Technical Reports

Presentation and report of engineering or scientific work are probably as important as the actual work. Credit for a discovery or development of new concepts cannot be received until the work has been described in a report or paper that is readily available for other people to read. It is often stated that engineers upon graduation will spend their first few months of work doing about 30 percent engineering and 70 percent writing. Other related statements are "graduates of engineering programs must have substantial communication skills if they are to function effectively in industry and government" and "engineering graduates often wish they had more training in communication skills in college." One goal of this course is to develop effective written and oral communication skills. This will be accomplished by requiring written technical reports for each experiment and an oral presentation by the group. Appendix A of Ref. [1] provides general guidelines for report writing.

In numerous environments, a report is written for a specific **audience**. Thus, it is important to first identify the intended audience (e.g., a supervisor as compared to a colleague) and to recognize the type and order of information the reader is seeking. The report format, therefore, varies. However, most reports include three essential elements: introduction, narrative, and conclusion. Remember that **brevity and clarity are important** and the report should be of high quality to be read. All reports should be written in the third person (e.g., use "the pressure was measured..." instead of "we measured the pressure...").

A good dictionary should be nearby when the report is being written. No excuses for misspelled words. Proof reading cannot be over-emphasized. If possible, have someone read the report for grammar, style, spelling, clarity, and typographical errors. Make sure nouns and verbs agree.

ABET, the accreditation board for college and university programs in applied science, computing, engineering, and technology, requires evaluation of reporting skills in terms of *Organization in Writing* (sequence of information, graphics, discussion and conclusions, design of contents) and *Writing Skills* (grammar, spelling, sentence clarity, syntax). These are graded in Experimental Engineering using the Technical Reports and reported to ABET. ***All students must have at least a Satisfactory grade in Organization in Writing and Writing Skills to pass the class***.

The report is limited to ten pages plus appendices, with the following format:

1 GRADE SHEET
2 TITLE, AUTHORS AND ABSTRACT
3 INTRODUCTION
4 EXPERIMENTAL CONSIDERATIONS
5 RESULTS AND DISCUSSION
    Error Analysis
6 CONCLUSIONS AND RECOMMENDATIONS
7 REFERENCES
8 APPENDICES

All material is to be written using computer word processing on double-spaced standard 8-1/2 x 11 in unlined paper. All margins (top, bottom, right and left) will be 1 inch. This allows space for grader's comments and marking. Any oversized sheets of paper that are necessary to the report (plots, figures, computer programs and listings, results, etc.) should be neatly folded and

easily unfolded and should not extend beyond the cited dimensions. No smaller or larger sheets are allowed. The entire report will be stapled in the upper left corner or with staples along the left-hand 11-inch-long side; stapler available at the MIE office. All pages must be numbered with the INTRODUCTION as page 1.

A. REPORT CONTENT

The contents of each section of the report are described briefly in the following discussion:

GRADE SHEET

This sheet is included at the end of this document and should be attached as the first page. Fill out the experiment number, title of report, date handed in, and author's name. Note the points awarded to each section.

TITLE AND AUTHORS

In the order shown, with appropriate spacing, include:

a) Title of report

b) Authors, group and affiliation

c) Date submitted

ABSTRACT

The abstract should report the basic accomplishments and attempt to entice the reader to read further. An abstract (or summary) should seldom be longer than one page and is typically around 200 words. The following items should be included:

a) Objective of work

b) Brief statement(s) on how objective was achieved (the work that was done)

c) Conclusions and recommendations are summarized (be quantitative!)

The abstract stands by itself. Note that equations or references do not, in general, appear in the abstract. The abstract should be written after the rest of the report has been completed. An **executive summary** is an extended abstract of up to about 500 words, and it may include an essential figure.

INTRODUCTION

The introduction places the work in perspective, i.e. cites relevance, motivation, some previous background, and, most importantly, the objectives of the work. **It should answer the question, "Why did you do what you did?"** It is convenient to introduce the objective as "The objectives of this study are...". It states the hypothesis and concepts tested. Remember that your objective IS NOT "to learn about this or that…" but to measure something that may help you discover or resolve a problem.

EXPERIMENTAL CONSIDERATIONS

The purpose of this section is to describe the experiment technique and how the experiment was performed. **It should answer the question, "What did you measure and how?"** This section should include a schematic diagram of the apparatus, important

measurements recorded, and method of data reduction procedure if it is uncommon or it lends credence to measurements. All figures and tables should be labeled with number and title (e.g. Figure 1. Schematic Diagram of Equipment). The figures are referred to by number in the text (e.g., "In Fig. 1, the....). See additional discussion of proper formatting of figures, tables, and equations below. You may choose to place tables and figures in appendices, rather than integrated into the text.

This section of the individual reports is used to evaluate the ABET criterion "Experimental Procedures," and ***students must have at least a Satisfactory grade to pass the class***.

