Lab Notes and Reports

Written communication of laboratory work

Records of real research laboratory work take at least two forms. Continual informal notes taken as work happens for posterity, and formal documentation which is intended for publication to a broader technical community to convery findings or encourage collaboration.

For legal and reference purposes, the primary record of lab work is maintained in a lab notebook. To count as a legally binding document (sometimes used as the basis for establishing ownership of patents), lab notebooks must convey a sense of unaltered accounting of chronological events. To be practical and functional to the researcher, lab notebooks must contain all information needed for a scientist to replicate their own work decades later if needed.

Lab work is summarized in technical reports. These reports communicate your main results and omit many details recorded in your lab notebook. Because the preparation of proper lab reports require considerable time and effort, we will not require a complete lab report for each laboratory. For many labs, we will ask that you submit a well written, partial report, where you focus on particular communication tasks. A full formal report is often comprised of six distinct sections: An introduction which conveys the intention and value of the work, a background section which frames the work in terms of work by others in the past, a methods section which briefly conveys the details of the work, a data section which conveys the results of experimentation without much analysis by the author, an analysis section which states the author's translation of the data, and a conclusion section to summarize the findings and once more frame the study within the broader academic field, as well as speculate on future work which can be done.

These two forms of communication employ different standards that can be only partially implemented in an instructional lab. What we require is described below.

Lab notes—official record of attendance and work performed

Lab notes include the notes you make before, during, and after performing an experiment. For grading purposes, we require that you use a commercial notebook with index pages at the front and numbered, carbonless copy pages for notes. Many introductory chemistry laboratories use suitable notebooks. If your chemistry notebook is otherwise suitable and has blank pages left, you are free to use it for this course. At the end of each laboratory, you will submit the copy pages from your notebook to your teaching assistant. You will submit the copies for any work you do outside

of class with the rest of the lab assignment. You will retain the original copies for your record and study. When you fill up one notebook, you are expected to purchase another.

Although neatness is important, the content of your lab notes is the main criterion for grading. Lab notes should be sufficiently legible to make it easy for you and others to read and understand exactly what you did. You must be able to communicate the procedures used and the results of your experiment in a coherent, organized way to receive a good grade. Remember the key requirement: Have enough details that you could set up the exact same experiment again in the future if required. This includes being able to select the proper equipment from our storage rooms, arrange it all on the table, and then get the precise arrangement you used for the specific trial in question.

With the exception of computer-generated graphs and tables printed during lab, lab notes must be handwritten in pen. Although lab notes are not formal documents, in real life they are legal records. Any attempt to remove information from the record after the fact destroys this value and is usually considered scientific misconduct. *If you decide that any original data or notes are in error, put a single "X" through it, make short note in the margin explaining why it is in error, then record the new information in a new entry.* Both sets of data must be legible in your lab notes. Your grade will not lowered by including these "false starts." This practice conforms to standard scientific and engineering practice. You are free to work through any derivations that should appear in your lab notes on scratch paper before entering them in your lab notebook.

Each entry in your lab notebook should start with the current date and time in the left margin. You will often be able to work on your lab notes at home after lab; these entries must also begin with the current date and time (the time of writing, not the time of the lab). Your lab notes must be recorded at the same time the work is performed. That is, notes about experiment details must be made during the course of the experiment. Notes about data analysis must be made when you analyze the data. Notes about conclusions should be made when you are prepared to conclude. Notes made after the fact are not valid records. If you rewrite or type your notes, understand that your original notes are the official record, not the rewritten notes. All your original notes must submitted in order to receive a grade for laboratory work.

Unlike lab reports, lab notes normally do not have formal sections. While it is especially important to include procedures, each step of your procedure is recorded as you actually perform it. You should have no procedures section. Likewise you should record your data as you take the data. There is no data section. If you print a graph or data table in lab, staple it with your other notes as close as possible to the handwritten notes that describe the data and how it was collected. Do not collect your computer printouts at the end. Your notes should be submitted in chronological order.

Your lab notes must be sufficiently detailed that you or another student with your background can reproduce your work. The reader must be able to "trace" your work from the original data, through your analysis, to your conclusions. Your notes should leave no doubt about how the data were collected, what sensor settings were used (if any), and which equations were used to calculate the quantities you report. Define any symbols used in your equations and include appropriate units for numerical data. Sample calculations are often necessary.

