Union College
Physics and Astronomy

How to Write a Formal Lab Report

A formal lab report is essentially a scaled-down version of a scientific paper, reporting on the results of an experiment that you and your lab partner(s) have carried out. As such, the key sections of the report are directly analogous to the sections of a formal scientific paper. In the order in which they appear, these are:

1) **Abstract**: The abstract is a *single* short paragraph stating the important results of your experiment, including the numerical values, with appropriate units and uncertainties, and the most important conclusions drawn from the experiment.

2) **Introduction**: The Introduction gives the important background for understanding the experiment, including both the motivation for making the measurement and a complete description of the theory underlying the measurement, with all the relevant equations.

3) **Procedure**: The Procedure section gives a complete description of the important measurements you made, and how you made them. It is a description of what *you did*, and is not to be written in the style of instructions to someone else.

4) **Results**: The Results section presents the important experimental findings, including figures and tables containing the data you collected in the course of the experiment, a description of any calculations made from the data collected, and text explaining the significance of the results. The Results section is *not* merely a collection of data tables and figures, but must include prose paragraphs as well.

5) **Discussion and Conclusions**: The Conclusion of the report explains the conclusions that you can draw from your measurements—whether they agree with theoretical predictions, what they mean for applications of the central physics principles, and what further experiments are suggested by your findings.

In the following pages we will explore these sections in more detail, explaining the key elements of each section, and how they should be presented.

A Note on Writing:

One of the most common complaints about the writing of lab reports, and especially the grading of lab reports, concerns the importance of writing. A lab report, like a scientific paper, is first and foremost about *communication*, conveying your results to the reader, and as such proper writing is essential. You can be a brilliant experimental scientist, able to produce great results in the lab, but if you are unable to communicate those results effectively to another person, all your lab skills are worthless.

The importance of communication is not limited to research science, either—whatever career path you plan to follow in the future, you will need to know how to communicate effectively in writing. If you are going to be a research scientist, you will need to write grant proposals and scientific articles. If you are going to be an engineer, you will need to write project proposals and reports. If you are going to be a doctor, you will need to write reports about your patients and their treatment. If you are going to be a lawyer, your entire career will be built around writing legal documents. Communication is essential for every profession, and written lab reports are a good way to learn and apply your written communication skills.

Some important elements of good writing to keep in mind when writing your report:

Think carefully about organization: Your report should be written in such a way as to lead the reader through a clear and logical progression from one idea to the next. Make sure that each sentence or paragraph follows naturally from the preceding sentence or paragraph. Each paragraph should deal with a single main idea, which should be stated as clearly as possible.

Write simply and directly: Students writing lab reports for the first time often try to "sound scientific" by using big words and complicated sentence structures. This is bad writing, and undercuts the effectiveness of the points you're trying to make. State what you did as simply and directly as possible. Writing "A calibrated rod was utilized to ascertain the physical extension of the wire helix" makes you sound ridiculous. "We measured the stretch of the spring using a meter stick" is much better.

Write in the past tense and active voice: Many students have the idea that scientific writing should be indirect, written in the passive voice. While there are times when the passive voice is appropriate, the active voice is much more direct and effective. When you are writing a report, you are describing what *you did*, and you should do that as directly as possible: "We measured the length of the spring using a meter stick" is much more direct and effective than "A meter stick was used to measure the length of the spring."

Proofread your report carefully: There are very few better ways to convince someone that you don't know what you're talking about than to have badly misspelled words in your report. Before you hand in your report, read it over carefully, and make sure that what you have written is clear and correctly written.

Please keep in mind that **"Check Spelling" is not sufficient proofreading**. Using the spelling checker in your word processor will ensure that all of the words in your report are correctly spelled, but it does not ensure that they are the correct words. All of the words in the sentence "Wee preformed thee experiment to sea how a projectiles mass affects it's trajectory" are spelled correctly, but there are at least six errors in the sentence. When you read your report over, make sure that you have used the right words in the right places.

Use technical terms with care: Most of the words used in physics have very precise technical meanings, which are sometimes at odds with the everyday usage of similar words. “Mass” and “weight” are not interchangeable terms in physics, nor are “speed” and “velocity”; “force,” “momentum,” and “energy” are related but very different quantities; not every upward-curving graph is an “exponential” curve, and not every straight line is a “proportional” relationship. When writing your lab report, keep this in mind, and make sure that you only use scientific jargon in an appropriate manner.

