Preparation of Laboratory Reports

Introduction
Writing is probably the most important aspect of professional communication. Good writing indicates sound thinking! Poor writing is a reflection of your work habits and will damage your credibility in the professional community.

The purpose of any report is to convey information in such a way as to convince the reader to accept your conclusions and recommendations. Be clear, concise, and factual. Have your conclusions and recommendations in mind before you begin writing and focus your report towards substantiating these ideas. Make a detailed outline before beginning any writing. The mere taking and reporting of data are insufficient; intelligent interpretation must be included.

The required form of a technical report will vary depending upon the kind and amount of material to be treated, the rules of the organization for which it is written, and the individual tastes of the managers for whom the report is intended. Whatever the form, it must be borne in mind that the primary purpose of the report is to convey information in the shortest possible time, clearly and completely.

I. Report Format
The following report form is a very general one and is recommended for the reports in this course:

Introductory material
1. Title page
2. Abstract or summary
3. Table of Contents

Body of the report
4. Introduction
5. Theory (if needed and not included in the introduction)
6. Apparatus and materials
7. Procedure (may be included with apparatus)
8. Safety Considerations (if needed and not included in the procedure)
9. Results, including key figures and tasks with final, polished data (as tables or graphs)
10. Discussion of the results (may be combined with results, but this course requires a separate Discussion section)
11. Conclusions
12. Recommendations (optional)
The description of a major report in this document should be considered as a suggestion, not a mandate. In some cases, deviation from this recommended form may be desirable, but **those desiring to modify the organization should discuss changes with the instructor before writing the report.** Keep in mind that your objective is to report information effectively, not to follow procedural rules for report format.

II. **Detailed Description of Major Report**
Detailed instructions in the sections that follow state the requirement for each section of the report.

**Title Page**
Consult the Laboratory Manual for an example of a Title Page showing both content and format.

**Abstract or Summary**
The abstract is clearly the most important part of the entire report. The abstract is a concise overview of the report directed at a person who has had little contact with the work and should enable this person to decide without further investigation on the relevance of your report to his/her needs. The abstract should provide the reader with a brief understanding of the objectives, the conditions studied, the important results, and their significance. The abstract should only contain statements supported by the report and may repeat some statements in the report.

The terms summary and abstract are sometimes used interchangeably. Often, however, a summary is somewhat longer and more quantitative, especially in regard to results and possible errors. In this course, neither the summary nor abstract should be more than one typewritten page, double-spaced, in length.

Do not write the abstract until you have finished writing the report. In preparing an abstract, first note the results and consider how they satisfy the objective of the experiment. Write the significant results with this relation in mind. Then being concise and specific, put down what was done to arrive at the results. **Do not include how the**
results were achieved in the abstract. Next identify the facility (equipment or setup) used.  

_Then reverse the order._ Do not reference any report item, figure, table, equation, etc., in the abstract. The abstract should stand on its own. Examples of abstracts may be found in the “ACS Style Guide”.

**Introduction**

This section provides a _concise_ description of the problem and its importance, plus a connecting entrance into the material in the body of the report. A synopsis of the theoretical methods used or tested and relevant equations may also be included. If extensive theory is needed, or if modifications to conventional theory have been incorporated, use a separate Theory section. It is generally difficult to decide where to start in giving background for the work. One suggestion is to give enough information and theory such that a competent engineer in another field (i.e. mechanical) could follow your explanation.

In this section of the report you will likely make references to information or equations which appear in books or journals. Be certain that you cite your references in the body of the report and properly record the literature citation in the Reference section. (Recommended styles for literature citations will be explained later.)

Do not give conclusions or recommendations in this section. The last statement in the introduction is often a concise statement of your objectives in this experiment.

**Apparatus**

Briefly describe the basic apparatus used to obtain data. Include a schematic drawing that is sufficiently labeled and gives important dimensions. When describing the equipment, concentrate on those items that have the greatest effect on the data obtained. Usually you should provide a thorough description of the analytical instruments used in the project as well. For example, when describing a thermometer, give the range and smallest divisions that are readable. The same applies to gauges, meters, and other types of devices.

**Procedures**

The Procedures section should be sufficiently clear and complete so that a worker at a later time could repeat the experiments that you performed and obtain the same results. The Procedures section is often combined with the section on Apparatus. The description of procedure will nearly always refer to the sketch of the experimental apparatus.

**Safety Considerations**

State all major hazards associated with equipment and chemical use during the experimental procedure. Define appropriate precautions used to avoid accidents and actions taken in case of an accident. Use this section to suggest safety-related improvements in the equipment, experimental procedure, analytical methods, etc. A Safety section is not normally included in a report unless a specific safety incident has occurred. We have included it as a necessary part of the lab report to increase student awareness of safety practices.
Results
The purpose of the Results section is to present, in an objective form, the important facts derived from the observed data. Where useful for continuity or clarity, other information may sometimes be included. This other material could be some important intermediate results, a basic calculation method, or important assumptions used in the calculations.

