**Modern Physics Laboratory (PHYS 1426/W1626), Spring 2025**

## Course Information

**Instructor**: Dr. Joyce Jiang
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**Lab manager**: Dr. Istvan Danko
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**Lecture**: 106 Allen Hall; Thursday 11:00 – 11:50 AM
**Lab**: 324 OEH for numerical methods, 318 OEH for other experiments; Thursday 1:00-3:50 PM
**Prerequisites**: PHYS 477 (Modern Physics) and PHYS 525 (Analog and Digital Electronics)

## Course Objectives

This course is designed to train students in experimental modern physics. Emphasizing on hands-on techniques for data collection, data analysis and presentation of results.

### 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 book is "Measurements and their Uncertainties", I. G. Hughes and T. P. A Hase, Oxford, 2010. This is a practical introduction and guide to error analysis specifically for undergraduate students in the physical sciences. It 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`

The following texts may also be useful references (and are available for borrowing upon request).

- "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

The class has two meeting times on Thursdays from January 9 - April 17.

- **Class (11:00-11:50 AM)**
  - Class time will be used for lectures on special topics, statistics and data analysis as well as for Q/A breakout sessions.

  - Towards the end of the semester the class time will be used for student presentations (schedule TBD).

- **Lab (1:00-3:50 PM)**
  - Lab sessions will be used for performing experiments as well as for help with data analysis after the data taking phase of the experiment is completed.

In this semester, each student will perform three experiments (see Experiment List below) plus one online exercise to introduce techniques needed for data analysis (Numerical Methods Lab).

The Numerical Methods Lab will be completed individually by each student in the first two weeks of class. After Numerical Methods, you will perform 3 experiments selected from the Experiment List below (besides Numerical Methods). Each experiment will take four weeks to perform and analyze. The report for each experiment will be due on Wednesday at 11:59 pm after the experiment is completed (the day before the new experiment starts). There will be no written exam for this class, instead, one experiment will be chosen in consultation with the instructor and presented to the class at the end of the semester as the final presentation.

**Timeline**

| **Experiment** | Start Lab | Finish Lab | Report Due at 11:59 PM |
|---|---|---|---|
| Numerical Methods | Jan 9 | Jan 16 | Jan 22 |
| Experiment 1 | Jan 23 | Feb 13 | Feb 19 |
| Experiment 2 | Feb 20 | Mar 20 | Mar 26 |
| Experiment 3 | Mar 27 | Apr 17 | Apr 23 |

**Experiment List**
**Select your 3 experiments + 1 backup by completing the quiz on Canvas by Jan 19.**

- Numerical Methods (mandatory for everyone)
- Acoustical cavity modes*
- Acoustical gas thermometer*
- Black-body radiation*
- Chaotic circuit
- Electron spin resonance
- Fundamental Noise
- Mass spectroscopy
- Muon lifetime

- Nuclear Magnetic Resonance
- Optical spectroscopy and the structure of atoms*
- Photoelectric effect*
- Radiation detection and nuclear structure
- RLC resonance*
- Scanning tunneling microscope
- Single photon avalanche detector (SPAD)*
- Single photon interference (two slits)†
- Single photon interference (which way)
- Ultrasound†

You can choose * experiments only if you did not do PHYS 520 (Modern Physics Measurements)
You can choose † experiments only if you did not do these experiments in PHYS 1361 (Wave Motion and Optics)

**Requirements**

1. **Before Lab**
   Before you start a new experiment, you should prepare by reading the lab writeup and additional materials posted in Canvas. Before you come to the lab, you need to write a brief summary of the motivation for the experiment, what you are going to measure and how. Use your own words and do not just copy sections of the lab writeup. Most experiment writeups also include prelab questions; you should answer these questions as well based on your understanding of the material. This part of the work may be checked by the instructor before you start the lab session.

2. **During Lab: Logbooks (Data Collection)**
   Maintaining a complete and well-organized record of the experiments is an essential part of the lab work. You can use either an electronic or a physical notebook as you prefer. Use it to keep track of everything that you do in the lab, including but are not limited to:
   (1) Describe the experimental setup and conditions as appropriate.
   (2) Include sketches of the apparatus with labels of different components and connections between them.
   (3) Describe alignment and/or calibration procedures as needed.
   (4) Record all the data neatly in appropriate tables and explain what is measured and for what purpose. If there are lots of data points, you can use Excel or other spreadsheet program to record your data. Make sure you copy (or print) and paste these data tables and plots into your notebook.

Every data entry should be dated and be detailed enough so that you (or someone else) can reproduce the experiment based on your notes. Do not leave gaps to be filled in later and do not count on your memory to remember experiment details. Never erase anything (or remove any page) from your notebook. If something needs to be corrected, you cross it out and make a note. 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.

3. **After Lab: Lab Reports**
   In the case of the Numerical Methods lab, you only have to submit a PDF printout of the annotated version of your Python notebook with all code, results, and plots included. For the other 3 experiments, you have to submit your lab report. Even if you work with a lab partner, you will have to keep separate lab notes and perform data analysis individually. Your complete lab report will have four parts (see below). The lab report must be well-organized, concise, and easy to follow. Nowadays, electronic notebooks (e.g. MS OneNote or Evernote) are preferred and more convenient than physical notebooks but you can use either. However, if you write your notes/comments by hand, make sure your handwriting is neat and easily readable. If that is not the case, then you will need to type your notes before submitting the lab report for grading. In either case, you will have to submit a PDF copy of your electronic or physical lab report at the end of each experiment.

## Lab Report Format

1. **Introduction and Experimental Technique**
   Summarize the background physics and how it is related to what is measured. 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).

2. **Logbook Notes**
   must be legible and well-organized, details see section above *During lab: Logbooks (data collection)*)

3. **Analysis and Results**
   Use your raw data to compute quantities that you can compare with theory. Present your data preferably in a computer-generated graph and indicate your fit or other theoretical trend line on the graph. Include a descriptive title for every figure/table and indicate measurement error (error bar), axis labels, and units. Describe how the data was analyzed, and present any necessary calculations for achieving the result.

**An important part of the result is the uncertainty analysis in the measured quantities.** The rationale for the uncertainty estimate and any related calculations (propagation of uncertainties, etc. should be presented in this section.

4. **Conclusion and Summary**
   Summarize the main results of the experiment. Compare the result with expectation (theoretical or other experimental) in terms of the statistical uncertainty of the measurement and discuss agreement or disagreement. You should also consider and describe any systematic effect/uncertainty that may have caused a discrepancy.

**Grading**

Your graded work will be weighted to determine your course grade. Late penalties will be applied for assignments submitted after the official deadline (10% per week). The final grade will be determined based on the total score percentage as follows >90% (A), >80% (B), >70% (C), >60% (D) with the top and bottom 1/3 in each decade earning a + or – designation.

| **Lab** | Fraction |
|---|---|
| Numerical Methods | 10% |
| Lab Writeups | 25% each |
| Homeworks (if any) | 10% each |
| Presentation | 15% |

**Writing option (this section is only for students taking PHYS 1626)**

To satisfy the writing option requirements, you will need to write two formal papers based on the first two experiments in addition to the regular lab report you submit for PHYS 1426. The formal papers are expected to be an expanded and improved version of your lab report both in style and content. They must follow specific rules and conventions that are typically required from manuscripts submitted for publication in scientific journals. Your instructor will play the role of the editor/referee and will make comments and suggestions based on the first draft of your paper before you submit the second and final version for grading. The formal paper and draft must be prepared using LaTeX typesetting (MS Word may also be used if necessary) and submitted in PDF format. Detailed guidelines and due dates will be provided later.

**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.