PHY4803L Syllabus
Spring 2019

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Contact Information

See the course homepage at http://www.phys.ufl.edu/courses/phy4803L/ for instructor contact information and office hours.

Course Evaluations

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results.

Course Objectives

For each experiment you perform in this laboratory you will be expected to demonstrate an understanding of the underlying physics, the experimental apparatus, the measurement techniques, and the data analysis. You should reach a level of mastery sufficient to suggest and explore such experimental refinements as improving the quality or quantity of the data, expanding the analysis, or widening the scope of the measurements beyond what is suggested in the handouts.

During your time in and out of the lab, you will:

- Learn new physics regarding the systems explored in the experiments.
- Use modern instrumentation and data acquisition computers to collect data on those systems.
- Learn about measurement uncertainty and systematic error and use statistical analysis procedures to determine experimental parameters and their uncertainties.
- Learn how to keep a lab notebook and how to communicate experimental results in a variety of formats.
- Learn the various concepts involved in designing a physics experiment.

General Instructions

Work will be performed in groups of two students with the experiment and partner rotations worked at the beginning of the semester. There will generally be seven sessions to finish each experiment with a total of four experiments to be completed during the semester. The fourteen available experiments are classified into four groups: (1) Particle Physics, (2) Condensed Matter Physics, (3) Spectroscopy, and (4) Other Topics. Try to avoid more than two experiments from any one group. You will give an oral presentation on the final experiment of the semester.

Lab Attendance Policy

Students are only allowed access to the laboratory equipment and computers during the lab access hours. It is very important that you attend at these times and that you use your time with the equipment wisely. Attendance will be taken via sign-in sheets. In addition, faculty will notice individual absences on the experiments. Attendance will affect performance in two ways, via pass/fail on individual experiments and through an attendance factor.

Attendance factor: Your presence in the lab is also monitored. Late arrivals, leaving the lab early, and being absent from the apparatus for extended time during the lab will be noted by the faculty on the sign-in sheet. Points earned per experiment will be scaled by the fraction of time you have been recorded as being in the lab and working on the experiment.

For example, a student has left his or her station for an hour without excuse during one of the rotations. Therefore, the student has spent 20/21 hrs of that rotation working on the experiment. The student's report was graded at 85 points. Due to the attendance factor, the report will contribute 85*20/21 = 81 points in the final grade calculation.

Several experiments have unusual data taking conditions which require additional access to the equipment. The additional/extended access will be arranged between the students performing the experiment and the instructors and *will not count to offset absence during normal lab hours.*

Failing an Experiment: Each rotation consists of seven 3-hour sessions. Unexcused absence from three or more sessions automatically leads to failing a rotation: no points will be assigned in any category for this experiment. Failing two or more rotations automatically leads to failing the class.

Special Circumstances: Excusing absence after-the-fact requires providing a letter from the dean of student affairs' office. Planned absences can be excused ahead of time, and involve discussion with the faculty and the lab partner.

Preparation

It is important to get up to speed quickly on each experiment. The first day of an experimental rotation should be spent working with the apparatus and getting a start on the experimental procedures and *not* reading the writeup for the first time. To prepare for the next experiment and complete the exercises on time, be sure to get the writeup at least one full week (two sessions) ahead. Read it and try out the exercises before the first day that you will be working with the new experiment.

Grading

Please refer to the Course Schedule at the end of this document and also on the class website for a schedule of assignments and due dates. Lab reports/presentations and during-lab interviews (individual discussions with faculty documenting your understanding of the experiment, methods, underlying physics, analysis, etc...) each carry the same weight, 9 points. The presentation for the fourth experiment carries the same weight as a lab report, 9 points. This means that lab reports, presentations, and interviews carry a total of 8x9 = 72 of the 100 points.

