Memorial University of Newfoundland
Department of Physics and Physical Oceanography

Writing a Formal Report

A formal report describes the results of a scientific investigation. Thousands of papers are written each year by scientists at universities and research institutions all over the world. These reports are published in scientific journals, many of which you can find in the University library. You will probably have difficulty understanding much of the material, however, *American Journal of Physics* and *The Physics Teacher* often contain articles of a more general nature, as well as other popular magazines such as *Scientific American*.

Your formal report will describe the results of an experiment which you have performed in the laboratory. It is **not** the same as the report you write in your regular lab notebook. The goal of the formal report is not to prove that you got the right answers; the goal of a formal report is to document your findings and communicate the knowledge you have acquired from a laboratory experiment. It must be written with the same care and attention that a professional scientist might use. Thus it must follow an accepted international format with emphasis on good english, spelling and grammar.

NEVER SUBMIT A FIRST DRAFT. Be prepared to make several revisions before submitting the final draft. Let somebody else read you report before you submit it. The Campus Writing Centre provides a free drop-in service for students who want help with their writing. You are strongly encouraged to use this service.

Upon reading the report, the reader should be able to understand

- what you have done,
- why you have done it, and
- what you have concluded.

Specialized fields such as physics have their own technical terminology. While appropriate in some situations, the use of jargon should be avoided if it causes confusion. **Do not include**

irrelevant details. You will have to use your judgement in determining what to include and what to exclude.

The report is divided into distinct sections, each with its own characteristic heading: *Abstract*, *Introduction*, *Apparatus and Experimental Procedure* (or *Method*), *Results*, *Discussion* and *Conclusions*. Each of these will now be described. There is no Table of Contents.

Abstract

The abstract is a miniature version of the whole report. Everything in the abstract is repeated in the paper, but with more elaboration. Your abstract should emphasize the objective, procedure, results and significance. Use this section to show how all the information holds together. Often, many people will not read beyond the abstract, so it is important that you are precise and specific. The Abstract should be no more than a paragraph in length.

Since the abstract is a summary of the report, you cannot write it until after you have completed the report.

Introduction

This section sets the scene. It brings the reader up to date so that the report can be understood in context. The background to the work needs to be clearly described. Some experiments have historical significance, e.g., Millikan Oil Drop, and the history of the experiment might be included, too.

The Introduction will include some theory. Derivations of standard formulae are not necessary, but if you develop an equation to fit your analysis, you should include the derivation. Mathematical expressions should be written in sentences, for example, "*The magnetic field at the centre of a plane circular coil is given by*

$$B = \frac{\mu_o n I}{2r}, \tag{1}$$

while the field along the x axis is given by

$$B = \frac{\mu_o n I}{2(x^2 + r^2)^{3/2}}, \tag{2}$$

where n is the number of turns in the coil.

Note that equations are written on separate lines and numbered consecutively, but otherwise fit smoothly within the sentence. Equations are also followed by appropriate punctuation marks. Ensure that you typeset subscripts and superscripts correctly.

End the Introduction by stating the objectives of the work. How will the basic information will be applied to your experiment? The best way is to start with a sentence like, "*The objectives of this work are to* ..." or might end with the phrase like, "... *and it is the purpose of this experiment to determine a value for the coefficient of viscosity of water.*"

The text book is the most obvious sources of reference, but you should not restrict yourself to it. Cite each reference you use, either by number, [1], [2], etc., or by author and year, e.g. *Smith and Jones (1994), Smith (1998)*. A list of references should be included in a **bibliography** at the end of the report. The laboratory instruction sheet is **not** an acceptable reference source since it is only a guide to the experiment; it is not intended to be complete and must be supplemented by outside reading.

> At this point the reader should have gained a clear understanding of the current state of knowledge as it applies to your experiment, and is now ready to read about how you actually did the experiment.

Apparatus and Experimental Procedure

This section should contain sufficient detail so that another researcher in your field can use your description to replicate the experiment. Be complete, accurate and precise. Do not copy the instructions given in the lab notes. Use your own wording to say what you really did and what actually happened. Do not waste time by stating the obvious: the reader does not wish to know that the power supply was switched on or that you connected a wire from point A to point B. Standard laboratory equipment does not need to be described, but if you used a special piece of apparatus to measure something, it is important to tell the reader.

Neatness and clarity are important. A clear, labeled diagram of the apparatus can save a lot of written description which would be difficult to read if it were part of the text, for example, *"Using the apparatus shown in Figure 1, the time required for a ball bearing to fall was measured over the range of heights 20 cm to 150 cm."*

Results

This section describes how you arrived at a final answer. Raw data and rough calculations are **not** included in the report and should stay in your laboratory notebook. Nor is the reader interested in going through the details of how you multiplied, divided, etc.

Introduce each block of information so that the reader knows what is coming up next. Usually a graph is the best way of presenting results because it shows what the data *looks like*. **A graph in a formal report is not the same as a graph in a regular lab report.** The main purpose of the graph in your lab notebook is to aid calculation; in the formal report, graphs serve mainly as illustrations which must be clear, neat and uncluttered so that readers do not have to work too hard to get the message. Do not fill up empty spaces on the graph with calculations of slopes and the like. In the professional literature, graphs **do not** usually have titles, but will have a descriptive figure caption. The axes will be labelled and additional information should either be placed in the main body of the report or in the figure caption.

