University of Massachusetts, Amherst

PHY 286: Sophomore Lab II (Modern Physics)

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Hasbrouck Lab Room 202
http://courses.umass.edu/phys286/

Introduction, Procedures & Policies

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Introduction

Purpose of the Laboratory

There are three important goals in this course:

1) To reinforce some of the concepts that you will learn in Physics 284, the lecture course on Modern Physics. Our experiments will demonstrate novel and essential concepts of optics, quantum mechanics, relativity, and nuclear and atomic physics. These are elegant experiments that reveal very non-intuitive results.

2) To gain some understanding of the interplay between theory and experiment. To learn to estimate statistical and systematic errors.

3) To obtain experience in some of the techniques employed by scientists in acquiring data, analyzing data, and drawing conclusions from "real world" experiments.

Important Notes

- The emphasis is not simply on finding the "right" answer. Rather, the emphasis is on learning to interpret natural phenomena by careful experiments.
- The most important attribute in carrying out an experiment is ***common sense***. As explained below, you should get an overview of what you are trying to accomplish each week before you begin your work. When you are carrying out the experiment, think about what your doing.
- Your laboratory notebook is your journal. You will document your experience in each laboratory session clearly, including any unusual results you may have obtained. Your ability to cope with seemingly unexpected results is an important skill to be developed from your laboratory courses.
- Learn to collaborate effectively with your lab partner.

Syllabus

We will do the following experiments. Many of these led to Nobel prizes when they were first done in the 19th or 20th century!

1) Radioactivity: Detection of α, β and γ radiation (2 weeks)

2) Atomic Spectra: Studying the discrete photon emission from atoms; measuring the Rydberg constant.

3) Interferometry: Use of the Michelson interferometer, a very powerful instrument that played a key role in the development of special relativity and is still commonly used today.

4) Franck-Hertz: The spectra of atoms, measured using electrons.

5) Relativistic energy: Measure momentum and kinetic energy of fast electrons to see the shortcoming of classical physics and the success of special relativity.

6) Photoelectric effect: The ejection of electrons from metals exposed to light provides evidence of the quantization of electromagnetic radiation (*i.e.*, photons). (2 weeks)

7) The Millikan oil drop experiment: The charge of the electron is measured by watching small, charged droplets of oil fall under the influence of gravity. (2 weeks)

Course Policies

Requirements

1. Attendance at all lab meetings is required.
2. Each student must turn in a lab report for each of the 7 experiments.

Grades

The course grade will be based on the lab reports and on your overall participation in lab. The 2-week labs will receive additional weight in the overall grade.

The laboratory reports will be graded on a scale of zero to 20. A report that contains all of the data and graphs required will receive a minimum grade of 8. A good report that gives a clean description of the experimental method will receive a grade ranging from 9 to 16. The best grades will be given for a good analysis of the experimental data, including a discussion of the errors and the overall accuracy of the experimental measurement.

Each student may consult with his or her lab partner when writing the lab report; collaborative work may be desirable for data analysis as long as both partners contribute. In other respects, the report must represent the work of each student. Copying or transcribing text is not permitted (except data, which is shared with the lab partner). Students should not consult with any students other than their partners. Students may, of course, seek help from the instructor or TA.

In addition, a grade equal in weight to one laboratory report will be assigned for general effectiveness during the lab sessions. This will include how well prepared the student is for the experiment, how well the student works with the apparatus, how well the student collaborates with the lab partner, and how well the student maintains his/her journal.

All lab reports are due one week from the completion of the relevant lab experiment. Late reports will be penalized 1½ points (out of 20) per week.

An interpretation of letter grades for the semester (adapted from D. Candela):

A – In addition to doing a good job at everything explicitly required, showing extra initiative such as (a) finding relevant scientific literature beyond those provided, (b) showing innovative ways of analyzing data, etc. (c) deriving innovative conclusions from data, or (d) developing new and improved ways of carrying out the projects, or new types of measurements, etc.

B – A good job at all required parts of course: solid lab work, effective group participation, readable and logical reports turned in on time. One should understand the relevant physics (and get help from the instructors when you are having difficulty), do the asked-for background reading, and get such results as the lab apparatus is capable of producing.

C – Lab reports are done on time, but less-than-optimal results are obtained owing to such factors as failure to read the handouts in advance, difficulty working with others, failure to ask the instructors for help when needed to understand the physics or data analysis, etc.

