Advanced Lab II: Lab Template

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Lab Group Number ie R3 or T10
Experiment Date: ...
Report Due Date: ...

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Abstract

Students are strongly encouraged to read this document carefully before preparing their first report for Adlab 2. This template document is organized into the typical sections found in a well-prepared report. Each section includes tips, recommendations and requirements relevant to that section. An appendix lists general tips and common mistakes to avoid.

The recommend length for an abstract for these reports is 5-10 sentences. One to two sentences about the physics and model you are investigating or the measurement you are making, 1-3 about the apparatus and method, 1-2 about the results. If results are quantitative, quote number and errors. If there are many quantitative results, quote a representative set. 1-2 sentences to summarize your conclusion.

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1 Introduction & Model or Measurement

Write a brief introduction stating the objective of the laboratory and the science to be investigated. This section should be brief. One paragraph is generally fine. Reference where you got the model or established result, for example [1].

An example equation [2]:

\[ V = \frac{x}{t} \]  \hspace{1cm} (1)

where \( v \) is the speed of the particle, \( x \) is the distance traveled, and \( t \) is the time. Note that all the variables in the equation are explained in the text.

2 Apparatus

Describe the apparatus using clearly labeled figures. The figures can include diagrams, photographs, block diagrams. Photographs should include labels of key components. Generally a photograph of the apparatus, especially a rack of NIM modules, is not a substitute for a diagram that shows how the experiment is organized.

Don’t forget to write captions for your figures. The captions should include a few sentences about what the figures describe.

3 Procedure

Describe procedure you did that was *not* listed in the instructions. Extra tests, other investigations.

4 Data Collected

This contains the raw data and the starting point of your data analysis. This is where we find table(s) and spectra of raw data collected, including units and, if applicable, errors. To make good tables, think about all the information you need to carry out further calculations. For example, you may have taken data over different time periods: your table would then indicate integrated number of counts, length of time over that the data were taken and finally count rate deduced. The latter column can then be used for further analysis. Also, do not put the errors in different columns, instead write the results as \( X \pm \Delta X \). Again explain things carefully in the caption. You need to include some text explaining how the data presented in the tables and plots were collected and/or deduced from basic calculations. Some information may be needed for further calculation, such as distance from the source, etc... things that did not change in the whole data collection. This can appear in the text outside of the tables.

If you collect many data sets, only show a few examples (label them as examples in the caption). You can put the others in the Appendix. Same for tables if you have a lot of data. For some labs, you may be asked to include sketches of oscilloscope traces with both axes labeled including units.
Table 1: Example of a data table. Energy from [3]

Signals rise time was $\approx 20 \, \mu s$ and a fall time that is large comparatively at $\approx 300 \, \mu s$.

5 Data Analysis

This section explains your data analysis and how you calculated/estimated the experimental uncertainties. You are often asked to carry data analyses involving different data sets and/or aiming at answering different problems. Create as many subsections as necessary. In each of them, you need to put the relevant information needed to carry out your calculations recalling the tables presented in section 4.

You may wish to put in key equations (including the ones used in error propagation), and a sample calculation. Make sure you define well the variables you are using in your equations. In general, you are not expected to show the derivation of equations used in your lab report. You can simply include a reference where you got them. However, there may be cases where outlining a derivation may be appropriate.

Present the qualitative results of the data and error analysis. This is typically one or more plots and a table. Write a few paragraphs describing the results including errors.

6 Results

This is where you put your "money" plots and other results of your analysis.
Figure 1: Example Figure. Energy calibration of the NaI detector used in this experiment. The vertical axis represents... The individual points correspond to the following sources: ...

Compare your results with model(s). A good way to do this is in units of the error that you estimated.

7 Conclusion

The conclusion is not a summary or a recap of what you did.

What conclusions can you draw based on the results from your report? This section does not need to be long. However it should make you really think and it should be well-written. Think about what your apparatus actually measured, and what the results, including errors actually show. What conclusions can you draw about the physics that you investigated? Can you make a statement that goes beyond the specific measurement you made? If you are comparing a measurement you made against the prediction of a model or against an established result, it is also helpful to think about the difference and the size of the error bars.

