Guidelines for Engineering and Laboratory Reports

This document gives a guide for the format of engineering reports in general and the MCG 4340 formal lab reports in particular.

1. General Requirements

The report is to be typed on one side of standard 8 ½ x 11" paper using an easily legible 12 point serif font (Roman or similar). Lines must be 1 ½ or double spaced. Page margins must be 1" (25 mm) on the top, bottom and right hand side and 1 ½" (33 mm) on the left to allow for binding. Titles should be in larger fonts and bold for emphasis. A title page must be included, and the report should be bound (not stapled). The report may be in English or French.

2. Organization

The report should be organized as follows, with the different items appearing in the order given. Chapters and sub-sections should be numbered: for example, 1. would denote a chapter, 1.1 a major section within a chapter, and 1.1.1 a subsection within the section.

Title Page

Abstract - a concise summary of the report, limited to one or two paragraphs.

Acknowledgements (if applicable - not usually part of a lab report)

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Nomenclature All mathematical symbols must be defined, except for very common standard ones. If only a few variables are used they may be explained in the text where they are first introduced, but if more than about a dozen symbols are required they should be defined in a separate Nomenclature section. There symbols should be listed in the following order: Latin letters, Greek letters (both in alphabetical order), other symbols, then subscripts and superscripts, again in alphabetical order. Units must be given for all dimensional variables; these units will normally be SI unless there is some particular reason for using English units. If you use many acronyms or specialized terms, provide a Glossary to define them.
Main Body of Report - this will comprise several major sections, typically the following:

1. Introduction - brief overview of objectives, reason for the work.
2. Background, Theory, or Literature Review - background information necessary to understand the work, including theory needed to interpret the results later on. In research, the main part of this is a review of previous work in the field.
3. Experimental Apparatus and Procedures - this includes statements of measurement accuracy for the instruments used (see §5. below). For the MCG 4340 lab, note any changes that you have made to the instructions in the manual
4. Results and Discussion Be sure to answer any questions in the lab manual. Make quantitative statements, not qualitative, wherever possible.
5. Conclusions and Recommendations - the main findings only. Do not summarize the whole report - that is what the abstract is for. Conclusions must be clearly justified by the data or theory given; they should not be unsupported speculation.

References - more details are given below. All works listed in the References must have actually been cited in the report. Works which you think are useful but have not actually cited in the text should be listed in a separate Bibliography section.

Appendices - contain details not important enough to include in the main report, but necessary for someone following up on your work, such as detailed derivations of equations or numerical methods, detailed error analyses, tabulations of data, and computer programs. Programs and listings can be reformatted to save space: unlike the main report, they may be single spaced with a font as small as 10 pt. Each appendix should have a letter (A, B, etc.) and a title, and should be listed in the Table of Contents. Appendices should be referred to in the main report.

Pages should be numbered in Arabic numerals, starting with the first page of the main body of the report. All pages before the main body are numbered in lower case Roman numerals (eg vi), starting with the Abstract as page i.

Since Canada is officially committed to the SI system of units, results should be presented in SI units. There are a few exceptions to this, such as inch system screw threads.

3. Figures and Diagrams

All figures must be clearly legible. Lettering should be equivalent to at least 10 points in size, and line widths must be sufficient to reproduce well (0.020" (0.5 mm) is recommended). All figures must be cited in the text. Figures may be placed in the text near the paragraph where they are cited, or they may be grouped at the end of a section. Each figure should have a caption which gives enough information that it can be understood without referring to the main text. Figures should be numbered in each section separately, so that Fig. 2.1, 2.2, etc. appear in Section 2 of the report.
4. Presenting Data - Graphs

Most data and calculations are best presented as graphs, although sometimes tables may be more appropriate. (Note, by the way, that the word data is plural: the singular, seldom used, is datum.) You should not present both graphs and tables for one set of data in the main report, although you may put tables of raw data in an Appendix. Graphs should conform to the following standards:

- individual measurements must be plotted as points. A dot is not sufficient: clearly visible symbols such as ○, □, ■, ▽, ∆ or ◊, must be used, which may also be used as keys to different data series.
- a number of measurements taken at one point may be shown as the mean value with error bars at plus or minus the standard deviation from the mean to indicate the range of scatter.
- experimental points should not be joined by lines or curves unless absolutely necessary to connect widely scattered data. The reason for this is that it is very easy to give a misleading impression by drawing a line: readers tend to assume that the line has been fitted, or represents the real behaviour of the system. Any such line must show the general trend of the data only; it must not pass through every point. Spreadsheets usually connect all points by lines; these lines will usually have to be deleted.
- generally, the only experimental data that are shown as curves rather than points are those from continuously recording instruments, such as a stress-strain curve from a tensile test or a thermocouple record over time.
- calculated quantities resulting from a curve fit to the data or a theoretical model are always plotted as lines, never as points. Points represent experimental data exclusively. Again, the points which spreadsheets automatically plot with lines must be removed.
- different curves should be drawn with different types of line, e.g. dashed, broken, etc.
- all axes must be clearly labelled with the variable plotted and its units, e.g. Pressure (kPa).
- avoid plotting too many data series or curves on one graph.

