

**Advanced Laboratory Physics**  
**Department of Physics**  
**Case Western Reserve University**

**Spring 2003**

The objective of this laboratory is to train students to undertake independent research with state of the art instrumentation. Computer interfacing is used wherever possible. You will be given practice in thinking about and solving real problems in order to obtain quantitative results. You are expected to be critical in evaluating your data and to develop a professional manner in recording your work and communicating your ideas. You will, along the way, become wiser and learn a good deal of new physics concepts.

In this laboratory course the experiments are largely in the realm of contemporary physics. Some of the experiments deal with problems that were current research only a few years ago. Most of the experiments are in areas of research that are active at the present time, or provide a basis in fields of emerging importance.

Each researcher, working with a partner, is expected to complete three experiments chosen from the list after consultation with the instructor. Whenever possible, you will be assigned a different partner for each experiment. Not all experiments can be performed simultaneously; every effort will be made to assign you to experiments of your own choosing. Each experiment will require up to 5 weeks, however keep in mind that there are only 14 weeks of instruction because of Spring Break. Assignments to experiments, starting and completion dates of experiments and due dates for reports will be displayed on a sheet posted in Rock 311 and 314. In general, you will have at most 5 weeks to complete an experiment and your report will be due at the beginning of the period before you start your next experiment. **PLAN AHEAD.** Time constraints at the end of the semester are no excuse!!

We expect that you will choose your experiments on a rational basis. We do not encourage concentration in a narrow field. In contrast to previous laboratories, you and your partner now have the responsibility for the design of the experiment you have selected. You are encouraged to explore different techniques in order to improve the quality of your data and subsequent analysis.

The condensed matter experiments typically involve electrical circuits for biasing and measuring the response of the sample under study. Researchers must determine the best measurement approach and choose appropriate values of R, L and C for their experiments and the appropriate frequencies for best operation. For all experiments the researchers must have a complete understanding of circuits and instrumentation used (equipment manual are available near the instructors desk in 314). You should be able to analyze, check and repair a simple circuit. Make sure all leads are properly connected to samples, sensors, and heaters before cooling the sample. It is a good practice to trace through, with a multimeter and a careful eye, all of the components in your experiment. Make a clear schematic in your notebook to refer to. Careful checks and familiarity with the instrumentation will save you much time in the long run.

The imaginary (ie, phase information) as well as the real part of signals contains valuable information. Plot data as soon as it is taken. Find out if there is a problem before spending a lot of time in data acquisition.

This laboratory will be run under a set of rules, which are outlined below. Some of them are for your safety, some are for the safety of other people and equipment, and some to insure that everyone has equal access to working equipment and information.

Housekeeping is always a problem. Keep your area neat. Return equipment, sources, and tools to their proper places after use. Respect your fellow students and clean your area when finished with an experiment. Note also that experimenters in another course may be using the same apparatus as you on alternate days of the week. When this is the case (consult the instructor) some

communication between you and the other groups will go a long way to minimizing confusion. This can be easily accomplished by leaving notes on the apparatus.

Instruction manuals and other information in the lab files are NOT to be taken from the laboratory except briefly to make photocopies. There are some books and a folder of photocopied references in Room 314. Be considerate of your classmates and return the references to the folder. Sign out any books taken out of the laboratory other than to the copy room. A number of books have not been returned in the past...

You are expected to learn to operate equipment as needed for your experiment and you are held responsible for damage if you are careless. If you do not know about the operation of a particular instrument, then find its instruction manual in the files and learn. All too frequently laboratory apparatus is damaged or put out of adjustment because instructions were not sufficiently studied. Please let the instructor know if equipment appears to be malfunctioning.

