INTRODUCTION

The principal goals of the course are

- to illustrate the experimental basis for some important concepts of modern physics.

- to introduce equipment and measurement techniques important in research and industrial laboratories, and to develop the ability to use them in a knowledgeable and professional manner.

- to develop some familiarity with the use of microcomputers in data acquisition and analysis.

- to develop your understanding of the significance of experimental uncertainties in your data, and the importance of these uncertainties in the analysis and interpretation of the data.

In the first term, each experiment is allotted two lab periods (one week). You will do seven experiments in this term, chosen from a list of ten. Some of these experiments are mandatory for all students and these may be scheduled by the instructors to ensure that everyone gets them done. Since there are nine weeks to do seven experiments, you will have some free weeks, but because of possible scheduling problems, there is no guarantee that you will be able to choose which weeks you have free.

In the second term, you will perform four experiments which are more extensive and less well-defined than those of the first term, giving you an opportunity to decide what to do and the best way of doing it given the available apparatus. Six lab periods (three weeks) are allotted to each experiment.

N.B. Attendance is mandatory from 2:00 pm to 4:50 pm at all laboratory periods with one exception - a student is not required to be in the lab if he/she has no experiment scheduled that week. Even if the experiment is running automatically and does not require your constant attention, you should spend the lab time reading background material, doing data analysis, etc.

LAB MANUAL: available online, from www.astro.uwo.ca/~jlandstr/p359/. (You will need the free Adobe Acrobat Reader, available for download from www.adobe.com/products/acrobat/readstep2.html,
or from a CD-ROM that you may borrow from the lab.)


NOTEBOOK: In any laboratory (and in many other situations) it is essential to have a clear permanent record of what you were trying to do, how you went about it, and what the results of your observations were. The record should be sufficiently complete that you could refer to it at any later time to check on what was done.

The record of your work must be kept in a bound notebook (nothing else is acceptable), in \textbf{ink}. (Pencils are a tool of primary school. Permanent records are kept in ink.) You should make it a habit to record in your lab notebook precise specifications of apparatus, such as make, model and serial number. This will permit a later check in case of any question about the calibration of operation of equipment. Note exactly what measurements were made, in case you have occasion to check or repeat them. Never remove anything from the book. If you conclude that some results are incorrect, note that fact with a brief explanation of the problem. Bad errors may be scored out with a single line, so that they are clearly rejected, but still legible.

Lab notebooks may be checked to ensure that they are being properly kept. This will usually be done during the lab period.

There will be a lab test in class on Nov 22. This will have a section in which you demonstrate that you have mastered basic laboratory skills from the projects you have done, that you understand the basic theory behind the those labs, and that you know how to analyze simple laboratory data (e.g. how to propagate errors from a measurement to a result).

\textbf{Fall Term 2004: Schedule}

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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<tbody>
<tr>
<td>September 13/15</td>
<td>Oscilloscope Lab (no lab report)</td>
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<tr>
<td>September 20/22</td>
<td>Lab week 1</td>
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<td>September 27/29</td>
<td>Lab week 2</td>
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<tr>
<td>October 4/6</td>
<td>Lab week 3</td>
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<td>October 11</td>
<td>Thanksgiving holiday</td>
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<tr>
<td>October 13</td>
<td>Lab Lecture</td>
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<td>October 18/20</td>
<td>Lab week 4</td>
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<td>October 25/27</td>
<td>Lab week 5</td>
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<td>November 1/3</td>
<td>Lab week 6</td>
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<td>November 8/10</td>
<td>Lab week 7</td>
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<td>November 15/17</td>
<td>Lab week 8</td>
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<tr>
<td>November 22</td>
<td>Lab test</td>
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<tr>
<td>November 24</td>
<td>No class</td>
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<tr>
<td>November 29/December 1</td>
<td>Lab week 9</td>
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<tr>
<td>December 6/8</td>
<td>Lab week 10</td>
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\textbf{REPORTS}

ALL REPORTS ARE DUE AT 1:00 PM ON THE WEDNESDAY FOLLOWING COMPLETION OF THE EXPERIMENT. The standard penalty for a late report is 20%. Reports more than one week late will not be accepted. (If you have some real problem with one of the deadlines, discuss it with one of the lab instructors, before the deadline if possible.)

The form of these reports is not rigidly prescribed. It may be somewhat different for different experiments, and individuals may have their own preferences for how they would like to arrange
the material. As a general comment, do not reproduce material from the lab manual in your lab report. The following is an outline, indicating the general arrangement that should normally be used.

**Title (page, or just a heading)** Title, date, name, partner’s name. Make it clear which name is the author and which the partner.

**Abstract** This is a very short section, summarizing the basic goal of the experiment and the results and/or conclusions in one (or at most two) paragraphs. It is a summary, not an introduction.

**Introduction** It is useful to have a brief introductory section which mentions things such as: background to the experiment, what its purpose is, how the technique used compares with other methods of making the same measurements, etc. In any case, you should use this section to explain briefly what the experiment will measure, and what the goal of the measurement is.

**Theory** For some experiments this may not be needed. In general, this section will include derivations or developments which you are asked to carry out. It is not necessary (and is a waste of your valuable time!) to copy into the report the theory which is found in the lab manual or in a textbook. Cite these sources whenever appropriate.

**Experimental Details/Method/Procedure/Apparatus** Under one or more of these headings go a brief discussion of the apparatus, and how it was used to make the measurements. A paragraph or two which outlines the general principles of the apparatus and measurement technique is usually sufficient. Any special aspects which are not discussed in the manual should be included. A schematic diagram of the apparatus is always helpful. You may choose to combine this section with the following one if it makes your presentation clearer. Again, do not reproduce all the material from the lab manual!