The remaining 28 points are divided as follows: Each prelab exercise carries 4 points. Therefore, the lab assignments account for 16 points. The statistics homeworks and LaTex assignment each carry 3 points for a total of 3x4=12 points. The grand total is 100 points. The following table summarizes the breakdown of points.

item	**points each**	**line total**
3 lab reports	9	27
1 presentation	9	9
4 interviews	9	36
4 prelab exercises	4	16
3 stats assignments	3	9
1 LaTeX assignment	1	3

The grade scale is shown below.

85	80	75	70	65	60	55	50	45	40	35
A	A-	B+	B	B-	C+	C	C-	D+	D	D-

Late Assignments All assignments must be turned in at the beginning of class. Assignments turned in late will be given only partial credit. The partial credit factor will decrease by 10% every 24 hrs that the assignment is late. If the assignment is late between 10 minutes and 24 hrs, it will yield partial credit corresponding to 90% of its value had it been turned in on time. If it is between 24 and 48 hrs late, the partial credit factor will be 80% instead of 90%. Assignments can not be turned in more than a week late. Zero credit is assigned to an assignment overdue by more than a week.

Waiving overdue assignment penalties after-the-fact requires providing a letter from the dean of student affairs' office. Overdue assignments can be excused of penalties ahead of time in exceptional circumstances, with the approval of the instructors.

Lab Conduct

Please read the following section carefully:

Safety: We have tried to minimize hazards but there are always possibilities for injury. Follow all safety procedures for handling lasers, X-ray machine, radioactive materials, and high voltage sources.

Care: Take care of the equipment. Know how to use it. Do not make connections unless you understand what you're doing. Read the equipment manuals.

Courtesy: Keep your area clean. Return tools, equipment, etc. to their proper place. Do not remove equipment from other experiments! If you need replacement equipment, see an instructor.

You should demonstrate preparation and progress during notebook inspections and discussions, which will be conducted informally more or less every session. You should always be prepared to answer the following questions. What are you doing or about to do? Why are you doing it? What do you think will happen? Do *not* rely on your partner to answer these questions. Your "interview" grade will be based on your individual performance.

Do not wait until you are writing your report before you begin graphing and analyzing data. Mistakes are common in laboratory work and can often be discovered as the data come in by graphing and/or analysis. Graphs and analysis should be displayed in your lab notebook. Instructors will be looking specifically for them during discussions and notebook inspections. In addition, a "checkpoint" has been included in each experimental writeup containing benchmarks that should be achieved by the end of the fourth session of an experiment. Evaluating data as it comes in and meeting the benchmarks on time will be a significant part of your in-class performance score.

By the end of the sixth session, data acquisition and data analysis should be mostly complete, as should be your understanding of all aspects of the experiment. You may be individually interviewed during that period where you will be expected to show your data and analysis. The seventh session is to clean up any remaining details, work on the report and prepare for the next experiment.

Notebook/Flash drive

Please refer to the Laboratory Notebook Guidelines for details on maintaining a laboratory notebook. *Both partners in an experiment must keep his or her own complete notebook.* Bring your notebook to every lab session. Failure to do so will result in a grade penalty.

Bring a flash drive to each lab session for storing your data and other files for an experiment. Use a separate directory for each experiment and subdirectories within it when appropriate. Do not assume your data will be on the computer from one day to another. Backup your flash drive files to your personal computer after each session in case your flash drive is lost or damaged. Do not rely on your partner to keep track of your data.

Reports

Please read the handout Writing Scientific Reports Using LaTeX for additional information on writing lab reports. Whereas the notebook is written chronologically and is a complete record of what occurred in the lab, the report components can be placed in a more reader friendly order and can be more selective in content. Also keep in mind, many of the notebook guidelines apply to the report as well. The reports are limited to four pages. This will force you to make some judgment calls about what should be included and what has to left out. Any material beyond four pages will not be graded.

The report should be written in the the style of a scientific publication and should show that you understand the physical system under study, the apparatus, and the experimental results. Each member of a group should independently prepare their own report including figures. The sections listed below should be included. The points associated with each section are a rough guideline and not binding.