Logarithmic scales are used when the data have a greater range than can be shown conveniently on a linear scale. If the largest value plotted is more than 10 times the smallest, a log scale will often make the lower values more visible. Log scales are also used when one expects data to follow certain mathematical forms. For example, a semi-log plot (1 log scale, one linear scale) is used for plotting reaction rates, because they usually follow an Arrhenius law,

$$ t = A yO_2 \exp \left( \frac{-E}{RT} \right) $$

which is a straight line when plotted on a log scale against (1/T) on a linear scale. A log-log plot is often used to deduce a power law relationship between quantities. The equation

$$ y = ax^b $$

becomes a linear equation with intercept (log a) and slope b if one plots it on log-log coordinates, because taking logarithms of both sides gives

$$ \log y = \log a + b \log x $$
Standard spreadsheets will plot both semi-log and log-log graphs. Log scales do not have a zero, because \( \log(0) \) is undefined. Note that log scales are simply a form of coordinate transformation - it is the variable itself, and not its logarithm, that appears on the scale.

Some samples of graphing practice are appended to this document.

5. Presenting Data - Errors

Any presentation of measurements should include a frank statement about their accuracy. There are two types of error present in most measurements:

- **systematic error** - results from bias in the measurement instrument, for example improper calibration, zero point drift, disturbances caused by probes (e.g. in fluid flows), mechanical or thermal inertia (failure to properly follow rapid changes or fluctuations), or external influences (e.g. heat transfer to a thermometer from its surroundings). These can often be estimated - and compensated for - by calibration against a known standard, or by developing a simple theory for the instrument response. Systematic error can also occur if one individual consistently makes measurements using a faulty technique (e.g. looking at a scale on an angle).

- **random error** - results from human error in observations, electronic noise, or random fluctuations in the measured quantity. They give a scatter of measurements about a mean value, and can be estimated by making repeated measurements of the same quantity or doing replicate experiments. The random error in reading a scale will be ± (half of the smallest measurement that one can read or interpolate from the scale). For example, one can read a scale graduated in whole mm to the nearest 0.5 mm, so the error will be ±0.25 mm.

- **error propagation** - Quantities calculated from several measured values will have a random error which depends on the errors of the measurements combined. If a quantity \( P \) is a function of measured values \( x, y, z, \ldots \), each with an error of \( \epsilon_x, \epsilon_y, \epsilon_z \ldots \), then the error in \( P \) is

\[
\epsilon_P = \pm \sqrt{ \left( \frac{\partial P}{\partial x} \right)^2 \epsilon_x^2 + \left( \frac{\partial P}{\partial y} \right)^2 \epsilon_y^2 + \left( \frac{\partial P}{\partial z} \right)^2 \epsilon_z^2 + \ldots } 
\]

This reduces to simple results for certain forms of \( P \). If \( P = x + y \), then

\[
\epsilon_P = \pm \sqrt{ \epsilon_x^2 + \epsilon_y^2 }
\]

If \( P = xy \), then

\[
\epsilon_P = \pm \sqrt{ (y \epsilon_x)^2 + (x \epsilon_y)^2 }
\]

If \( P = Ax^n \), then

\[
\epsilon_P = A n x^{n-1} \epsilon_x
\]

The \( \epsilon \)'s are absolute errors, in the units of the quantity measured; the corresponding relative or
percentage errors would be $\epsilon_P/P$, $\epsilon_x/x$, etc.

It is considered acceptable practice to reject one - but only one - measurement which clearly has a much larger deviation from the mean behaviour than do the other data. The logic of this is that it is possible to make a mistake in reading one value, but more than one "outlier" point suggests either faulty equipment or unexpected system behaviour which should be investigated.

