Syllabus for (Advanced) Experimental Physics: PHYSUA112/PHYSGA2075

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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.

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 (***although not necessarily completely up to date***) description of most of these experiments can be found at:
`http://physics.nyu.edu/~physlab/Experimental_Phys/Experimental_phys.html`

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.
- 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 he/she 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 he/she 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). I will ask you to turn in an electronic copy by email or by uploading the report to the course website. I will read the report within one week and will probably ask you to make revisions, in which case the revised version should be handed in (i.e., emailed or uploaded) within one week after I email 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.

When doing experiments, it is important to look at and think about the collected data as it becomes available. To encourage you to do this, I will ask you to tabulate as well as plot (if appropriate) any data you collect in a given week and turn it in to me no later then the Tuesday of the following week. (Data, such as oscilloscope traces with more than a few hundred points only need to be graphed [not tabulated].) Graphs of data should be drawn using some kind of graphing software, such as Python or Mathematica, with clearly marked axes, and a caption. 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 in an actual research paper). It should also be typed (including equations). The scientific typesetting program LaTeX is **strongly encouraged**, but other writing software is acceptable with permission from the instructor. Also, please 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:**
  You should briefly discuss the objective of the experiment and its connection with relevant theory. You can assume that the reader of the report is familiar with the theory presented in the write-up, so you should not simply repeat what is said there. You should concentrate on the aspects of the theory that are specialized 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 writeup. 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.

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

  All data (except oscilloscope traces) should be presented in tables. If these tables are long, they should be placed in an appendix at the back of the report, with any graphical representation of the data in the body of the report. 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 and include a caption. For example "Figure 3: Graph of counts *vs.* time delay".

  The analysis or your data should always include an error analysis, providing an estimate of the experimental uncertainty in any measured quantities. If computer programs are used for analysis, they should be included 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 it should be indicated 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

an/or the accepted values *within your estimated experimental uncertainties.* You should also include any other significant observations.

Suggestions for improvement of the experiment can also be made in the conclusion. Also, please point out any places where the experimental writeups are incorrect or difficult to understand (also, please send me such information in an email).

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

Questions

Some of the writeups (documents that describe the experiment and procedure) include a *Questions* section. You'll notice that the format of the report described above does not include a **Questions** section. The answers to the questions given in the **Questions** section of the write-up's should be integrated into your report at the appropriate place, for example, in the "Results and Discussion" section.

Plagiarism

You are not allowed (it is never allowed) to copy text you find elsewhere into your lab report without putting it in quotation marks and citing the source of the original text. Doing this is called plagiarism. Also, if you use figures from another source (that is, that you don't create yourself) you need to cite the source of the figure. The sample lab report (available on the 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.** You may find it surprising how easy it is to recognize plagiarism.

Due Dates for Lab Reports

Assignment	Due Date
First Class: Intro and choice of Experiments	Jan 30
Lab 1 Draft Due	March 6
Lab 1 Instructor Comments	March 13
Lab 1 Final Due	March 27
Lab 1 Graded	April 3
Lab 2 Final Due	April 10
Lab 2 Graded	April 17
Lab 3 Due	April 24
Lab 3 Graded	May 1
Presentations	May 8