Each graph printed during lab should fill a full sheet of paper to allow room for notes. In some cases it is useful to display computer-generated graphs, for example, showing position, velocity,

and acceleration as functions of time, on the same page to facilitate comparison between the graphs. Computer-generated graphs should normally be printed in the "landscape" (rather than "portrait") mode. Landscape mode will print the x-axis along the longer dimension of the paper and thus makes most graphs about 50% larger. All graphs must have a descriptive title that indicates what is being graphed. ("Graph 1" or "Exercise 1" is not sufficient.) Labels and units are required for both the x- and y-axes. If you are asked to draw a "curve" through your data points, this should always be a best-fit curve (for example, a straight line if appropriate) that best represents your data. Best-fit lines can be drawn by eyeball and a ruler, or with the help of the computer. If you are asked to calculate the slope (or perform other analysis) of the graph by hand, show the results of this analysis directly on the graph, clearly identifying which points are being used to calculate the desired quantities. When a computer-generated best fit curve is displayed on a graph, the resulting equation (with parameters and uncertainties) should also be written on the graph. This allows the reader to evaluate the curve fit results without referring back to the text. Refer to the "Uncertainty/Graphical Analysis Supplement" near the back of your lab manual for more information about using graphs to find mathematical relationships between graphed quantities.

At the end of the semester, you will take a lab exam in which part of a few selected experiments are to be reproduced—usually with a small change. You will be free to refer to your lab notes during the exam. The exam can be relatively easy if your notes are complete. In the exam, remember that we are grading for proper approach, thought, and technique. Not for "accurate results" specifically (though most experiments are set up for you with great care, and should come out with accurate results if you perform the experiment correctly).

Keeping good records during lab takes time, and it is virtually impossible using formal English, with complete sentences and paragraphs. Record your actions and data in the most clear, efficient way possible. Use phrases instead of sentences. Annotated diagrams—simple sketches with the parts labeled and notes—can save time and be more clear. Descriptive titles for graphs and table columns are important. If an equation is used to describe the data in a graph, write the equatstressedion on the graph. Putting it elsewhere usually requires additional text.

Lab reports—formal communication with peers

Although lab notebooks are the primary records of lab work, they are poor communication devices. Experimental results are usually communicated in technical reports. Unlike lab notes, these reports omit most "historical" aspects of the work: false starts are omitted. While one often reports the manufacturer and model number for important pieces of equipment, operational details are usually omitted. (The operational details must be recorded in your lab notes.) While lab notes often include derivations, technical reports normally include only the result. As communication devices, we expect lab reports to conform to the standards of formal written English, with appropriate word choice, grammar, and structure.

Because writing formal lab reports is time consuming, an entire report will not be required for each lab. Rather, most labs will focus on one part of an entire report—perhaps an introduction or an experiment section. If the teaching assistant believes a submission is inadequate, the teaching assistant may require that it be rewritten and resubmitted for partial credit. For final evaluation, we will require a complete, formal report to showcase the best of your ability. The deadline for the

submission of complete reports will be at least a week after the lab is performed. Your teaching assistant will inform you of the report requirements on a week by week basis.

Lab reports (partial or complete) must be typewritten or printed from a text editor, using the format specified in the "Formal Lab Report Instructions" supplement near the back of the lab manual. You will have the original copies of your lab notes home to use in preparing your report. Carbon copies of all relevant lab notes must be submitted to your teaching assistant for credit. Failure to turn in lab notebook copies of work done during the lab and at home will normally result in no credit for the report. We expect that statements in your report (partial or complete) are supported by the data and analysis in your lab notes. Omissions and gaps in logic, when observed, will require rework.

Special requirements for lab assignments

Cover Page

A cover page is required for every submission. It must include:

- The title of the experiment
- Your name and student ID number
- The name of your lab partner
- The date that the lab was performed
- The name of your teaching assistant
- The course and lab section numbers (for example, Physics 101, Lab Section 5)

Nothing else should appear on this page. Lab reports that are submitted in the wrong slot or are otherwise misplaced take much longer to reach your teaching assistant if the information on the cover page is incorrect or incomplete. Work submitted during lab may not require a cover page. Please ask your teaching assistant if you are not sure.

Uncertainty analysis

Many experiments involve a quantitative comparison between values of the same quantity determined by two or more distinct methods. When you compare two values, you must address the question of whether or not they agree within the limits of the expected or measured uncertainties. Methods of uncertainty analysis will be introduced as appropriate throughout the semester for Physics 101 and 201 students. As the semester progresses, you will need to make decisions by yourself on appropriate methods for calculating the uncertainties in your various measured and calculated quantities. Physics 102 and 202 students are expected to be aware of all the uncertainty methods learned in Physics 101 and 201, respectively, and to use them appropriately. The Uncertainty/ Graphical Analysis Supplement near the back of your lab manual defines important quantities, such as the standard deviation, and supplies details about determining uncertainties

Students are highly encouraged to make use of Khan Academy as a resource to familiarize themselves with basic statistics. This branch of math does use relatively basic mathematical techniques,

but has nuance which can catch a new practitioner unaware. Since there is not a statistics prerequisite for the course, it is expected that many students will lack experience with these techniques. However, the value of statistical analysis in scientific research is immense.