Abstract: (10%)
The abstract should briefly summarize the motivation, the method and most importantly, the quantitative results with errors. Based on those, a conclusion may be drawn.

Introduction and Theory: (20%)
This section should succinctly report the motivation, purpose and relevant background to the experiment. It should define all the major variables involved and provide equations and assumptions.

Apparatus and Experiment: (10%)
This section should provide schematics of the apparatus and discuss how the raw data are generated. It should also include an assessment of their random and systematic errors.

Analysis and Results: (40%)
This section should explain the data analysis and how it leads to the results, including random uncertainties and possible systematic effects.

Conclusions: (20%)
Summarize and discuss the findings of the experiment including quantitative comparisons between your results and theoretical expectations or other experimental values. Suggestions for experimental improvements and possible future studies are also appropriate here.

Appendices:
Here you may include any additional information and/or figures that do not fit into the four page limit. It should not be necessary to read this section in order to understand the main results and conclusions presented in the body of the paper.

Presentations

For rotation four, you will deliver a conference-style oral presentation of your work. In order to keep all of the talks within the time alloted for our lab meeting, strict time constraints will be enforced. Each group has 17 minutes to talk plus 3 minutes to answer questions from the faculty or other students. The 17 minutes should be divided roughly equally between the two members of a group, who should prepare the talk cooperatively and should agree before-hand how the speaking will be divided.

You should utilize visual slides that help to present your results and organize the flow of your presentation. Each group's slides should be in the form a single PDF file. This PDF file should be emailed to the instructors by 11:59 pm on the evening prior to the day of the presentations. This is necessary so that we can efficiently transition from one presentation to the next without delays. Other file formats, such as Powerpoint or Keynote are not acceptable.

We strongly recommend that you practice your talk several times before delivering your presentation in class. Given the short time alloted, you will need this practice in order to make sure that you can deliver all of the necessary information clearly and concisely. The breakdown of topics covered in your presentation should roughly follow the breakdown listed for the written reports, minus the abstract. "Appendix" slides at the end of your PDF file can be included that are not presented during the main body of your presentation, but may be shown in order to help answer questions from the audience.

In any scientific presentation it is important to tailor what you cover to the specific audience. For this presentation you need to provide enough background information that students that haven't performed your experiment can learn something. At the same time, you should provide enough detail that the instructors and other students that have performed your experiment can gauge your results and any technical issues you may have run into. Some useful (if technologically out-dated) information on scientific speaking can be found here: Advice on speaking.

Experiments

Our experiments range from simple to sophisticated on several levels. To help you decide which experiments to request, we have assigned scores from 1 (relatively easy) to 3 (relatively difficult) in the following three categories

Physics—the sophistication of the theory of the system under study.

Experimental technique—the sophistication of the apparatus and techniques used to make the measurements.

Analysis—the complexity of the data analysis required.

Brief descriptions of each experiment are given below along with their **PEA** scores based on the judgment of several instructors.

ACS *ac Susceptibility Measurements in High-*$\mathrm{T_c}$ *Superconductors:* **231** A magnetic susceptometer is used to observe the superconducting transition in a high temperature superconductor.

CP *Chaotic Pendulum:* **323** A driven pendulum-spring apparatus is used to study deterministic chaos in nonlinear dynamical systems. Special graphing and analysis techniques are used to display the data and determine invariants such as fractal dimensions and Lyapunov exponents.

CRM *Cosmic-Ray Muons and the Muon Lifetime:* **222** Four scintillation detectors and coincidence techniques are used to determine the flux and angular distribution of muons created in collisions of cosmic rays with atoms in the upper atmosphere. The muon lifetime is measured using rare events where, after passage of a muon into the system is detected, its decay is also detected. Statistical techniques for low counting rate experiments are employed.

FCS *Fluorescence Correlation Spectroscopy:* **322** Fluorescence correlation spectroscopy describes a range of techniques that use the fluorescence of diffusing molecules to measure dynamical properties of those molecules, including their rate of diffusion, chemical reaction rates, and more.

