PHYSICS 474: ADVANCED LABORATORY
Unique 56355

Fall Semester 2016

Instructor:

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Office Hours: M: 1:30 pm, W: 1:30 pm.
TAs: Ramon Salazar(ramonmsalazar@gmail.com) and Tom Carroll (tjcarroll@utexas.edu)

Texts: Recommended: *Building Scientific Apparatus*, by Moore, Copland and Davis and Required: *Data Reduction and Error Analysis for the Physical Sciences*, by Bevington and Robinson

Senior lab fulfills the flags: II-Independent inquiry, QR-quantitative reasoning, and WR-writing. This course may be used to fulfill three hours of the communication component of the university core curriculum and addresses the following four core objectives established by the Texas Higher Education Coordinating Board: communication skills, critical thinking skills, and quantitative skills.

Class Organization:

1. Class will meet Tuesday and Thursday in RLM 7.216 from 9:30-5:30 for lab. At 9:30 am Tuesday we will have a 1 hour lecture on experimental techniques in RLM 5.116. We will also use this room for student presentations beginning the 6th week of class. **Attendance** at the lecture, student presentations and for the duration of Tuesday and Thursday lab **is mandatory**, except for the attendance of one class and lunch. Attendance in lab, lectures, and student seminars are part of your grade as shown below.
2. Access to the lab on non-class days may be necessary for some experiments such as the speed of light; consult with one of the TAs for access to the lab.
3. Students with disabilities may request accommodations from the Division of Diversity and Community Engagement, Services for Students with Disabilities, 471-6259.
4. The course drop deadline with refund is Sept 12, 2013. The final deadline for a Q drop is Nov. 1, 2013.
5. Please contact me for assistance in dealing with disabilities. See http://www.utexas.edu/diversity/ddce/ssd/ or contact Services for Students with Disabilities (SSD) in CNS.

Course Requirements:

1. Do either 1) Three experiments from Group A, or 2) One experiment from Group A and one from Group B. For more detail

about these experiments see the class website http://www.ph.utexas.edu/~phy474/administrative/.
The username and password is on the lab blackboard. I will also have selected lab reports on Canvas.
2. Submit a full report on each experiment, following accompanying guide lines, by the due dates listed. Reports will be prepared individually. If you are doing an experiment from Group B, the second report will be in the form of a progress report.
3. Class will include oral reports on experiments. These reports should be in the spirit of an Am. Phys. Soc. conference talk, should be well practiced with viewgraphs, and be exactly 20 minutes in length. The talks will be given individually and will be scheduled on Thursday starting after the first lab report. See below for starting date.
4. Grades will based 20% on each of the three laboratory reports, 20% on your oral reports, and 20% on attendance at lectures/presentations. All reports are due by 5pm on the day indicated. All reports will be turned in at my office or under my office door, if closed. Do not leave reports in lab or my mail box. Late reports are penalized 25% for the first late week (1hr. to 7 days late) and no credit thereafter. No incompletes will be given without just cause. In addition to the required printed report, you must email me a pdf version of the report.
Report #1 is due Sept. 22.
Report #2 is due Oct. 27.
Report #3 is due Last day of class, Dec. 5.
Oral Reports begin Oct. 6.

Lecture content:

August 27: First class: This lecture will cover a review of the syllabus, and tour of the lab and review of the available experiments (see below).
Aug. 30. Radiation safety presented by the radiation safety office, Scott Pennington
Sept. 1. Radiation safety, cont., Scott Pennington. Passing this course is necessary to remain in Senior Lab.
Sept. 6. Safety in the lab, handling chemicals, laser safety, and high voltage safety practices.
Sept. 13. "Electronic Instrumentation," Introduction, Thevenin Equivalent circuit for detectors, Transfer functions, Preamplifiers: operational amplifier configurations.
Sept. 20. Signal-to-noise in analog systems, noise sources and their effect on electronic circuits.
Sept. 27. Filtering: Complex representation of the frequency domain, low pass filters, high pass filters, the time and frequency spaces
Oct. 4. Digital data processing, convolution theorem, signal averaging, the lock-in amplifier
Oct. 11. Nuclear electronic for pulse processing: counting and pulse shaping, spectral analysis, multichannel analysis, pulse shaping.
Oct. 18. Interface standards in NIM electronics, nuclear detectors
Oct. 25. No class
Nov. 1. Error Analysis: precision vs. accuracy, standards in measurements, sampling statistical distributions, estimating the parent distribution from the sample

