PHYS 4672/4674 HONOURS PHYSICS LABORATORY A and B

INSTRUCTOR: Dr. C-M. Hu
Office: Room 301, Allen Building
Tel: 474-6189 (Emergency calls after hours: ***-***)
Email:

LAB. RESOURCE: Peiqing Wang
Room ***, Allen Building
Email:

CONSULTATION TIMES (Dr. Can-Ming Hu): *TBA*

LABORATORY ORGANIZATION

Students are required to complete four experiments (2 in each of PHYS 4672 and PHYS 4674) from the attached list. It is recommended that the choices be varied over the different fields: nuclear and particle physics, optics and atomic physics and condensed matter physics. This list is not exhaustive: realistic proposals for alternatives will be considered. Students, normally work together in pairs and are expected to set up their own apparatus and design their own procedure. Technical support is provided by Gilles Roy. Each student will submit their own laboratory report on all experiments. Generally, for each experiment, four weeks of laboratory work and two weeks of library work, analysis and report writing are required. In addition. Each student will deliver a short (30 min) PowerPoint presentation on one experiment (selected by the student and the instructor) at the end of each term. The talk will be followed by a 30 min period of questions from the instructor.

Where possible, students are encouraged to perform their experiments during the regular laboratory periods. Even when an experiment requires lengthy data acquisition or analysis outside these times, students are required to report to the instructor each laboratory period to discuss the progress of their experiment.

Laboratory notebooks are to be used to permanently record all data, questions, ideas, rough sketches of apparatus, etc. As in any professional's notebook, entries are expected to be chronologically ordered, complete, dated, and original (no scrap paper). Erroneous entries may be crossed out (with comments!) but should not be removed. Copying of data from a partner's book should be rare (provide a reference for the page number), and should be done by photocopying. It is normal for these day-to-day entries to be somewhat free-form. Please do not attempt to sanitize them. If you wish you could generate thoughtfull summaries of the work on a separate page in your log book. The notebooks may be called in at any time. Their contents will be a contribution to the instructor's evaluation.

Students are expected to learn and retain the principles of operation of all apparatus that they use. Analysis of the underlying uncertainties in the data and their sources should receive serious attention. An attempt should be made to estimate these uncertainties from the characteristics of the apparatus and these predictions should be compared to estimates arrived at by examining the data obtained. Where possible, results should be compared to theoretical estimates and experimental values from literature.

Guidelines for Laboratory Reports – PHYS 4672/4674

Content of the Reports

The report on a given experiment should be similar in many ways to a journal paper, but should also contain a more complete description of the experimental details and data. This means that it should include the following:

1. A title page that includes your name and student number, your partners name and student number, the date of submission and the number of the report (e.g. 1, 2, 3 or 4), course number and the date of submission. It should also include the title and an abstract that very concisely describes what was measured, how it was measured and the conclusions reached.

2. A brief (½ to one page) description of the context of the experiment, including the main objectives. This corresponds to the customary "Introduction" section of a journal paper.

3. A concise summary of the theory used to interpret the experimental data. In your own words, introduce the basic physics, write down the main theoretical equations needed to analyse the data (defining all relevant symbols and terminology), and outline the approximations used to derive these expressions. However it is *not* necessary – in fact it is definitely not recommended – to copy out a derivation from some textbook just summarize the main points and give the reference. In some reports, it will be useful to put this information in a separate "Theory" section; in other cases, it will be sufficient to include the relevant theory in the discussion section where it is being used to interpret the data.

4. A description of your experimental procedure. Describe how the experiment works and what you did in sufficient detail that another 4th-year student could duplicate your results. While this corresponds to the "Experiment" section of a journal paper, this part of the report should be somewhat more detailed than is commonly found in published papers. In particular, you should include:

    - A list of apparatus (name of unit, make, model). If you like, you can put this in a separate section, or if you wish to preserve the similarity to a journal paper, provide this information in an Appendix to the report.

    - A diagram of the layout and connections, etc., and a description of the equipment's operation.

5. The data, the analysis of the data and a discussion of the results. This part of the report should resemble a journal paper in style, use of references, etc. However, we do want to see a more complete record of the data than usually appears in publications. Often it will be appropriate to include only some of the graphs showing the raw data and its analysis in the main body of the report (as in a journal article), and to put additional graphs (or tables) showing the rest of the results in an Appendix, or on a floppy disk that is included with the report.