Do not merely include tables or figures as the Results section. Tables and figures are merely illustrations that may be used to document the observations you are presenting to the reader. The writer should provide interpretation of the illustrations. Present only the most pertinent (bottom-line) results in the body of the report and place all raw data and tables of calculated intermediate data in the Appendix. Avoid presenting the same information by two different methods. In other words, do not have a table of values and then have a graph showing the same values.

In most cases, the results should be quantitative, not qualitative and should include uncertainty analysis based on propagation of experimental error or on statistics (multiple repeat trials) and a statistical analysis of observed trends (variance, correlation coefficient, and residual plot). State how the error was calculated.

Discussion of Results
This section of the report is second in importance only to the Abstract. Here you present a critical interpretation and theoretical and practical evaluation of the results. Consider discussing any of the following items that are appropriate to your particular experiment:

- The physical significance of the observed results and their impact on practical applications of the technology.
- The reliability (reproducibility) and accuracy of the results, identification of major sources of error and their impact on the physical interpretation of the results.
- A comparison of observed results with expected and/or predicted values. and an explanation of discrepancies (analysis of model assumptions, etc.)
- A critique of experimental methods, procedures, and equipment and suggested improvements.

In many reports, the results and their discussion are included under a single heading. In this course, however, the two should be separated so that the student may demonstrate that he can distinguish between the results and their discussion.

Conclusions and Recommendations
This section is generally rather short because there should be relatively few significant conclusions. The conclusions that you reach should be based on the results obtained rather than on opinions and speculations. A suggested aid in writing this section would be to review the specific objectives of the project. For each objective, there should be a conclusion that can be scientifically drawn based on the results. In other words, each objective should pose a question and each conclusion should answer one of these questions. List the conclusions in order of importance. Any recommendations the writer
wishes to make for improvement or expansion of the experiment may be included here. All recommendations should be specific and should be backed by supporting statements.

**Nomenclature Table (optional)**

Summarize the nomenclature used in the report. Symbols are arranged in alphabetical order, first the Roman letters, then the Greek letters, then special symbols. The units in which each is expressed must be stated. If extensive symbols (in equations or otherwise) are used, a nomenclature table must be included, even though the variables in the equation are defined as they appear.

**References**

Books, articles, and web sites referred to are listed in this section using a standard citation convention. This always includes, at least, all authors last names and initials, the journal, publication title, volume #, the year and the page. It can include the title of the article, the issue number and the page range. For web sites you must list the URL address, title of the web page, and the data accessed. Use of “et al.” in place of author’s names is not acceptable in this list (although it can be used in the body of the report). The two main conventions for the order of citations in your reference list are alphabetically by last name of first author, and by appearance in report body. Each has its advantages. If you choose the former convention, refer to the article is the report by author(s) and year, e.g. Lewis (1927). If by the latter convention, use the number from your reference list, e.g., 2. In the body of the report, reference to this list is made by inserting the number of the article, in brackets, e.g., [2], at the appropriate point in the report.

Every book, article, or web site included in the reference list must be cited in the body of the report. Do not include any reference in the list unless you cite it in the report. All figures, data and quotations from the work of others must be properly referenced as such. The following reference page example lists references by their order of appearance in the body of the report.


**Appendices**

Appendices should include any details not needed in main body of report – tables of data, additional graphs, details of apparatus, procedure, sample calculations, raw data, etc. They may also include design problems, when given.

Copies of raw data records must be included in the Appendix and must show the date, title of experiment, names of members of group, and signatures of persons who recorded
the data. Record the data neatly so that the reader can check it. Collect and record in your data notebook all data that can possibly be used, being sure that you have the correct references to instruments, etc. It is difficult to obtain information after a test has been completed. A data book that cannot be read represents wasted time and energy. Make each record complete so that data can be fully understood, both by you and by others at a later date. The data book should be a record of the exercise or experiment as it was conducted; as such, nothing should be added to a data page at a later time without a written explanation and date. Avoid entering derived data except when needed for the experiment. Record raw instrument readings - do not subtract values for tares, blanks, etc. in your head. Sufficient copies of the data should be made so that each group member will have a copy of the original data-book pages at the end of the experiment.

The sample calculations should be sufficiently detailed in theory, equations, methods and numbers so that a reader may reproduce your calculated results from the observed data given in the main body of the report with a minimum of effort. This requirement holds regardless of the method used to work up data. Include calculation of errors.

It is extremely important for all reports to be brief and to the point. All graphs and tables should be carefully chosen to help you present your results, discussion, conclusions and recommendations. Other material may go into the Appendix.