Introduce each figure by pointing out its most important feature, for example, "*We see from Figure 2 that the temperature becomes constant after approximately half an hour.*" Similarly, each figure should have a caption so that the reader can understand its content, for example, "*Figure 2. Variation of temperature with time, using the specific heat apparatus.*"

Then just say what you did to obtain the result. For example, "*The value for the coefficient of viscosity was obtained from the slope of the graph of Q versus P.*" or "*The experimental value for the speed of sound in air was calculated using Equation (6).*", and state the final result. Include the uncertainty where appropriate, but keep the arithmetic details in your lab notebook.

You can save graphs in various formats (e.g., jpeg or pdf) which can be imported into your document. In the final document, the graph will be placed in the body of the report, with text above and below as you might see in any text book. You can, if you wish, print the graph on a separate page and attach it to the back of the report, making sure to include a clear figure caption. Do not use brand names such as *Mathematica* in your report. You should say something more generic, like "a mathematical software package".

> If an experiment consists of several parts, you should describe the procedure and results for each part separately rather than list everything together.

It is essential that you present your results carefully. Merely supplying the equations or diagrams and expecting the reader to interpret them without guidance from you is not sufficient. Only then can you effectively discuss your results and present your conclusions.

Discussion

The Discussion is the most difficult part of the report to write, but it is also the most important because it describes the relation between your results and the theory. The reader needs to know the outcome of such a comparison. You must provide evidence that you have thought carefully about the meaning of the results.

Try starting with the words, "*The results show that* ..." and then say what happened. For example, "*The results show that the data can be modeled by a straight line fit, exactly as predicted by theory. From this, we can conclude that our hypothesis is correct.*"

State your conclusions as clearly as possible and summarize your evidence for each conclusion. Excessive length is not a virtue. If you have performed an experiment to determine the acceleration due to gravity and you find that your value for g agrees with an accepted value for your location, there is probably little else to say besides that. On the other hand, if the result shows something unexpected, you might write something like, "*We note that* *the straight line does not pass through the origin, as expected. This may be due to* ..., and carry on from there, telling the reader what you consider to be important.

The Discussion is not the place to list "sources of error", or to include a verbose description of why things might have gone wrong. To say that certain conditions of the experiment "*may have caused error*" communicates no useful information unless you cite some specific evidence or a plausible mechanism pointing to that fact. As an experimentalist, you should have already taken care to minimize uncertainties.

Focus your attention on questions like these:

- What results were expected? What results were obtained? Is some other physical phenomenon showing itself that had not been predicted by theory?
- Do any of your results have particular technical or theoretical interest?
- How do your results relate to your experimental objective?
- How do your results compare to those obtained in similar investigations? Have you discovered anything new or unexpected?
- What are the strengths and weaknesses of your experimental design?

The reader should come away from the discussion with a clear message about what you have done and what you have discovered. What do you want the reader to remember about your work?

Conclusions

Take an overview of the experiment. Draw conclusions from the results and discussion that answer the question, "So What?" Avoid phrases like, "*The results agreed with theory within the limits of experimental error.*" In this section you may also criticize the lab experiment and make recommendations for improvement. However, such critiscisms should focus on the lab as a learning experience; mere complaints about faulty equipment or the amount of time spent are not appropriate.

Note: The **Results**, **Discussion**, and **Conclusions** sections can be combined in various ways. Use whatever combination is most appropriate for your situation.

Bibliography

Each reference that you cite should be listed at the end of the report. It should be as complete as possible so that the reader should have no trouble locating it. A references to a book should look like this:

Baird, D. C., *Experimentation: An Introduction to Measurement Theory and Experiment Design.* 3rd Edn., (Prentice-Hall, Englewood Cliffs, 1995), pp. 157–170.

A reference to the melting point of sodium chlorate might be given as

CRC Handbook of Chemistry and Physics. 71st Edn., **4**-103, edited by David R. Lide, CRC Press (1990).

Journal articles are referenced like this:

Deacon, C. G., *Error analysis in the introductory physics laboratory*, The Physics Teacher, **30**, 368–370 (1992)

Documents retrieved from the World Wide Web should be cited as follows:

Jacobson, J. W., Mulick, J. A., & Schwartz, A. A. (1995). *A history of facilitated communication: Science, pseudoscience, and antiscience: Science working group on facilitated communication.* American Psychologist, 50, 750–765. Retrieved January 25, 1996 from the World Wide Web: http://www.apa.org/journals/jacobson.html

It is important to use “Retrieved from” and the date because documents on the Web may change in content, move or be removed from a site altogether.

Never use *Wikipedia* as the sole source for anything. Always verify with original sources. Wikipedia is useful, and can be highly accurate. But you cannot count on any single page being completely accurate at the time of viewing. Always go to the primary source cited in Wikipedia first, if you're going to use it that way. Using Wikipedia as a professional standard is not encouraged.

Appendix

An appendix is not necessary, but may be used to put additional information about the experiment, where it will not interrupt the flow of the main text. The derivation of a complicated equation might go here, for example. You would refer to it in the body of the report with a sentence like "*A full derivation of Equation (7) is given in Appendix 1*". This way, the reader should be able to follow what you have done without reading the appendix (but the details are there if the reader choses to look at it). Raw data is not normally put in an appendix, unless you believe that the reader should see it. You always have your lab note book as evidence of your original measurements. Do not put final graphs in the appendix. If you choose to include an appendix, it must be readable as a separate document.

These notes were prepared with the aid of resources from: University of Toronto Engineering Writing Centre; Rensslaer Polytechnic Institute Writing Centre; Macquarie University (Australia), Physics Department; Lock Haven University.