# Writing Scientific Reports*

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This part, the abstract is an essential part of a scientific paper—often the only component freely viewable from search engines. It should briefly summarize the background, the purpose, the method, and most importantly, the quantitative results with errors. Based on those, a conclusion may be drawn. Your paper should demonstrate your mastery of the entire experiment. It should be neat in appearance with correct English. It should be concise; four single-spaced pages including figures should suffice. Not included in the four-page limit, appendices can be used to present data that is summarized in the main body, for derivations referred to in the main body, and for answers to questions posed in the experimental guides.

## 1. INTRODUCTION

The introduction typically places the current work in context with prior work and explains what new contributions are involved and why the article is worth reading. Use one or more paragraphs to succinctly explain the motivation, purpose and relevant background to the experiment. This should be done at a level so that another lab student could follow your development.

In the introduction section, provide the point of this work. Think about why you are implementing this lab work and how it helps you understand and perform the theoretical developments we have gone through so far. What is the particular problem that you are addressing as part of this lab session? Do not provide derivations, but do describe what new assumptions are needed. Formulas involving measurement conversions, instrument settings or other apparatus details should be relegated to the apparatus and experiment section.

An important part of your education as an engineer is learning to use standard tools for sharing your work with others. The writing process involves at least three distinct steps: prewriting or outlining, drafting, and revising or editing. Given the tight time constraints in Controls Lab, students are advised to begin the drafting process **before** finishing their lab sessions [1]. Most of the first draft can be accomplished during the later sessions of an experiment.

The essence of expository writing is the communication of understanding through a clear and concise presentation of predominately factual material.[2, 3] Most people cannot compose successful expository prose unless they put the need to communicate foremost among their priorities. Two things predominate in generating understanding in the reader:

**Organization:** The reader must be provided with an overview or outline, know how each fact fits into that overall picture, and must be specifically alerted about any especially important fact. Furthermore, the facts must be presented in a logical order—so that fact 17 is not important for understanding fact 12.

**Depth:** Bearing in mind the preexisting knowledge of the reader, the writer must budget the length of discussion allotted to each topic in proportion to its importance.

Writing a journal-like article for the lab report is a great practice for improving your technical writing. We strongly recommend that you:

1. Base your report on an outline.

2. Begin each paragraph with a topic sentence which expresses the main area of concern and the main conclusion of the paragraph. Put less important material later in the paragraph.

Point 2 is frequently absent in novice reports; topic sentences are your mechanism for telling the reader what is under discussion and where it fits into the overall picture. You can check your topic sentences by reading them in order, i.e., omit all the following sentences in each paragraph; this should give a fair synopsis of your paper.

If you are writing up results you obtained with a partner, use we for work performed together and I for work performed alone. Use the past tense for your procedure and analysis, and the present for your results. "LiF xray diffraction angles *were* measured to $\pm 0.2°$ and *are* consistent with an FCC lattice with a spacing $a_0 = (4.035 \pm 0.014)\,\mathrm{nm}$." Note that units are in normal (not math) fonts.

**Lastly: Remember to proofread your paper for spelling and grammar mistakes. Few things are as offensive to a reviewer as careless writing and such mistakes will count against you!**

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*This document was adapted from the original—written for MIT Junior lab students, `web.mit.edu/8.13/www/`

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## 2. APPARATUS AND EXPERIMENT

With reference to one or more figures, this section describes the apparatus and procedures that give rise to the raw data. Also discuss the data's random errors and the sources and sizes of possible systematic errors. Include here critical observations of any noteworthy issues associated with the apparatus.

The apparatus figure should contain a block diagram or schematic of the equipment and perhaps include the most important signal processing steps. The figure should be referenced and placed as early as possible in this section.

Place additional information within the figures or in their captions to help you stay within the four page limit. **Example first sentence of an experimental section:** The experimental apparatus consists of a specially prepared chemical sample containing $^{13}CHCl_3$, an NMR spectrometer, and a control computer, as shown in Fig. 1.