III. Minor Report
The minor report should consist of:
1. Title Page
2. Abstract
3. Introduction (usually one paragraph maximum)
4. Results and Discussion
5. Conclusions and Recommendations
6. References
7. Appendices

For minor reports, do not discuss the experimental part unless special problems occurred. Be brief.

IV. Report Craftsmanship
The following rules for report craftsmanship should be followed to give reports a professional appearance and to make them easier to read quickly.

1. Reports are to be printed from a suitable word processor. Double-spaced, 12-pt printing should be used to facilitate inserting comments and corrections during grading. Very few insertions correcting typographical blunders will be permitted. Write on one side of the paper only. Leave adequate margins: 1.5” (top and left), 1” (bottom and right). The report should always be submitted on 8-1/2 x 11 white paper. The report should be contained in a binder or folder of professional quality. For this course, the pages must be mechanically locked into the binder (no clamp-type binders).
2. The pages, including those carrying figures, should be numbered at the top center of the page. Lower-case Roman numerals (i.e., i, ii) should be used for the abstract and the table of contents. Arabic numerals should be used for all other pages except the title page, which is unnumbered.

3. A table is a page containing tabulated numerical data only. All other non-verbal material is to be called a figure. Tables should be identified with the word "Table" followed by a number. A descriptive title for the table should follow on the same line. The table identification should be placed at the top of the table. A table itself should have appropriate headings for each column. A column heading should include, on one line, a description of the quantity in that column and, on the next line, the units used for that value. Tables should be placed on the first page following the first reference to the table (for large tables) or may be integrated into the text of the report (for short tables). Every table must be referenced at least once in the report.

Figures in your laboratory reports generally will include graphs, sketches, flow sheets, and schematic diagrams. Figures should be identified and placed in the report in the same manner as tables, except that figure titles can be placed either above or below the figure. A title of a graph should explain the significance of the graph and should not be a restatement of the coordinate axes. For example, a poor title is “Heat-transfer Coefficient versus Flow Rate.” A better title is “Effect of Water Flow Rate on Overall Heat-transfer Coefficient in Methanol Condenser at 1 Atm.”

All graphs and drawings should be neatly drawn or printed. Axes of graphs should be set well in from the margins of the paper so that lettering is not forced into the margins. Do not include illegible photocopies of figures. All tables and figures must be referred to in the text; otherwise there is no need for them in the report. However, the contents of the tables and figures must be clear without having to refer to the report’s text.

Use words for labeling axes. Do not use symbols except those that are widely recognized in chemical engineering (e.g., $Re$) and are not ambiguous. Thus, use “Flow rate” instead of “$F$. ” The units must be included in all figures and tables. Be careful about transforms of the axes labels: does a label of “Weight x $10^{-2}$ lbm” mean that a 1 on the axis scale is really 100 lbm or 0.01 lbm? For SI units, use prefixes instead of multipliers, e.g., $\mu$m instead of $10^{-6}$ m. Use the correct number of significant figures in all data. Additional guidelines for preparing figures and tables are given in the course textbooks.

4. Equations should be placed on a separate line and numbered to facilitate reference.
5. In writing the report, assume that the person reading the report knows as much as you did after reading the Introduction, when you started the work. Thus it is not necessary to make statements such as “…First, the pipe is screwed into the elbow…” since any fool (including your instructor) knows this. However, you should not give unfamiliar equations and data from the literature unless you give its origin and limitations. Many researchers become so engrossed in their own subject that they forget that the average engineer is not familiar with the specialized work they are doing.

6. A major shortcoming in student report writing is that of being too wordy and including too much detail. The goal of the report is to present to the reader the necessary information so that he will understand what was done, why it was done, how it was done, and what was learned, but no more.

7. All written material must be the student’s own work, plagiarism, copying or paraphrasing is not permitted, under any circumstances. Figures or tables not originating from the writer(s) of the report must be referenced! Never use text from other’s work, even with a citation. See section VI, Forms of Academic and Scholarly Misconduct, of this document for more details.

V. Additional Hints for Writing Reports
1. Prepare a detailed outline for major reports (1 or 2 pages). You should have a nearly complete outline constructed before you begin to write. Do not hesitate to modify the outline as new ideas occur during the writing of the report. The report should explain the purpose of the work, place it in perspective relative to published information, describe the experiment, which was performed, and results, which were obtained, and present the conclusions that were reached.

2. Identify the tables and figures by number to illustrate the points being made.

3. Write short paragraphs containing typically 3 to 5 sentences. Use subheadings to divide the report into logical units. Use of subheadings and short paragraphs make reports easier to read and improve the mood of the reader (grader). Avoid long sentences. Vary the lengths of sentences. Do not put more than a single idea in a sentence.

