INTRODUCTION

TO

ELEMENTARY LABORATORY I & II

Objectives of the Course

Physics is firmly rooted in experiments. Physical theories (Newton's laws, Maxwell's equations, etc.) might be regarded as extremely convenient and useful summaries (usually stated in mathematical form) of experience gained through observation and experiment.

Theory, however, serves in another role more profound than simply summarizing. Once a pattern is recognized in the results of various experiments and a general law is formulated, the theory can be used to predict the outcome of experiments that have not yet been performed. In this role the theory then forms the basis for our understanding of the physical universe and for engineering and technology. Although the theories may be stated in terms of abstract mathematical concepts, ultimately all physics is concerned with observable and measurable quantities.

Some objectives of this course:

- To introduce you to some techniques for making and analyzing physical measurements, and for assessing errors that limit the accuracy and precision of the measurements
- To demonstrate some important general concepts in relatively simple experimental guises (e.g. the oscillations of an LCR circuit exhibit general features that have direct analogs in many fields of physics including mechanics, atomic and nuclear physics)
- To demonstrate some important phenomena from various fields of physics
- To help you develop a more intuitive and deeper understanding of physics
- To have you experience some of the enjoyment, and also some of the challenges of experimental physics

Much of this course will be devoted to studying electric and magnetic fields, electric circuits and electronic measurements. Because of the ease, speed and precision of electrical measurements, in modern physics labs nearly all physical quantities (even ones not inherently electrical – e.g. displacement, time, force, pressure, temperature) are converted to voltages or currents with devices called "sensors" or "transducers". These electrical quantities are then measured with electronic instruments or coupled through electronic interfaces to computers for rapid and efficient data acquisition. Many of your experiments will involve the use of computers for data acquisition and analysis.

Course Organization

The Elementary Laboratories are stand-alone courses; they are not components of the lecture courses usually taken concurrently. However, the general areas of physics that you will explore in the lab will

overlap considerably with those you will study in those courses. There will be no synchronization between the two courses in the sense of making the experiment of any given week relate directly to the lecture of that week. In fact, you will often be involved in an experiment before you understand the physical theory explaining it. In this respect though, you will be no different from the typical experimental physicist, who is usually in that position! The physical theory, after all, grew out of attempts to understand the results of experiments, so obviously the person who first did the experiments did not understand the results until after the measurements were made and analyzed.

The Laboratory Manual is available in pdf format on the course Collab site. It is available as individual "elements" as well as a single (large) pdf. The single pdf is useful if you want a "hard copy". [I recommend that you get printed spiral bound and duplexed.] You will also find your lecture texts invaluable. Highly recommended references are *Introduction to Modern Electronics* by J. C. Sprott and *Practical Physics* by G. L. Squires. These and other possibly helpful books are on the Reserve Shelf in the Physics Library.

The faculty member responsible for organizing and directing the course is Rick Marshall (Office: Physics 103B, phone: 924–3080, e–mail: rmm5a@virginia.edu). You are welcome to consult with him at any time about the course. Marshall will present the lectures each Friday and will be available for help and discussion at various times during your lab period.

There are two laboratory instructors (TA's), each of whom supervises two lab sections. They will give you some specific instructions relating to their individual sections and also information about how best to contact them outside of class periods. Your TA will help you work out exactly what is required of you each week and is the person to see if you wish to modify a given experiment or otherwise alter procedure. It is important to discuss special arrangements with your TA if you should miss a lab period. The TA's grade all of the reports for their own sections. At the end of each semester, letter grades are assigned to the numerical averages in such a way that the letter grade distribution is the same for the students of both TA's.

There are two parts to the course:

1. Each Friday at 2:00 p.m. in Physics 216 there will be a 50–minute lecture covering topics pertaining to the following week's experiment and describing the apparatus and techniques you will be using. Here you will have an opportunity to learn about and discuss the physical principles involved and the context and importance of the particular experiments you will be doing.

2. Laboratory Period – There are four lab sections that meet from 2:00–5:50 p.m. Monday through Thursday. You should be enrolled in one of these sections and always attend the particular section in which you are enrolled.

