**Overview of the lab course**

A lab course is intended for you to develop hands-on skills in designing and conducting experiments that measure quantities which can be used to understand the behavior or properties of a system. Such hands-on experience, and the resulting skills you develop, will be useful to you not only in college, but wherever you go next, whether it is into a job, or graduate/professional school. The objectives of the labs that accompany the lecture courses are to (i) develop critical thinking and analysis skills, (ii) learn experimental design, data collection and interpretation, and (iii) develop scientific communication skills. To accomplish these goals, your TAs will be guide you throughout the semester, but it is imperative that you stay in communication with them and discuss your work regularly with them.

***Critical Thinking, Experimental Design:*** Unlike labs in high schools, you will not be given detailed, highly prescriptive, step-by-step instructions; instead, the TAs will give you a broad outline of what question(s) a particular lab addresses, what physics you should know to answer the question(s), what equipment you will use, and how many weeks the particular lab should take. So, for example, if a lab requires you to determine the resistance in an electrical circuit via measurements of voltage and current, you will not be specifically told how many measurements of voltage and current you should make, or what range of currents you should choose. You should think about what range of currents will give meaningful results, and how many different measurements you should make. You can discuss with your TAs, but don’t expect them to tell you exactly what range to use. Sometimes, you may find that after you have done the experiment for, say, four currents, and obtained the four corresponding voltages, the resistance is still ambiguous. You may then have to take additional data at other currents to definitively obtain the resistance. Or, you may have to refine the experimental set up with the equipment provided. This process of taking some data, doing a rough check of what the data reveals, and then refining the experiment to take more data, is experimental design.

***Data Analysis***: Once you have collected data, you should think about what kind of data analysis makes most sense for that lab. If you vary one quantity and measure another, the relationship you measure has a meaning. You should be able to say what each parameter in a “curve fit” represents. How you handle “errors” is also important. In experimental work, errors are not “mistakes,” they are inaccuracies that may be inherent to the equipment or even to nature itself. In everyday language, we use the terms accuracy and precision interchangeably, but in scientific measurements they have specific meanings. Accuracy refers to how well the measured value agrees with the accepted and known value, e.g., if your measurements of the Earth’s magnetic field give you a value of 0.4T and the known value is 0.5T, you can quantify the accuracy in terms of percentages. Precision refers to how reproducible your measurements are, i.e., if you measure the Earth’s magnetic field ten times, and get values of that are all tightly clustered around 0.9T, then your measurements are precise but not accurate. In general, when we don’t know what the expected outcome is, we try to design experiments that give precision. When reporting results of measurements, it is important to not only report average values, but what is the error in the average. In some instances, calculating standard deviation may suffice, but in other cases, especially when the final results is derived from measured values, one may have to do more sophisticated error analysis. Your TAs will guide you in calculating errors.

***Scientific Communication***: At the end of some labs, you will write a report that describes your work. Write the report from the perspective that if a student like you, the following year in the same course, does the same lab, that student will get enough information to perform the experiment the same way you did. At a minimum, your report should be typed, in essay form (not bulleted lists), and contain the following sections: title, abstract, introduction, theoretical background, experimental procedure (including any re-design or refinements), data (in tabular form or a format that makes sense for that lab), analysis of data including errors, your interpretation of the results, and a conclusion section that reflects on ways to improve the experiment, how well your results agree with known values, why there are deviations, and if you could do the lab again, how you would change it to make better measurements and get an improved result.

For other labs, you will submit a summary; please see the handout on Summary Template for the format of the summary.

**Error Analysis:** Please see the document Error Analysis to get started on errors in experimental measurements. There are a vast array of resources on the web, and library, where you can get into as much detail as you wish on error analysis. You may find some of the links below useful for data analysis, though note that this list is not meant to be exhaustive or comprehensive.

https://www.webassign.net/question\_assets/unccolphysmechl1/dataanalysis/manual.html

http://www.phys.lsu.edu/classes/phys2109/2108\_intro.pdf

http://www.physics.nmsu.edu/research/lab110g/html/ERRORS.html

<https://labs.physics.msstate.edu/pdfs/dataAnalysis_physics.pdf>

**Lab Handouts:** Note that some of the labs will be on-campus, and others can be done off-campus (dorm rooms, residence, etc.), and also that some labs are one-week long while others are two or three weeks long. For each lab, you will receive a handout which will state (i) duration of the lab, (ii) on-campus or remote, (iii) objectives of the lab, (iv) what you will learn in the lab, (v) an outline of what information should be recorded in your lab notebook and what material should be included in your lab report, (vi) the equipment you will use/need, (vii) a list of do’s and don’ts, (viii) and the activities you will undertake.

Please read the entire handout for each lab before starting a lab so that you have a full picture of what is expected and what you will do, since there may be differences from lab to lab regarding the details of the activities. Re-read the handouts as you do the labs, as often as needed, to refresh your recollection of what you are doing and what you need to do.

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| **Labs** | **Report type** |
| * Weeks 2&3- Electric Fields simulation lab (remote).docx * ***Activity 1*** on Weeks 4-7- DC Circuits (F2F).docx * Weeks 8-13 Magnetic Field of coil (F2F).docx | A full *lab report* must be submitted. Check “Handout 3 Lab Report Grading Standards.docx” for more details. |
| * Week 1 - Multimeters & DC Power Supply (F2F) * Weeks 2&3- Potential lines (F2F).docx * ***Activity 2*** on Weeks 4-7- DC Circuits (F2F).docx * Weeks 4-7- DC Circuits PhET (remote).docx * Weeks 8-13- AC circuits (remote).docx | Only a *lab summary* must be submitted. Please check “Handout 4 Summary Template.docx” for a template of the summary. |