Writing the Report

When it comes to writing the various sections of the report, it is not necessarily a good idea to start with the Abstract and continue writing until you reach the Conclusion. For the purposes of thinking about what belongs in each section, it is often better to consider the sections in reverse order, starting with the Conclusion and ending with the Abstract. The Lab Report Outline file provides a handy template for this, and in what follows we will consider the sections in reverse order.

5) Conclusion

The whole point of whatever experiment you have performed is to draw some conclusions from the data that you have collected. For a typical lab, there will be only one or two main conclusions to be drawn from your results. It is important to have these conclusions in mind before you begin writing—the entire lab report should be building toward these conclusions.

There are a number of different types of conclusions you can draw from a typical lab experiment. Examples include (but are not limited to):

- Determination of a physical quantity (the speed of a projectile, or the mass of a particle, for example)
- Agreement or disagreement with theoretical predictions either quantitative (a simple model predicts a mass of 7kg, we measured 6 ±3kg) or qualitative (the measured force is proportional to the stretch, consistent with Hooke’s Law)
- Comparison of different techniques (one method gave 6.0±0.2 m/s, the other 6.019±0.002 m/s, thus the second is more precise)
- Applications to real-life situations (the measurement technique effectively determined the force needed to break wood, and could also be used to measure the force needed to snap bones).

Not every experiment will involve all of these types of conclusions, but these are some of the most common types of conclusions to be drawn from lab experiments.

When you are writing the Conclusion section of a report, you want to make sure you clearly state all the major conclusions, with numerical values where appropriate. The Conclusion should also include a discussion of the limits of the measurements and techniques used in the experiment—What are the main sources of measurement uncertainty? What steps did you take to minimize the uncertainty?—along with a statement of how the measurement could be improved or extended—What could you do to significantly reduce the uncertainty? What other interesting systems could you apply this technique to?

The Conclusion section of the report should focus on the measurements you made, and what can be learned from those measurements. Do not discuss the pedagogical purpose of the lab (i.e., do not write sentences of the form "This experiment helped us gain a better understanding of the concept of momentum."). Also, please do not start the Conclusion section by declaring that the experiment was a success.

4) Results

Each of the major conclusions that you draw from your data must be supported by at least one feature of your data. When writing the Results section, you should make sure you know which parts of the data support each of your conclusions, and make sure that you clearly explain those features to your reader.

The data that you present in the report will usually include one or more tables and figures. Each figure or table should be numbered in the order in which they appear in the report (starting at the beginning, so Figure 1 will typically be in the Introduction or Procedure), and referred to by number in the text. Figures and tables are numbered separately, but no distinction is made between types of figures (so a schematic drawing of the apparatus may be Figure 1, and a graph of several data points may be Figure 2).

Each figure or table should be accompanied by a descriptive caption explaining what is shown in the figure or table. The caption should contain enough description for the reader to understand what is being displayed without reference to the text of the report. Graphs of data must include clearly labeled axes, including the appropriate units. Tables of data must include clearly labeled rows and columns, including the appropriate units and uncertainties.

While the figures and tables are the most important part of the results, the Results section is *not* merely a collection of figures and tables with captions. The Results section should include text highlighting and explaining the important features of the data, referring to figures and tables by number (i.e. "As we see in Figure 3, there is a linear relationship between the applied force and the acceleration of an object.”). The text should include enough detail for the reader to understand what is going on in the data, even if the figures and tables are absent. Do not string together one table or figure after another with no sentences between them to guide the reader.

The Results section should also include an explanation of any calculations done using the data, including uncertainty calculations. Calculations should not be presented as large blocks of equations set off in a separate box, but should be presented as equations interspersed with text, as in a typical textbook. Equations that are presented in the Introduction do not need to be repeated here, but can be referred to by number (e.g., “We use our measured spring constant and mass to determine the potential energy using Equation 7”).

3) Procedure

The Procedure should include a detailed explanation of the steps that you followed to make the measurements presented in the Results section. When writing the Procedure section you should make sure that there is a clear explanation of how you determined every number that you present in the Results.

The Procedure is a description of what *you did* in making the measurement, and should not be written in the form of instructions to another person or lab group (i.e, you should write “We measured the height with a meter stick,” not “Measure the height using a meter stick.”). The description should be detailed enough for the reader to reproduce your results, without reference to the lab handouts or other documentation.