4. If there is the slightest doubt about spelling, consult the dictionary. There is no excuse for misspelled words, especially when using a word processor.

5. Hyphenate compound adjectives. For example: 20-in. pipe, copper-constantan thermocouple, heat-transfer coefficient, stirred-tank reactor, 8-in. impeller.

6. Effective writing usually places the verb near the beginning of the sentence, close to the subject. Examples:
The mass-transfer coefficient, shown in Figure 1 as a function of temperature and compared with theory in Table 2, was calculated from Equation (3).

The mass-transfer coefficient was calculated from Equation (3). Figure 1 shows the effect of temperature on that coefficient and Table 2 gives a comparison with theory.

The temperature of the liquid, the flow rate of the vapor, the pressure of the evaporator, and the power input to the motor were measured.

The following were measured: liquid temperature, vapor flow rate, evaporator pressure, and power input to the motor.

Use tenses carefully. Use the past tense for acts that are now history and the present tense for results that are contemporary. Avoid the future tense; it is rarely needed. Example:

The temperature of the vapor was measured with an iron-constantan thermocouple. Figure 1 shows the variation of vapor temperature with time.

Short qualifying phrases are best placed at the beginning of a sentence. Example:

Although the pressure meter fluctuated, the average evaporator pressure was nearly constant at 3 psia.

Use relative pronouns properly. In defining clauses (i.e., those necessary to define or identify the noun) the pronoun that is appropriate.

Example: The particle volume that was measured by displacement was greater than the calculated volume.

In non-defining clauses (i.e., those providing additional information about a noun) the pronoun which is appropriate, and the clause should be set off by commas.

Example: The measured particle volume, which was greater by 3% than the calculated volume, was used in the porosity determination.
10. **Avoid unattached (dangling) participles.** Active participles should be attached to a noun or pronoun except in rare circumstances where, by usage, they have acquired the power of adverbs (e.g., roughly speaking).

**Poor**
Substituting for x from Equation (6), the expression for velocity becomes:

**Better**
Substituting for x from Equation (6), we find the expression for velocity to be:

**Best**
Avoid participles by using a preposition. Example:

Upon substitution for x from Equation (6), the expression for velocity becomes:

11. **Avoid extra words.** Consistent with clarity, use only the minimum number of words necessary to say what you want to say. After writing a paragraph, go back over it and remove all words that are not essential.

12. **Use simple, direct words and sentences and avoid jargon or false elegance.** Here is an example of a passage written by a sociologist on three characteristics of teenage culture:

a. Compulsive independence is an antagonism to adult expectations and authority. This involves recalcitrance to adult standards of responsibility.

b. Compulsive conformity within the peer groups of age mates. It is intolerable to be “different.”

c. Romanticism: an unrealistic idealization of emotionally significant objects.

This wordy passage can be expressed by one simple sentence:
Teenagers tend to be disobedient, group-minded, and unrealistic.

13. **Avoid essentially meaningless phrases such as**

   It may be stated that…
   You will find it interesting to know…
   For your information…
   In this connection the statement may be made that …
   At this point in time it may be appropriate to…
   In order to…. 
14. Avoid generalities and be as specific as possible. Also whenever possible, be quantitative rather than qualitative and positive rather than negative. Examples:

**Poor**
The temperature measurement was not accurate because the thermometer was no good.

**Better**
The accuracy of the temperature measurement can be improved by better thermometer calibration.

**Poor**
Figure 1 shows that the data are in bad agreement with the values calculated from Equation (3).

**Better**
Figure 1 shows that the experimental heat-transfer coefficients are about 60 percent larger than those predicted by Equation (3).

Additional examples of proper writing style are contained in the references given previously.

**VI. Forms of Academic and Scholarly Misconduct**
The University of Connecticut publication, *Responsibilities of Community Life: The Student Code*, categorizes academic and scholarly misconduct as follows:

- Cheating
- **Plagiarism** (taking the thoughts, words, or ideas of others and passing them off as your own)
- Misrepresentation (e.g. claiming work done by another individual as your own)
- Unauthorized Possession, Use, or Destruction of Academic or Research Materials
- Computer Violations
- **Fabrication or Falsification in Research** (e.g. deliberate falsification of experimental results)
- Research Violations
- Conflicts of Interest
- Tampering
- Any Attempt to Influence Improperly
- **Aiding or Abetting** (e.g. helping someone commit any act of academic misconduct)
- Any Impropriety or Act of Misconduct Committed by a Graduate Student in a Teaching Role
- Deliberate Obstruction

When an instructor believes there is sufficient evidence to demonstrate a clear case of misconduct, the instructor must notify the student in writing that he/she shall impose the appropriate academic consequences warranted by the circumstances. The student may request a hearing to contest the instructor's belief. The consequence for serious offenses is generally considered to be failure in the course.