ADVANCED LABORATORY

Physics 3340/4430/5430 Spring Semester, 2013

INSTRUCTORS

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E-MAIL LIST

Make sure you are receiving e-mails from our class list. You should have already received one.

WEB SITE

The web site for the class has general information, the most up-to-date scheduling information, and most of the lab guides:
http://www.colorado.edu/physics/phys3340/phys3340_sp14/

ON BEING AN EXPERIMENTALIST

How much time does an experimentalist spend doing physics? The answer depends deeply upon your understanding of how physics, an experimentally based field of knowledge, actually works. You might think the answer is, "Not much.", and you'd be right IF you think of 'doing physics' as making the discovery, or even simply conceiving of an experiment. In fact, an experimental physicist's time is largely spent 'doing physics' throughout the design and construction of experimental systems and components. If you don't understand the physics of your experiment, then there is only a small chance that you'll use it to successfully understand NEW physics. Often an experimentalist's time is spent trying to understand why an experiment isn't working, or at least is not working as expected. They need to figure out what modifications, both in apparatus and in understanding, they need to make.
Experimental physicists wanting to detect gravity waves using a laser interferometer (the LIGO project) have been at it for two decades and they have yet to actually run an experiment where they expect to detect the very weak signals. The recent demonstration of Bose-Einstein Condensation here at the University of Colorado generated a lot of excitement in the scientific community. That was an experiment five or six years in the making. It could be said that is was five or six years in the trying, before everything, intellectual understanding and experimental techniques, converged to a successful outcome.

So what is experimental physics training all about? A good experimental physicist has a deep knowledge of physical principles and a broad range of skills in addition to an expertise in some particular field of physics. The standard intellectual equipment list includes familiarity with several engineering disciplines such as electronics, mechanical design, strength of materials, and vacuum technology and familiarity with instrumentation such as oscilloscopes, frequency counters, spectrum analyzers, voltmeters, and the like. What distinguishes a good experimental physicist from a highly skilled technician? A good experimentalist is a highly skilled technician, yet the physicist has a very different set of goals: the outcome is verification of a theory, or a demonstration of some new principle, or the like, and the skills are used is to get from here to there in the shortest path. During the test of the first atom bomb, Enrico Fermi was said to be seen dropping bits of paper; by observing their horizontal motion relative to their vertical fall, Fermi was able to estimate the energy of the blast. Nothing fancy, no sophisticated instrumentation, just simple physical principles gave him the rough answer he was looking for. Furthermore, a physicist’s knowledge of physical principles allows them to be a generalist -- in this lab what you might learn about impedance matching in electronic circuits will enable you to generalize to impedance matching in mechanical systems to make a better machine, or in quantum physics to transfer wave functions.

The Advanced Laboratory course is designed to expose you to and equip you with some of the essential skills that an experimentalist should have. It is also designed to expose you to a variety of experimental physics topics, and to provide a sense of truly independent research.

**ORGANIZATION**

The three courses, Physics 3340/4430/5430 share facilities, instructors and meeting times. Physics 3340 is for undergraduates who have already taken Physics 3330, or an equivalent course in laboratory electronics. Physics 4430 is for undergraduates who have already completed Physics 3220 and 3320 and have completed or are currently taking Physics 4410. Physics 5430 is for graduate students, without prerequisites. The various course requirements are summarized in Table I and are described here and in following sections.
Summary of Laboratory Requirements

<table>
<thead>
<tr>
<th>What</th>
<th>When</th>
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<tbody>
<tr>
<td>Lecture attendance</td>
<td>Tuesday and Thursday, 9:00-9:50 AM (Section 200) or 1:00-1:50 PM (Section 300) each week. You must attend the section that you are registered for.</td>
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<tr>
<td>Lab attendance</td>
<td>10 AM-12:50 PM Tuesday (Section 201) 2:00 PM-4:50 PM Tuesday (Section 301) You must attend the section that you are registered for.</td>
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<tr>
<td>Pre-lab report (1 question)</td>
<td>5 PM the Tuesday you start an experiment. Submit it to D2L.</td>
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<td>Lecture Activities</td>
<td>See course schedule. Due at the end of lecture.</td>
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<tr>
<td>Lab notebook scans</td>
<td>Tuesday following completion of an experiment. Submit it to D2L. Due at start of lecture.</td>
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<tr>
<td>Oral reports (Labs 1-4)</td>
<td>Tuesday following completion of an experiment. Due at start of lecture.</td>
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<tr>
<td>Written report (Lab 5)</td>
<td>Tuesday following completion of Lab 5</td>
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<tr>
<td>Project written report</td>
<td>End of semester</td>
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<tr>
<td>Project oral report</td>
<td>End of semester</td>
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Each Laboratory section will have instructors familiar with the experiments. Other instructors with expertise on particular experiments will be "on call" and you may need to find them to get additional help. The laboratories are available for working on experiments except between the hours of midnight and 7 a.m. Please note, though, that attendance during your regular scheduled laboratory period is required unless you have made specific other arrangements with your lab instructor.

