SCIENCE LABORATORY ANALYSIS MANUAL (SLAM)

This Laboratory Reference Manual is your combined resource for General Chemistry (CH101/2 & CH151/2) and Introductory Physics (PH201/2 & PH251/2). Use this manual to assist you in completing laboratory requirements in both courses.

This manual will serve as a valuable reference for your future science and engineering courses at USMA.

9 August 2014

The objectives of the Science laboratory program at USMA are to develop in each cadet:

- The ability to operate safely in a science laboratory.
- The skill of meticulous, careful, and accurate observation.
- The ability to ask questions about what he/she sees, hears, and reads.
- The ability to formulate questions for which data can be obtained.
- The skills necessary to obtain the quantitative data to answer questions.
- The ability to form conclusions from data.
- The ability to use evidence to back up conclusions.
- The ability to defend conclusions both orally and in writing.
- The ability to adapt a concept learned in one context to another situation.
- A basic knowledge of the principles of how to design a research effort.
- A realization of how scientific knowledge is obtained.
- A realization of the logical thinking process involved in scientific efforts.

Chapter 4

Laboratory Reports

A. Introduction

1. Lab Reports. Written laboratory reports are a means of communicating to the reader the results of an experiment, the method used to obtain those results, and the conclusions of the experimenter as to the reliability and meaning of the results.

2. Audience. The writer must remember when preparing the report that it is for the reader and, as such, should be tailored to the intended audience. A student working on a subset of a larger work may write a report for a lead experimenter. This audience would obviously require almost no background into the need for or theory of the experiment. Similarly, an article for publication in a technical journal may assume a certain level of knowledge by the reader. In contrast, a report written for publication in a general journal of undergraduate research would require a much more thorough introduction to satisfy the broad range of backgrounds of different readers.

3. Format. Because of the different possible audiences for reports, there is no standard format or procedure. However, all reports begin with some form of introduction which states the purpose of the experiment and the scientific model or hypothesis to be tested. This is followed by a description of the experiment itself and the results obtained. The report ends with a discussion of the important conclusions drawn from the results and suggestions for future work. The written report also includes acknowledgments and references as appropriate.

4. Primary Literature. Each scientific discipline and journal has its own requirements as to the specific format for written reports of scientific information. Few undergraduate programs include what is known as primary literature in introductory courses. If you continue to study in a science discipline you will find that reading and understanding primary literature is one of the most essential skills a scientist must have.

B. Chemistry Written Laboratory Report

Cadets in CH151 and CH152 will have the opportunity to read primary literature and are required to write laboratory reports, or sections of laboratory reports, using the format described below.

1. **Cover Sheet**. Ensure that the cover sheet is formatted as specified in the Documentation of Academic Work. Include all lab group members listed in alphabetical order.

2. **Abstract.** The abstract may be the most important 200 words a scientist ever writes. This short paragraph completely summarizes from start to finish the purpose, result, and significance of your experiment. The abstract should start by providing a basic framework, then move into the specific background of the study. The results of the study should be clearly stated, followed

by a conclusion that puts the results in perspective relative to currently known information in the field of study, and in the greater scientific community. A well-written abstract stimulates the reader's interest in the study.

3. **Introduction**. Clearly state the scientific purpose of the experiment. Provide background that explains why this experiment is important. Give sufficient detail so the reader understands how your experiment fits into the big picture, what information the experiment will provide, and why it is important. Present the fundamental concepts, reactions or equations and explain how these concepts, reactions or equations apply to your experiment. State any assumptions that were made and explain the impact on the experiment.

4. **Materials and Methods**. This technical section describes the equipment, supplies, and procedures used in the experiment. Include sufficient detail so that a reasonably competent individual could independently replicate your experiment and obtain the same result. If needed, include a picture or diagram and refer to it when describing the procedures used to perform the experiment. State what quantities were actually measured during the laboratory and the method used to obtain these quantities (for example, we measured the optical absorbance of the solution at 470 nm with the MicroLab™ spectrophotometer). Present the uncertainty of each measured quantity and discuss how these uncertainties were determined. Describe statistical methods used in determining the measured quantities.

