Syllabus for Advanced Experimental Physics: PHYS-UA112/PHYS-GA2075

Instructor: L. Andrew Wray (lawray@nyu.edu)
Teaching Assistant: David Stickles (djs754@nyu.edu)

This course provides an opportunity for physics students to have an intensive laboratory experience that concentrates on experiments in 20th-century physics. Each student will work alone or with a partner on three experiments over the course of the semester and write a detailed lab report for each of those experiments. Students will also have the opportunity to give a short slide presentation to the rest of the class describing one of the experiments he/she worked on. The course grade will be determined by the quality of the work done in the lab, the laboratory reports and the class presentations. Class meets once per week on Wednesdays from 12:55 PM to 4:55 PM in Room 202 Meyer Building. If needed, additional time in the lab will be made available on an individual basis. **If you are not planning to attend the start of the course in person, please contact me as soon as possible - preferably before the first day of class.**

The experiments that are potentially available during any given semester are as follows:

1. Relativistic Electron Momentum
2. The Muon Lifetime
3. Pulsed Magnetic Resonance and Spin Echo
4. Rutherford Scattering
5. The Mössbauer Effect
6. Magnetic Susceptibility Under Phase Transitions
7. Optical Pumping of Rubidium
8. Diode Laser Spectroscopy
9. Quantized Conductance
10. Quantum Optics of Photon Pairs
11. Laser particle trapping and Brownian motion

A detailed description of these experiments, including pdf instructions for download, can be found at:

http://physics.nyu.edu/~physlab/Experimental_Phys/Experimental_phys.html

Options for remote data analysis projects are discussed in a separate document hosted on the NYU Classes page (titled **"AEL Data Analysis Projects Fall 2021.pdf"**).

It is assumed that students entering the course have the following skills and knowledge:

- Familiarity with estimation of errors for various kinds of measurements.
- How to propagate errors from directly measured quantities to the physical quantities being measured.

- Properties of the Poisson and Gaussian distributions, including the relationship between the mean and variance, and examples of physical process that produce these distributions.
- How to display data in an attractive easily readable form with the use of plotting software, such as Python or Matlab.
- Most remote projects will require some basic comfort with one programming language. We recommend using a profiling language such as Python or Matlab, but other high level languages such as C/C++ are also suitable. If you are not comfortable with programming, your first project can be defined to support the acquisition of this skill.
- Techniques of curve fitting and parameter estimation.
- It is strongly recommended that students complete at least one semester of quantum mechanics before enrolling in the course.

Descriptions and other information about the experiments are available on the course website, which you can access through NYU Home. You'll find information about the experiments in the "Course Documents" section of the course web pages. During the semester, each student will do three of the above listed experiments. Each experiment will be done by groups of two students, and will take four weeks to complete. On the first day of class, the instructor will briefly go over the experiments. You will then make a list of preferences for the experiments and then it will then decide who does what experiments. During the remaining time of the first class, you will start working on the experiment, mainly to familiarize yourselves with the equipment. Each experiment has a writeup and/or other supporting information. Please look over this information before the first class, so you can make a more informed choice of what experiments you would like to do during the semester.

Requirements

- For each experiment performed by a student s/he should produce a lab report. Joint reports by lab partners are also acceptable. See the next section for more information on the lab reports.
- Each student should have a bound lab notebook (can be spiral bound), into which s/he records all data, and other notes related to the experiment (e.g., file names of oscilloscope data saved to the computer). This notebook should be brought to all lab meetings, and to the lab at other times data are being collected. I will periodically ask to see the contents of your lab notebook.
- During the last class of the semester, we will have a "mini symposium" where each group presents one of the experiments done in class as if they were presenting it at a scientific conference. The duration of the talks will depend on the class size.
- You are required to attend class during most of the scheduled class time. If you must miss a class, you are required to have a legitimate excuse, and must inform me in advance if possible. You will also be expected to make up for the missed time.
- Do not bring food or drink into the lab. If you need to have a snack at some point during the lab period, you are free to leave the lab for a short time.

Laboratory Reports: Procedures and Format

Procedures

Reports will be due two weeks after a given experiment is completed (due dates are listed at the end of this document). Please turn in an e-copy by emailing me directly or uploading the report to the course website. For Lab Report 1, I will read the first draft of your report within ca. one week and will probably ask you to make revisions, in which case the revised version should be uploaded within one week after I have sent you my suggested revisions.

You should not spend extended class time working on your reports, although you are welcome to discuss the details of your report with me during class. It is probably a good idea to think about your analysis and report before you are completely finished taking data.

If you like, you may turn in a single report for the group. You may also turn in separate reports. In either case, both members of a group are responsible for all aspects of the report (from analyzing the data to producing the final text of the report). For example, if a computer program is written to analyze data, both students should understand in detail how this program works. If you write a single report, both contributors will receive the same grade. If you write separate reports, it is possible the grades will differ.