The first week all students will do a Gaussian laser beams experiment. You are to submit a proposal for a sequence of additional experiments that you wish to complete. We do this so that we can schedule all of the requests to avoid conflicts with equipment usage. The proposal is further described below.
Scheduled lecture time is Tuesday and Thursday from 9:00 to 9:50 AM (Section 200) or 1:00-1:50 PM (Section 300). The first lecture period will be an organizational meeting that will include a brief description of the available experiments and the facilities. Experimental write-ups that note any special prerequisites are available on the web site. The prerequisites may differ for the three courses. The remainder of the lecture periods will be used to cover a variety of topics including laboratory safety, and experimental methods, materials, and techniques. These periods may also be used for organizational purposes, reports, and meetings with students. Attendance at the lectures is required. Please note that various room changes, depending on the lecture, may be possible.

TEXT

The following texts are available in the lab:

*Building Scientific Apparatus: A practical guide to design and construction*, John H. Moore, Christopher C. Davis and Michael A. Coplan, Perseus Books, Cambridge, MA, 3rd edition, 2003. This text is a valuable resource for experimentalists. Although there are no planned specific assignments from the book, its utility will vastly outlive the semester.

*Experiments in Modern Physics, A. Melissinos and J. Napolitano, Academic Press, 2nd ed., 2003.* (The 1st edition from 1966 is dated in some parts but still very useful.) Once again, there will be no assignments but this book will be useful this semester as well as in your future endeavors. The lab has a few copies of the first edition.

CONDUCT

Everything you do in the context of this lab, from writing lab reports, to taking care of your equipment, to giving presentations, is expected to be at a professional level. Please take responsibility for your equipment, take responsibility for your own safety and for the safety of others.

For many of the assignments you will work with a lab partner. Please treat your lab partner with the same degree of courtesy and respect that you would want to be treated with yourself.

Note that while you will often work on the labs with a partner, the notebooks/data analysis/presentations/lab reports you submit must be YOUR OWN work. If you submit identical work, then we will grade the work and divide the score by the number of partners.

PROPOSALS
By 4:00 PM Friday of the first week you should submit a written proposal for a sequence of experiments. In completing your list, remember that only 5430 students can do the standard electronics lab experiments, each of which are one week labs. Phys 5430 students are also expected to do all "optional" parts in the 3330 labs and to go beyond the material presented in the experiment instructions on some experiments. Phys 4430 students who have taken 3340 cannot repeat experiments they have done previously. The instructors will approve proposals during the first two weeks, taking care to resolve equipment conflicts. The time spent on each experiment should not deviate from two weeks without good cause. Students will normally work in pairs throughout the term. When turning in your proposals please indicate the name of your partner for each experiment.

PROJECTS

Several weeks at the end of the term will be set aside for projects. Projects should be selected in consultation with your instructor during the middle of the semester. They can be anything that offers you a chance to demonstrate independence and creativity. A wide variety of possible experiments or construction projects are acceptable as long as it is something that is not part of a standard experiment presented in one of the write-ups.

GRADING

The grading will be based on pre-labs, lab notebooks, lab reports and oral presentations, and class participation. The table below summarizes the grading scheme. All work is submitted into the corresponding “dropbox” on D2L.