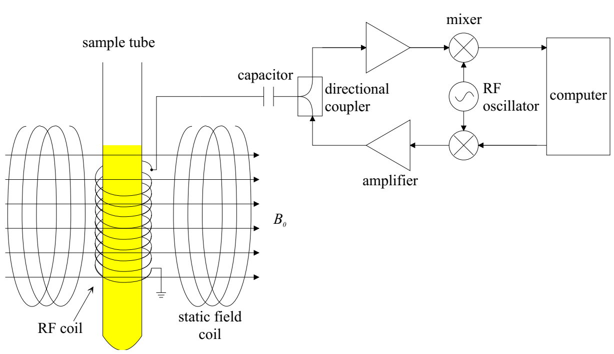


FIG. 1: This part—the caption—should be clear and comprehensible. Use the caption to elaborate on specific issues, features, complications, or operating procedures.

Here are some general guidelines:

- Give the controller used in your experiment.
- What type of sensors were used, what were their resolution?
- How did you compute the velocity?
- What was the sampling rate for running the real-time system?
- What are your voltage limits?
- Make sure the font sizes in your block diagrams are large enough so that they can be easily read.
- Do not copy paragraphs from the lab manual that I wrote up for you!
- Do not copy my block diagrams or figures.

## 3. ANALYSIS AND RESULTS

This section should demonstrate how the raw data lead to the main results. Make a complete estimate of the uncertainties in your results—both random and systematic.

Either here or in the previous section, be sure to display representative raw data. Where there is an abundance of data, consider using an appendix to present it. See, for example, Fig. 4.

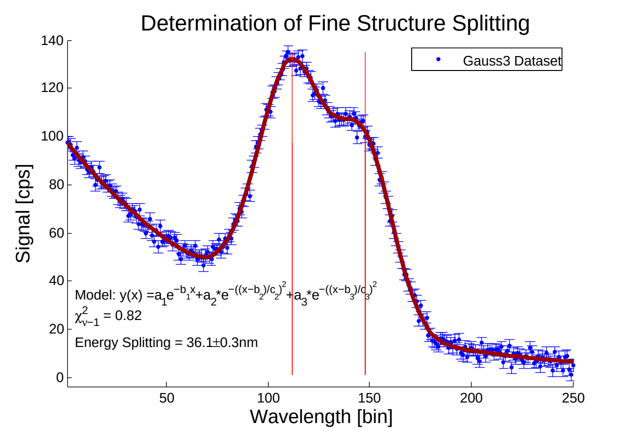


FIG. 2: Sample figure describing a set of data, fit procedures and results. Use the caption space to provide more details about the fitting procedure, results or implications if you do not have sufficient room in the main body of text.

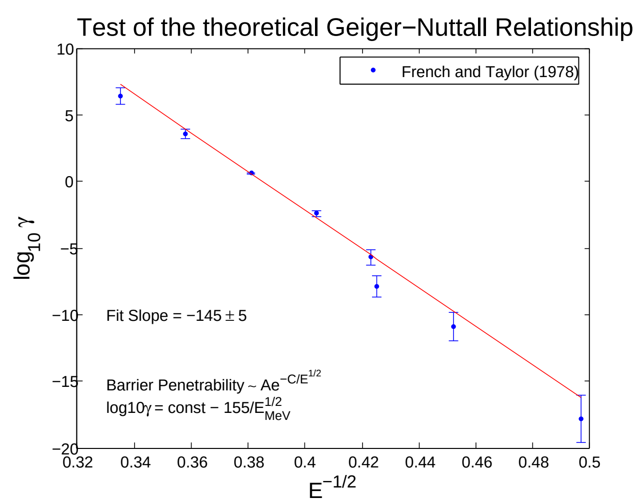


FIG. 3: Sample figure showing overall physical relationship you set out to test.

Often the raw data are analyzed in a specific way that needs to be clearly communicated to the reader. For example, the peak positions in a spectrum may be required. A graphic demonstrating a typical fit result, functional model, and reduced $\chi^2$ is shown in Fig. 2. Finally, there should be a graph or table which summarizes the experimental data, and which conveys the primary findings of the laboratory exercise. For example, the Geiger-Nuttall relationship as shown in Fig. 3 or Table I containing results of xray spectra analyses.

TABLE I: An example table with footnotes. Note that several entries share the same footnote. Always use a preceding zero in the data you record in tables. **Always display units**.

| | $r_c$ (Å) | $r_0$ (Å) | $\kappa r_0$ | | $r_c$ (Å) | $r_0$ (Å) | $\kappa r_0$ |
|---|---|---|---|---|---|---|---|
| Cu | 0.800 | 14.10 | 2.550 | Sn[a] | 0.680 | 1.870 | 3.700 |
| Ag | 0.990 | 15.90 | 2.710 | Pb[a] | 0.450 | 1.930 | 3.760 |
| Tl | 0.480 | 18.90 | 3.550 | | | | |

[a]Here's the first, from Ref. [4].