The Procedure must include a description of the apparatus used, which will almost always include a diagram of the lab set-up. This diagram should be clearly labeled, and include a descriptive caption explaining the important features of the apparatus. The diagram should be assigned a number as a figure, and referred to using that number (“The apparatus consisted of a spring-loaded projectile launcher bolted to the table, as shown in Figure 2”). The text should include enough description of the apparatus for the reader to understand what is going on, even if the figure were absent.

When writing the procedure, make sure that there is a clear and logical flow from one idea to the next, to make it as easy as possible for the reader to follow. Keep in mind that the clearest explanation of your measurements will not necessarily be a chronological list of the steps that you followed in exactly the order in which you did them.

The Procedure is a description of what you actually did in making the measurement. Your lab instructor may make changes to the procedure described in the lab handout, telling you to skip certain steps, or adding additional measurement steps. When this happens, your report must reflect the actual procedure that you followed in making your measurements, *not* what is written in the handout. Make sure you have careful notes reflecting what you did in the lab.

2) Introduction

The Introduction of a lab report should contain all of the background information a reader would need to understand the measurements described in the Procedure and Results sections. This includes both the motivation of the experiment (What did you measure, and why should the reader care?) and the theory behind the measurements, including all of the equations that will be used in the report, and how those equations are obtained from basic principles of physics.

When discussing the motivation of the experiment, focus on the important applications of the ideas to interesting real-world situations. Do not talk about the pedagogical purpose of the lab (i.e., do not write sentences of the form "The purpose of this lab was to help us learn about conservation of energy."). The idea of the motivation section is to give a reader who isn't in your class a reason to read the whole report and care about the measurements you made.

The Introduction should include a complete description of the theory underlying the experiment, including all of the important equations. Any equation that you plug numbers into in the Results section should be presented first in the Introduction, and given a number for future reference. If you need to refer back to an equation later, you should use the number: "We combine Equation 2 and Equation 7 to get an expression for the moment of inertia in terms of the measured velocity of the hanging mass."

Equations should be set off on a separate line, and indented with respect to the rest of the text, as with the following presentation of Newton's Second Law of Motion:

$$\vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}} \qquad (1)$$

Any symbol that appears in the equations should be identified the first time it appears (e.g. "*F*=*ma*, where *F* is the applied force, *m* is the mass, and *a* is the acceleration"). If the same symbol is used again in a later equation, it is not necessary to define it again.

When deriving the important equations in the Introduction, equations should be interspersed with text explaining what the various equations mean, and what operations are done to get from one equation to the next. Large blocks of equations one after another are not a sufficient explanation of the process by which important results are derived.

Most modern word processors include tools that will allow you to typeset professional-looking equations, such as the Equation Editor in Microsoft Word. Please make use of these tools to produce the equations needed for your report, and do not express equations in pseudo-computer code (i.e., $K = \frac{1}{2}mv^2$, not K=0.5*m*v^2). If you do not have these tools on your own computer, either use one of the public computer labs, or talk to your instructor about what to do.

For simple in-line equations or units, all modern word processors allow you to insert symbols (the "Symbol" font can be used to get Greek letters) and do superscripts and subscripts.

Please read the appropriate help files, or ask your instructor how to produce the necessary symbols in your reports.

1) Abstract

The Abstract is a single short paragraph describing the important results of your experiment. The purpose of an Abstract in a scientific paper is to allow the reader of a journal (which typically contains dozens of research articles) to quickly determine whether a given article is interesting or important enough to read in full. The Abstract in your lab report should serve the same function, providing all of the important results, including the numerical values of the key measured quantities, with appropriate units and uncertainties.

The Abstract of a typical report should be no more than three or four sentences, and should be self-contained. The Abstract should not contain equations or references to figures that appear in the main body of the report. The main text of the report should not assume that the reader has read the Abstract first—stating the key results in the Abstract does not absolve you of the responsibility to describe them in the Results and Conclusion. The Abstract should not include details of the procedure beyond those that are absolutely necessary for understanding the results. It is generally sufficient to name the method used to obtain a measurement, without going into any detail about the measurement technique: "We measured the speed of a ball leaving a spring-loaded projectile launcher by measuring the horizontal distance traveled after launching it from the top of a lab table," rather than "We measured the speed of a ball leaving a projectile launcher by clamping the launcher to the top of a 1.00 m high table, and launching the projectile horizontally into the room. We measured how far from the table the ball hit, and used that number with the height of the table and the acceleration due to gravity $g=9.8m/s^2$ to determine how fast the ball was moving when it left the launcher."

