PHYS 3600: Experimental Physics I (fall and winter)

Calendar description: This course provides the student with the necessary skills to be a successful experimental (astro)physicist. Students assemble labs from advanced experiemental equipment including computers and other digital devices, perform the experiment possibily over several weeks, and communicate their results in a scientifically useful fashion.

Note: While this is a three (3) credit course, it will be taught over two semesters.

Lab 3 hrs. per week; 2 semesters.

Contents

Overview

This is the first stand-alone lab course (with no accompanying lecture series) in the programme, and is where students start to gain a full appreciation of how a physics lab is run. As with the lower-year labs, emphasis is on developing the skills and tools necessary for experimental physics. Secondary aims include reinforcing physical concepts introduced in the lectures, and learning how to communicate results in a scientifically meaningful and useful fashion.

Labs are still assembled from written directions, though the details are fewer than in second year, and students are expected to be able to fill in any “gaps” in these directions. Traditionally, students have also done a lab “project”, mostly in the second semester, for which a formal presentation has been expected. Fourth year labs in PHYS 4600 (Experimental Physics II) resemble more the lab project and is where students learn to construct sophisticated labs with little guidance from written procedures or manuals.

As much as is practical, labs are designed and sequenced so that the physical concepts are reviewed in the lectures before they are used in the lab.

From time to time, instructors may wish to develop new experiments to enhance the students’ education, skill sets, lab experience, etc. Any new experiments should be reviewed and approved by the Curriculum Committee in consultation with the physics technician and lab coordinator before being implemented.

Prerequisites

PHYS 2400L Electricity and Magnetism Laboratory

Lab skills are imparted upon students throughout the second year, in both PHYS 2400L and PHYS 2300L (Vibrations, Waves and Optics laboratory) and should arrive in the third year lab fully accustomed with proper lab etiquette, safety, and protocol. Students will have submitted several physics lab reports with emphasis on professional presentation, proper uncertainty propagation (partial differential method), computer-assisted analysis, graphs, tables, *etc.* Thus with the additional practise students gain in this course, lab reports of finishing third year students should very much resemble professional-quality reports suitable for publication.

Dependent courses

PHYS 4600 Experimental Physics II

This course is a follow-on to PHYS 3600, but is taken only by Honours Physics students. The labs performed in PHYS 4600 resemble the project performed in PHYS 3600, and students who do well in the project will therefore be well-prepared for the advanced lab.

Student Outcomes

Students completing the third year lab should have developed the following skills:

1. a methodical, systematic approach to gathering data
2. experimental design
3. familiarity with data analysis tools:
    - choosing variable quantities reasonably
    - propagation of uncertainties (using partial-differential method)
    - advanced statistical analysis, function fitting with uncertainties
    - use of computer software to facilitate analysis
4. use of advanced experimental equipment
    - program computer interface for digital data acquisition
    - advanced use of oscilloscopes
    - basic digital electronic devices (lock-in amplifier)
5. communicate scientific results, including:

- search for and use results from the literature
- succinct, clear prose (impersonal) in written reports
- analytical expression
- experimental methodology
- representing data using tables and graphs
- uncertainties: systematic *vs.* random, and sources
- qualitative and quantitative discussion of results,
- proper use of citations
- preparing an oral presentation

Curriculum

Before beginning the experiments, students complete the instructional modules (from a course-pack entitled "Tools of Experimental Physics") to include:

1. LabView programming
2. standardised software usage for plotting and curve-fitting
3. statistics for data analysis
    - probability distributions
    - error analysis (error-propagation equation)
    - method of least squares (and χ^2)
    - fitting a line (maximum likelihood), and parameter uncertainty
    - general function fitting
4. basic theory of digital electronics (Boolean algebra, bits, buses, registers, *etc.*)
5. overview of general electronic devices (digital and analogue)
    - transistors, diodes, op-amps
    - differentiator and integrator circuits
    - bridge rectifier; Wheatstone bridge
    - voltage dividers; band-pass filters
    - lock-In amplifier
6. technical report writing instruction

Students select from the following labs:

1. Current balance
2. Hall effect
3. Critical temperature of a high-T_c superconductor
4. Acoustic diffraction
5. Gamma-ray spectroscopy and radioactive decay lifetime
6. Electromechanical charge transport (pendulum)
7. Earth's field NMR
8. Frank-Hertz experiment

Suggested texts

The labs listed in the curriculum section have a written procedural description of one form or another available in the lab; many of these may even be arranged in third year lab manual at some point. Regardless, these directions are intentionally curt, and the students are expected to be able to assemble the labs with these brief directions and the lab experience they have gained to date.

In addition to these notes, the following resources have been found to be useful:

Data Reduction and Error Analysis for the Physical Sciences, by P. R. Bevington and D. K. Robinson (ISBN 0 071 19926 8)

The Art of Experimental Physics, by D. W. Preston and E. R. Dietz (ISBN 0-471-84748-8)

Practical Physics, by G. L. Squires (ISBN: 0 521 27095 2)

Notes to the instructor

1. Unlike the second year labs which are part of lecture courses, this course is a stand-alone lab course. The departmental memory and experience of this course is retained by the physics technician, the lab coordinator, and any previous instructors of this course still on faculty. Particularly for the first-time instructor, this is a demanding course to teach because of the need to get students "up and running" in a relatively short period of time with equipment that may or may not be well-designed for the task required. Thus, the instructor is strongly urged to consult frequently (*e.g.*, weekly) with the physics technician and the lab coordinator to ensure students get the maximum experience out of this lab.

2. This course is actually the last physics lab for most students in our programme. This includes all double major and honours students, astrophysics students, even physics majors. Only the physics honours students are obliged to continue with PHYS 4600

(Experimental Physics II). Thus, the project becomes a very important part of this course as it may be the *only* experience students get in designing and assembling a multi-week lab with little or no written direction. The project also provides students with the opportunity to do up one extensive lab report right, and to give an oral presentation based on work in a lab.

3. Because labs at this level, especially the project, involve complex and often expensive equipment and lab components, the physics technician retains a somewhat limited list of what labs can be done on site, and it is from these that students normally choose a project. If the expertise of the lab instructor permits them to assemble other physics labs from existing equipment or if a new lab can be designed with a modest capital outlay, he or she is encouraged to discuss this with the physics technician and the lab coordinator. Particularly if there is a student keen on doing a particular lab not currently in the Department's repertoire, such designs and/or purchases can often be made quickly.

4. Occasionally, students have linked their third year lab projects with their projects in PHYS 3210 (Computational Methods in Physics). Students may choose to do a lab (*e.g.*, heat conduction through various media) for which there are well-known numerical techniques (solving the heat-diffusion equation) that can predict the results in the lab. Such a synergy is strongly encouraged, and the instructor may suggest this to students in the fall who plan to take the computational methods course in the winter.