8 Contributions

List briefly the contributions of each team member to report preparation.

References

A Appendix: Tips and common mistakes to avoid

A.1 General Tips

1. Read the lab instructions/write up before you arrive in lab. At least one group member should bring a printed copy to lab.

2. Unlike Adlab 1, the entire lab is done in a day. Making a first pass analysis during lab is highly recommended. You are encouraged to ask the TAs and the instructor questions. You will catch problems that may not be obvious when you took that data.

3. At least one of the team members should bring their laptop and start the report during lab. A good way to collaborate on the writing is to share the latex and other files, including figures, using overleaf.

4. Save your data in more than one place and verify that the data format you used is the one you need. For making plots of spectra generated by the Ortec Multi Channel Analyzer (MCA) the ASCI files in .Spe format are especially useful. Several example python scripts that will produce a spectrum plot from an .Spe file are available on the course website. Examples include the python (.py) script, sample input data, and an example plot.

5. Use your smart phone for photos as you go. For example recording, settings of the NIM modules, images of computer screens, configurations of detectors and sources, the date and type of sources can be invaluable references.

6. Once you leave lab, stay in touch with your partner as you prepare the report. Especially important if you have to reschedule a meet-up or encounter a problem or delay with a section, plot or analysis. Most groups work quite well together. Exceptions are often traced to breakdowns in communication. People issues are best handled by talking together.

7. When you get your report back, read the comments as well as the grade. The comments represent an effort by the instructor to help you improve.

A.2 Writing

The abstract and the conclusion section of your report are often the parts read most closely. Take extra care when writing these.
If your name appears in the author list, you share responsibility for what is in the report. Even if you didn’t write that part that lost grading points. Circulate the near final draft with enough time for your group to read it carefully. If you are responsible for making a plot that your partner will use in section they will write, give them the plot with plenty of time for the writing.

Use descriptive verbs: less “is”, “did”, and “used” type verbs and more verbs like “measured”, “compare”, “constrain”, “configure”, “fails”, “solves”, “ionizes”, “demonstrated” “tests”, “agrees”, “drives”, “decays”, “radiates”, “attenuates”, “amplifies”. “Measure” is an especially good verb for a lab report.

Use shorter sentences when possible. A common “feature” of student writing is introducing too many ideas into a long complex sentence. At best, this taxes your reader unnecessarily. At worst, your reader concludes that you don’t understand what you are talking about. Neither is desirable. Especially if the reader happens to be your grader (or referee, or grant reviewer, or potential employer). Break these sentences down in to shorter simpler sentences. And think!

Avoid using 30 words when 10 would do. Read each paragraph of your report carefully. Then cross out as many words as you can while keeping the sentences coherent and without changing the essential points in the paragraph. Eliminating content-free fluff will improve the clarity of your report. A simple example is “In order to”. Just use “To”.

Apply the “So what?” test to your writing. Consider, for example, “The oscilloscope is an important tool that scientists often use to make complex measurements in the laboratory.” So what? Skip that fluffball. Start with something like: “Using an oscilloscope, we measured the…”.

Review the adjectives you are using. Where possible make them quantitative. For example, “the first counter had larger signals than the second…” becomes “the first counter produced signals that were about twice as large as the signals produced by the second counter, as estimated with an oscilloscope. Also note that “had” was replaced by the more descriptive verb “produced”.

Oscilloscope not O-scope

Run a spell checker and proof read. Don’t submit a lab report titled “Compton Shattering”. Yes, that happened.

Make an appointment with the Mines writing center if your group is struggling with report writing.

### A.3 Formatting and Figures

How you choose to display your data and fits in the figures that you put in your lab report can enhance the quality of the report significantly. While you do the lab, discuss what are the “money” plots going to be and how will you make them.

Various examples of how to plot and fit data using python are provided on the course website. While plots from any package are acceptable, provided they meet the requirements below, python is the recommended option. Python with the numpy, scipy, and matplotlib packages provide a powerful tool for plotting and fitting data. Producing clear data figures that illustrate critical steps or results of your work clearly is a valuable skill. You will apply it beyond this course. You are encouraged to experiment with python plotting to improve these
skills. The plots in this document were generated by python using the examples provided on the website.

