General Description

[edit]

In this class, you you'll learn

- how to conduct an experiment, collecting data with special attention to estimating systematic and statistical measurement errors,
- how to model the data,
- and how to present your work through scientific writing.

These three aspects essentially define the course. Each lab will be evaluated based on how well the three aspects are realized.

Welcome to Advanced Physics Lab 2014! [edit]

Instructors [edit]

Professor: Tobias Marriage (marriage@pha.jhu.edu), Office: Bloomberg 215

TAs: Ian Anderson (ianderso@pha.jhu.edu), Office: Bloomberg 429

Lab Guru: Steve Wonnell (wonnell@pha.jhu.edu), Office: Bloomberg 478

Wiki [edit]

This page (https://wiki.pha.jhu.edu/advlab_wiki/index.php/2014) is your source of much course-related knowledge. Useful materials will be distributed here.

Also check out general descriptions of labs and pages for previous years at

https://wiki.pha.jhu.edu/advlab_wiki/index.php

or just Google "JHU advanced lab wiki"

(As always: ask questions as we go)

Classes

[edit]

Times: Monday 10:00-12:50 and 1:30-4:30

Classes will run in a seminar format. They will begin with a lecture, sometimes involving computing/laptop participation, followed by discussion and short updates on experimental work from students. A shared online directory (Google drive) will be used to upload update material.

At the beginning of a new experiment, an introduction to the new experiment will also be given in the class.

Experiments

[edit]

While much effort will be spent with data analysis and scientific writing, the exciting centerpiece of the course is executing four advanced experiments. You'll have a generous three weeks to work on each experiment. The first experiment will start in the second week of the course. The planned experiments we will work through are the following.

1. **Brownian Motion**: The goal of this experiment is to estimate the Boltzmann constant using a measurement of the brownian motion of microscopic spheres.
2. **Speed of Light**: In this experiment you use the classic Foucault spinning mirror measurement to estimate the speed of light.
3. **Single Photon Interference**: This experiment explores the interference of quantum wave functions.
4. **Radio Astronomy**: In this experiment you'll use a 1.4 GHz (21 cm) radio telescope to look out into the galaxy and (possibly) beyond.

The first two experiments are intended to be a good match to the beginning data analysis being taught in lectures and readings during the first half of the course. These should help you ramp up in terms of your familiarity with data and errors. They are also very cool measurements of two of the most important numbers in physics!

The second two experiments, to be completed in the second half of the semester, are intended to be matched to the more advanced material presented in lectures and readings during the second half of the course. These are new experiments that we've developed over the last two years and think are particularly exciting.

Location and Access

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The all experiments associated with the lab are located in room 478 of Bloomberg Hall: the Physics Undergraduate Computer (PUC) lab. Access to the lab is managed by Steve Wonnell (wonnell@pha.jhu.edu). A PUCLab login for the computers will also be useful. Steve Wonnell is also the person to contact for this.

Safety

[edit]

Use your common sense in all situations. In these labs you'll encounter lasers (where appropriate goggles) and other manageable hazards. Follow the safety instructions at all times. Food and drink are not allowed near the labs. Safety also follows from orderliness: please keep the lab in a tidy state. When in doubt: ask the professor, Steve Wonnell or the TA.

Readings

[edit]

I will lecture weekly from the classic Bevington text, which is mainly on data analysis. In principle you can work from lecture notes, but you will get more out of the class if you make an effort to read the text and take your own notes.

Bevington & Robinson, *Data Reduction and Error Analysis for the Physical Sciences*, 3rd Edition, McGraw-Hill, ISBN 0-07-247227-8, 2003

I will have a couple class copies that you can read in the lab. (Please keep these in the PUCLab!)

Schedule

[edit]

Below is the nominal schedule for the course.

Date	Lecture	Weekly Reading	Other Notes
Jan 27	Class Overview, Measurement & Errors	Bev. Ch1	Work on basic LaTeX and Python examples
Class material to go here.			
Feb 03	Probability Distributions, Exp. 1 Introduction	Bev. Ch 2	Start Exp. 1
Feb 10	Propagation of Errors	Bev. Ch 3	Updates on Exp. 1
Feb 17	Estimates of Mean and Errors	Bev. Ch 4	Updates on Exp. 1; Exp. 1 Report Draft Due
Feb 24	Monte Carlo Techniques	Bev. Ch 5	Exp. 1 Report Due, Start Exp. 2
Mar 3	Linear Least Squares 1	Bev. Ch 6	Updates on Exp. 2
Mar 10	Linear Least Squares 2	Bev. Ch 7	Updates on Exp. 2
Mar 17-21 Spring Break			

Schedule continued

Mar 24	Nonlinear Fitting 1	Bev. Ch 8	Exp. 2 Due, Start Exp. 3
Mar 31	Nonlinear Fitting 2	Bev. Ch 9	Updates on Exp. 3
Apr 7	Maximum Likelihood	Bev. Ch 10	Updates on Exp. 3
Apr 14	Testing the Fit	Bev. Ch 11	Exp. 3 Due, Start Exp. 4
Apr 21	TBD	-	Updates on Exp. 4
Apr 28	TBD	-	Updates on Exp. 4

Groups and Scheduling

[edit]

You should team up into lab groups of two or three for executing the experiments. It's probably best to have one group through all labs, so you become used to working with one another and fall into a schedule. It would be good to form these in the first week.

