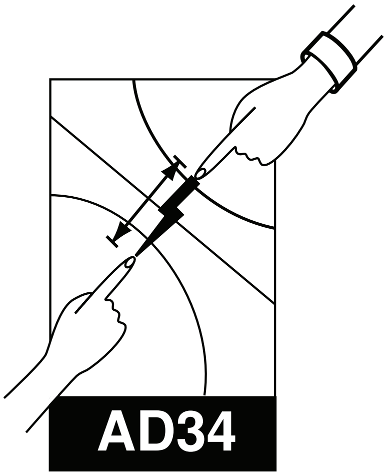
the art of scientific report writing



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1 Abstract

Accurately communicating work so that it can be understood, discussed, reproduced and continued is a vital skill for any scientist. We provide training in this by expecting you to write up experiments and projects. This document is an introduction to presenting scientific experiments and results.

2 Introduction

Physics relies on experiments to test theories and models of physical phenomena. Write-ups of these experiments should provide enough information for a reader to understand the aims and outcomes of the experiment, the approach taken, the measurements made, the analysis conducted and the results obtained. The language used should be precise wherever possible, with the data and analysis presented in a manner that allows the reader to evaluate the significance of the results. It should be written at a level understandable by another physicist in your year, perhaps one who is taking different options to you. Remember that the person who marks your work is likely not to be a specialist in that field.

The write-up should be self-contained, and structured so that it is easy to follow. A standard approach is to break the report into a number of sections with clear headings. You can use bold fonts, underlining, numbered lists and bullet points to make the report easier to follow. You should not regurgitate large chunks of text from other sources. Ensure that you reference the script (for lab write-ups) and any other sources (see section 5).

Make sure that you answer all of the questions in the laboratory scripts and that you complete the report with conclusions. The validity of an experimental outcome depends critically on the uncertainties associated with your work, so it is important to discuss them.

3 Structure

Scientific reports often take a structure similar to that described below.

Header The information required varies depending on the type of report. First year lab reports usually need your name on them, whereas if a report is submitted for examination you must NOT put your name on it, to allow anonymous marking. Please read the instructions for your piece of work carefully.

Title A sentence describing the experiment

Abstract A brief (couple of sentences) summary of the experiment and results, expressed quantitatively. You may find it easiest to write the abstract at the end, after you have written the report, but it should appear at the front of the report.

Introduction A few paragraphs summarising the motivation, aims and context of the experiment. The introduction to a scientific paper describes the background to the problem the paper addresses with reference to the underlying theory: what the problem is, why the problem is interesting, how it came to the attention of the community, what significant work has been done on it, and why this has left important questions open. This section should derive, explain, or at least mention all the theoretical formulae used later in the report. Finally, the introduction says how the paper advances the field and explains the paper's layout.

Experimental Arrangement (for experimental work) A description of the apparatus used, the way in which components were put together, and including any particular problems or issues that arose. A diagram is usually helpful.

Measurements (for experimental work) A description of the measurement made, and the techniques used. This may include qualitative descriptions of phenomena and quantitative measurements. Data should usually be presented in tables and may be placed in an appendix at the end of the report (before any references) along with important but tedious details, or peripheral results.

Methods (for computational work) Describe the numerical approach you have taken to solving the problem, for example, any physical or mathematical simplifications or assumptions made to get the underlying equations in the form you need. Explain the numerical and computational techniques used.

Analysis and Results The manipulation of your data to provide the information you need. The analysis should include estimates of uncertainties and may require propagation of errors calculations; graphs should be included. There can be several sources of error in a numerical or actual experiment and these should be taken into account in producing the final answer and the error upon the derived quantities.

Conclusions The results of the experiment should be summarised, together with a comparison of other values and some comments on the outcome(s) and the significance for the wider field. The conclusion may also indicate what further work would be profitable.

References Sources of information, previous studies.

Appendices Programs, derivations etc. too detailed to include in the main text (although you should avoid including excessive amounts of material). These are not usually read by the marker.

The abstract and figures are the most important parts of a paper, as they are the only parts many people will look at. They help to draw readers in to the other sections. If the Abstract and figures are interesting, one often scans the Introduction, paying particular attention to the last part, and then moves to the first part of the Conclusions. The middle sections are often only read much later, if at all.

Sections and subsections should be numbered, as should equations, tables and figures. This makes it much easier for the reader to find information. For example, you might want to write "Applying equation 59 (see section 4.3) to the data in figure 12 produces the fit parameters shown in table 9".

It is important to compare your results with those in the literature. Demonstrators will be able to help you to locate e.g. the paper or book which reports the most accurate and recent value of a physical constant that you have attempted to measure, or you can try to find more background information on the web or in a library (see also AD15 — information sources in physics[1].) It is best to obtain this information at the same time as you do the experiment. Remember that the labs are closed and demonstrators may not be available when reports are written. For this reason you should also make sure that the data you need is somewhere you can access it subsequently, so not stored on the hard drive of a lab computer.