You are encouraged to use vector graphics files for your figures that include data plots. Vector graphics can be scaled without loss of resolution, in contrast figures produced by cutting and pasting screen shots. The graphics files that python +matplotlib will produce in .pdf or .png format are examples of vector graphics files. The use of vector graphics is becoming a standard requirement of many research journals. However journal manuscripts require more time to prepare then you have to prepare you lab reports. So vector graphics figures are not strictly required. Use them when you can.

Each tables and figures is accompanied by a caption. The caption should convey meaningful information specific to that figure. “Plot of the Data” is not a meaningful caption. In some cases it can be appropriate to group similar plots together, label them A, B, C . . . and have one caption. Make sure the figures as they appear in your report are large enough to read easily, including the axis labels and features you want the reader to notice. The default font size of Mathematica figures is much too small for lab reports. Assume that that key features or text too small to be seen easily by the grader will be treated as invisible when the report is graded. All font should be at least size 10. This includes the abstract, body of the report, captions, labels. 12 point font is preferred for the body of the text. Use 1” margins. Not 1.5” or 2”. Do not refer to colored features in a figure of a report that has been printed in black and white and submitted for grading.

Accompany a table of results with a plot. Nearly all of the major results in these labs should be displayed in tabular form and in plots. Make sure your plots include axis labels with units and captions. Data points should have errors bars, or a discussion explaining why they are not shown. Use a leading zero and a space before the units, i.e. 0.1 km (not .1 km or 0.1km or .1km)

A.4 Errors, Significant Figures, and Background Noise

Error is NOT the difference between your result and the accepted result! Suppose you measure the lifetime of the mu lepton. You get 2.4 microseconds. The accepted value is 2.2 microseconds The error in your measurement is NOT 2.4 - 2.2 = 0.2 microseconds. That would be the DIFFERENCE between your result and the accepted value. The error of your measurement is determined by estimated the quantitative uncertainties in your apparatus and method. Estimating the error of a measurement is often harder than obtaining the measurement. Yet it is the error that gives meaning to the measurement. Do not quote a difference as an error in your reports. Difference and error have very different meanings in experimental physics.

How many significant figure? Your calculator or spreadsheet can present a number using 10 digits or even 20! What does your calculator or spreadsheet know about the experiment you just did? Absolutely nothing. The experimental error of the final results of experiments in this course generally range between 1% and 20% In your report, quote a number of significant figures appropriate to the data you collected or the result you obtained from your data analysis. Same for the error that you estimate. For example, 1.040203 ± 0.23452 m makes no sense. If the error is really that large, it is not known to that many figures. Neither does 1.0 ± 0.234 m. 1.0 implies the number was estimated to one figure
right of the decimal point. 1.040203 ± 0.23452 should be presented as 1.0 ± 0.2 m or possibly 1.04 ± 0.023 m. (If you were making a super-precise research-grade measurement where the final result actually was 1.040203 m, a compatible error would be, for example, 0.000005 m or 0.000012 m. In such a case you would also provide separate systematic and statistical errors.)

The noise and background radiation ate my results. Think carefully before invoking this Deus Ex Machina to fix the unexplainable. Draping this infamous carpet over mysterious bumpy things that apparently sent your results south is an old ploy to hide sub-standard lab work. Your instructor was once a student too. However, there are cases where background noise or radiation really does limit a result significantly. In such cases, you also need to support this interpretation. Discuss carefully what these backgrounds might be. Explain, quantitatively why you think they are large enough to matter. Writing this discussion is easier if you managed to investigated the matter during the lab. Especially if you managed to reduce the noise as well.

A.5 Conclusion

Your report conclusion is not a recap or summary of what you did, or a summary of your results. Rather, it is a discussion of the conclusions that can be drawn from your results. This is more more challenging to because it requires more critical thinking. And that’s why a conclusion is required rather than a summary or recap.

A.6 References

In the bibliography each item should be referenced in the report (in latex use cite). Do not just list a reference without citing it explicitly in the text.