Additional graphics, such as Figure 2, should be well thought out and crafted to maximize their information content while retaining clarity of expression. Try to avoid the temptation to inundate the reader with too many graphics. It is worth spending some time thinking of how best to present information rather than just creating graph after graph of uninformative data.

Some results you should provide for our lab sessions are listed below with some additional suggestions.

- Show the circuitry used in your lab set-up.
- Provide the code you pushed to your Teensy microcontroller.
- Post-process any data you collect in Python, Julia, or Matlab and make nice plots out of them.
- Make sure the fonts in your plots are large enough for readability.
- If you print in black and white (which is fine), then do not refer to a "red" plot!

## 4. DISCUSSION AND CONCLUSIONS

Summarize and discuss the findings of the experiment. Report all your results with appropriate significant digits, units, and uncertainties, e.g., $Q = (2.12 \pm 0.06) \times 10^{10}$ disintegrations $s^{-1}$. Compare your results with theoretical expectations and simulations. How well did they match? Was the steady-state tracking error zero? If not, why not? Make suggestions for improvements and describe additional experiments that could be attempted with this or an improved apparatus. Be adventurous with your suggestions.

It is worth mentioning here some thoughts on **ethics and writing in science**.

When you read the report of a systems and controls research in a reputable journal (e.g., Transactions on Automatic Control) you can generally assume it represents an honest effort by the authors to describe exactly what they observed. You may doubt the interpretation or the theory they create to explain the results. But at least you trust that if you repeat the manipulations as described, you will get essentially the same experimental results.

Nature is the ultimate enforcer of truth in science. If subsequent work proves a published measurement is wrong by substantially more than the estimated error limits, a reputation shrinks. If fraud is discovered, a career may be ruined. So most professional scientists are very careful about the records they maintain and the results and errors they publish.

In keeping with the spirit of trust in science, we, as the instructors, will assume that what you record in your lab book and report in your written and oral presentations is exactly what you have observed.

Using other people's words without acknowledgement is a serious intellectual crime and possible causes for dismissal from the University. The appropriate way to incorporate an idea which you have learned from a textbook or other reference is to study the point until you understand it and then put the text aside and state the idea in your own words. Fabrication or falsification of data and using the results of another person's work without acknowledgement are offenses of similar gravity.

One often sees, in a scientific journal, phrases such as "Following Bevington and Melissinos [4, 5] ..." This means that the author is following the ideas or logic of these authors and not their exact words. If you do choose to quote material, it is not sufficient just to include the original source among the list of references at the end of your paper. If a few sentences or more are imported from another source, that section should be

> indented on both sides or enclosed in quotes, and attribution must be given immediately in the form of a reference note.[5]

## 5. BIBLIOGRAPHY REMARKS

Bibliographies are very important in scientific papers. Beyond the requisite citation of source material, they provide evidence of your literature research beyond the experimental guides. Literature searches, appropriate references to other research, and bibliographies are an integral part of any type of research. Bibliographic entries are made within a separate '.bib' file which gets attached during the process of building a final PDF document.

[1] R. DeSerio, *Title of the lab manual/experiment*, http://this.is.the.url.of.the.lab.manual.pdf (20xx, year the manual was last updated), Phy 4802L, Department of Physics, University of Florida.
[2] J. P. Leslie C. Perelman and E. Barrett, *The Mayfield Handbook of Technical and Scientific Writing* (Mayfield, 1998), URL https://web.mit.edu/21.guide/www/home.htm.
[3] D. Pritchard, *Junior lab written report notes* (1990).
[4] P. Bevington and D. Robinson, *Data Reduction and Error Analysis for the Physical Sciences* (McGraw-Hill, 2003).
[5] A. Melissinos, *Experiments in Modern Physics* (Academic Press, 1966).

## Appendix A: Lab Report Policy

1. Everyone needs to hand in their own lab report. If you work with someone in the lab, then put that person's name on the lab report as a collaborator.

2. Each of you need to collect your own data and write your own report. I do not want to see two reports with exactly the same data (even though everyone's data will look similar) nor with the same lab report.