Take good care of the equipment: Make sure "O" ring-matching surfaces are not scratched. Place an "O" ring-matching surface on cardboard and not on a hard surface. Scratching of such a surface will cost you a great deal of time leak checking. When exchanging cards from computers or checking the circuit of a piece of equipment, be sure to replace the cover and secure it properly. Do not run the cryocoolers or thermoelectric coolers overnight unless taking data and notifying the instructor. Take special care with the liquid helium transfer tube. Always replace it into its position on the wall in room 311. Turn off water lines when the thermoelectric experiments are not in use. Do not over tighten valves. This will ruin the valve seat. Do not strip screws by over tightening them. Turn off hand-held multimeters when finished using them.

Some experiments may require soldering of leads. See your instructor for training. Making a good solder joint is not as easy as it appears. A poor solder joint can cause problems and cost you time. The temperature of the soldering iron is important. Overheating of small leads can weaken the lead or oxidize it so that it is difficult to make a good solder contact. Insufficient heating of both parts to be joined can lead to a "cold" solder joint and an intermittent contact. This is especially troubling in low-temperature experiments because the failure may appear only when cold.

The laboratory computers contain special purpose data acquisition cards. Manuals for the operating systems and programs are available in 314. Software disks are kept in the lower drawer of the Jr. Lab file cabinet. An RS232 program for operating the Marlow Power Supply to drive the thermoelectric coolers is also kept there.

You are free to store program and data files on the hard disks under your own directory. It would be wise to keep copies of your files on your own 3.5" floppy disks. There are a few that can be loaned to you for that purpose. The equipment is shared by the undergraduate and graduate laboratory courses. This includes the computers. It is wise to copy your interfacing program so that it cannot be altered by others. Origin and Excel are installed on the main computer in Room 314, which can be accessed from the web.

## RESEARCH NOTEBOOK AND REPORTS

Information pertaining to the performance of the experiment **must be written in a bound notebook** by each student. This notebook is not a finished document; it is a continuing, working record from which you should be able to reconstruct just what you did in the lab. Nothing is to be written down except in this notebook; scraps of paper get lost. To be effective, it is not practical to keep a notebook that is free of errors, missteps, cross-outs, etc. However, you must keep a neat enough so you can follow what you did. Keep in mind that you may be referring back to information that is weeks old; don't rely on your memory – an isolated number, equation, or filename may seem clear when you are writing it, only to appear obscure when you look back on it. Include brief sentences and annotations to yourself to explain what you are doing. The notebook is

also a useful place to write out brief plans of what you are going to do, and can be invaluable in picking up where you have left off in the previous lab period.

Data that is acquired through a computer need not be transcribed into the notebook but a record of what you did, when you did it, and the conditions under which the data were taken should be in the notebook, along with the name of the file where it is stored.

The notebook is to be examined by the instructor following the grading of the written reports. Each student should keep their own notebook and is required to analyze the data and write a report, independently. You can consult your partner, reason out issues, and generally collaborate, but both partners must contribute significantly to all aspects of the experiment and do independent analysis and reporting.

Students are to submit 'hard copies' of their report. Electronic copies will not be accepted. Use Word or TeX or similar word-processor programs to write up your report.

The report should follow the style and content that is used in publishing research in the physics journals. If in doubt, consult the AIP Style Manual. Keep in mind the report is the final product of your research. It need not be long, but it must be comprehensive and contain the physics that you wish others to learn from you. You should write assuming a readership with a level of physics comparable to your own but with no specific knowledge of the specific phenomenon you are studying. The report must be clearly written and follow accepted rules for grammar and spelling. Carefully proofread your writing and allow time for revisions. The report should contain the following sections:

An **abstract** that summarizes the report in a half page or less.

An **introduction** that concisely describes the nature of the physical phenomenon that is treated in this experiment and summarizes the theory. Do not copy derivations of formulas out of other books and articles; merely state the relevant equation, defining all quantities, and give a reference to the source. The introduction is not to be a description of your experiment or results, but it should bring the reader to understand the theory behind your experiment and the reason for doing it.

A section, or sections, presenting a description of the **apparatus and procedure** used.