The number of significant digits given to experimental data must reflect the precision of the measurement. The same is true of any quantity calculated from these measurements. In multiplying or dividing numbers, the answer should have the same number of significant digits as the least precise of the input numbers. In adding or subtracting, the answer should have the same number of decimal places (not significant figures) as the least precise input. For more complex calculations, the number of significant digits can be determined using the error propagation equation. See Marks’ Standard Handbook for Mechanical Engineers, p. 2-4, for more on this topic.

6. Equations

Equations should be prepared using the equation editor in WordPerfect or Word. Except for very simple equations, it is difficult to prepare a proper-looking equation in ordinary text. It is not acceptable to write an equation in spreadsheet format, for example $y = 3x^2$ for $y = 3x^2$. Most equations should be set off from the text, as were the ones in the previous section, but very short equations can be written as inline equations, for example $y = Ax \sin \omega t$. Equations should be numbered if you are going to refer to them later on, but you do not have to number all the equations - just the ones you need to refer to will suffice. Equations may simply be numbered 1, 2, 3.... etc., but you can also number them by the chapter they belong to: 1.1, 1.2, 1.3, etc.

All symbols used in an equation must be defined somewhere in the report, either in the text at the point where each symbol is first introduced, or in a Nomenclature table at the beginning of the report, after the tables of contents. A Nomenclature table should always be used if you have a large number of symbols or a lengthy report - don’t make your poor readers search back through pages of material to find the definition of a symbol! You can use both a Nomenclature and definitions of symbols in the text if it will make it easier for your reader to follow.

An equation is part of a sentence, and the text preceding and following the equation should be punctuated exactly as it would be if you were reading the equation or writing it in words. Here is an example:

The fuel composition is described by the distribution $f(I)$, which is defined by

$$f(I) = \frac{(I - \gamma)^{\sigma-1}}{\beta^\sigma \Gamma(\alpha)} \exp\left[-\left(\frac{I - \gamma}{\beta}\right)^\sigma\right]$$

(1)

where $\alpha$, $\beta$, and $\gamma$ are the parameters of the distribution.
Some word processors (eg Word) automatically capitalize “where” in this example, but this is grammatically incorrect, as this is not the start of a new sentence. Change this if it occurs. Strictly speaking, there should be a comma after the equation itself, but this is usually omitted.

7. References

The purpose of references is to allow the reader to identify the original source of all important information in the report. Any material reproduced from another work, whether it be text, data, graphs or diagrams, must be properly attributed to its source. For text, this means putting the material in quotation marks and giving a reference for it; for other material, this means writing (Reproduced from...) in the caption. Reproduction of material from other peoples' works without giving credit is plagiarism, and can lead to action for academic fraud.

There are two accepted systems in engineering for giving references to published material:

- **the number system** (the more common): the work is cited in the text with a number in square brackets [4]. The numbers are assigned in the order in which the works are first cited, and the works are listed in numerical order in the list of references. If a work is cited more than once, the same number is used for each citation. Citations take up less space in the text with this system, but the disadvantage is that if you revise the manuscript and add more references, any following new references will have to be re-numbered.

- **the author/date system**: the work is cited in the text as Smith and Jones (1975), or, if there are more than two authors, as Smith *et al.* (1975). The works cited are listed in alphabetical order by first author in the list of references.

In each case all references are gathered together in a list at the end of the report. The references are not placed in footnotes: footnotes are not usually considered an acceptable format for citations in engineering, although they are the standard in the humanities.

In the list of references, each work is cited with the names of all authors, the title, and the year published. For journal papers, the journal name, volume number, and page numbers must appear; for conference papers, the name and location of the conference and the page numbers in the proceedings; for books and reports, the publisher and city. Web material must be referenced with the URL and the date posted. Avoid heavy use of web references, because web sites are frequently changed and the material cited may become unavailable. Typical formats for references:

that...”. If the book has no author, for example a users’ manual for a piece of equipment, list the company name as the author.

- to verbal information: Chrétien, J. (2002), personal communication.

If in doubt about reference formats, follow the format used in a reputable engineering research journal. The “bottom line” with references is that you must give enough information for the reader to find the work in the library.

Prepared by W. Hallett
MCG 4340 - Graph Examples

(Left above) Graph as plotted by a spreadsheet program; (right) as “cleaned up” and formatted for presentation. Below: two graphs that have been properly labelled. Labelling curves and points makes the graph easier to read than using a legend.

(Above) The same data plotted on a linear scale (left) and on a log-log scale (left).
(Left above) Measured points and fitted line. (Right) Logarithmic scales. (Below) the same data plotted on a linear (left) and on a semi-log scale (right).

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