## Appendix B: Typesetting with LaTeX

This document was created using the typesetting language LaTeX, which allows you to create very professional-looking documents with minimal effort. If you are interested in learning how to create such documents using LaTeX, I can provide the code that generated this document as a template that you can start with.

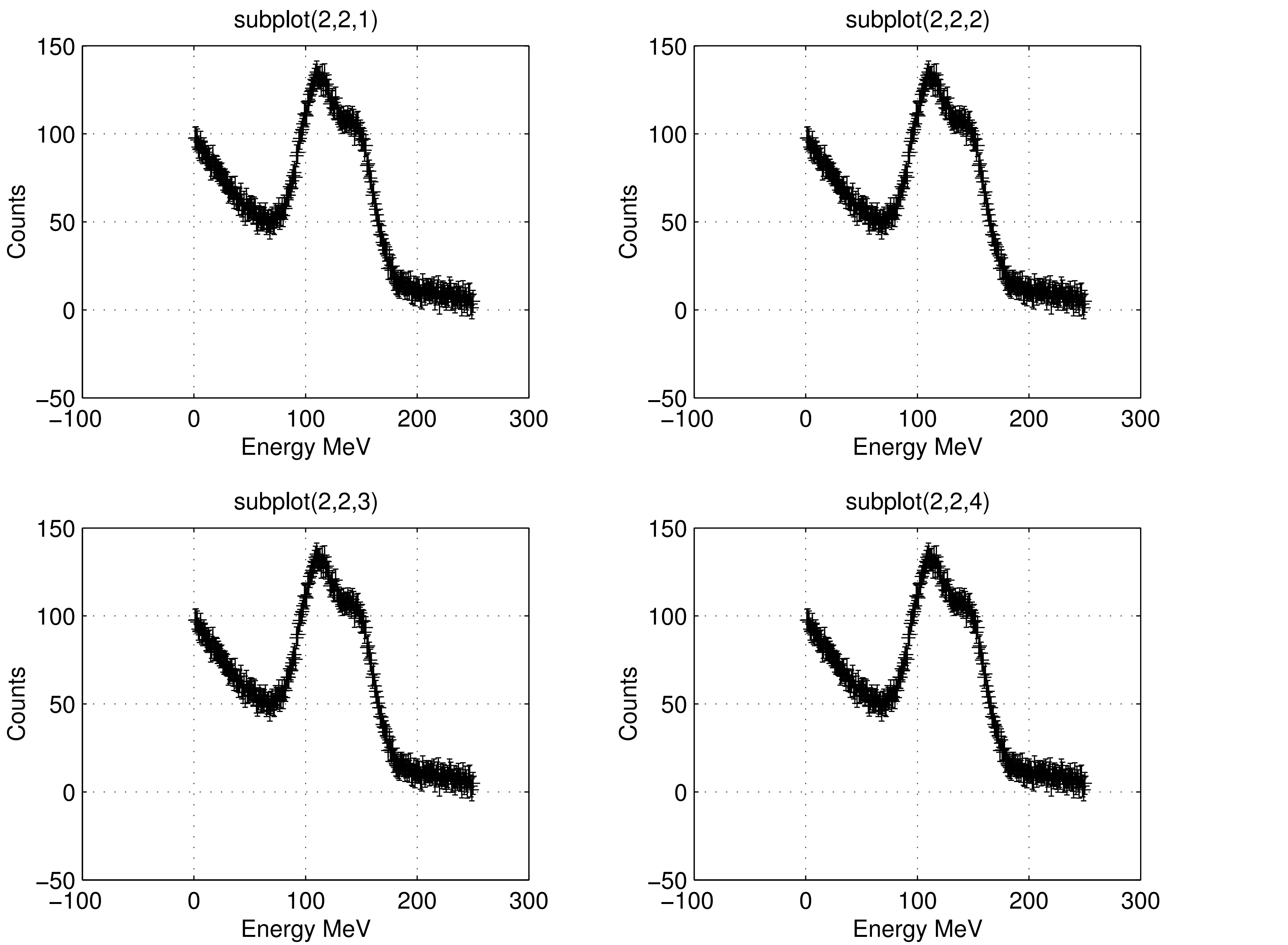


FIG. 4: For very large plots where important detail might be lost if too compressed. These full page graphics are usually best kept in appendices so as not to impede the flow of the paper. Note that large tables can also be presented in this landscape environment if desired.