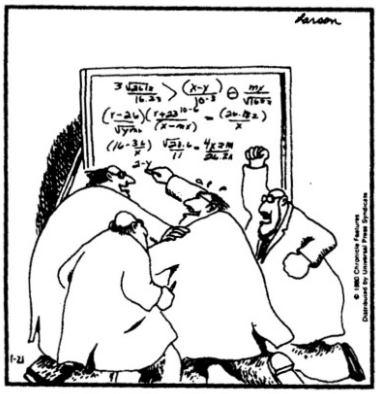


Go for it, Sidney! You've got it.
You've got it! Good hands! Don't Choke!"

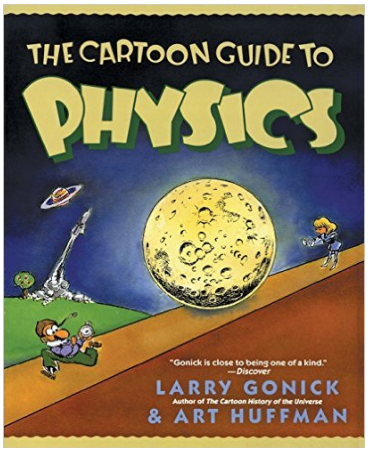
Course Description

PHYS 3600 - Advanced Physics Lab

- Summer 2021 -

Don Heiman, Northeastern University, 5/10/2021

←Theory ---------- Experiment→



"All life is an experiment. The more experiments you make the better." - Ralph Waldo Emerson

Doc is *" interested in knowing something about everything" "His mind had no horizon"*
- Steinbeck's Cannery Row

"Even theorists have an advantage when they thoroughly understand experiments." - Don Heiman

INTRODUCTION

Experiments in the Advanced Physics Lab-1 course are substantially different from those in introductory physics laboratory courses -- they go beyond the simple demonstration of basic physical principles. More advanced physics concepts will be explored by in-depth analysis of the data. For fun, check out Richard Feynman's 1937 MIT lab report.

Among the main goals of the course are:

(1) Become familiar with each **apparatus** in order to collect precise as well as accurate data;

(2) Determine the **uncertainties** in the both measured and final values;

(3) Look for deviations from initial expectations and basic theory in these "real life" systems. Historically, these unexpected results have led many researchers to new discoveries, even Nobel awards;

(4) Provide sustained practice in working within the conventions of scientific writing, particularly the methods of experimental documentation.

Although many of the experiments are given as *cookbook* recipes to be followed item-by-item, you are expected to continually ask yourself questions about your observations. Even chefs experiment with new ingredients and techniques while periodically tasting the results. In a similar vein, a successful experimental scientist continually asks, "**why is that happening**" or "**what if I do this**." All the while the scientist periodically examines the results. A great mentor of mine at MIT, Dr. Si Foner, the inventor of the modern magnetometer, cautioned against taking too many sequential steps. Instead, his experience taught him to:

(*i*) take a few steps;
(*ii*) look (plot) at what is happening; then
(*iii*) determine what to do in the next few steps.

Thus, it is essential to ***plot data as it is taken*** so that strategic decisions can be made quickly and errors discovered. Incidentally, behavioral scientists have found evidence that people learn better by not seeing answers clearly at first, rather it is often better to see things not so clearly at first so that the brain gropes for preliminary answers along the way. This groping leads to stronger neural connections in the brain. Be prepared to be frustrated at various times during these experiments, as this is closer to reality and increases your problem-solving ability.

EXPERIMENTS

Six of the following experiments will be performed during the semester. Experiments will be performed by groups of 2 students.

Acoustics and Fourier Transform - A variety of sound waves will be recorded as a function of time in order to mathematically obtain their Fourier spectra. The harmonic components of various sounds and musical instruments will be investigated.

Coupled Electrical Oscillators - This experiment explores the properties of single LRC oscillator circuits and investigates qualitatively what happens when two such oscillators are coupled and allowed to exchange energy.

Nanomagnetism - Ferromagnetic particles smaller than ~100 nm are no longer able to sustain their ferromagnetic moment at room temperature due to thermal fluctuations. Rather, they become *superparamagnetic* at low temperature. The superparmagnetic properties of magnetic nanoparticles will be measured as a function of temperature in a SQUID magnetometer.

Faraday Rotation - An optical system will be constructed that is capable of measuring the rotation of optical polarization to a sensitivity of 10 microradians (1/1000 degree). Linearly polarized light passing through a sample material experiences rotation of the polarization vector when a magnetic field is applied. The Verdet constants of glass and water are thus obtained from measurements of the rotation angle as a function of the magnetic field strength.

Fuel Cell - This experiment measures the efficiencies of converting energy between light, chemical and electrical energy. The apparatus uses: (1) a photovoltaic (PV) solar cell to convert light energy into electrical energy; (2) an electrolyzer to convert electrical energy into chemical energy by splitting water into hydrogen and oxygen; and (3) a hydrogen fuel cell to convert the chemical energy back into electrical energy.

Hall Effect - This Lab demonstrates the Hall effect in a semiconductor and uses it to measure the carrier type (electrons or holes) and carrier concentration in a doped semiconductor wafer. The carrier mobility is determined from the measured resistivity.

Ruby Spectroscopy - The energy levels of chromium in a ruby crystal are investigated using the technique of absorption and photoluminescence spectroscopy. A spectrometer and white light source are used to measure the absorption spectrum of the Cr ions. Next, a green laser is used to excite the Cr ions and the emitted fluorescence spectrum is measured and analyzed. Finally, the excitation laser is pulsed and the fluorescence lifetime of the photoexcited Cr ions is determined.

Speed of Light - This experiment introduces optical communication apparatus. A high-frequency voltage pulser and diode laser generate nanosecond light pulses. Using a high-bandwidth photodiode and 500 MHz storage scope, the time of flight of individual light pulses will be measured as a function of distance. Several different materials will be inserted into the beam path to determine the speed of light in these media, including water and glass optical fibers.

Driven Harmonic Oscillator - A horizontal sliding mass and spring system is mechanically driven by a reciprocating motor. Measurements of the amplitude versus frequency lead to determination of the resonance frequency and damping, which is then compared to theory.

Spectroscopy: Guess the Material - An optical spectrometer is used to measure the emission spectra of hydrogen, unknown gases and phosphorescent mineral rocks. The hydrogen emission is modeled by the initial and final state quantum levels. The unknown gases and minerals are identified by their spectral fingerprints.

FORMAT FOR LAB REPORTS

This course focuses on technical writing as it provides credit for the NUpath, *Writing Intensive*, and the NU Core, *Writing Intensive in the Major*. Each student must submit a separate electronic Lab Report that should include diagrams of the apparatus, tables and appropriate plots. The writing and general format of the reports are aimed at providing a clear and straightforward description that contains the important information without extraneous (and often boring) minutiae. The following ˝publication˝ format is **recommended**:

Template-PHYS3600.docx

ASSESSMENT OF STUDENT WRITING

Writing is an important component of the course, providing credit for the NUpath Writing Intensive and NU Core Writing Intensive in the Major. Lab reports are submitted weekly and are assessed on organization, format, grammar and style. This training provides experience in writing high-quality documents for your managers, scientific publications, grant proposals, etc. In the first weeks, general deficiencies common to the class will be discussed and remedied. This is an iterative process: revisions will not generally be made on single lab reports, instead, students' particular deficiencies are corrected for subsequent lab reports. With this iterative process, we expect to see significant improvement in the students' abilities in written scientific communication.