RESULTS AND DISCUSSION

Experimental results in reduced form are presented and discussed in this section. **This section should answer the question, "What did you find?"** Any anomalies and regions of questionable data should be cited. General trends along with physical meaning are useful for explaining results. The results could be plotted or tabulated (if resulting tables are small), however, the former method is more readable. A graph should have labels and titles for the abscissa (independent) and ordinate (dependent) axes. Data points are generally plotted with symbols and may be connected by lines not passing through the symbol. **Error bars should always be shown in the plots!!** Results from an analysis are presented by solid, dashed, or other broken lines. No colored lines should be used as these are difficult to reproduce. Label all curves. The discussion should cite the important trends and findings, and should include uncertainty statements. See more discussion below on formatting of plots.

This section of the individual reports is used to evaluate the ABET criterion "Data Analysis," and ***students must have at least a Satisfactory grade to pass the class***.

Also, a detailed error analysis must be included in this section, identifying elemental errors and the procedures to obtain a final uncertainty. This subsection and the results from Exam I are used to evaluate the ABET criterion "Error Analysis." ***All students must have at least a Satisfactory grade to pass the class***.

CONCLUSIONS AND RECOMMENDATIONS

This section should be brief and concise. The conclusion should refer back to the objectives. The recommendations should indicate future work or improvement of experimental procedures. Maximum section length is two pages. **It should answer the question, "What did you find?"**

REFERENCES

Cite only articles, books or manuals used in the experiment and cited in the reports. References are a courtesy to recognize the work of others and serve as sources for further information for the reader. The references are listed in numerical order as cited in the text of the report (not necessarily alphabetic order). Sometimes, a bibliography may be included. As an example for reference citation, further reading on technical writing can be found in Appendix A of Ref. [1]. Example:

1. Figliola, R. S. and Beasley, D. E., *Theory and Design for Mechanical Measurements*, Third Ed., Wiley, 2000, pp. 509-515.

APPENDICES

Material that is somewhat bulky and does not necessarily contribute to the overall presentation of the report is placed in this section. Give the appendices titles; for example, "Appendix A: Tables" or "Appendix C: Example Calculations". Several items that may be included are:

- List of Nomenclature and Symbols Used: See example below
- Tabulated Data: Give the raw data in a neatly tabulated format. Also include any summarized results.
- Figures: if you choose not to place the figures in the text, you can place them in an appendix, but still have them in the proper order as they are referred to in your text.
- List of Equipment: See the LOG BOOK. Include the major pieces of equipment identified by name o should be identified.
- Methods: Discuss in greater detail how the experiment was performed, but do not give a minute by minute presentation.
- Error Analysis: Estimate the accuracy of all measurements. Give statistically meaningful results.
- Sample Calculation: Give a sample calculation including a unit analysis. Insert typical data into calculations.
- Theory: If possible, attempt to correlate measurements with a theoretical model.
- Computer Program: When a computer program is utilized, a listing with a representative case should be given.

B. FORMAT OF PLOTS, TABLES AND EQUATIONS

1. General things to remember about references, figures and tables

- References, figures and tables should be referred to and numbered in order of appearance.
- Make sure **all** figures and tables are referred to, don't just put some table or figure into your report.

2. Graph and Plot Rules of Thumb (for reports, memos and log books)

- X-axis for independent variable, Y-axis for dependent variable; y = f(x)
    - Label all axes on the outside of the axis borders; the format should be:
    - LABEL, symbol, units for example – " Stress σ, [MPa] " Label is in quotes …
    - Include important information inside your plot frame, such as -test conditions -assumptions -material type -data legends, etc., only when necessary.
- Provide an equation in the plot frame if: -analytical curve used and the equation is relevant -empirical curve is found that describes the data well, and, for example if it is a linear fit, don't just leave it as y = mx + b, instead use something like:

  Voltage (V) = 10.23 (lbf) + 0.02

- Provide a small sketch if it is helpful and necessary
- Place figure number and a descriptive title at the bottom of the figure, for example in Appendix A of see the figure below