D – Seriously late manuscripts, half-hearted and hastily-prepared presentations or manuscripts, thorough lack of group participation, etc, can result in this unhappy grade.

F – Results from failure to fulfill the course requirements (at top of this page) or failure to participate in the lab.

Weekly Procedures

Preparations before arriving at each session

1) There will be a handout for each experiment that will be given to you the previous week. Please read it, try to understand it, and refer to your Physics 284 textbook if necessary.

2) Bring along basic necessities: the handout, a lab notebook, pen/pencil, and a calculator.

Before you start your experiment

1) Get a perspective on what you are trying to achieve in the experiment.

2) Formulate a plan with your laboratory partner.

3) Develop a basic understanding of how the apparatus works.

Points to keep in mind during the experiment

- Keep an informal but detailed record in your laboratory notebook. You will need to refer to your notebook to write your report. Write the date and experiment title on the 1st page for each experiment and date each subsequent page. Writing notes in your notebook requires time, but it is well invested; it can save time later and lead to a better report. Include qualitative observations ('it turned bright green and became hot') as well as numbers and units.

- When you are stuck, first discuss the problem with your laboratory partner. If you are still unable to make progress, then ask the laboratory instructor. Do not routinely turn to other groups.

- During the lab session, keep in mind the ultimate goals of the experiment. Carry out frequent checks with sample calculations in order to convince yourself that the data is making sense.

When you finish your experiment

1) Show the instructor your data and get your lab notebook signed out.

2) If you have time, start your data analysis and report.

Laboratory Reports

Each of the seven lab reports is due during the lab class following the completion of the relevant lab experiment.

Each laboratory experiment will be performed in groups. Each student should use the data obtained to write his or her own report (not one report per group).

The laboratory report should communicate clearly and concisely the following: goals of the experiment, what was done, the results obtained, and their implications. You should write the report assuming the reader is not taking this course but has the same background that you and your colleagues have.

There are no strict length requirements. As a rough guide, however, you might initially plan on ~3 pages of just text (not counting plots, etc.). A two-week lab might be slightly longer, but not twice as long. **Please note that when the lab handout asks specific questions, they should be answered in your lab report**.

Tables and figures can be attached to the end of the document; they need not be embedded in the document. (Especially relevant for the first experiment.)

The report should be typed or printed from a computer, with the exception that hand-made sketches or plots may be included.

Here is a suggested outline for your report (with a *rough* guide to point values.)

Cover Sheet: A standard Physics 286 cover sheet will be provided to you, which will be used to summarize the evaluation of your reports.

Title Page & Abstract (typically 5%): The title page should contain the title, your name and that of your laboratory partner(s), the date(s) the experiment was performed. The abstract should be an extremely short description of the object of the experiment and the statement of the principal results, including numerical values, units, and uncertainties. The abstract should be no more than a few sentences long, or roughly 100 words.

Motivation and Theory (typically 5%): Start with the motivation for the experiment, including the theory behind the experiment. Briefly present in words the ideas behind the experiment. If you use any formulas, make sure you define all symbols. No derivations are necessary. The purpose of this paragraph is to establish context and write down any relations that you will be using during data analysis.

Apparatus and Procedure (typically 15-25%): Describe the apparatus and procedure, in your own words, briefly and clearly. This might be brief because the handout typically describes the procedure – but it is still required. If you deviate from the procedure described in the handout, you might need some additional detail.

To explain an experimental apparatus, it almost always helps to include a schematic drawing. A schematic drawing is a sketch, not necessarily to scale, with the main components of the apparatus marked.

Data and Error Analysis (typically ~40%): Present the data obtained during the experiment, including any graphs. A photocopy of the original data in your laboratory notebook might be sufficient – if it is neat enough – but a printed table might be more effective.

Include units. Also include uncertainties, such as standard deviations and systematic uncertainties when appropriate. Discuss the accuracy of your experimental measurement. Make corrections if needed.

Write down your observations, including any unexpected or unusual results you might have obtained.

The handout on each experiment typically ask you to print plots and data tables; these should be included in your report.

The handouts also ask specific questions; these should be addressed in your report.

Results and Discussion: Organize your results neatly and compare them with theoretical predictions or calculations when appropriate.

Conclusion (with discussion, typically ~30%): Summarize the experiment and your results. Discuss the performance of your specific experiment. Comment on the physics of the experiment and what you learned from it. It can be brief but specific.

Again, the total length of text (not including figures and tables) can be about 3 pages if you are reasonably efficient, or a bit longer for 2-week labs.