Physics 4300

THE CAPSTONE PAPER

There are many ways to successfully write a scientific paper. Here I describe, first the important elements to be included in a CAPSTONE PAPER, followed by some helpful hints on how to go about writing such a paper. The hints section is broken into two sections: the first describes the importance of the outline in the initial set up of the paper and the Capstone project itself, while the second describes how to go from this outline to your final paper.

ELEMENTS OF THE PAPER

The paper that you will write for this course should ***not*** be a letter-journal-type paper. (These tend to be very condensed, sometimes unreadable except by other experts.) Rather, it should be the sort of paper you would see in the Journal of Applied Physics, Physical Review A- or B (not Physical Review Letters) or Journal of Vacuum Science and Technology. That is, a paper that is more complete with sections for an introduction, procedure, results, discussions, *etc.* You should address the paper to the non-expert in the field, for example a classmate. The reader should get a clear idea of what you have done in this project.

Below there is a list of suggested section titles and what they should contain. All of these titles will not necessarily apply for each Capstone paper.

ABSTRACT
This is a very short (less than one page) condensed stand-alone summary of the work; *i.e.*, what was done, how it was done, what results were found and conclusions.

I INTRODUCTION
This introduces the work (again, for the non-expert).
It includes motivation –why this work is important, a discussion of past and current work and how your work fits in with this –any controversies it resolves, *etc.*

II APPARATUS and DESIGN *(not usually relevant for theoretical* projects)
Here discuss the apparatus you used for your project. Give an overview of the set-up. Describe improvements that you made. Include any electronics, mechanical equipment or software designed for the project. Include detailed drawings or flow charts as an appendix. Here you describe your design criteria, design approach, *etc.* Discuss any compromises. Finally, discuss the success of your design. What improvement would you make, if you did this project again.?

III PROCEDURE *(important for both theoretical and experimental projects)*
Here discuss the procedure you followed. Often the procedure change over the course of your work, *i.e.*, you discover new parameters that are important. Fully describe your procedure and discuss improvements that you made to it.

IV MODELS or CALCULATIONS
Describe any modeling or calculations that were important to your project. Often it is useful to run through a sample calculation. Use enough detail for the non-expert to understand what you have done.

V RESULTS
Here *describe* your results. Use of figures and tables are typical. Make sure the figures are neat, straight forward and for the most part self-explanatory they are *very important* in any paper.

VI DISCUSSION
Here *discuss* your results. Often combine this with the RESULTS (see above), so that you describe and discuss your different results one by one. Often, it useful to tabulate your results and discuss trends in this table. This is where you compare data to calculation or your results with the results of earlier work. Also include a discussion of your error analysis.

VII CONCLUSIONS
Here link your discussions together into a coherent conclusion. If clear conclusions are not possible, discuss what new measurements are necessary to make solid conclusions.

VIII SUMMARY
Often it is useful to combine the SUMMARY with the CONCLUSIONS. It should summarize the whole experiment including the conclusions.

ACKNOWLEDGMENTS

REFERENCES
Use the format,
Author, "Title," *J. of Phys.* **Vol#**, pp, (1999).

APPENDICES
Put any useful drawings or flowcharts of software here.
Especially information that is useful for the continuation of the project.

HINTS ON WRITING THE PAPER

Here I break the process into two parts the first describing how to prepare to write the paper, entitled the OUTLINE, and the second on how to actually write the actual paper. The first part has many of the same elements as the approach to your particular Capstone itself. Indeed, by having you hand in an outline of your paper at the start of each term (even before you have done much of the work) it will be easier for you to keep track of your project.

The OUTLINE
An outline is a list of the chief features or parts of a paper. Usually it starts as a list of the ideas that you want to cover in a paper, *i.e.*, about one point per paragraph. While still in the outline stage you should be thinking and working on the figures that are important for the paper. It is best to start from an outline because it is easier to reorder distinct points than flowing prose. In this course, as an exercise to keep you on track with your project, you are going to hand in Outlines at the beginning of each term. Below I describe first what should be in your first term Outline, then your second term Outline and finally the outline you should have before writing the paper itself.

PASS 1: Even as you start your project it is possible to outline parts of your paper. For example this is when you are reading background papers that motivate your project. Read them carefully, keep the reference if not the paper itself, and use the important points as points in the Introduction section of your outline. For the Apparatus and Design you will certainly know many of the important features, even though you may not be familiar with the entire system. Include the parts you know in the outline. Similarly for the Procedure, even though your not completely familiar with the details, you should be familiar with enough to include the important parts in your outline. Clearly you will not yet have results, however, you should be familiar with related or earlier results. Include, these in your outline as well. Finally, you will certainly not be able to discuss and make conclusions on non-existent results. Instead outline the effects you will be looking for and the evidence you need to observe these effects. This will get you thinking about the experiments you will need to make to make your conclusions. That is it for PASS 1.

PASS 2: Now that you have completed one term, you should be much more familiar with the project that you are doing. Go back to your Outline and include any new points that you have learned in the Introduction. You are very familiar with the apparatus, or you have now completed your Design, include this knowledge and work in the outline. Include the figures that you feel are appropriate. By this time you should have results. They may not be the final results that you will include in your paper, but they should be getting close. Put these results into figures or tables and incorporate these into your outline. Think about what sets of figures and plots are needed. This will help you make sure you don't forget to take important data. Since your results are not final, your conclusions will not be final. However, you should have *provisional* conclusions. Put these conclusions in your outline. (This should get you thinking on the measurements or calculations that you must make to test these provisional conclusions.) That is it for PASS 2.

The PAPER

Based on following the procedure above, you have a detailed Outline from which you will write the paper. In the second term you will be making measurements or calculations that solidify or disprove your provisional conclusions. Include these new results in your earlier Outline to come up with your final Outline.

Go back to your figures. These are critical for your paper. They are the starting point. Most readers will flip through your paper and look first at the figures. They should communicate the essential results clearly. Perfect them and write their captions. Label the figures appropriately. Use legends if necessary. Make sure that they contain all the points that you want the reader to carry away. (You may want to leave detailed figures of software flowcharts or equipment design to an appendix.) Usually it is good to put more than one curve on one clearly labeled x-y plot. Often it is good to put two figures next to each other to enhance the comparison between them. Figures make or break a paper – polish them.

Now flesh out this Outline into your paper. This is not an easy task; you must work at it. In your writing be specific, avoid the passive voice and use short single-idea paragraphs. See the attached Guide to Writing a PRL-length Paper to guide you through sentence and paragraph structure. (Ignore rule 1, it is rules 4-9 that are important for you here.)