Nov. 8. Statistics of a Random source.
Nov.15. Propagation of errors, estimates of means and errors, counting of a signal in a background
Nov. 22. Least squares fitting
Nov. 23-27 Thanksgiving Holiday
Nov. 29 Measuring pressure, flow conductance in a vacuum system, estimating pressures from molecular flow in steady state. Contribution to ultimate vacuum from outgassing and and seal permeability—an example vacuum chamber design
Dec. 1 Vacuum seals and vacuum pumps

Experiments:

Group A	**Group B**
Neutron Activation	Compton Scattering
Zeeman Effect	Raman spectroscopy
Microwave interferometry in plasmas	Speed of light
Pulsed NMR	Plasma temperature (new device)
LEED of a surface, (simple)	T dependent LEED
Diode Laser spectroscopy	Tunneling microscope
Josephson Junction	X-ray fluorescence
Nonlinear mechanics	Muon lifetime
Berry Phase experiment	
Optical pumping of Rb	
High Tc superconductors	
Acoustic Optic Modulator	
Magnetic torque	
Noise fundamentals	

Experiments from Group A are briefer and more straightforward; hence one should obtain results fairly quickly. Experiments from Group B are more challenging (some may say impossible, with the given equipment!) You may also do an experiment in Group B of your own design. Your must prove you have adequate resources and equipment to do the experiment. If you choose to do a Group B experiment of your own design you must turn in a proposal by September 30. This proposal should convince me that you are capable of doing the experiment. It should include a list of equipment required, what results you anticipate, and estimates of expected signal strengths and equipment sensitivities. If you are repeating one of the experiments listed above, your proposal should state what you intend to do differently from past groups.

Laboratory Procedure

1. Work in pairs if you wish, but prepare separate reports and presentations.
2. A bound laboratory notebook is required. Write all data, notes, original records in ink, and do not tear pages out. Date each entry.

Tabulate and/or plot you data while taking it, and endeavor to understand it qualitatively then, not when you go to write your reports. Keep notes every time you work, even if they seem trivial. Notebooks will be checked periodically during the semester by the TA's.
3. Work steadily. Don't try to cram everything in before the report is due.
4. Read reports and literature in advance of laboratory. There is a sign out book for the reports.
5. Report broken equipment immediately to a TA.
6. Film badges are required to be worn in the laboratory at all times.
7. Think about safety. There are many dangers in the lab which will be discussed during the first lecture.
8. Protect your equipment. Test circuits at low voltages before burning out the meters. Read the manuals and note the safe operating conditions for the instruments. If you are unfamiliar with the equipment or confused **ASK**.

Safety:

There are many dangers in a research lab. The four principal ones in senior lab are high voltage equipment, chemicals, lasers, and radioactive sources. There is a good on line course offered by the safety office that you must take, OH 101, see http://www.utexas.edu/safety/ehs/train/. I will lecture on safety the first day of class, but in general your best defense is to think before you act. We will also have required radiation safety classes in early September. Attendance of these classes is mandatory and there will be sign up sheets. It you miss the special classes you will be required to take the 8 hour classes taught bye OEHS.

Wear protective clothing goggles and gloves when using chemicals. Look up each chemical in the MSDS reports (give details of hazards of chemicals) which are on line at https://ehs.utexas.edu/programs/labsafety/sds-chemical-information.php. If you do not know specifically about a chemical assume that it is highly toxic; just because they are commonly used does not make them safe. Contact a TA before disposing of any chemicals. Wear proper goggles when using lasers and protect bystanders from your beam. If you do not know how to safely handle high voltages talk with the instructor or a TA. Know how to properly handle radioactive sources before removing them from their lead vaults.

Facilities:

1. You are free to have work done by the professional shops. Even though you will receive priority, there will be at least a 4 week delay

so get your drawings in early. There is also a student machine shop and instructor available.