The Abstract should also include a short statement regarding the most important conclusions drawn from the experiment. If measured values are being compared to a known value, state the result of the comparison briefly (do the results agree to within experimental uncertainty? If not, why not?). If two different measurements are being compared, state the result of the comparison (do they agree to within experimental uncertainty? If not, why not?) and comment on their relative quality (which measurement had lower uncertainty?). If the uncertainty is unusually large, state the main source of the uncertainty.

The Abstract should boil the whole report down to a single, short paragraph. As a result, the Abstract should generally be the last thing written, even though it will be the first section the reader sees.

General Notes:

A few general items to keep in mind when writing lab reports:

- **Uncertainty:** All measured quantities have uncertainty associated with them, and all numbers calculated from measured values will have some uncertainty due to the uncertainty in the underlying measurement. Any time you give the value of a measured or calculated quantity, you should also give the uncertainty.
- **Units:** All measured quantities have units. Almost all quantities calculated from measured values will have units, with the exception of some ratios and fractions, which are dimensionless. Any time you give the value of a measured or calculated quantity, you should also give the associated units, along with the uncertainty. The usual format is: $v = 6.13 \pm 0.02$ m/s.
- **Significant Figures:** The general rule for reporting numbers with uncertainty is to round the uncertainty to one significant digit, and round the reported value to the same decimal place as the uncertainty. Thus, 6.12384756 ± 0.00314 m/s becomes 6.124 ±0.003 m/s, and 9192.45 ± 28.39 kg becomes 9190 ± 30 kg.
- **NO HUMAN ERROR:** "Human error" is not an acceptable source of uncertainty. When discussing the sources of the uncertainties in your measurement, you should assume that you have made the measurement as well as it could possibly be made, given the tools you used. If you are discussing an uncertainty in the height of some object, it is appropriate to say that you have an uncertainty of half a centimeter because there were only 1cm marks on the meter stick used; it is not acceptable to say that the uncertainty was half a centimeter because the person reading the meter stick might have read it incorrectly. If you suspect that the measurement was made incorrectly, you should re-do the measurement, not report it with an uncertainty attributed to "human error."
- **Analog vs. Digital:** Electronic read-outs showing many digits give the illusion of very high precision, but they are subject to all the same uncertainties as measurements made using analog gauges where a needle points to a numbered scale. Do not assume that a digital read-out or a computer-based measurement will automatically be better than an analog device.
- **References:** In reports which require references to external sources (books or articles beyond the lab handout), material drawn from these sources should be clearly marked, and the lab should include a list of references at the end. References should be listed in the order in which they appear, and referred to by number, by placing the reference number in square brackets at the appropriate point in the text: "As shown by Lastname and Surname [4], the force increases as…" Citations of books are in the form: author name(s), title, edition, publisher, (year): "[3] Firstname Lastname, *Physics Book* (2nd edition), AIP Press (2003)." Citations of journal articles are in the form: author name(s), journal name, **volume number** (in bold), page number, (year): "[4] Lastname, F. and Surname, G. N., *J. Irrep. Results* **17**, 289 (1997)." Other types of references should be listed

following the format given in Table I of the Physical Review Style and Notation Guide (http:// forms.aps.org/author/styleguide.pdf).

Academic Honesty:

Lab reports handed in for a grade must reflect your own understanding of the material, and only your own understanding. While you should discuss the lab results and data analysis with your lab partner(s), the written material you hand in for a grade must be entirely your own work, except in the case of group lab reports assigned by your instructor. You may not collaborate on the writing of the report, or even on a first draft.

Lab reports that your instructor deems to be excessively similar will be referred to the Dean as plagiarized. The typical punishment for reports that the Dean finds to be plagiarized is failure in the course.

Additionally, the figures and text in your report must be your own work, unless your instructor says otherwise. Any figures or descriptions from other sources (used with permission of your instructor) must be properly attributed to their original source. Excessive use of figures or descriptions from other sources (other students, lab handouts, Internet resources, etc.) will be referred to the Dean as plagiarism, as described above.