Structure of the report

Title
Abstract
Table of Contents
List of Tables
List of Figures
Introduction
Theory
Experimental Procedure
Results
Discussion
Conclusions
Error Analysis (can be part of Discussion)
References
Appendices and Raw Data

20 pages maximum, including figures and tables

As described in the Report Writing lecture, each of these sections is expected to contain specific types of information:

Title – Should be short and descriptive, and should convey the essential nature of the work to a reader. This is the first thing most readers will see and is what will either catch their attention, or will divert their attention to some other topic or report.

Abstract – Is a short (usually one paragraph) very brief summary of the entire report. By reading an abstract, a reader should be able to learn what work is discussed in the report, what experimental techniques and theory were used to obtain and analyze the data, what the key results were and what the implications of the work are. Often other colleagues and supervisors will first read an abstract; only then if the work seems interesting or important enough will they then take the time to go through the rest of the report. Thus a concise and well written abstract is essential.

Introduction – The introduction should address why you performed the work described in the report as well as explain the larger motivation or implication of the work to a reader. Deal with these questions in a straightforward and interesting manner, make sure to cite relevant previous work, and indicate what approach was used in the experiment.

Theory – Usually the experimental data is either interpreted into a final meaningful result using one or more theoretical interpretations or analyses, or the experimental results are being used to test one or more theoretical descriptions of phenomena. This section should summarize the key elements of the theory used in the data analysis or experimental comparison. A reader should learn the essential assumptions and implications of the theory by reading this section. Depending upon the complexity of the theoretical models being used, the section may also need to make reference to other more in-depth theory discussions in which detailed derivations and discussions are given.

Experimental Procedure – This section tells the reader what type of apparatus was used in the experiment, and how the apparatus was configured for the particular experiments being described within the report. Their should also be a step-by-step description of how the apparatus was setup and operated, how the measurements were made, and how the data were recorded for subsequent analysis. Some authors also describe the location of the facility as well. One or more diagrams, photographs, or drawings of the apparatus are often useful to help guide a reader through the procedure section.

Results – Here you are answering the question "What did you observe or measure in the experiment?" Readers will often read the abstract and then jump to this section. Thus you should try to write this section so that it stands on it's own. Make sure that this section answers the

question or questions that you posed in the introduction – don't start answering questions that were deemed secondary or irrelevant during the writing of the introduction. Discuss your results in the order of their importance, listing principal results first and secondary results later. Do not suppress legitimate, valid results that contradict your expectations or theory. Doing so in not only unethical, it may also mislead you into a false or unsubstantiated conclusion. If possible, try to explain why such results might be obtained or why they are anomalous. Make wise use of tables and figures to help explain quantitative results, and make sure to incorporate the results of your error analysis (contained in a separate section) in the results section. For example, if you are computing the drag coefficient upon a body immersed within a flow, you should state the value of the estimated drag coefficient as well as the uncertainty in that estimate, e.g. you would state that the drag coefficient was found to be Cd=0.12 +/- 0.01. The theory that led to this value for Cd, and the error analysis that led to the error estimates would then be given in the theory and error analysis sections respectively.

Discussion - In this section you are answering the general question "What do your finding mean, and what are the implications of these findings"? The discussion is where you answer the specific question(s) that you indicated would be addressed in the introduction. Thus a useful way to open the discussion is to use the end of the introduction as a starting point. Discuss any possible errors in your method and assumptions, and point out how these possible errors may explain discrepancies in your experiment-theory comparisons. However, try to avoid the temptation to refer to every detail of your work again. Usually if a reader has made it this far in your report, she will have already read the preceding contents as well.

Conclusions – This is a brief summary of the key findings of the experiment. Often an author will very briefly describe the experimental approach that was used in the work using one or two sentences, and then describe the key results of the work listed in order of importance (i.e. most important results given first, less important results second, etc…). It is important to carefully distinguish between clearly drawn conclusions based upon solid data, analysis, and theory, and speculations or suppositions what might be drawn from the work and yet which are not completely substantiated by the experimental results. The essential implications of the results should also be summarized, and suggestions for future studies can also be given.

Error Analysis – This section describes the error propagation that occurs in the key equation(s) used in analyzing the data and drawing conclusions. Uncertainties in the measurements need to be described, and then used in the error analysis to arrive at estimates in the uncertainty of derived quantities. These uncertainties then need to be included in the body of the report – e.g. in the results and discussion sections – and used in reaching your key conclusions.

Figures and Tables – Well constructed and designed Figures and Tables can help make or break an engineering report, and will usually form the basis around which the entire report is constructed. Thus students should take special care in choosing what figures and tables to include in the report, as well as in how these elements are arranged and put together. It is

essential to clearly label figure axes, data types, and so forth such that the conditions of each dataset or curve can be easily distinguished. Each figure and table must have a caption that briefly describes the contents and significance of the information contained therein, and should have a unique identifying label (i.e. Figure 1, Figure 2, and so on). Each figure and table important enough to put into the report must be cited and discussed within the text. It is usually good practice to provide the figures and tables in the order in which they are first presented and cited in the text. A list of figures and tables will also help guide your readers, particularly in longer reports where they might not be able to easily locate data of interest.

Raw Data – Depending upon the volume of raw data produced in the experiment, it may or not be practical to list all such results. Judgment is key here. If it is only possible to display a subset of the raw data, then one may deem to show that here, and describe to the reader why this subset was chosen for display. Likewise, of the volume of raw data is modest, then perhaps it might be useful to provide it here. Raw data may be show in tabular form or in graphical form.