2. To get supplies from the chemistry storeroom, get help from the TAs. **DO NOT USE MY NAME**.
You must provide a printed copy of each of your lab reports which I will grade and return to you. The reports will have two grades, one for your work in the lab and another for the quality of the data analysis and report. In addition you must email me a pdf version of the paper for the senior lab web site. The reports will be read by the instructor, the TAs, and generations of future senior lab students. The instructor and TAs are familiar with previous reports and reproduction of part of them is considered plagiarism. More important, many are not written in a desired style. For a model style see Phys. Rev. or other professional journal. The guidelines below are traditional. Your experiment may require an altered format:

Generic Outline for Papers

1. Title Page: experimental title, your name, your partner's name, semester and supervisor's name.

2. Abstract: Concise summary of your experiment, 100 words or less.

3. Introduction: State succinctly the goal or motivation of your experiment. This should include the basic theory of your experiment.

4. Experimental Procedure and Apparatus: Describe your experiment in sufficient detail that someone unfamiliar with the experiment could perform it from reading your report alone. Do not simply list equipment and model numbers; but describe the operation and procedure and show equipment in the form of block diagrams. Point out experimental difficulties and observations.

5. Experimental Data: Show data in the form of tables or graphs. Error bars are essential " a measurement with an error is not a measurement".

6. Analysis: Extract quantities of interest (speed of light, transition energies, etc) from your data. Include an error analysis. Compare your result with theory and previous experimenters.

7. Conclusion: Summarize the major results, suggesting any improvements.

8. References.

Philosophy of Senior Lab

In a recent course evaluation a thoughtful student suggested that a "summary, written by a professor, should accompany each lab to present 1) What is done in the experiment, 2) What is possible in each experiment, and 3) What is expected." Somehow this student missed the point of senior lab. Since many of the students that semester seemed to look for the shortest path; somehow I had failed at the beginning to communicate the correct spirit of the course.

Like all his previous courses, the student wanted a concrete set of problems presented to him. Real research doesn't happen this way, and the purpose of senior lab is to present the beginnings of what it is like to do research. In an ideal atmosphere the scientist investigates a phenomena which is of interest to him. There is no set method and no prescription for success. The scientist usually begins by studying in the literature what is already know about a phenomena and by studying measurement techniques which might be relevant to his exploration. The process of conducting research is a creative one; in addition to choosing the experimental techniques an individual is free to invent a new approach. We have not made the experiments in senior lab "canned" in order to present a flavor of this individual creativity.

The past lab reports are similar to the literature; some papers are well written, creative and correct; others are poorly written with obvious errors. You should consider the reports as a starting point and a bibliography to important papers in the literature. We expect you to use the library. Read some more recent papers on the experiment of your choice. Read review articles in the library on the experimental techniques you are using, read the equipment manuals in the file cabinets, ask questions when you are confused. I have done most of the experiments in the laboratory, but perhaps not recently. Memory fails. I may have not done some of the experiments recently developed by other faculty. I can at least point you in the correct direction.

The goal of a lab is the process of research, not to necessarily "complete" an experiment. First, in a real world a research project is never completed. There are always new questions to explore. A project is successful if you have made a contribution, perhaps new apparatus, and new analysis technique. You may become blocked by a broken piece of equipment which cannot be repaired on time. A project usually ends either because the investigator becomes more interested in another topic or the funding terminates; here it artificially ends when the report is due or the semester ends.

If you have already been working in a lab and pursuing a senior thesis, Senior Lab is an opportunity to expand your hands on experience in a different subfield of physics. If you are working with someone in atomic or molecular physics, for example—learn the details of new measurement techniques in solid state research such as LEED or a scanning probe technology. This added breath of knowledge will expand both your knowledge and capability in future graduate research.

Many of the past lab reports have received a grade of "B", the average for senior lab. Most students succeed in getting the apparatus functioning and repeating previous measurements. If the experiment is not difficult or no major obstacle overcome, this is an average accomplishment. It is equivalent to the average paper in the literature, good work which is not particularly creative or exciting. An excellent grade requires a unique, creative effort.

This course is an opportunity to begin to apply the classroom physics you have learned as undergraduates. It is an opportunity to experience both the frustration and exhilaration of research. You are limited only by your own imagination, innovation and the short time a semester represents.