5. **Results**. This section consists of data and observations from the experiment, but does not include any assessment regarding the meaning of the data. Present all of your directly measured data, physical constants, or other experimental parameters (with uncertainties and proper units). The data should be easy to understand and are often presented in a table format with supporting graphs when applicable. Include text, captions, or legends as needed to explain how the data is organized or presented.

6. **Discussion**. This section interprets the facts presented in the results section and is often the longest section in the written report. As needed, refer back to the Introduction section and address the significance of the results relative to the scientific objective of the experiment. Specifically discuss any evidence of systematic and/or random error in the data. If systematic error is the dominant form of error, identify at least one source that is consistent with the direction of your discrepancy and analyze its effects on the measurement of the objective quantity. If random error is the dominant form of error, identify at least one likely source and analyze its effects on the measurement of the objective quantity. Focus on the relative uncertainties of the measured quantities and identify which quantity made the largest random error contribution.

7. **Conclusion**. A good conclusion begins with a clear and concise summary of the research findings. Make an assessment of how well your results satisfied your experimental objective. Suggest changes to the experiment that would reduce the dominant form of error and propose future research steps to be taken to discover more information relevant to the scientific principles explored in the report.

8. **References**. List all of the sources you used in preparing your report in accordance with the Documentation of Academic Work.

C. Physics Written Laboratory Report

In PH201/2 and PH251/2, you will be required to write a laboratory report. Use the format below and address each of the items listed in each section.

1. **Cover Sheet**. Ensure that the cover sheet is formatted as specified in the Documentation of Academic Work. Include all lab group members listed in alphabetical order.

2. **Introduction**. State the scientific objective(s) of the experiment, for example, validate a theory or measure a particular quantity, and how you accomplished that objective. Give sufficient detail so the reader understands not only what you are doing, but why.

3. **Theory**. Present the fundamental physics theories involved. Start with common equations that your readers will accept without question. Ensure that you define all symbols and parameters you use. State any assumptions you must make in order to use these equations must also be stated in this section. While the equations demonstrate the appropriate physics in the experiment, you need to show how these equations apply specifically to each experiment by rearranging these equations into a model equation and identifying the quantities to be measured from the model equation. If linear regression is used to analyze the data, explicitly show the relationship between the slope of the regression line and the objective quantity.

4. **Procedure**. Explain the "mechanics" of the experiment itself. The first step is to briefly explain the experimental apparatus. Include a picture or diagram and refer to it when describing the procedures used to perform the experiment. State what physical quantities are actually measured during the laboratory and the method used to obtain these quantities (for example, we measured the voltage across resistor 1 with a digital multimeter). Present the uncertainty of each measured quantity and discuss how these uncertainties were determined. Describe statistical methods used in determining the measured quantities.

5. **Results**. Present all of your directly measured data, physical constants, or other experimental parameters (with uncertainties and proper units). You will also present any statistical analysis and/or regression results. Present any plots of your data on a full-page graph. Present the calculation of the objective quantity using the derived equations developed in the Theory and Procedure sections. Present the calculation of the absolute uncertainty of the objective quantity. Present the rationale behind selecting the method used to determine the absolute uncertainty. The details of the calculations may be placed in an appendix, but in any case, complete calculations must be present. Report the experimental value as a confidence interval.

6. **Discussion**. Present a number line with the objective quantity and reference value confidence intervals. Discuss the significance of the number line (precision, accuracy, dominant form of error). Discuss any evidence of systematic and/or random error in the data. If systematic error is the dominant form of error, identify at least one source that is consistent with

the direction of your discrepancy and analyze its effects on the measurement of the objective quantity. Revisit the Theory section and address the significance of the systematic error introduced by your assumptions. If random error is the dominant form of error, identify at least one likely source and analyze its effects on the measurement of the objective quantity. Focus on the relative uncertainties of the measured quantities and identify which quantity made the largest random error contribution.

7. **Conclusion**. Make an assessment of how well you met your experimental objective. One of the goals of experimental procedure is to learn from the tasks performed and pave the way to the next iteration of the experiment, building on what you have learned, not repeating the same procedure. Suggest a change(s) to the experiment that would reduce the dominant form of error (refer to the number line and propagation of error calculation as appropriate for establishing priority).

8. **End Notes**. List all of the sources you used in preparing your report in accordance with the Documentation of Academic Work.