Laboratory Report Format

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Scientific progress is predicated on the steady, incremental accumulation and integration of experimental results and analyses. Formal dissemination (*e.g.* publication) of scientific results is therefore an important aspect of scientific progress, as it makes each contribution permanent and gives all researchers access to the body of scientific results. The format of scientific publications has evolved to reflect this process and the structure of the scientific method itself.

It is important that you learn and use this format in your laboratory reports. Not only will your results be easier to present and evaluate, but the process will guide and reinforce your understanding of the scientific process.

General Guidelines

Your laboratory report should be divided into several sections as described below. The body of the report should be concisely written and in the present tense, except when referring to the actual experiment, which is in the past.

Diagrams, graphs, and tables are very efficient and appropriate for use throughout the report. Devote an entire page to each figure, assign numbers and titles to each, and provide brief captions.

The text should be 12 pt, double-spaced, with bold headings and 1 inch margins. Each page should be numbered on the bottom right, including figure and table plates, which should be collected at the end of the paper (after the references).

Report covers are not recommended. Instead, carefully staple the paper together in the upper left corner.

Title Page

Name of the experiment. The title should be short as possible, but still descriptive of the work. Composite titles are sometimes used to help identify the specific focus of the work. For example, "Pendulums: Effect of Length on Period." Note that all words in the title are capitalized except for prepositions.

Date of submission. When the completed report was *submitted*. (Not when the work was performed or the paper was written.)

Authors. Include team members and co-authors, with contact information for each person listed (name, institution, address). Include the name and teacher of the class.

Abstract. A one paragraph summary of the entire experiment. Describe what was done, how it was done, the outcome, and the conclusions. Typically 100 to 200 words in length, single-spaced, and in the past tense, the abstract should be written after the rest of the report is completed.

Since the words in titles and abstracts are used extensively in electronic media for cataloguing and searching, make sure that any important keywords are included.

Introduction

The introduction usually begins with a one paragraph discussion of the objective, historical context, and significance of the work to be discussed. Introduction topics could include: the point of the present study, what is understood already, discussion of other work in the area (with references), a clear statement of the current hypothesis and the reasoning behind it, and any predictions.

A concise description of the logical design of the experiment is important. Make sure to discuss the experimental controls and the dependent and independent variables, and describe how the controls are effective with regard to the other variables. An important principle of experiment design is that something is always learned, and therefore progress made, even if the experiment comes out differently than anticipated.

Is the objective of the experiment to test an existing theory? To gain understanding or explore a new phenomenon?

The introduction is where terms are defined and the reader is educated, if necessary. Thus, the flow of the introduction should be from the general (broad context) to the specific (the precise work performed in the current report).

METHODS AND MATERIALS

This section is frequently brief and shown in tabular form. It is essentially a list of the things used to perform the experiment. Ask yourself what someone else would need to *have* in order to exactly reproduce the work. Make sure to list equipment used, measurement tools, brands, vendors, sizes, concentrations, participants, and any preparatory procedures.

EXPERIMENTAL

Chronologically describe the experimental steps that were carried out employing the 'Methods and Materials' (prior section) to acquire the 'Data and Observations' (following section). Ask yourself what steps someone else would need to execute in order to reproduce your data. Since the experimental section describes exactly what was done, it should be in the past tense.

It is important to report what was *actually* done, not what was supposed to be done. Data are meaningless without a clear description of their acquisition. Refer to the notes in your lab notebook to make sure that you recount your methodology acurately. Resist the temptation to over-describe the experiment. Only include information necessary to replicate your study. For example, you may need to provide the reasoning for executing a step in a specified faction.

DATA AND OBSERVATIONS

This section contains all of your observations and data, typically displayed in tables and graphs. Be careful to avoid interpretations of the data, which belong in the Results and Discussion section. Instead, try to guide the reader through the results, to help them gain an unbiased understanding of the outcome of the experiment.

Give careful thought to how to most efficiently display your results. Employ graphs, photographs, and tables creatively and elegantly. Use one page per plate, and make sure to label everything, including images, figures, and axes. Assign a number and title to each plate, and attach a brief caption. Use standard scientific units on all data (SI).

If some of the data you gathered in the experiment are not going to be used in the paper, you must give an explanation for their omission. (The word 'data' is plural, 'datum' is the singular.) Never, *never*, erase or destroy data. In science, data are sacred. When mistakes occur, neatly draw a line through the erroneous data, with an explanation, if appropriate.

Unexplained data or extraneous values can only be omitted if there is a valid reason why the data are not relevant. Just because some of the data do not fit the model does not mean that the data are invalid.

If there is a particularly important result or piece of data, do not leave it buried within a large amount of other data. Instead, prepare an extra figure which elucidates it. In other words, make sure you are preparing for the discussion.

A carefully prepared data presentation is often the most important part of a paper. If it is well done, the discussion and conclusions become lucid and efficient. A picture is worth a thousand words.

RESULTS AND DISCUSSION

Here is where the data presented in the previous section are analyzed and discussed. All analysis procedures and equations should be listed. If derivations are extensive, only summarize them here, and document the complete derivation in an appendix. Comparison with predicted values and hypotheses are mandatory. Such comparisons naturally lead to statistical analyses and a discussion of erroneous data and experimental error. References to existing physical laws and other current work is advisable and important.