[1] `http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD15.pdf`

4 Graphs, diagrams and tables

First of all, please remember that it is crucial to put SI or commonly used units attached to the numerical values of the quantities you have measured or calculated (unless they are dimensionless). Graphs of your data should be included as they are an efficient way of showing trends and scatter. Axes should be labelled, with units, and titles provided, so that it is clear what the graphs represent. If you have made a fit to the data points on a graph, the parameters should be included. Make sure the labels on the plots are big enough to read for the size the plot will be in the report. A basic guide to plotting is given in AD35 — software and effective plotting[2].

One of the skills of report writing is appropriate selection of data. Try to think of ways of plotting several sets of data in one figure. For example, you might have several curves or sets of points, each representing data (such as current versus voltage) for (say) a different temperature; try plotting all of the data on one set of axes, using different shapes of point (crosses, filled circles, open circles etc.) or types of curve (dashed, dotted etc.) to distinguish between the data sets. You can also put smaller figures as insets in a larger figure (for example, it might be useful to have a schematic of part of the experimental apparatus as an inset to a figure showing data).

Diagrams may also be included; they can efficiently illustrate something that can be difficult to say precisely with text alone. Again, they should be labelled with titles.

Tables should be organised with clearly labelled column headings and titles.

Figures and tables should be placed within the text, close to the place where they are being discussed. Don't collect them all at the end of the document. Each figure (and table) should have a number (for ease of reference — see above) and a caption explaining exactly what it shows; in other words, the figure (or table) and its caption should be a self-contained unit, allowing one to understand what is displayed without looking in the text (for example a caption might read "Figure 2: detector signal plotted against detector position. The filled circles are data from run 1; the open circles are data from run 2. The curve is a fit to equation 9"). Conversely, all figures and tables should be discussed in the text and form a relevant part of the story.

5 Referencing

When writing a report, it is important to state clearly which parts represent your own work and which parts are derived from other sources. It is not acceptable to just say "It is well known that…"; such statements must be backed up with a reference. For example:

"The data in the present report suggest a value of $g = 2.004 \pm 0.001$, which compares well with the study of Grollick et al. [24] who obtained $g = 2.00 \pm 0.01$. Earlier work [25,26] produced much lower values ($g \sim 1.8$); such underestimates are now known to be due to neglect of the double-zeta basis function [27]…"

Here the numbers refer to literature listed in the references. Typical references for an MPhys project report will tend to be scientific papers, e.g.

24. A.G. Grollick, J. Sprule and Z. Frisk, Phys. Rev. B 34 2005 (1994).
25. O. Whacklow, T. Futtle and H. Crun, Solid State Commun. **291**, 567 (1968).

The references in other work will more commonly be text books, e.g.

B. Bleaney and B. I. Bleaney, "Electricity and Magnetism" (OUP 1987) p33.

Although it may be obvious to you where the derivation of (say) the etalon equation comes from, it may not be at all clear for the reader. Refer to the textbook from which you got the derivation or data.

You can use either the Harvard (alphabetical) or numeric style of referencing, but pick one style and

[2] http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD35.pdf

use it consistently and correctly. More information is given in section 3 of AD15 — information sources in physics[3].

Please note that all reports are written individually, and the only thing it should have in common with anyone you have worked with is the same data. You must always do your own work. Do not copy anyone else's. The University takes plagiarism very seriously, and it can lead to serious mark penalties or being required to leave your course. Most of your reports are run through plagiarism detection software as part of the assessment.

6 Finally…

Let us finish with a few notes and pointers to local documentation to help you on your way.

6.1 An example report

We provide an example report[4] for a dummy experiment, which follows the above guidelines. The LaTeX source for that report is also available[5] for use as an initial report template. You are free to use any typesetting or word processing package for document preparation.

6.2 Typography

Enthusiasts can read our typography primer AD30 — typography[6] and more information on typesetting a report is given in AD33 — document preparation[7].

Bibliography

[1] Various, *The Chicago Manual of Style*, 16th edition, University Of Chicago Press, 2010.

[2] W. Strunk Jr., E. B. White, *The Elements of Style*, 4th edition, Pearson Education, 2003.

[3] Various, *AIP Style Manual*, 4th edition, AIP, 1997.

[4] M. Young, *The Technical Writer's Handbook*, University Science Books, 2003.

[5] K. Friedman, Writing a Better Scientific Article, `http://rmp.aps.org/files/rmpguapa.pdf`

[6] Various, Duke Graduate School Scientific Writing Resource, `http://cgi.duke.edu/web/sciwriting/index.php`

[3] http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD15.pdf
[4] http://www-teaching.physics.ox.ac.uk/practical_course/CO5x_report.pdf
[5] http://www-teaching.physics.ox.ac.uk/practical_course/CO5x_report.tex
[6] http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD30.pdf
[7] http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD33.pdf

