Modern Physical Measurements (Phys 520/w1661), Fall 2021

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Course Objectives

This course is an introduction to laboratory techniques with an emphasis on measurements related to modern physics. Students will learn the skills of experimentation including operation of equipment, collection and analysis of data, and presentation of findings.

Textbook and References

There is no available textbook that covers all the topics in the course. We will use techniques of data analysis which include error analysis and curve fitting. There are a number of good references that cover these topics. The recommended reference is "Measurements and their Uncertainties", I. G. Hughes and T. P. A Hase, Oxford, 2010. This is available as an ebook to view from the Pitt library at Pitt Library ebook

`https://pitt.primo.exlibrisgroup.com/permalink/01PITT_INST/g3767l/alma9998511997106236`

A link to the ebook is also provided in **CANVAS**. Additional useful references include:

- "Experiments in Modern Physics", A. Melissinos, Academic Press, 2003.
- "The Art of Experimental Physics", D. Preston and E. Dietz, Wiley, 1991.
- "Experimental Physics: Principles and Practice for the Laboratory", Walter F. Smith, Taylor & Francis, 2020.

Course Structure

This lab course is designed to be a hands-on learning experience. Each student will perform a total of six experiments over the course of the semester. There are two preparatory experiments (Group **I**) and four experiments grouped by topic (Group **A, B, C**, & **D**).

Group **I** (Introductory)

- Numerical methods: practice using the data analysis software tool **python**.
- Test Measurements: Operating test and measurement equipment (oscilloscopes, DMMs, waveform generators, etc).

The Group **I** will be completed individually by each student. After completing the introductory experiments, students working in pairs will perform one experiment from each topic **A, B, C**, & **D** in rotation.

List of Experiments

Group **A**

- LRC circuit (2 setups)

Group **B** (Quantum Mechanics)

- Photoelectric effect
- Blackbody Radiation

Group **C** (Resonance)

- Acoustic cavity modes
- Acoustical gas thermometer

Group **D** (Statistics with SPAD)

- Statistics with Single photon avalanche photodiode (SPAD).

Each experiment will take approximately 2 weeks to perform and analyze. A writeup will be submitted for each of the experiments performed (a python notebook will be submitted for the Numerical Methods lab, more details will be provided).

Experiment	Start Date	**Completion**	Report Due
Group **I**(1)	9/2 (Thursday)	9/14 (Tuesday)	9/19 (Sunday)
Group **I**(2)	9/16	9/28	10/3
Rotation 1 (Group **A**-**D**)	9/30	10/12	10/17
Rotation 2 (Group **A**-**D**)	10/14	10/26	10/31
Rotation 3 (Group **A**-**D**)	10/28	11/9	11/14
Rotation 4 (Group **A**-**D**)	11/11	12/3	12/9 (Thursday)

Students are strongly encouraged to keep up with the work. Assignments submitted after the deadline will be penalized for lateness.

Lab Materials

You should prepare by for each experiment by reading the write-up and other posted materials before you start each experiment. Lab write-ups for each experiment as well reference material can be downloaded from the class **CANVAS** page.

Logbooks Each of you is required to keep a bound lab notebook to log information while performing the experiment. Please purchase a bound logbook for this purpose. You should keep a complete record of your experimental work in this logbook. Use it to keep track of all that you do to perform the experiment, for example, the experimental parameters, the changes you made, the data tables, conditions, etc. You may also include

sketches of the apparatus and details on alignment and calibration steps where applicable. It may also be used to outline analysis steps, calculations, and perhaps preliminary plots of the data. You need not be concerned style here- completeness and accuracy are the goals. However, the work must be legible and well organized enough to follow. Maintaining a complete and organized record of the experiment in your logbook is considered an essential part of the lab work. **A scan or photo of your logbook pages must be uploaded along with each report**. The logbook work will count as a fraction of your grade for each assignment.

Lab Reports

Results of the two introductory experiments will be submitted in an informal format. In the case of Numerical Methods, students should submit and annotated version of the python notebook (.ipynb). For the test measurements experiment, the detailed logbook notes and calculations produced while performing the experiment along with the answers to questions should be submitted. (Please be as neat as possible).

The results from experiments in Groups **A-D** will be written up and prepared as a report by each individual student (not in teams). The Lab Reports are required to have the following sections:

1. Logbook notes scan (must be legible and well organized) [10 points]
2. Introduction and Experimental Technique [20 points]
    - Summarize the background physics and how it is related to what is measured or sought. You should provide important formulas and explain how you will determine the quantities of interest (you do NOT need to derive formulas in the report). Also include diagram or sketch of the apparatus and describe in your own words how the experiment works and how the data were taken. You should not repeat content directly from the write-up. This section should be brief (less than two pages).
3. Analysis and Results [40 points]
    - This section includes a presentation of the data (in plot format and/or in tabular format). Each plot should have a Figure number and a caption and be referenced from the text. A full description of how the data were analyzed (including corrections and calibrations needed) and an outline of the calculations for arriving at the result should also be presented in the text.
4. Analysis of Uncertainties and Discussion [30 points]
    - An important part of the result is an estimation (and justification) of uncertainty in the measured quantity or quantities. The rationale for the uncertainty estimate and any related calculations (propagation of uncertainties, etc. should be presented in this section. This section must also include a discussion of the results. The discussion should center around the agreement

or disagreement with the prediction. If disagreement is found the probably cause(s) should be further discussed. (If applicable, This section should also include answers to discussion questions in a separate subsection or appended).

Students taking the writing option will have additional requirements which are outlined in the writing option document and will be discussed in a separate meeting with the instructor.

Grading
Your graded work will be weighted to determine your course grade.

Lab	Fraction
Introductory 1 & 2	10% each
Group **A** - **D** labs	20% each

Academic Dishonesty: Plagiarism and cheating are serious offenses and will not be tolerated. Punished may include failure on the exam; failure in the course; and/or expulsion from the university.

Accommodation for Disability If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services, 216 William Pitt Union, (412) 648-7890/(412) 383-7355 (TTY), as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.