It is good practice to make frequent references to the figures in the data and observations section while describing your analyses. Possible discussion topics include: Did the experimental controls function properly? Did you discover bias in the experiment? What were sources of error in the experiment, and how important were they? How could the experiment be improved?

CONCLUSIONS

At this point in the paper, the reader knows why you did the experiment, what you did, and how you did it. They have examined the data and analysis, and understand the outcome. Now, it is time to apply the inductive method, draw some conclusions, and explore the implications of those conclusions.

Start by stating your conclusions, and then develop the arguments which support them. Was the theory substantiated? How did your hypothesis fare? Were there ambiguities or surprises? Is further research indicated? Since the best experiments usually point to more experiments, what experiments would be appropriate to pursue? What limitations hinder your ability to carry out such experiments before reporting these results?

Having substantiated your conclusions, explore their implications. What predictions can you make based upon your results? Are there any implications for society in general? Do you need to revise your understanding of the phenomenon? (Remember, scientists do not revise their 'beliefs.' Scientists cease to be scientists if they believe their own theories.)

Be careful when making your conclusions not to overstate the implications. Remember that scientific results are never *true*, they are only *more probably correct* after having withstood the scientific method. Watch out for personal bias in your discussion, and try to limit yourself to only those conclusions that can be demonstrated directly from the data. It is fine to infer a new hypothesis, but do not stray far from the data and state clearly that you are speculating. Make sure that your speculation logically follows from your data, and reference other work which may support your inference. Rambling speculation only casts doubt upon the rest of your report. If you are employing statistical analyses, remember that statistics are only descriptive, not predictive.

In cases where there are alternate or competing explanations for a given phenomenon, you should first describe each explanation, and then compare their merits. An important axiom in science is 'Acham's Razor,' which states that if you have two explanations that work equally well, the simpler one is more likely to be the correct one. Can you propose an experiment to resolve the ambiguity?

Remember that the more important the implications of your work, the more scrutiny your work will receive. If performed properly, the experiment and data are your best defense. Stay close to the data, and your work is more likely to survive the test of time!

ACKNOWLEDGMENTS

You should acknowledge anyone who has helped you to complete the present work, especially peer reviewers and granting institutions.

At least two peer reviewers should be employed. Peer reviewers should check spelling, calculations, formats, and the reasoning of your paper. Peer reviewers are your allies! They help you to avoid silly mistakes and improve the quality of the finished product. Remember, if a paper is to stand the test of time, it needs to be clearly written, rigorous, and accurate. Science is a self-purifying enterprise, and peer-review is the front line of the purification process.

REFERENCES AND FOOTNOTES

Here is where you list references to other work and explanatory footnotes. (Do not intersperse them throughout the paper). If you use someone's work without footnoting it, it is plagiarism. This includes ideas as well! Keep in mind that there is nothing wrong with building upon and borrowing from prior work, as long as you reference it. Scientific progress is predicated upon the steady, incremental advancement of ideas.

Footnotes should be numbered, and have the following book or article format:

1. D.G. Frank, *The Meaning of Life* (Big Book Publishers, New York, 2000), pp. 200.
2. D.G. Frank, I.M. Silly, *Science* **247**, 182 (1990).

APPENDICES

Appendices contain information for readers who want to explore your results more carefully. Tables of raw data, equation derivations, or computer program listings are included in this section.

For grading purposes, include photocopies in this section of the appropriate pages from your laboratory notebook.

Example Title Page for Laboratory Report

July 17, 2002

John A. Doe
100 Puppy Dog Street
Cincinnati, OH 45242
JohnDoe@internet.com

Jane B. Doe
100 Sugar & Spice Road
Cincinnati, OH 45242
JaneDoe@internet.com

Physics 101
Dr. Douglas G. Frank
Excellent School, Cincinnati OH, USA

ABSTRACT

This page illustrates the proper format for the title page of a laboratory report. Note that the abstract is single-spaced, in contrast with the body of the report, which is double-spaced. The abstract should be a one paragraph summary of the entire experiment. Describe what was done, how it was done, the outcome, and the conclusions. Typically 100 to 200 words in length and in the past tense, the abstract should be written after the rest of the report is completed. Since the words in titles and abstracts are used extensively in electronic media for cataloguing and searching, make sure that any important keywords are included.

Figure 1. Pendulum Period vs. Length

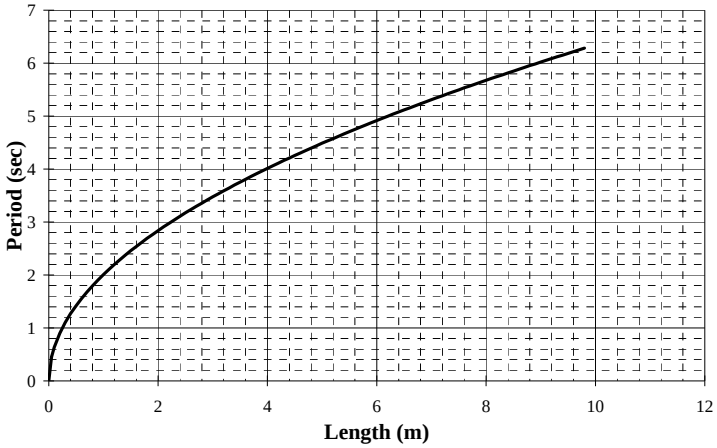

Figure 1. Example illustration of proper plate format. A complete page is allocated for every table, graphs, and figure. Note that axes are labeled with SI units.

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