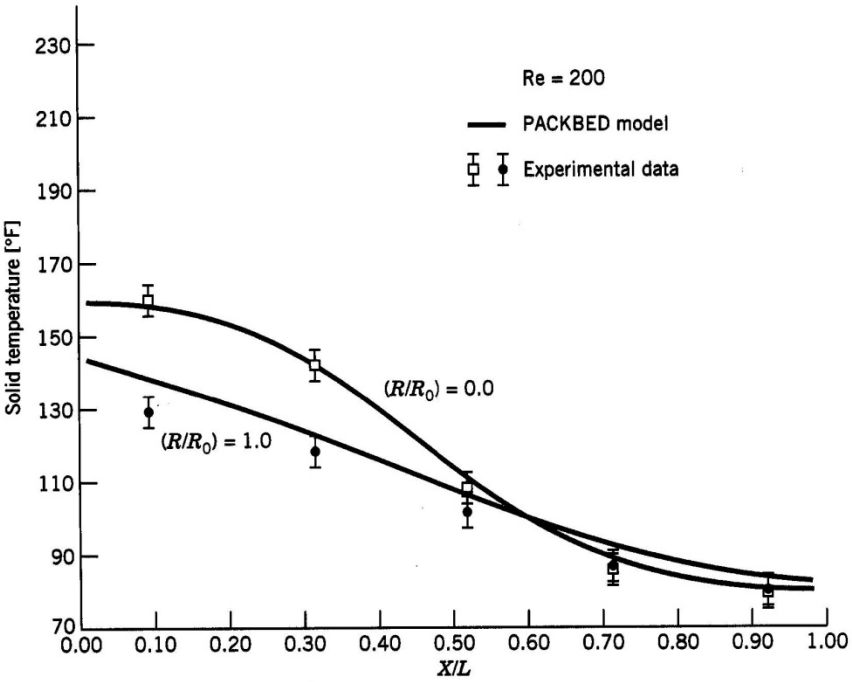

Figure A.1. Comparison of experimentally measured and computed results for axial temperature distributions for spheres of radius R in a thermal energy storage bed of radius R_0.

- For experimental data, even with empirical curves, always show data points using symbols and add error bars
- For analytical or theoretical curves (from equations) do not show symbols, use a line.
- If more than one symbol is used you must provide a legend (unless you identify the data or curve clearly using a title and arrow). If there is only one curve or data set, use no legend.
- Finally, ask yourself the following questions: Can the figure stand alone and tell the entire story by itself without any accompanying text? It should be able to… If it can, ask yourself, is it a "pretty" figure that uses:
    - -same font throughout -does the font match the text -effective use of capitalization and bold lettering -do all the plots of similar type and results look similar? -be consistent so as not to confuse the reader: once they understand one plot, and if other plots are presenting similar information and are consistent, they can be quickly and easily understood by the reader.

3. Table Format Rules of Thumb (for reports, memos and log books)

- Table number and descriptive title should be located **above** the table. Consider the example shown in Table A.1
- Use borders to properly separate headings and columns of data
- Clearly label all columns of data **including the units**

Table A.1 Characteristics of a Thermistor Anemometer in a Uniform Flow Field

Velocity [ft/s]	E[V]
0.467	3.137
0.950	3.240
2.13	3.617
3.20	3.811
3.33	3.876
4.25	3.985
5.00	4.141
6.67	4.299
8.33	4.484
10.0	4.635
12.0	4.780

- Keep raw data and reduced data separate to avoid confusion
- Can the table stand alone? Is it a "pretty" table that uses: -same font throughout -does the font match the text -effective use of capitalization and bold lettering -do all the tables of similar type and results look similar? -Consistency

4. Equations

Equations used and referred to in your work will be numbered sequentially in order of reference. The number for an equation will be in parentheses (X) and this number will be justified at the right hand margin as in the example equation below:

$$h_{nat} = 0.84\left(T_{surf} - T_{amb}\right)^{1/3} \tag{1}$$

Symbols or variables used in your equations will be defined. These definitions will be made either in the text with the equations, or in an appendix that contains your nomenclature. An example of defining the variables in your text is shown below:

"Where there is no spray or roll contact, a natural convection heat transfer coefficient correlation is used

$$h_{nat} = 0.84\left(T_{surf} - T_{amb}\right)^{1/3} \tag{2}$$

where h_{nat} is the natural convection heat transfer coefficient (W/m^{2}K), T_{surf} and T_{amb} are slab surface and ambient temperatures (K), respectively."

An example of nomenclature listing is:

NOMENCLATURE

c_p specific heat (kJ kg^{-1} K^{-1})

C mass concentration of an element (wt pct)

D_s mass diffusion coefficient in the solid ($m^2 s^{-1}$)

h_{spray} spray cooling heat transfer coefficient ($W m^{-2} K^{-1}$)

Δh latent heat ($kJ kg^{-1}$)

w* spray cooling flux ($L m^{-2} s^{-1}$)

x slab thickness dimension (m)

z casting direction, distance from meniscus (m)

Greek

κ partition coefficient (wt pct/wt pct)

λ_2 secondary dendrite arm spacing (m)

Subscripts

s solid

l liquid

Superscripts

i refers to the i-th chemical element

C. FINAL THOUGHTS AND RECOMMENDATIONS ON REPORTING WRITNG

A major emphasis of this course is the writing of a good technical report. It is unlikely that a good report can be prepared beginning just a day or two before the due date. Some suggestions are presented here to make the writing proceed smoothly.

Begin writing as soon as possible. The Introduction can be written after the lab period spent organizing and setting up the experiment. The Experimental Considerations section is the easiest one to write because it is just a description of what you did. The procedure for all members of a group should be very similar, but in each member's own wording. Make an outline of this section and have all group members agree to the outline.

A sample calculation for the appendix can be prepared as the data are reduced. As the data are reduced, the group can discuss the results. Do the results show what was anticipated, and if not can this be explained? Are any discrepancies between experiments just due to experimental error, or are they the result of some physical phenomena?

The Abstract is written last. Take key sentences and phrases from the rest of the report and put them together to form the abstract.

Proofreading the report is essential. Read forward to check for grammar and logic. Have someone else read the report to check for errors. The lab report should be thorough in its coverage of the experiment. The report should also be concise; excess material should be avoided.