

PHYSICS 491 - ADVANCED LABORATORY II

(Formerly Phys 490 – Second Semester)

This is a 1 -unit course in experimental physics for upper-division physics majors who have already completed Phys 490. There will be 3 hours of laboratory and data analysis work each week, during which students will complete four experiments of more complexity than those of Advanced Lab 1.

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Office hours to be announced in class + other times by appointment. You are encouraged to make use of my office hours. Small gaps in understanding can be easily corrected if taken care of promptly, but can lead to much greater difficulties later if ignored.

11. Texts/Materials:

Required:

Laboratory Notebook. National # 43-591 or #53-108 or equivalent. Must be bound, with numbered pages.

Recommended:

J. M. Lockhart, Modem Data Acquisition and Analysis (Sold by Phys/Astr Club)

R.A. Dunlap, Experimental Physics - Modem Methods (Oxford Univ. Press).

Pratap, Getting Started with MATLAB 7. (Oxford, 2005).

III. Prerequisites: Phys 490. You must have completed Advanced/Project Lab I before taking this course. CSC 209 or 210 (UNIX and C) recommended. You will likely need to do some programming in MATLAB or LabView.

IV. Requirements: You are expected to attend all lab sessions. You must maintain a lab notebook in which you record all your work. Normally you will complete 4 experiments and submit a full, publication-quality report (5-10 pages) on each.

V. Grades: Grades will be assigned according to the following approximate percentages: lab notebook, 20%; written reports, 80%.

VI. Skills to Be Developed: A. Data reduction & error analysis; computerized data analysis & plotting. B. Laboratory instrumentation and measurement techniques. C. Computerized data acquisition. D. Preparation of clear scientific reports following publication standards. E. Maintenance of a proper lab notebook.

VII. Cheating/Plagiarism: All work you submit must be your own, or must be credited to the original author. Any material copied or paraphrased from books, journals, or on-line resources (including figures) must credit the original source. See the Physics and Astronomy Dept. Plagiarism policy on <http://www.physics.sfsu.edu> under Department Policies

VIII. Withdrawals: See the Dept. withdrawal policy on <http://www.physics.sfsu.edu> under Department Policies

IX. Disability Accommodation: Students with disabilities who need reasonable accommodations are encouraged to contact the instructor. The Disability Programs and Resource Center is available to facilitate the reasonable accommodations process. The DPRC, located in SSB 110, can be reached by telephone at 338-2472 (voice/TTY) or by e-mail at dprc@sfsu.edu.

X. Procedure for Individual Experiments:

1. No later than the beginning of the first, third, seventh, and eleventh weeks of the semester, you will sign up for an experiment and obtain a lab write-up for that experiment. (You are encouraged to sign up for all your desired experiments at the beginning.) You will be working individually on your experiments.
2. You should read the lab write-up and examine all the equipment for the experiment. It is best if the reading is done while in front of the equipment. Occasionally, you will find that the equipment is a bit different than that described in the manual. The write-ups often do not contain step-by-step instructions, but they do contain useful information and serve as a guide for how to do the experiment. It is your responsibility to figure out the physics of the experiment and learn how to do the experiment and to seek help from the instructor as needed.
3. Before starting the experiment itself, you are required to have a procedure review with the instructor. You should arrange for that review when you understand what you will be doing and have completed all experiment prerequisites and any preliminary calculations called for in the write-up. In general, you will be asked a bit about the physics of the experiment and about the lab procedure, including the equipment settings and values you plan to use. You will also be asked about relevant safety considerations.
4. You are required to keep and use a lab notebook while you do the experiment. All information about what you did, data that you took, etc. should be recorded either in that notebook (in ink) or on a computer if the data taking is computerized (with reference in the notebook to the data file name and location.). This is a working notebook. It should be sufficiently neat and organized so that you can understand what you have done, under what conditions data were taken, etc. A handout describing lab book standards will be distributed.
5. You should do a rough analysis of the data as or just after you take it. Failing to do that may result in your wasting your time taking useless data that you only find is useless when you later go to analyze it. A corollary to this is that you should have some idea of what the expected result is.
6. Write a lab report using the long format, following example handouts. The long report in standard Physical Review format will have four sections:
 - a. an introduction where you clearly state the purpose of the experiment and introduce the physics behind the experiment;
 - b. a section on experimental technique, in which you describe the experimental apparatus and methods;
 - c. a section on results and analysis where you present the data in figures and/or tabular form and perform the relevant data analysis with special emphasis on the uncertainties and limitations of the measurement;
 - d. a final section in which you state the conclusions (best estimates, uncertainties, comparison with accepted values) based on your data, and your interpretation..