While the first lab has multiple stations, the following labs have one apparatus. Therefore groups will need to schedule times throughout week when they will be using the instrument. We will set up a scheduling system (likely Google calendar or spreadsheet). Groups may "team up" if necessary to collect data together, but preferably it can be done group by group. In any case, just make sure everyone gets to take some data! And also be friendly and considerate when sharing the equipment.

Grading

[edit]

Grades breakdown as

- 80% Labs
- 20% Preparation (weekly updates and submission of drafts)

Each lab grade will be divided into three equal sections: experiment execution (20 pts), data analysis (20 pts), and presentation (20 pts).

Collaboration Policy

[edit]

Execution of the experiment is a group effort, so is necessarily collaborative. Furthermore, students are encouraged to discuss experiments, analysis, and other course related issues with their peers (and, of course, with the instructors). However, each person should carry out their own data analysis (e.g., no code sharing), produce their own plots, and write their own report.

Ethics

[edit]

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition. For more info: http://e-catalog.jhu.edu/undergrad-students/student-life-policies/.

Work Submission and Late Reports

[edit]

Work should be submitted by email in PDF format to the professor (marriage@pha.jhu.edu) and TA (ianderso@pha.jhu.edu). To help us organize, the subject of the email should be "Advanced Lab: [last name]" where [last name] is your last name. Also the PDF should be titled advlab_[lab number]_[last name].pdf. For instance if your last name is Smith and you've completed the first lab, then you would title your report "01_FH_Smith.pdf".

The reports are due by midnight on the day before the next lab begins. The grade of late reports will be multiplied by exp(-(days late)/7), where days late can be fractional (starting from midnight).

In this class it's crucial not to procrastinate. You should aim to have a reasonable draft of your report by the second week of the lab.

All reports will be returned within 2 weeks from the submission date.

Participation

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Update material (plots etc) for discussion should be uploaded to the shared drive before class. Drafts should be submitted in the same way described above for the final report, though the filename should indicate that it's a draft to avoid confusion.

You can start writing in week one of the lab.

Anatomy of an Experiment

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Experiment Execution. The first step in executing an experiment is to have a good idea of the phenomenon being measured -- the reason why you're doing the experiment. Then you need to have a thorough knowledge of the experimental apparatus. With this preparation you will be able to take data. But obtaining measured values is not enough. You need both values and errors. You need to conduct the experiment in a way that estimates systematic errors and statistical errors. Systematic errors can be checked for by conducting the experiment in more than one way that should, e.g., give the same result and checking for discrepancies. Statistical errors may be obtained by repeating the experiment and evaluating the sample variance of the data or there might be an analytic expectation for the statistical error, as in the case of counting experiments.

Data Analysis and Interpretation. The input to data analysis consists of measured values and their errors. You then fit this data with some physical model. If the fit is "good", then you can believe the best-fit model parameters and associated model parameter errors. These model parameters tell you something about the physical world.

Presentation Lab reports constitute the language of the course. The sections of a report are

- Abstract -- Summarily say the aim of the experiment and what you used to measure the phenomenon. Then quote your result which is usually some physical parameter *with errors*.
- Introduction -- Describe the phenomenon being measured and any historical info. This should not contain much information about what you did in the experiment-- just roundly what you aim to do. The intro is mainly useful background.
- Theory -- Introduce the physical effect that you're trying to probe. Introduce equations.
- Experiment Description and Data -- Describe the experiment setup and procedure. Also describe the data and errors.
- Data Analysis -- Derive a theoretical interpretation from the data propagating errors to theoretical model parameters etc. If appropriate, discuss the "goodness" of the model fit.
- Discussion -- Interpret your results and discuss what may have gone wrong if, e.g., the fit in the Data Analysis section was not good.
- Conclusion -- A short section where you summarize the paper. This section could possibly include future directions to take the work.

Good figures are crucial!

Lab Report Specifications

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The reports are to be created on a computer with computer generated graphics, plots, etc. The document preparation system for the reports is LaTeX. The computers in the PUC lab have various installations of LaTeX editors/compilers. You can also download freeware for your personal computers. I think the online editor "ShareLaTeX" is pretty good.

The lab reports should have an abstract, an introduction, description of the experiment (apparatus and procedure) and derive data and errors, description of the analysis, discussion of results, a conclusion, and a bibliography.

The format should have 1" margins with no smaller than 11 point font. The maximum number of pages is 6, including figures and tables. Be concise.

A standard strategy is to create your figures first in order to guide the body of the text.

Other Useful Resources [edit]

Data Analysis

- Press, Teukolsky, Vetterling, Flannery, *Numerical Recipes in C* (Available online)
- Lupton, "Statistics in Theory and Practice"

LaTeX

- Lamport, *LaTeX: A Document Preparation System*
- A Not Too Short Introduction to LaTeX: media:not_too_short.pdf

You might also find useful websites from previous years.

Tutorials: In particular, see the previous year's tutorials.

And of course... Wikipedia!

Things to do this week

- Make sure you have access to PUCLab (Rm 478) and have a PUCLab account (Contact Steve Wonnell; wonnell@pha.jhu.edu)
- Work out starter exercises with LaTeX and Python. Get help if you need it!
- Read Ch 1 of Bevington
- Group up
- Read ahead about Brownian Motion

Questions?

Lab Tour!