Fall 2022 **Syllabus**

Physics 251: Atomic Physics Lab

W 2:00-4:50 pm & Th: 9-11:50 am in Small Hall room 133

Undergraduate co/pre-requisite: PHYS 201 (Modern Physics)

Instructors

Prof. Seth Aubin
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Office hours: (Aubin) Tuesdays, 12-1 pm; open office hours policy (come when you want).

Course Objectives

The primary purpose of this course is to introduce basic experimental methods, data analysis, and error analysis. The experiments focus on the wave and particle aspects of light and matter, i.e. their underlying quantum nature.

The course will cover the following topics:

- Standard electronic lab equipment (oscilloscopes, etc).
- Optical sources (lasers, spectroscopy lamps, etc).
- Optical measurements (photodiodes, spectrometers, etc).
- Wave and particle nature of light.
- Data analysis (plots, fitting data, statistics, etc).
- Error analysis (evaluating uncertainties, error propagation).
- Scientific communication: writing and presentations.
- Lab book note keeping.

Textbook

A lab manual is provided on the course website:

Some useful texts (on reserve at Swem Library):

Introduction to Error Analysis, by J. R. Taylor (2nd ed.), University Science Books.

Practical Physics, by G. L. Squires (4th ed.), Cambridge.

Experiments in Modern Physics, by Melissinos and Napolitano (2nd ed.), Academic Press.

Course Structure

Sections: There are two independent sections for this course. In general, you cannot switch between the two sections after the first experiment, since you will have a lab partner, and some of the experiments require at least two people.

Schedule: Each experiment is scheduled to take two weeks (2× 170 minutes of class time). Broadly speaking, the first week is intended for understanding the experiment, getting it to work, and taking data; the second week is for data analysis and retaking new data, if necessary. **You must attend both weeks.**

Experiments: You will conduct five canonical experiments, analyze data from them, and then write a report for each one. Typically, we do not have more than 4 setups for each experiment, so while half the section is doing experiment A, the other half will be working on experiment B (and then swap after two weeks). The experiments are:

1. Optical interferometry
2. Blackbody radiation
3. Single photon interference
4. Faraday rotation
5. Superconductivity

Special project: During the final two weeks of class, you will conduct an experiment that is not documented in the lab manual.

Presentations: At the end of the semester, in place of a final exam, we will have a mini-conference in which you lab team will give a brief presentation on your special project. ***Please plan to be present for the final exam dates:***

Wednesday section: Monday, December 19, 2022, at 2-5 pm.
Thursday section: Tuesday, December 13, 2022, at 2-5 pm.

Evaluations

Your final grade for the course will be determined from the following grading weight distribution:

Lab reports:	55%
Pre-lab exercise:	10%
Lab book:	10%
Special project:	25%

You must do all the experiments and turn in a report for each one in order to pass the course. Make-up labs are only allowed with prior permission and for a good reason (e.g. illness). Unlike PHYS 101/102 lab, there is no scheduled make-up time allotted.

Pre-lab reading and exercise: Each experiment has a lab manual that will be posted on the course website. You should reserve about 0.5 hours to read over the relevant manual before coming the lab. There will also be a pre-lab exercise that you will need to complete and submit before coming to the lab.

Lab book: Your lab book is the original record of your work, data, and analysis. It should include raw data, sketches, pictures of equipment and setup, notes your methodology,

calculations, analysis. Completeness is more important than neatness. Everything you do goes into the lab book, and it provides the basis for your lab reports. The lab book will be graded for each experiment, and it can be paper-based or digital (but not both).

Lab reports: You will write a lab report for each of the standard labs. While you will do the experiments with your lab partner, your lab report must be your own work. The reports are due at the start of class in the following week. Late reports will be penalized by 5% per day.

Special project: The special project will be graded on its own, based on your lab book, experimental success, and presentation. The special project is a required component of the course.

Computer software

Data analysis: You will need to make graphs and do computations on the raw data. We will use Python and the two of its function libraries, Matplotlib and NumPy. More specifically, we will use Python in the online Google Colaboratory environment:
https://colab.research.google.com

Alternatively, you can also use MatLab for data analysis, which has functions similar to the above Python libraries. MatLab is available for free from the university's software webpage:
https://www.wm.edu/offices/it/services/software/licensedsoftware/mathstats/matlabstud/index.php

In many cases, a computer spreadsheet can be used for simple data analysis and plotting (e.g. MS Excel, Google Docs).

Report writing: In physics and mathematics, LaTex is the standard program for writing and formatting scientific papers. It is specifically designed for handling formulas, figures with captions, and tables. It is available for computers with Windows, Apple, and Linux operating systems. There are many Latex editors and compilers, but the easiest way to get started is with the on-line Overleaf environment:
https://www.overleaf.com

Important academic deadlines

Add/drop deadline: Monday, September 12, 2022
Withdraw deadline: Monday, October 31, 2022

Weekly Schedule (tentative)

Week 1: 8/31-9/1 **Introduction to Error Analysis**
Basic error estimation, basic error propagation.

Week 2: 9/7-8 **Data Analysis and Scientific Writing**
Plotting data, Python (Matplotlib & NumPy), MatLab, Excel, LaTex.

Week 3: 9/14-15 **Experiment 1: Optical Interferometry I**
Pre-lab exercise & reading, experiment setup, data taking, basic data analysis.

Week 4: 9/21-22 **Experiment 1: Optical Interferometry II**
Data analysis, improved data, write lab report (due following week).

Week 5: 9/28-29 **Experiment 2: Black Body Radiation I**
Pre-lab exercise & reading, experiment setup, data taking, basic data analysis.

Week 6: 10/5-6 **Experiment 2: Black Body Radiation II**
Data analysis, improved data, write lab report (due following week).

Week 7: 10/12-13 **Fall Break – no lab**
Whoo-hoo!

Week 8: 10/19-20 **Experiments 3-4: 1-γ Interference & Faraday Rotation**
Pre-lab exercise & reading, experiment setup, data taking, basic data analysis.

Week 9: 10/26-27 **Experiments 3-4: 1-γ Interference & Faraday Rotation**
Data analysis, improved data, write lab report (due following week).

Week 10: 11/2-3 **Experiments 4-3: Faraday Rotation & 1-γ Interference**
Switch: Pre-lab exercise & reading, experiment setup, data taking, basic data analysis.

Week 11: 11/9-10 **Experiments 4-3: Faraday Rotation & 1-γ Interference**
Data analysis, improved data, write lab report (due following week).

Week 12: 11/16-17 **Experiment 5: Superconductivity I**
Pre-lab exercise & reading, experiment setup, data taking, data analysis, lab report.

Week 13: 11/23-24 **Thanksgiving Break – no lab**
Note: Superconductivity lab report due Week 14.

Week 14: 11/30-12/1 **Special Project I**
Pre-lab preparation, experiment setup, data taking, basic data analysis.

Week 15: 12/7-8 **Special Project II**
Data analysis, improved data, presentation preparation.

Dec. 13, 2022, 2-5 pm **Final Presentation (Thursday section)**
Dec. 19, 2022, 2-5 pm **Final Presentation (Wednesday section)**