A section, or sections, presenting the **results** and their interpretation. Graphical presentation is encouraged. An error estimate should always accompany a numerical result. The estimate should be determined by objective error analysis techniques wherever possible. It is assumed that students in this course are familiar with error analysis methods at the level of Bevington: Data Reduction and Error Analysis for the Physical Sciences (McGraw Hill, 1969)

A list of **references**.

All figures must be numbered and referred to in the text. All figures must have captions although most material should be in the text. **Appendices** are for long calculations that would disrupt the flow of the text. Computer programs are not part of the report.

Written material in the report must be the original work of the individual student submitting the report. Graphs, diagrams and tables may be shared between partners working on the experiment (but not with students who have performed the experiment at other times).

## GRADING POLICY

The experiment report is due at the beginning of the period one week following the completion of laboratory work on that experiment. The final word on due dates is therefore the Lab Experiment schedule posted in room 311/314. NO excuses for late work, except for documented medical

problems, will be accepted. If you fail to complete a report on time, at least turn in your lab notebook to receive partial credit. Failure to submit any written material for an experiment results in an automatic grade of zero for the portion of the grade based on that report (see the grade allocation below). The report will be read and graded and returned to you with written comments therein. The instructor will contact you during lab to examine your notebook following the completion of an experiment. The deadline for submission of the report for the last experiment is 5 PM, Friday, 2 May 2003.

The grade received for an experiment will be based on two criteria: how well the student performed as a physicist and how well the student communicated the results. To elaborate on the first of these two points, the task of an experimental physicist is to perform measurements designed to test a physical model and to interpret the results in terms of theory. It involves an intimate connection between an understanding of physical theory, the actions one takes in the laboratory, and the interpretation of the results. A student who acquires a lot of data but who fails to understand its significance (or lack of significance) can expect a low grade in the experiment, no matter how beautiful the report may be.

The total grade for an experiment will be the sum of the grades assigned in the following areas, up to the maximum indicated. **Note item 4: significant weight will be assigned to the quality of your writing!!!** In your professional life, your ability to write clearly and express yourself to others – even in a technical field! – is critical for success. If you do not already own one, consider purchasing a style manual, eg, Elements of Style, by Strunk and White.

1. Comprehension of physical phenomena and laboratory techniques as it is evinced by student's work in the lab, discussion of the experiment and the overall quality of the results. (8 points)
2. Laboratory notebook – clarity and completeness are crucial. (3 points)
3. Contents of report: introductory material, presentation of data, and validity of data analysis and conclusions. (8 points)
4. Expository style, writing quality and form of report. (6 points)

## SAFETY REQUIREMENTS

### General Safety Issues

You have an obligation to be aware of hazards that exist for your experiment and to carry out the appropriate precautionary actions. **EVEN IF YOUR INSTRUCTOR ALLOWS YOU TO WORK IN THE LABORATORY OUTSIDE OF SCHEDULED HOURS, YOU MAY NOT WORK ALONE.** OSHA places legal restrictions on our facilities and procedures. Some common sense rules follow, but continual concern on your part is necessary.

**No food or beverages** are to be brought into the laboratories. This restriction is good practice, required by the CWRU Department of Occupational and Environmental Safety (D.O.E.S.) and mandated by the Nuclear Regulatory Commission in the case of those rooms that are marked "Radioactive Materials". Students violating these prohibitions will not be permitted to work in the laboratory outside of normal class hours. If you require sustenance, it must taken outside the lab.

