary position and accelerated for 3 seconds and then maintained a constant velocity for 20 seconds and then decelerated over 1.5 seconds to stop at a light. The graph representing this motion is presented below.
>
> ********* Graph Here *********
>
> Figure 1. Figure 1 shows a graph of the position of the car (meters) as a function of time (seconds). Note the quadratic change in position during the acceleration phase, which stands in contrast to the linear change in position during the periods of constant velocity.
>
> From the data represented in the Figure 1 above the following information was derived.
>
> ************Some information involving acceleration and velocity values with their uncertainties for given periods and things of that nature. Along with some analysis of what it might mean. (Maybe tables or more graphs)

The Conclusion is a very brief description of what was done and what was learned from the experiment (look familiar?)