<table>
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<tr>
<th>For each standard two-week guided lab:</th>
<th>Semester Total Points</th>
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<tbody>
<tr>
<td>- Pre-labs (5 points per lab)</td>
<td>25</td>
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<tr>
<td>- Lab notebooks (10 points per lab)</td>
<td>50</td>
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<tr>
<td>- Oral presentation or written lab report (20 points per lab)</td>
<td>100</td>
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<th>Class participation during semester</th>
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<tr>
<td>- 8 Lecture activities (5 points each)</td>
<td>40</td>
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<tr>
<td>- Attendance</td>
<td>30</td>
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<tr>
<td>- Feedback during oral presentations: 4 labs+final project (3 points each)</td>
<td>15</td>
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<table>
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<tr>
<th>Final Project</th>
<th>Semester Total Points</th>
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<tr>
<td>- Proposals (10 points for each stage)</td>
<td>40</td>
</tr>
<tr>
<td>- Lab notebook</td>
<td>30</td>
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<tr>
<td>- Final written report</td>
<td>30</td>
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<tr>
<td>- Final oral presentation</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>390</td>
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What is expected for pre-labs, lab notebooks, lab reports, and oral presentations will be discussed in class, and further information, such as grading rubrics, will be available on the course web site.

Attendance is required so if you miss a scheduled lab period without being excused by your instructor, you will automatically lose points. If you convince your instructor that you had a sufficiently good reason for missing class (always much easier if you contact the instructor to discuss it before you miss the class) you will be able to make up the class. In addition to the assigned three-hour lab period, it is expected that additional time (usually at least an additional 3 hours /week) in the lab will be needed to complete the experiments plus additional time outside the lab to prepare for the lab, analyze the data, and produce reports. The instructions for each experiment as well as other reference material should be read before each scheduled lab period. Instructions for each experiment are available on the course website.

LAB BOOK

You will be given a lab book with numbered quadrille ruled pages for use in this course: The 9" X 12" Ampad No. 22-156 Computation Book carried by the bookstore is provided. You must keep this lab notebook, which will be used to record your data and all relevant information, including calculations and answers to all questions asked in the guide. Each lab book record must include the original data as recorded in the lab. While your entries must be legible, do not be overly concerned about neatness in the original recording of data; it is more important to record the data directly in the lab book as you do the experiment. It is okay to make mistakes, just make corrections obvious, and strike through sections that should be ignored. Your lab book should be sufficiently complete so that one could reconstruct the experiment at some later date from the information in the lab book without recourse to memory. Upon completion of a lab, you should submit a scan of all relevant lab notebook pages into the same D2L “dropbox” used for submitting your oral or written lab report. The main office scanner can quickly scan your notebook into a single PDF document and email it directly to you. This is the most efficient way to scan your notebook. If you use Mathematica as a lab notebook, you are still required to print out the notebook pages and tape them in your lab notebook.

LABORATORY

The Laboratory is organized into two major geographic sections: Optics, and Modern Physics. Storage of components and equipment is arranged accordingly. The laboratory equipment, electronic and optical components, and tools are organized and labeled. The optics rooms and the electronics lab are equipped with kits of components for the standard experiments. There is a single location in the lab for other components or equipment, except for standard tools, of which there are two
sets, one in electronics and one in optics. Please tour the lab and familiarize yourself with the location of these items. The lab is to be maintained in the condition in which it begins the semester. Of course, while equipment, tools and components can be collected and kept during the course of an experiment, they are to be returned to their homes when the experiment is finished.

EXPERIMENTS

Optics
Gaussian Beams
Diffraction and Fourier Optics
Michelson Interferometer
Holography
Hydrogen and Mercury Spectroscopy
Polarization of Light
Laser Spectroscopy
Laser trapping and cooling

Modern Physics
Absolute Measurement of the Faraday
Scanning tunneling microscope
Gamma ray spectroscopy
Earth’s field nuclear magnetic resonance
Pulsed nuclear magnetic resonance
Laser spectroscopy
Laser trapping and cooling
Lifetime of muons generated by cosmic rays
Soliton propagation
Acoustic reflectometer
X-ray photoemission spectroscopy
X-ray (and other optical) diffraction

CU POLICIES

(1) If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu.
If you have a temporary medical condition or injury, see Temporary Medical Conditions: Injuries, Surgeries, and Illnesses guidelines under Quick Links at Disability Services website and discuss your needs with your professor.
(2) Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. See full details at http://www.colorado.edu/policies/fac_relig.html

(3) Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. See policies at http://www.colorado.edu/policies/classbehavior.html and http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

(4) The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. (Regent Law, Article 10, amended 11/8/2001). CU-Boulder will not tolerate acts of discrimination or harassment based upon Protected Classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "Protected Classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, or veteran status. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550. Information about the ODH, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at http://www.colorado.edu/odh

(5) All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Further information on the Honor Code can be found at

http://www.colorado.edu/policies/honor.html and at
http://www.colorado.edu/academics/honorcode/