## Radiation Safety

Some experiments in this laboratory involve the use of radioactive sources. Many of these sources are relatively weak (less than 10 microcuries) and are sealed in plastic. Under our current procedures these sealed sources are the only ones that students are permitted to handle. The following rules apply to the use of these sources:

- 1) The sources are to be used in Room 314B. Sources may be used in Room 314 with the instructor's permission. Under no circumstances are they to be taken outside Room 314.
- 2) Sources are to be checked out from the instructor when needed and returned no later than the end of the lab period. An exception is made when long data-taking runs are required.
- 3) All possible preparatory work that can be done before obtaining the sources should be done.
- 4) Do not place any mechanical stress on the sources. They should not be held in place by clamps nor should any weight be placed on them.
- 5) Always reduce your exposure to radiation from the sources as much as possible. Minimize the amount of time that you handle them. Store sources behind lead bricks for shielding. When using a source in an experiment, shield as much radiation from the source as possible, consistent with performing the experiment.
- 6) If any mechanical failures of a source is observed (cracks, for example) notify the instructor at once and do not touch the source.
- 7) Prior to using sources, a student must take Radiation Safety Training offered by D.O.E.S. Check their website for scheduling: <http://does.cwru.edu>.

All other sources used in the laboratory are to be moved and handled only by the instructor. These sources include the americium-beryllium neutron source and the high activity Cs-137 source used for the Compton scattering experiment. Under no circumstances is the Cs-137 source to be dismantled!!

When using any source, its location must be labeled with one of the magenta on yellow "Radioactive Material" warning signs. These signs are kept in the radioactive sources cabinet in Room 314B. The sign must be removed when a source is no longer present.

## Electrical Safety

Voltages in the 100-10,000 volt range are more dangerous than those above or below because your muscles contract and you are unable to "let go". Around such hazards use only one hand near the equipment to hold probes and other tools. Voltages of 1-3 kV are common to operate photomultiplier tubes (PMTs). Keep high voltage (HV) supplies off when changing connections. Turn HV supplies to "standby" whenever changing ranges or polarity on them. This will avoid damage to preamplifiers.

## Mechanical Safety

When setting up an experiment, use proper clamps and supports so that the apparatus is stable and would not fall if you accidentally bump it or trip on a cable. Route cables along the back and around equipment, never across an aisle or dangling from lab tables.

## **Cryogenic**

Safety rules for handling cryogenic fluids are in the DOES Safety Manuals in room 314. You should be thoroughly familiar with these instructions before handling liquid nitrogen and liquid helium. With regard to LHe, you must first perform a transfer under the supervision of the instructor before attempting one on your own.

## **High Magnetic Fields**

Safety rules for the use of high magnetic fields are posted at the appropriate stations and are in the DOES Safety Manuals in room 314. Never use the superconducting magnet in the continuous mode without help from the instructor.

The potentially most dangerous situation is a quench of the 2D Hall experiment magnet at high current. If the magnet quenches, a voltage  $V = L \, dI/dt$  appears across the magnet terminals where  $L = 0.4 \text{ H}$  is the inductance of the magnet. We have taken precautions and this condition should not arise. However, any student working on this experiment must read and comply with the safety protocol.

## **Optical Safety**

Be careful of eye damage, especially by a laser in a darkened room. Be aware that various arc lamps and open arcs emit damaging ultraviolet light that is not necessarily absorbed by plastic shields or plastic lens eye glasses. Protocol for using lasers is included in the DOES manual.

## **Chemical Safety**

Chemicals used in this laboratory are regulated by OSHA. Use chemicals only in the hood in Room 311. All containers holding chemicals must be marked to indicate their contents. Supply containers should bear warning labels that indicate the type and degree of the hazards associated with the contents. Flammable liquids should be stored in the yellow, fireproof "Flammable Materials" cabinet located beside the hood. Other chemicals should be stored under the hood. Used chemicals should be stored in a sealed container labeled "Used" along with the name of the chemical.

Material Safety Data Sheets (MSDS) can be accessed on the Web via the DOES web site (go to <http://does.cwru.edu> and click on "Chemical Safety"). MSDS sheets for most chemicals stored in Room 311 are in a manila envelope attached to the side of the hood. You must study them to familiarize yourself with the hazards and precautions associated with any chemicals that you use.