**Results/Measurements and Calculations** Tabulate your measurements, with titles for the tables, and units for the quantities tabulated. Be sure that all graphs have titles, and that the axes are labelled with quantities and their units. *Don’t forget error estimates where appropriate.* It is not necessary to include every last detail of your observations in the report. For example, if you take a series of observations to verify that an instrument behaves linearly, it may be sufficient to say that it was linear to within x%. But the detailed observations on which this result is based must be in your lab notebook.

Always provide enough detail about your data that the instructor can check your data analysis. In some experiments where only a few numbers were collected, you may choose to include all your data in the report, with several intermediate steps in your data analysis. For experiments in which a lot of data is collected, you should provide an example of the data, and an example calculation. This section should lead to your experimental results with their uncertainties.

**Conclusions/Discussion and Summary** Here you summarize the results of the experiment, including discussion of any peculiar results or inconsistencies. Final results should have error estimates, and if appropriate there should be some comment on agreement between the results and theoretical or standard values. (Note that a comparison with a standard or accepted value is *not* the same as an error analysis! If your results are known from your error analysis to be rather uncertain, they may agree with standard values within your errors even if they are significantly different, and if your estimated errors are very small, your value may not be consistent with a standard value even if it does not differ much from the standard value.)
References List the works consulted in the preparation of the report. Please use good judgment in the use of old lab reports from previous years if you have access to them. If you use in them in any way, cite them as references.

COMPUTATION

The widespread use of computers in science is common knowledge. While some of the experiments in this lab are done 'by hand', others are interfaced directly to a computer to facilitate data acquisition and analysis, and would be impractical otherwise. You are encouraged to make use of the lab microcomputers for data analysis wherever possible. You will be required to write programs either in Matlab or in Fortran, for which support is provided on all the computers. A useful reference for many aspects of numerical analysis is W.H. Press, B.P. Flannery, S.A. Teukolsky, W.T. Vetterling, Numerical Recipes, (Cambridge 1986). Packaged Fortran subroutines from this book are available on the lab computers. Use of the laboratory computers for game-playing is not permitted.

EVALUATION

Your grade in this course will be determined as follows:
- First Term Lab Reports 32%
- Second Term Lab Reports 33%
- Lab Test 10%
- Evaluation of Lab performance by instructors 25%

SUMMARY OF EXPERIMENTS

First term, 2004-2005

Each student must do 7 experiments.

- SC The scintillation counter *
- MC The multichannel analyzer *
- VS Vacuum systems *
- IE The isotope effect in the spectrum of hydrogen *
- CF Curve fitting *
- DP The driven pendulum: deterministic chaos
- BR Blackbody radiation
- SL The speed of light
- DL Digital logic and pulse circuits **
- TE Thermionic emission of electrons

* Mandatory for all students
* Not permitted for students who are taking or have taken P266b and/or P367a
Second Term 2004-2005

You are required to do 4 experiments, with 6 laboratory periods allotted for each. As in the first term, your report on each lab is to be submitted by the Wednesday of the next lab.

Most of the basic experiments outlined in the write-up can be readily completed in 3 or 4 lab periods. The extra time is provided so that you will be able to go beyond the basic experiment - making additional measurements, doing additional experiments, repeating experiments with improved technique, etc. Students who use this time effectively will be rewarded accordingly. Even if you are finished all experimental work in less than 6 lab periods, you should use the lab time to work on your data analysis and report.

**ZE Zeeman Effect** Splitting of atomic energy levels by a magnetic field due to spatial quantization of angular momentum; determination of e/m for electrons; high resolution optical spectroscopy using the Fabry-Perot interferometer.

**ME Moessbauer Effect** Recoilless emission of gamma rays and resonant absorption. Applications in solid state physics.

**RE Determination of Energy-Momentum Relationship for Relativistic Electron** Simultaneous observation of E and p for fast electrons from -decay using a surface barrier detector and a magnetic spectrometer; measurement of m and c.

**IS Infrared Spectroscopy** Study of the infrared absorption of various gases using a grating monochromator with a cooled infrared detector.

**FT Fourier Transform Spectroscopy** A technique in optical spectroscopy in which the spectrum is reconstructed from an interferogram produced by translating one mirror of a Michelson interferometer; an opportunity to use fairly advanced computer processing in data analysis.

**CS Compton Scattering of Gamma Rays** The scattering of gamma rays by nearly free electrons; measurement of the probability of scattering and gamma ray energy loss as a function of scattering angle.

**HE The Hanle Effect** Use of a quantum interference effect (zero-field level crossing) to measure atomic excited-state lifetimes in the nanosecond range.

**NL Nuclear Lifetimes** Use of the photon-photon delayed coincidence technique to measure the lifetimes of short-lived intermediate nuclear states in radioactive decay.
SECURITY & SAFETY

RADIATION SAFETY: There is a radiation hazard associated with some of the experiments this term. Be sure that you have read and understood the necessary precautions outlined in Appendix D of Melissinos & Napolitano before attempting these experiments.

The rooms in the 3rd year laboratory suite must be left locked when unoccupied to protect both the equipment and your personal belongings. All students in P359E will be able to sign out a key to the room from the university so that you will have access to them for study and computer terminal use whenever the building is open.

PLEASE FOLLOW THESE COMMON SENSE RULES:

1. If you are the last to leave, turn off the lights and lock the door.
2. Never lend your key to anyone.
3. Don’t work at any experiment outside normal laboratory hours without permission.
4. Even with permission to do lab work outside normal hours, never work alone.
5. The rooms are for the use of P349E, P359E and P369F/G students only. NO guests.
6. Don’t bring food into the laboratory
7. Never take any equipment from the lab yourself without permission and never allow anyone else to do so. Borrow books from the lab collection only with permission of an instructor.
8. Keys must be returned by May 1st.