6. A conclusion. Sometimes this will be just a summary of the main results, but it really should include your thoughts on how well the experiment's objectives were reached. If appropriate, suggest how to improve the experiment, or what additional experiments would be helpful. When you do original research, this is also the place to point out the general significance of what you have discovered, but in a laboratory experiment that has been done many times before, such conclusions may not be appropriate!

7. A list of references. A list of references to the materials used must be provided. While web sites may be cited it is expected that a majority of the references will be to printed materials available in books and journals.

The report should be intelligible to an informed, but non-expert reader, such as one of your classmates who has not yet done the experiment. This means that, for example, an acronym must be defined in the text when it first appears, and insider knowledge should not be assumed. *Above all, the report should be written clearly, concisely and in good English.* Many of us do not find this easy, but the development of good writing skills will be very valuable no matter what career you ultimately choose.

As a loose rule, reports should be about 15 to 20 pages long. The pages should be numbered. All tables and figures should be captioned and numbered. Except in very special cases, tables should be contained on a single page. Equations should be numbered as well. Sections of the report should be titled and numbered. Use 12 pt text and double space the lines. Take care to ensure that the report is neat and readable.

General Comments

The purpose of performing these experiments is not only to get "hands-on" experience with the use of increasingly sophisticated equipment, and thereby become familiar with the technological tools involved, but also to build sensitivity to data analysis. Keep in mind that any physical measurement must be accompanied by a meaningful and sensible estimate of its error if it is to be taken seriously. Not only must the process of "error management" begin at the beginning of the experiment (through careful experimental design and optimization), but it must also be carried through to the end. There must be constant attention to evaluating precision and removing systematic effects at every step. For example, one should learn how to: decide what effects are important, account for systematic effects that cannot be simply removed and extract the parameter of interest in the most efficient way. At the measurement stage, think carefully about possible measurement pitfalls, and don't forget that there is a wealth of information available from such mundane sources as equipment manuals and books on measurement techniques. At the post-measurement analysis stage, consider the analysis alternatives with a view to minimizing the uncertainty in your final result; when choices are available, you are expected to explain the reasoning behind the method of analysis used. We assume that you are already familiar with the rules of error propagation; it is critical to use them to assess your experimental uncertainty, as this will be a guide in helping to choose the best analysis procedure. At all stages of the measurement and the analysis, it is important to be able to justify the approach used.

Please number all pages except the title page. All sections, tables, figures and equations should be numbered. Figures and tables should have concise and informative captions that are clearly separated from the body of the text. Figures and tables should be placed in the text to make it easy for the reader to follow the discussion. All of the columns in the tables should be captioned.

TEXTBOOKS

There is no required textbook for this course. For general background information on laboratory techniques, students may find it useful to consult:

Experimental Physics, R. A. Dunlap (Oxford University Press, 1988)

Building Scientific Apparatus, J. H. Moore, C.C. Davis, M. A. Coplan (Addison-Wesley, 1988)

Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer-Verlag, 1987)

For data analysis some useful books are:

Statistics for Nuclear and Particle Physics, Louis Lyons (Cambridge University Press, 1986)

Data Reduction and Error Analysis for the Physical Sciences, P. R. Bevington (McGraw-Hill, 1969)

Before performing an experiment, students will generally have to look up reference material (books and/or journal articles) in the Science Library. See the notes for each experiment in the lab for suggestions.

ADDITIONAL MATERIAL:

PHYS 4672/4674 HONOURS PHYSICS LABORATORY A and B

Manuals for the equipment and for computer programs are available from Peiqing Wang

Each experiment has an associated folder containing information about the apparatus. Please replace all materials and return the folders to their resting place after use.

COURSE GRADING AND SCHEDULE

Four (4) laboratory reports are required and must be submitted by the following tentative deadlines:

PHYS 4672
1st report to be submitted by 27 October, 20**
2nd report to be submitted by 6 December 20**

PHYS 4674
1st report to be submitted by 14 February, 20**
2nd report to be submitted by 5 April, 20**

Late reports will be penalized by 5% of the grade per day overdue, unless a satisfactory reason for the delay is given..