Final Suggestions

Like any complex skill, the production of a well written technical report is learned primarily by repeated practice and hard work. The challenge is further increased when the report is written in a team where each individual approaches the problem with their own style and skill level. Students often underestimate this challenge, and in particular underestimate the amount of time needed to edit contributions from each team member into a comprehensive and internally consistent report. Don't procrastinate! Get an early start, and make sure someone on the team takes the time to read and edit the entire report cover-to-cover for content, style, and grammar.

Title and Format (5%)

- Title: use a descriptive title that describes the objective of the experiment that was conducted. Include class, section number, student names, group number, experiment, and date.
- Table of Contents: include descriptions and page numbers.
- List of Figures: include descriptions and page numbers.
- List of Tables: include descriptions and page numbers.

Abstract (5%)

- Purpose: state the purpose or objective of the report. This would normally require no more than a few sentences. Do not use "The objective of this..."
- Experimental methods: describe the experimental methods used to perform the experiment. Do not include details of equipment unless some very special equipment was used or developed for the experiment.
- Analytical methods: describe the major analytical tools used to analyze the data.
- Conclusions: list the major conclusions or results of the experiment and indicate the measure of certainty of the results. Include a few numerical results if appropriate.
- Do not refer to figures, tables, references, or any other part of the report in the abstract -- it is supposed to be self-contained.
- Look at a technical journal for an example.

Introduction and Theory (20%)

- Objective: state the general objective of the experiment. Include more details than contained in the abstract. Again, do not use "The objective of this report is..." Why is the experiment worth doing. Are there any practical uses for the experimental results?
- Background: presents any relevant background to the experiment. Put the present work in perspective. Review any previous work from class notes or related experiments of a similar nature that are presented in references.

- Summarize the relevant theoretical methods used to analyze and interpret the experimental results.
- Include derivations if requested in the lab write-up, but cast the derivation in your own words. Avoid copying directly from a book or other "source".
- If a derivation is not requested, then summarize the derivation of the analytical methods.
- Describe the method used to analyze the data. Be more descriptive than in the abstract, but do not repeat what will be contained in the section devoted to the theoretical methods.
- Discuss some of the relevant physical principles of phenomena that are important to the experiment.
- Include a short description of the experimental method so that the reader can begin to form a complete picture of what the report is all about.

Experimental Procedure (10%)

- Include block diagrams of the experimental layouts. You do not need complex perspective drawings, just a simple set of boxes and lines that are clearly labeled. Include all connections between equipment. Arrows must be used to denote signal directions.
- Include a table listing the experimental equipment used. This is in addition to the block diagram. There are usually items that will not appear in the block diagram that should be included in the list of equipment. You do not need serial numbers, but include the model

numbers of commercial equipment. For equipment made at UCSD, give it a descriptive name and indicate its origin, UCSD.
- Describe in detail the calibrations used in the experiment.
- Describe in detail the methods used to take the data for all parts of the experiment.

Results (20%)
- Present the results of the calibrations and experiments. The actual results should be listed in tables or presented in figures, or sometimes both. Either include the tables and figures in this section or possibly in an appendix if there are to many of them. It is extremely important that this section contain significant discussion -- use words, sentences, and actual physical paragraphs!!! Too many reports are handed in with a jumble of unreadable tables and figures stuck in the middle of the report headed up by the words "Data and Results" -- don't do it!
- Point out the major features of the data, but don't draw the major conclusions in this section.
- Refer to the write-up for the particular experiment for the results expected in this section.

Discussion (15%)

- Discuss the significant results of the experiment.
- Compare the experimental results with theory.
- Discuss the errors. Do not include large tables of percent differences and don't confuse percent differences between theory and experiment with a true error analysis. In an error analysis, the observed difference between the theory and experiment is compared with the expected error determined from the known errors in the instrumentation and transducers.
- State the major conclusions and the significance of the results. Do not give any vague conclusions. Be assertive; state what you have found, and prove it.
- Make any recommendations that would improve the experiment. None of the experiments are perfect and some improvements can be suggested. Funny recommendations get laughs, not points!

Conclusions (5%)
- Brief summary of the finding of your experiment
- State experimental procedures in 1-2 sentences
- Describe key results in order of importance
- Implications of the results

Error Analysis (10%)
- Analytically derive equations for the propagation of errors from the equipment and their contributions to total error.
- Include sample calculations of these errors using real data.
- Consult references (lecture and notes) for more information on error analysis.

Figures and Tables (5%)
- All calculated values shall have corresponding values for error expressed in percentage to one decimal point. These error values need not be shown for raw data points, but certainly should be given with any calculated values shown in the Results or Discussion sections.
- All graphs should show some representation of error. Usually this is done with error bars, however sometimes this causes the graph to be cluttered in which case it may be best to put error bars on every other data point, or more. Other methods of error representation are fine so long as it easily informs the reader on the limitations of the data that is presented.
- Any values in tables or figures which are obviously outside of what should be expected should be explained. Generally, a point greater than two standard deviations from the mean should be discarded. However, there should be a satisfactory explanation for doing this, such as specifics on equipment problems or otherwise.

- All information required by the reader shall be included and easily found. These might be such things as Reynolds number, air temperature, or others that may be appropriate.
- Keep in strict adherence to the appropriate number of significant digits.

Raw Data (part of Overall Impression)

- Include your raw data in an appendix. These do not need to be typed, but should be neat and legible.

Overall Impression (5%)

This is not a section in your report, but the form of the report will be judged. Read the report for poor sentence structure and spelling errors. Have someone who is not taking the class read your report; if they can understand what you have written, it is probably a good report. Check that tables and figures are numbered in the order of which they appear in the report. The order of the figures and tables should also correspond to the order in which they are referred to in the text. Use the third person in most cases, especially in the abstract. Do not use an outline format for any of the report sections. Be sure that your sentences are clear and unambiguous. Be wary of awkward and wordy sentences, and do not add redundant statements.