Do not underestimate the time needed to write a good lab report. Your lab reports are due by Fridays of the 4th, 8th, 12th and 15th weeks.

7. Make safety a major concern. Very few of our experiments have safety issues, but for those which do, be sure to follow appropriate procedures. Typical concerns are avoiding exposed high voltage, direct viewing of laser light, and care in handling the stronger radioactive sources.

Faraday Rotation. Observe the rotation of polarization of light produced by applying a magnetic field as the light propagates through glass. Interesting effect; good use of lock-in amplifier.
Difficulty: Low - Moderate *Time:* Short *Computer Data Acq.:* No *Data Acq. Programming:* No
Pre-requisites: Lock-in amp tutorial. *Notes:*

Lifetime of Cosmic Ray Muons. Capture cosmic ray muons in a scintillator detector; build up a distribution of decay times from which the muon lifetime is determined. Learn high energy physics techniques.

Difficulty: Low-Moderate *Time:* Short *Computer Data Acq.:* Yes *Data Acq. Programming:* No
Pre-requisites: Basic nuclear counting experiment. *Notes:*

High Resolution Optical Spectroscopy. Tune up the high resolution spectrometer and observe the isotopic shift of the deuterium spectrum. A CCD detector can be used to get digital data.

Difficulty: Moderate *Time:* Medium *Computer Data Acq:* Option *Data Acq. Programming:* No
Pre-requisites: *Notes:*

Resonant Circuit Impedance Vs. Frequency: Construct a capacitor-inductor resonant circuit with variable damping (resistance); use computer-controlled. data acquisition to plot impedance response.

Difficulty: Low-Moderate *Time:* Short *Computer Data Acq:* Yes *Data Acq. Programming:* Yes
Pre-requisites: AC circuit theory, IEEE programming *Notes:*

Gamma Spectroscopy of Co60. Use computer pulse height analyzer to study the decay of Co60 observe evidence for creation and annihilation of antimatter.

Difficulty: Moderate *Time:* Medium *Computer Data Acq:* Yes *Data Acq. Programming:* No
Pre-requisites: Radiation Safety; Basic nuclear counting *Notes:*

Energy gap in a Semiconductor: Computerized data acquisition of the variation of the reverse saturation current of a pn diode with temperature; determine energy gap.

Difficulty: Low *Time:* Short *Computer Data Acq:* Yes *Data Acq. Programming:* Yes
Pre-requisites: IEEE programming *Notes:*

Specific Heat of Copper: Fit prediction of Debye theory of heat capacity dependence on temperature; computer collects data using IEEE-488 program which you write..

Difficulty: Low *Time:* Short *Computer Data Acq:* Yes *Data Acq. Programming:* Yes
Pre-requisites: IEEE programming *Notes:*

Shot Noise and Electron Charge: Measure the charge of the electron by observing the fluctuations in current flow from a photoelectric cell. (Computerization possible).

Difficulty: Low/moderate *Time:* Short *Computer Data Acq:* No *Data Acq. Programming:* No
Pre-requisites: Knowledge of filters and bandwidth *Notes :*

Capacitance of a Ferroelectric: Use computerized capacitance meter to study ferroelectric phase transition as a function of temperature.

