Modern Physical Measurements (Phys 520/w1661), Fall 2025

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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 (See link in CANVAS). I have also posted three Zoom lectures which discuss data analysis techniques in CANVAS (See Uncertainties Lectures Module). Additional useful references with information about measurement techniques and instruments include:
Experiments in Modern Physics, A. Melissinos, Academic Press, 2003.
Experimental Physics: Principles and Practice for the Laboratory, W.F. Smith, CRC Press, 2020.
(Both references are available in the lab.)

Course Structure

This lab course is designed to be a hands-on learning experience. There are a total of seven labs in the course. Three are preparatory labs (Group **I**) which serve as an introduction to data analysis tools (Python) and basic scientific measurement instruments. These will be followed by "Rotations" through four experiments grouped by topic (Group **A, B, C**, & **D**).

Group **I** (Introductory)

1. Numerical Methods (4 lab sessions): Learn **python** and data analysis to prepare for the subsequent labs.

2. Test Measurements (3 lab sessions): Learn how to use test and measurement equipment (oscilloscopes, DMMs, waveform generators, etc).

3. RC Circuit (3 lab sessions): Study characteristics of simple RC circuits and learn to use spectrum and network analyzers.

Numerical Methods will be completed individually by each student while for Test Measurements and RC Circuits students have the option to work in groups or individually depending in individual preference. After completing the introductory experiments, students will work in pairs to perform one experiment from each topic **A, B, C**, & **D**.

Group **A** (Resonance)
Acoustic cavity modes
RLC circuit

Group **B** (Foundations of Quantum Mechanics)
Photoelectric effect
Blackbody Radiation

Group **C**
Optical Spectroscopy and the structure of atoms

Group **D**
Detecting and counting single photons with an avalanche photodiode (SPAD).

Each experiment will take approximately 2 weeks to perform and analyze. A lab report (details below) will be due a week after the final lab session for each experiment. Submissions will be in the form of a .pdf upload to CANVAS. The Numerical Methods lab submission will be in the form of a python notebook (with annotations). **Please name the files using your last name and the name of the lab** (abbreviated form of name is fine). For example, my lab report for the SPAD lab would be named: Naples_SPAD.pdf or something similar. A tentative schedule is shown below (the due dates will also be available in CANVAS).

Experiment	Start Date	**Completion**	Report Due
Group **I**(1)	8/26	9/4	9/11
Group **I**(2)	9/9	9/16	9/23
Group **I**(3)	9/18	9/25	10/2
Rotation 1 (Group **A**-**D**)	9/30	10/9	10/16
Rotation 2 (Group **A**-**D**)	10/14	10/23	10/30
Rotation 3 (Group **A**-**D**)	10/28	11/6	11/13
Rotation 4 (Group **A**-**D**)	11/11	11/20	12/4

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

Lab Preparation

Lab write-ups for each experiment as well reference material can be downloaded from the class **CANVAS** page. You should prepare by for each experiment by reading the write-up and other posted materials before you start each experiment. Most labs include a series of Prelab questions. The Prelab should be completed before coming to the lab. It will be graded as part of the lab report.

Lab Notes and Logbooks

Each of you is required to keep a lab notebook to log data and other information while performing each experiment. You may purchase a bound logbook or use an electronic note taking platform (Googledocs, Evernote, etc.) 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, relevant changes, the data tables, conditions, etc. You may also include sketches of the apparatus and details on alignment and calibration steps where applicable. 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. Even if you perform the experiment with a partner, **you are required to keep your own individual copy of the lab notes including analysis and calculations. Your lab report submission will include a .pdf upload of the lab notes in electronic or scan form.** The logbook work will count as a fraction of your grade for each assignment.

Lab Reports

Results of the introductory experiments will be submitted in an informal format. This should include lab notes, data tables, plots and sketches along with an calculations required and answers to the posed write up questions. In the case of Numerical Methods students should submit an annotated version of the python notebook saved in .pdf form. (make sure plots are visible in the file and scaled appropriately).

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

    - This may be uploaded as a separate .pdf file. It must be well organized; and if hand written neat and legible.
    - Raw data should be in the form of tables with well organized rows and columns that are clearly labeled. All important experimental details including parameters and conditions should be noted. The data tables should include appropriate units if applicable (in column labels). You may also include sketches of the apparatus and details on alignment and calibration steps where applicable.

2. Introduction and prelab questions

    - In your own words, briefly summarize the goals of the experiment and how the measurement will be performed. Any formulas you will use to perform the measurement should be included along with definitions of all symbols. Describe in your own words how the experiment works and how the data were taken. If applicable, include diagram or sketch of the apparatus and You should not repeat content directly from the write-up. You should also include

answers to prelab questions if applicable. This section should be brief (less than two pages).

3. Presentation of Data and Data Analysis

   - This section includes a presentation of the data in table and/or plot format. Each Table and plot should be labeled and have a caption that explains what is in it. Tables need to have clearly labeled columns and rows (with units!). In the case of a plot, include a legend to describe the plotted data points, fits, and/or theory curves if relevant. Plots and tables should be referenced by number from the text where they are discussed.
   - Show and explain how you use your raw data to compute quantities of interest. 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 be presented in the text.

4. Results and Discussion

   - This section should state the main result(s) of the experiment. A crucial 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 included. If multiple trial measurements are performed, you should compare the results.
   - The discussion should also include a comparison with prediction or theory, if applicable. The discussion should center around the agreement or disagreement in the context of the measurement uncertainties (statistical and systematic). If disagreement is found the probable 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	20%
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.