Physics 117 LAB MANUAL

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The Role of the Laboratory in Physics

A. Central Role of Measured Data in Physical Science

The task of physical science is to provide a quantitative and predictive description of every physical phenomena with as few assumptions as possible. In Physics 117 the laboratory is the playing field where your conceptual reality meets nature's physical reality. Sometimes one brings an idea to the lab to be tested and sometimes one uses laboratory measurements to suggest how best to understand and organize the phenomena under study. In any case science considers data-the results of careful observation and measurement of physical processes, as the ultimate arbiter of physical truth; physical hypotheses are accepted or rejected on the basis of measured data. This physical empiricism distinguishes Physical Science from Mathematics and Philosophy.

B. Modes of Experimental Inquiry

Some of the ways in which one inquires about physical reality in the laboratory are as follows.[1]

1. Observing phenomena qualitatively and interpreting observations.
2. Forming concepts as a result of observations.
3. Building and testing abstract models in the light of observation and concept formation.
4. Subjecting a piece of equipment to examination in context, figuring out how it works and how it might be used (rather than simply being *told* how it works and what it is supposed to do).
5. Deciding what to do with a piece of equipment, as well as deciding how many measurements to make and how to handle and present the data.
6. Asking and pursuing the "How do we know…? Why do we believe…? What is the evidence for…?" questions associated with a given experiment.
7. Explicitly discriminating between observation and inference when interpreting the results of experiments.
8. Practicing hypothetico-deductive reasoning (i.e., asking and addressing "What will happen if…?" questions) in connection with the laboratory situations. This includes visualizing, in the abstract, the effect of changing the relevant variables or boundary conditions, visualizing outcomes in extreme or limiting conditions, and,

where possible, forming an a priori hypothesis and then testing it by performing an appropriately designed experiment.

C. Cooperative Lab Activity is Efficient and Rewarding

The lab experience is improved by sharing with others in the lab. Everyone can improve both his/her conceptual and his/her technical mastery of any given laboratory effort, and the pooling of your own ideas and skills with those of others is a good way to optimize the effort. The more you share your understandings, your expectations, your predictions, and your skills, the more they will improve.

D. Personal Responsibility

To make the Physics 117 Lab work for you and your colleagues, you should enter into a partnership among you, your lab partners, the TA, and the professor. Each of us has a responsibility to fully participate in your learning, but you must also learn to sense and monitor your own personal understanding. When you feel that there is something lacking, you must be ready to call on your partners (other students, the TA and the professor) to help you attain the high level of understanding which will provide you with personal pride and satisfaction in your work.

Also, one should understand that the pre-eminent role of data in science requires a special respect for measured observations. Every measurement involves some margin of error and experimenters are fallible humans who may sometimes commit blunders in the lab. To make a mistake is no disgrace. But in science, the presentation of results which in fact were not actually measured as the product of measurement is shameful; it is in fact the equivalent of perjury in a court, because it threatens the very integrity and operability of the whole scientific process. A measurement may be wrong, but it must never be concocted.

[1] Arons, A.B., "Guiding Insight and Inquiry in the Introductory Physics Laboratory," in *The Physics Teacher*, Vol. **31**, May 1993.

In the Laboratory

A. Functioning in the Lab

In the lab you should

1. Observe and measure carefully, recording your results into your lab notebook.
2. Describe your observations with accurate and succinct notes.
3. Keep the observations (data) and the explanations hypotheses and/or theories well separated in your thinking.
4. Recognize graphical and mathematical representations of physical processes as quantitative versions of the relevant hypotheses or explanations which are to be tested by comparison with the data from your observations.
5. Be critical of your observations and the data they produce. Consider possible sources of error or inaccuracy and learn to judge how reliable and valid they are. One method is simply to repeat the measurement as carefully as you can (or to remove any possible subjective bias on your part, to ask someone else to repeat it). If such repetitions *vary* by some amount Δ then it is not reasonable to believe that your measurement is more precise than $\pm\Delta$.

B. Graphical Interpretation

1. Physics is a *quantitative* science. Graphs are pictures of quantitative mathematical statements which in turn quantify verbal statements about the underlying physics.
2. The translation of verbal statements to and from mathematical statements and of mathematical statements into and out of graphical images is an important technique for mastering physics.

C. Laboratory Graphing

1. You should purchase a supply of cm graph paper with 10 divisions per unit.
2. Whether your graph is plotted by the computer or by hand you should always be careful to:

   (a) Label all axes clearly and correctly and state the units;

(b) Give each graph a correct title (and alter the computer-given title if it is appropriate;

(c) Choose scales appropriate to the message the graph is intended to convey. (E.g., if you wish to show that a measured quantity is essentially constant [or, alternatively, that it definitely has fluctuations of a certain size], then choose a gross enough scale that the small variations do not dominate the picture [or, alternatively, a fine enough scale that the small fluctuations are evident, despite the fact that the quantity may be nearly constant on a larger scale.]

D. Laboratory Journal Notebook

1. Get a blank notebook to use as your PHYS 117 LAB JOURNAL. In this journal you should accumulate all of the notes you write in the lab during the semester.

2. A notebook with cross-ruled paper (i.e., a square-ruled pattern) allows you to make rough graphs conveniently wherever it seems convenient.

3. Also, a notebook which has pressure-sensitive paper for every other page allows you to automatically make two copies of everything: Then you can remove a copy to submit as, or with, your lab report while retaining the original copy intact in your notebook. (But there are disadvantages: E.g., one has to be careful to use a stiff underbacking to avoid pressing images onto the rest of the book. Also, these notebooks tend to be expensive.)

Laboratory Reports

Each student must prepare and submit his/her own laboratory report, preferably before the end of the lab period, but in any case not later than the following day. (This policy is designed to discourage procrastination, and to avoid any tendency to spend excessive effort creating over-elaborate lab reports.)

A. Elements of the Report

The lab report should be short and simple. It should present

1. The NAME of the author;
2. The NAMES of his/her collaborators, and the DATE when it was performed;
3. The TITLE of the lab;
4. The PURPOSE of the lab;
5. The PROCEDURE: WHAT WAS actually DONE in the experiment (briefly);
6. The DATA which were obtained (with numbers clearly labeled, including units);
7. An example of any CALCULATIONS performed;
8. A brief statement of the CONCLUSIONS which the results support;
9. A CRITIQUE of the lab, the experiment, the results, or of your own execution of it, if appropriate.

Note that each student's lab report should be complete and self-contained. Therefore a copy of any computer or other data should be made and annotated individually by each student.

Generally, the lab report should fit onto less than two sides of a page, apart from any graphs or tables which are attached.

B. What Counts in the Lab

Note that you gaining *understanding* is the goal of the laboratory program --- not experimental prowess or precision. A large deviation from an expected value does not necessarily reflect poorly on the experimenter. What counts is the student's understanding of the experiment, how it might have gone wrong, and how it might be made to go better next time. And the worst intellectual crime in the lab would be to falsify the data.

C. Scoring Laboratory Reports

Each lab is worth 20 points, to be distributed roughly as shown:

- (5) Participation and collaboration
- (15) Quality of lab report; as follows
  - (3) Readability
  - (5) Completeness
  - (7) Insights shown