Difficulty: Low-moderate *Time:* Short *Computer Data Acq:* Yes *Data Acq. Programming:* Yes
Pre-requisites: IEEE Programming *Notes:*

Transmission lines and speed of light in Dielectrics: Study propagation of voltage pulses on an electromagnetic transmission line (coaxial cable) and determine the speed of light in a dielectric material

Difficulty: Low *Time:* Short *Computer Data Acq:* No *Data Acq. Programming:* No
Pre-requisites: *Notes.*

Bragg Diffraction of X-Rays* : Use computer controlled motor to automate the scanning; determine lattice spacing in a crystal.

Difficulty: Low-Mod. *Time:* Short/med *Computer Data Acq:* Yes *Data Acq. Programming:* Opt.

Pre-requisites:

Notes:

Thermionic Emission of Electrons: Study emission of electrons from heated metal; Steffan-Boltzmann law, etc. Develop computer program to control power supplies.

Difficulty: Expt-Low; Anlyz-Med. *Time:* Short *Computer Data Acq:* Option *DataAcq.*

Programming: Option *Pre-requisites:* *Notes:*

High Temperature Superconducting Quantum Interference Device (SQUID). Observe flux quantization in superconductor and produce quantum state transitions using microwave photons.

Difficulty: Low/med *Time:* Short *Computer Data Acq:* Option *Data Acq. Programming.* No

Pre-requisites:

Notes:

Cavendish Experiment - Measurement of G. Direct measurement of weakest force of nature. Use capacitive angle detector (or laser "optical lever") and computer data acquisition.

Difficulty: Moderate-high *Time:* Medium *Computer Data Acq:* Yes *Data Acq. Programming:* No

Mossbauer Effect. Observe resonant gamma-ray absorption, to incredible precision. Uses computer-based multichannel scaler.

Difficulty: High *Time:* Moderate *Computer Data Acq:* Yes *Data Acq. Programming:* No

Pre-requisites: Radiation safety; basic nuclear counting *Notes:*

Hall Effect in p-Germanium. Observe the magnitude and sign of the Hall effect in p-doped Germanium as the sample temperature is varied. Interesting combination of electrical, magnetic, and thermal measurements.

Difficulty: Low/med *Time:* Short *Computer Data Acq:* No *Data Acq. Programming.* No

Pre-requisites:

Notes:

Earth-Field NMR - Advanced. Observe precession of nuclei in the Earth's magnetic field as their magnetic moments are polarized and depolarized. Observe spin echoes and do imaging.

Difficulty: Low/med *Time:* Short *Computer Data Acq:* Yes *Data Acq. Programming.* No

Pre-requisites:

Notes:

Single Photon Interference. Use photon counting techniques with a very faint light source to observe two-slit diffraction when only one photon at a time is passing through the system of slits.

Difficulty: Low/med *Time:* Short *Computer Data Acq:* No *Data Acq. Programming.* No

Pre-requisites:

Notes:

Laser Spectroscopy of Rubidium. Use a tunable diode laser to study the optical absorption spectrum of hot Rubidium gas. Application of a magnetic field allows the Zeeman effect to be observed.

Difficulty: Medium *Time:* Shot/Med *Computer Data Acq:* No *Data Acq. Programming.* No

Pre-requisites: Laser Safety Training *Notes:*

Electron Spin Resonance: Use radio-frequency signals to interact with electron spins polarized by a dc magnetic field and achieve resonance with the electron spin precession..

Difficulty: Medium *Time:* Short/Med *Computer Data Acq:* No *Data Acq. Programming.* No

Pre-requisites:

Notes:

Pulsed NMR: Use radio-frequency pulses to polarize nuclear spins, observe spin echoes, and study molecular structure by observing the effect of local magnetic fields on nuclear magnetic moments.

Difficulty: High *Time:* Med. *Computer Data Acq:* No *Data Acq. Programming.* No

Pre-requisites:

Notes: