Modern Physics Laboratory (Phys 1426/1626)

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Scope

This is a lab course normally taken by advanced physics majors; the first semester of Modern Physics (0480) and Electronics Lab (0525) are prerequisites. It carries 2 credits. The subjects cover material from the 20th century; you are expected to know many of the topics covered.

Objectives:

This course is aimed at training students in the area of experimental physics. Even for those students who are more inclined towards theoretical physics, this part of training is invaluable. The course is organized so that it offers students a great deal of flexibility in selecting the projects and performing the experiments. Students will decide what experiments to perform, what approach to use, and the amount of time he/she would like to devote to the project. Although the standard lab hours are from 1-4 every Thursday afternoon, students are welcome to conduct measurements in other times during the week when the laboratory is open. Students are required to do independent reading, to think about the physics behind the measurements, to analyze the data, to reach their own conclusions, and to write up a report. There is no required minimum that a student needs to accomplish for each experiment. Rather, students will be expected to demonstrate that they have researched and understood the underlying principles behind the experiments, and that they have performed meaningful experiments that probe those principles. They will also have to perform the data analysis and justify their conclusions. Some of the experimental instructions are relatively short but may have deep implications for physics. If one just simply goes through the instructions, the experiment can be done very quickly. However, students should go beyond what is described in the instruction manual and be creative in the measurements and in the discussion of experimental results. Creativity and initiative will be rewarded.

Policies:

Students are expected to do three lab projects during the semester, plus the introductory project on data analysis. Every two students should team up for each experiment. Students are allowed however to change partners during the semester if they are interested in different experiments. Each two students at the end of every experiment are required to submit one report. The report should be typed and submitted by e-mail either as word or PDF document.

Both students should be involved in writing the report and stand behind every word in the report. This will be tested during the presentation at the end of every experiment.

Lectures
There will be 1 lecture per week; attendance is required. In each lecture, each group is expected to give a 10 minutes ***presentation*** describing their progress in the experiments. The first presentation of each experiment should be dedicated for describing the background and the motivation for the experiment. The fourth presentation will be a summary of the main findings and conclusions.

Textbook –none required
Experiments in Modern Physics, Napolitano and Melissinos, 2nd ed**.** is a very good resource.

Lab
Official class time is 1-4pm (lab). In practice, you should not miss lab sessions because of the work required to complete labs. The professor will generally only be available during regular class times; other students can also help with problems. However, sometimes there are conflicts with religious holidays, or other reasons that can prevent you from attending. Students who miss lab sessions have to make up for it at different times. The lab will be open Mon-Fri roughly 8am-4pm and every student is welcome to use the facilities outside class times; in fact, many students have found this time important to keep up the pace required.

Notebooks
Each student is required to keep a lab notebook. Progress on each experiment should be documented in the notebook. When *each* experiment is finished, a 2 page summary of findings and issues should be added. The notebook should contain all relevant steps/findings; experience will be the best guide. The goal is to write enough that a reader, e.g. the professor, can follow the key steps and understand the problems encountered along with their solution. A typical lab session should produce a few pages of notes.
The report you submit at the end of each experiment should be a summary of your notes and describe your results and their interpretations.

Grades
The data-analysis project counts 10%, the three lab reports count 90%, 30% per lab.
10% for the presentations
10% for the report
10% for the lab performance
Regular lab reports will be graded on the basis of clarity and correctness of analysis. New ideas, extra analysis, etc. can earn bonus points. Each report should have the following sections:

1) Introduction: about 2 pages, which explain the physics behind the experiment.
2) Materials and Methods: details of all the apparatuses and materials used in the experiment. How were the measurements carried out, and how was the data analyzed.
3) Results: Summary of all the data acquired in the experiment and their analysis (including tables, graphs, images, etc.).

4) Discussion and conclusions: 1 page summary of the main results of the experiment, and the conclusions from these results.

Experiments
A list is provided below. Handouts for all experiments are in Courseweb.

Lab Techniques and Procedures
In this course your own work is the emphasis. Thus, an enterprising student can go as far as he/she wishes.

- Computer analysis is an important component of many labs. The computers in Thaw 210 are available for you. You can use whatever analysis program (MATLAB, Mathematica, MathCAD, Python, R….) you like. My expertise is in Methematica and Matlab.
- The time required for each experiment should be close to 4 weeks; don't plan for slippage of more than a week because April is not far away. Depending on the circumstances, experiments can be truncated with or without penalties. You will be required to answer questions or do exercises before you can start each lab.
- Error analysis is a key part of every experiment, the best way to assess the quality of your measurement. You will be required to go through an error analysis of your results.
- Quality of the equipment and the lab manual varies considerably. In recent years, we have added new experiments and upgraded older experiments. The prof. is always available during class period for discussion. Sometimes, you will be learning about a new experiment with less than perfect lab manual. Your notes will then contribute to the upcoming version of the lab manual.
- ***Notebooks*** should always be with you during the lab, and everything you do should be recorded as you do it.

Writing option - Those of you taking this option will do more writing. You are required to prepare a more formal document for 2 of your 3 experiments. You will submit a draft which will be marked up heavily so that final version will be improved. These documents must contain sections for abstract, introduction, descriptions of measurement and analysis, results, and bibliography, following the format of the American Journal of Physics, available online from the Pitt library site. These reports will be graded on style and correct journal format (references, etc.). There will be a two weeks interval between the first draft and the final draft in order to allow editorial suggestions. There will be occasional lectures.

Tentative Experiment List

Introductory (mostly for students who need brushup on previous material)

1. RLC circuit
2. Acoustical cavity
3. Acoustical gas thermometer
4. Microwaves
5. Ultrasound

Main experiments

6. Single photon interference
7. Black body radiation
8. Electronic noise/correlations
9. Stellar Interferometry
10. Magnetic resonance imaging (MRI)
11. Approach to chaos
12. Muon lifetime
13. Radioactivity
14. Scanning Tunneling Microscope (STM)
15. Mossbauer effect
16. Brownian motion in an optical trap