GGC *Gamma-Gamma Correlation:* **222** Two NaI detectors, and various nuclear instrumentation modules are used to observe the coincident emission of two photons arising from the annihilation of positrons emitted by a ^{22}Na source.

GRS *Gamma Ray Spectroscopy:* **122** A NaI scintillation detector and pulse height analyzer are used to analyze gamma rays from a variety of radioactive isotopes. The metastable ^{137}Ba isotope is extracted from a ^{137}Cs source and the exponential decay of its radioactivity is measured and used to determine the nuclear halflife.

IRS *Rotation Vibrational Spectrum of the HCl Molecule:* **312** The absorption spectrum of the diatomic HCl molecule is measured using a Fourier transform infrared spectrometer. The spectrum shows a characteristic shape that can be understood based on the quantum mechanics of the non-rigid rotator, and analysis of the spectrum provides information about the molecular bond, such as bond length and strength.

LTT *Low Temperature Transport:* **122** Temperature has dramatic effects on the transport properties of metals and semiconductors. The electrical resistance of pure metals can decrease by several orders of magnitude as temperature is reduced from room temperature to cryogenic temperatures. The junction voltage of a *p*-*n* junction increases in a characteristic way as temperature is lowered, allowing the Si diode to be used as a thermometer. A cryostat capable of reaching extremely low temperatures is used for studies of these properties at temperatures between about 10 and 350 K.

NMR *Pulsed Nuclear Magnetic Resonance:* **232** The nuclear magnetization of a sample immersed in a strong magnetic field is manipulated using a pulse of resonant radio frequency radiation. Time-resolved measurements of the sample magnetization after the pulse are used to determine the time constants associated with the magnetization's return to equilibrium.

SAS *Saturated Absorption Spectroscopy:* **332** Properties of laser absorption in a rubidium vapor are measured. Single beam, Doppler broadened absorption and sub-Doppler saturated absorption using counterpropagating beams are observed and measured.

TFH *Quartz Crystal Tuning Fork in Superfluid Helium:* **233** The resonance behavior of a tiny quartz tuning fork is measured to investigate the hydrodynamic properties of the medium in which it is immersed. The tuning fork is immersed in helium gas at various pressures and in liquid helium at temperatures around the superfluid transition in a study of the changing density and viscosity of the medium. Lock-in impedance measurements and cryogenic techniques are involved.

VIS *Visible Spectrometer:* **122** A transmission grating spectrometer is calibrated by measuring the spectrum from a mercury and/or helium discharge lamp and using their known wavelengths compiled in reference tables. The spectrometer is then used to obtain wavelengths of the Balmer series observed with a hydrogen discharge. A comparison with the Rydberg formula is made and the hydrogen Rydberg constant is obtained.

XDA *Xray Diffraction and Absorption:* **222** An xray spectrometer is used to observe diffraction from single crystals and determine the emission spectrum of the xray tube. Diffraction spectra from powdered crystals are obtained and analyzed to determine the crystal structure and interatomic spacings. Xray absorption through a variety of metal foils is measured to observe absorption edges and determine their dependence on atomic number.

OT *Optical Tweezers:* **233** A laser beam is focused through a microscope objective to a micron-sized spot. A microscope slide is prepared containing spherical micron-sized silica beads dispersed in water. When a bead is placed near the laser beam, it is drawn toward the focus with a Hooke's law restoring force that arises from the laser light scattered by the bead. The microscope slide is mounted on a piezoelectric stage that can be be put into small amplitude oscillations. The bead is also constantly subjected to the random impulsive forces responsible for Brownian motion. The scattered light is collected on a quadrant photodiode and used to determine the bead motion which is fourier analyzed to obtain the force constant and other system parameters. These parameters are studied as the laser intensity, bead size, and other conditions are varied. Micro-organisms can also be manipulated and studied.