The experimental work will be done by teams of two people. We encourage free exchange of ideas between partners and also generally throughout the lab. We expect you to share the work of taking data and creating a lab journal. Lab partners will be switched each week in order to minimize correlation in grades between people.

Homework

In your Laboratory Manual, you will find instructions and background information for each week's lab period. Before your next lab, you should study this material and complete the pre–lab report that is due

at the beginning of the next lab period. The contents of the pre–lab report will vary, but it will usually include answers to some questions about the objectives, concepts or techniques involved in the upcoming experiments. Some weeks it will include solutions to some problems. It is extremely useful to prepare a list of theoretical results that you will need for your experiments and a concise summary of the procedures you will be using. You should keep a copy of your pre–lab report to refer to as you do the experiments. You will often use a result that you have obtained for the pre-lab report to compare with your data.

Clearly, a primary purpose of the pre–lab report is to have you prepare for the experiments before you come to lab. In spite of the great time pressures and inclinations not to do so, you should be conscientious in preparing for the experiments. You will learn much more, you will be able to complete the experiments in the allotted time, and you will not waste your time and that of your partner.

Pre–lab reports are to be handed in to your TA at the beginning of the lab period.

Laboratory Journal and Report

An essential part of experimental science is a short but carefully written record of what was done in the laboratory together with data, data analysis, and carefully and rigorously drawn conclusions and interpretations of the results. This is what distinguishes scientific experiments from just playing around in the laboratory. There will be two other distinct parts to your written output for this course in addition to your pre–lab report.

1. The Laboratory Journal (Not pledged)

The first part is a laboratory journal where you record every relevant thing you do in the lab as you do it. Your journal should consist of short statements about what you are doing, apparatus diagrams where appropriate, tables of data, calculations and graphs etc. In short, what you do while actually in the laboratory should be recorded in your journal, and there should be enough words so someone reading it can understand what you did. Every pertinent fact and procedure should be recorded in clipped but clear English. Neatness and legibility count!

Your journal is a chronological record with data placed right in the text as the data are taken. You should record the raw data, the actual readings you take. Then in separate columns in the data table record any results of calculations, *even simple ones such as changing units*. You should plot graphs as you proceed. Since you will probably create some of your data tables and your graphs with a computer, they will necessarily be on separate sheets, but they should be attached as part of your journal.

We emphasize the importance of understanding what you are doing at each step, and knowing, while you are in the lab, whether your data are correct and meaningful. This necessitates making some "sanity check" calculations and graphs as you go along in order to ensure that you have recorded all relevant data, have not made errors in your readings of meters or use of equipment, and have no defective apparatus.

You are to upload your journals and reports to Collab in pdf form (no other formats accepted). The site is configured so you each have a "Drop Box" where you can exchange documents with your TA. The Journal should be a single pdf document uploaded to your Collab Drop Box before you leave the lab if possible, but no later than the end of the day of the lab.

Please make sure that you name your Journals with the following convention:

- Journal01_mst3k.pdf for the first journal

and so on, where "mst3k" is to replaced with your computing ID.

Summary of Lab Journal:

1. Your name, name of lab partner, date of lab.
2. Record of data, with enough explanation to enable you and the instructor to determine the experimental setup and to do the calculations. Detail should be sufficient that, together with your report, someone could reproduce your results.
3. Description of any problems in procedure.
4. Estimated or calculated errors in measurements.
5. Calculations and graphs.
6. No changes or additions to journal after leaving the laboratory.
7. The journal is not pledged.

2. The Laboratory Report (Pledged)

The second part of a working physicist's written output is a series of formal reports on completed experiments. These are the published papers, in which the results of the experiment and the conclusions drawn are written in a more formal and logical way. The experiment is described in enough detail so that the scientific community can understand what was done, but many of the details in the journal are omitted. The raw data may be included, or only the results of a complicated data reduction calculation may be presented. Maybe only graphs of the data are included if this is sufficient to support the experimenter's conclusions. These reports are the scientist's communication with the world. Normally, nobody sees the journal except the experimenter.