There will be an oral examination at the end of each term to test the student's knowledge of experimental techniques and theory. The format will be a PowerPoint presentation for approximately 30 min followed by a 30 min question period (the durations are estimates only). The tentative dates are:

PHYS 4672 orals	–	~6 December, 20**
PHYS 4674 orals	–	TBA

The final grade will be made up as follows:

60% on laboratory reports
30% on the oral presentations and question period
10% on the instructor's evaluation of performance in the laboratory, of the laboratory notebooks and, interim oral reports and discussions

PHYS 4672/4674 HONOURS PHYSICS LABORATORY A and B

Fourth Year Laboratory Experiments

(greyed assignments may not available)

NUCLEAR EXPERIMENTS

1. **Muon Lifetime** – A cosmic ray counting experiment utilizing coincidence techniques. Theory involves interactions between particles at relativistic speeds.
   Location: 109DE Allen Bldg.

2. **Compton scattering** – A study of the Compton effect using scintillation counters and coincidence techniques.
   Location: 109DE Allen Bldg., Source available 2nd term only

CONDENSED MATTER EXPERIMENTS

3. **Electron Spin Resonance (ESR)** – Paramagnetic materials (e.g. DPPH, MgO containing several transition metal ion impurities, ruby (Cr3+ in Al2O3), chrome alum) are studied through the absorption of microwave electromagnetic radiation by electronic magnetic moments. An introduction to magnetic resonance techniques. **Location: 521A Allen Bldg.**

4. **Magnetophonon effect in indium antimonide** –The magnetoresistance of InSb is measured at ~100 K. A resonant interaction between electrons in cyclotron motion and optic phonons causes small oscillations in the ρ versus B curve. An introduction to phase sensitive detection and the use of field modulation to obtain $d\rho/dB$ versus B. **Not currently available.**

5. **Ferroelectric phase transition in triglycine sulphate (TGS)** – The dielectric susceptibility of TGS is measured in the vicinity of its ferroelectric phase transition at 49° C using a sensitive capacitance technique. **Not currently available.**

6. **Mossbaüer spectroscopy** – A study of nuclear gamma resonance using ^{57}Fe with a variety of absorbers. An introduction to multichannel scaling experiments.
   Location: 521A Allen Bldg. Not currently available, needs a source

7. **Propagation of Ultrasonic Waves in Phononic Crystals** – Phononic crystals can be made from ordered crystalline arrays of mm-sized beads in a fluid or solid matrix. In such materials, ultrasonic waves are Bragg scattered, leading to the formation of band gaps in which wave propagation is forbidden. Both the dispersion relations and the transmission can be measured. This experiment gives insight into the general properties of waves in crystalline materials, a topic that is also relevant for understanding the electronic properties of metals, insulators and semiconductors, as well as the optical properties of photonic crystals now being developed for optical communication applications. These experiments

are performed in Dr. Page's lab, where a range of other experiments on novel wave propagation phenomena are also possible.
Check for availability

8. **<u>Static Light Scattering: Structure of Silica and Polystyrene Aggregates</u>**.* By measuring the intensity of scattered laser light as a function of the scattering angle, the structure of fractal aggregates formed from submicron spherical particles is investigated. Analysis of the data allows the mass fractal dimension to be determined. Dilute suspensions of fumed silica (Cab-O-Sil) and colloidal aggregates of tiny polystyrene spheres are typical of the materials that can be studied using this technique. **Not currently available.**

9. **<u>Brillouin Scattering</u>**:* When a parallel beam of laser light passes through a medium (e.g. toluene), some of the light is scattered inelastically by creating or annihilating sound quanta (phonons). The frequency shift of the scattered light is measured with a Fabry-Perot interferometer which is scanned using a piezoelectric crystal. Signal averaging is required to extract the signal from the photomultiplier noise. Measurements as a function of different scattering angles allow the velocity of sound in the medium to be determined as a function of frequency. **Not currently available.**

** Experiments 8 and 9 involve the use of optical techniques to study the properties of condensed matter systems. They can therefore be counted either as Optical or Condensed Matter Experiments.*

OPTICAL EXPERIMENTS

9. **<u>Static Light Scattering: Structure of Silica and Polystyrene Aggregates</u>**. *(See description under Condensed Matter Experiments).*
10. **<u>Brillouin Scattering</u>**: *(See description under Condensed Matter Experiments).*

11. **<u>Lifetime of atomic states</u> –** Study radiation trapping and measure the mean lifetime of an excited state using the Hanle effect.
Location: 202ABC Allen Bldg.

12. **<u>Fresnel diffraction</u>** – Diffraction of light by various apertures to observe Fraunhofer and Fresnel diffraction.
Location: 202ABC Allen Bldg., Usually in 2nd term for pedagogical reasons.