When doing experiments, it is important to look at and think about the collected data as they become available. To encourage this habit, I advise you to tabulate as well as plot (if appropriate) any data you collect in a given week and look it over, with your partner, before you continue in the following week. Data, such as oscilloscope traces with more than a few hundred points, need only to be graphed [not tabulated]. Graphs of data should be drawn using a profiling language such as Python, Matlab, or Mathematica, with clearly marked axes, and a caption. If further annotation of figures is needed, it can be done with vector graphics software such as Powerpoint, Adobe Illustrator, or Corel Draw. Do not use Excel to plot your data.

Format

The report should be a well written (complete sentences, correct grammar, etc.) readable document, intended to provide enough information for the reader to reproduce your experimental results, in principle (as would be the case in an actual research paper). It should be typed (including equations). The scientific typesetting program LaTeX is **strongly encouraged**, but you will turn in a PDF document. Be sure to date your report (with the date you turn it in) and number the pages. I will provide help for anyone who wishes to write up their report using LaTeX. There is an *example lab report* written in LaTeX in the Course Documents section of the course web pages. It contains further information about how your lab report should be formatted and organized. You can also download all the files required to produces this example lab report. These files will provide a template for you to use.

The format for the reports should be roughly as follows:

- **Abstract:**
  This consists of few sentences stating what was measured, the result of the measurement, and any significant conclusions.
- **Introduction:**
  This section briefly lays out the objective of the experiment and its connection with relevant theory. You can assume that the reader is familiar with the theory presented in

the instructions, so you should not simply repeat what is said there. You should concentrate on the specific aspects of the theory that are most relevant to the experiment.

- **Theory:**
  Depending on the level of detail of the theory you are presenting, you can put the theory in its own section.
- **Methods:**
  Here you should describe the arrangement of the apparatus and the experimental procedures used. The description of the experimental procedure should include details and observations that are not explicitly discussed in the instructions. If you are counting particle detections, for example, you should state the period of time over which you accumulated counts. The experimental description should also contain a discussion of problems encountered in carrying out the experiment and how these problems were solved. In other words, include any relevant information that the interested reader would need to check your results. In other words, this section will tell a reader how you conducted the experiment, and this may differ in certain respects from the instructions.

- **Results and Discussion:**
  This section should include any tables or graphs of data, as well as any analysis, discussion and conclusions derived from your data.

  All data (except oscilloscope traces) should be presented in tables. If these tables are long, place them in an appendix at the back of the report, but include any graphical representation of the data in the body of the report. As noted above, graphs of data should be drawn using some kind of graphing software, with clearly marked axes, and a caption. All diagrams, figures, and graphs should be labeled below with "Figure 1", "Figure 2", . . . in ascending order. For example "Figure 3: Graph of counts vs. time delay".

  Your data analysis should always include an error analysis, providing an estimate of the experimental uncertainty in any measured quantities. If you write your own computer program for this analysis, please include it in an appendix. In the analysis, indicate the formulas used, the units of each quantity entering the equations, and a numerical example for each computation. Statistical and systematic error should be clearly distinguished and you should indicate how the assignment of error was made. Graphs should be presented with the error of each experimental point indicated.

- **Conclusion:**
  The conclusion should include a discussion of whether your results are in agreement with the theory and/or the accepted values within your estimated experimental uncertainties. If they do not agree, can you suggest plausible reasons for the disagreement? You may also suggest ways to improvement the experimental protocol.

- **Bibliography:**
  If you use information obtained from any articles or books, you should cite the source in the body of the report, and include a reference list at the end. You may cite and reference the lab instructions that you used to guide you through the experiment.

Questions

Some of the instructions include a Questions section. You'll notice that the format of the report described above does not include a Questions section. Answers to these questions should be integrated into your report at the appropriate place, for example, in the "Results and Discussion" section.

Plagiarism

Copying text you find elsewhere into your lab report without using quotation marks and citing the source of the original text is plagiarism, and inexcusable. Similarly, if you use figures from another source (that is, figures that you don't create yourself) you must cite the source of the figure. The sample lab report (course web site) shows an example of how you can do this.

If it is found that you plagiarized your report or part of your report, **you will fail the course.**

Due Dates for Lab Reports

Assignment	**Due Date**
First Class: Intro and choice of Experiments	Sept 8
Work on Lab 1	Sept 15 Sept 22 Sept 29 Oct 6
Lab 1 Draft Due + Work on Lab 2	Oct 13
Lab 1 Instructor Comments + Work on Lab 2	Oct 20
Lab 1 Final Due + Work on Lab 2	Oct 27
Lab 1 Graded + Work on Lab 3	Nov 3
Lab 2 Final Due + Work on Lab 3	Nov 10
Lab 2 Graded + Work on Lab 3	Nov 17
No Class	Nov 24
Lab 3 Due, No Class	Dec 1
Presentations	Dec 8

Deadline extensions will be granted upon reasonable request. If your work involves remote projects, you will be given a new list of due dates specific to each project.