For this lab, your report should be a concise, logical description of what you did, the results you obtained and the conclusions you can draw from them. Your report should contain the following elements:

1. The title of experiment, your name, the name of lab partner, and the date report is handed in.
2. OPTIONAL: An abstract concisely describing the work and major results.
3. Introduction: A very brief overview of the objectives, emphasizing the physical principles involved, and the conceptual basis of the experiments.
4. Body of report. Organize this into sections corresponding to the individual experiments in the lab notes. State what was measured and how. Include sample calculations and tabulations or graphs of the results. You will probably produce some tables and graphs that are in essentially final form while you are in the lab. You can add annotations by hand as needed (titles, labels, figure and table numbers) to make them fit logically into your report.

5. Do any data analysis beyond what was necessary in the lab; plot any additional graphs for clarification, interpretation, or cosmetics, if necessary. Answer any questions in the lab notes. Pay attention to your units! Think about the magnitudes of the results. Are they reasonable? How precise are the principal numerical results you obtained? Include appropriate error analysis. Discuss the data, and explain its significance.

6. Write your conclusions. Are they consistent with the introduction? This section should be short.

7. We expect the report to be the work of each individual. While you are allowed to consult with colleagues and the like, the words and analysis should be your own. Write out and sign a pledge that the report is your own work.

Do not underestimate the time required to write the reports. Recent course evaluations indicate that a majority of students spend at least eight hours per week. Expected length of report: No more than 8 to 10 pages, including graphs and tables. Note that recent "journal like" two-column formatted reports (see sample report on Collab) have come in more like 5-8 pages.

When writing any report it is important to have in mind the audience you are trying to address. Assume for this report that you are writing for a hypothetical classmate who has a substantial interest in what you did, why you did it, and what conclusions you can reach from your measurements.

One characteristic of a good report is concision. Credit is not earned for sheer length. You do not need to repeat derivations of equations or lengthy explanations contained in the notes or the texts. However, credit is given for demonstrating your understanding of the physical principles, the experimental techniques and accuracy of measurement, correct use of units of measurement, and intelligent analysis of your data, including error analysis. Neatness and legibility count.

Writing your report promptly is very important. Generally, late reports suffer double jeopardy – in addition to deduction of late points, they are usually of lower quality than those turned in promptly. For maximum effectiveness your report should be done while the experiment is still fresh in your mind. In order to encourage you to write the report as soon as possible after doing the experiment, we require you to submit the report one week after finishing the experiment, BEFORE the next lab period starts.

You are to upload your reports to Collab in pdf form (no other formats accepted). Please make sure that you name your files with the following convention:

- Report01_mst3k.pdf for the first report

and so on, where "mst3k" is to replaced with your computing ID.

After your TA grades your work, they will key in your score into the appropriate Gradebook entry. The TA will return the graded reports by the following lab period. They'll upload a marked up version to your drop-box with the naming convention "Report01_mst3k_Comments.pdf".

Grading Summary

Four items will be considered in determining your grade for the lab:

1. Attendance at Friday lectures and performance in lab 15%
2. Homework 20%
3. Lab Journal 15%
4. Lab Report 50%

There is no fixed mapping from a given "score" to letter grade. Final grades are assigned on the basis of how you do relative to your peers, after correcting for differences between how the TA's grade. The "relative deviation" of your score is calculated as the difference between your score and the average score for your TA, divided by your TA's standard deviation. Historically, the average score (or zero "relative deviation") maps to a high B to B+.

So that you can keep track of how you are doing in the course, each week your TA will report averages and standard deviations for the week's graded work. Please use these data to see how you are doing. [If you are "below average", don't expect the average grade!]

Late Penalties: The "late penalty" policy is to linearly ramp down credit from 100% for work submitted on time down to 50% credit for work fourteen days (or more) late. Anything later than two weeks will receive 50% credit. [For example, work submitted one week late would receive 75% credit. That would mean that if the grader gives the report a score of 40 points, the late penalty would reduce the score to 30 points.]

Nominal Time Allocations (based upon past course evaluations)

Study of instruction sheets and references, homework: 2–3 hours

Friday lecture: 1 hour

Lab period: 4 hours

Lab report: 8–10 hours