Physics 409B: A Course in Experimental Physics

Spring Session 2006

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Course Web Site: `http://www.physics.ubc.ca/~phys409`

Important Dates

Feb 1,2, 2006	Oral Presentations, Experiment 1
Feb 10, 2006	Draft for Report on Experiment 1
Feb 24, 2006	Final Report for Experiment 1 due after break Feb 13-17
March 15,16, 2006	Oral Presentations, Experiment 2
March 27, 2006	Draft Report for Experiment 2
April 7, 2006	Last Day of Class Final Report for Experiment 2

INTRODUCTION TO PHYSICS 409

Physics 409 is designed to be a practical introduction into how experimental physics is performed beyond the undergraduate level; whether it be in industry or within academia. In this regard, undergraduate students must learn how to integrate all of their previous training and how to be resourceful when confronted with the unfamiliar. From the standpoint of the student, there are two things that one may want from this course:

- **A Grade.**
- **A Letter of Reference.** You will be graduating soon. Whether you are aiming for graduate school or a career in industry, you will need someone within the university to vouch for your abilities. The instructors of laboratory courses are often a good choice when requesting letters of recommendation.

From an instructor's perspective, we want students to learn the following from this course:

- **New Physics.** The phenomena studied in this laboratory may not necessarily be taught in one of your classes; in fact, the experiments may outpace your theoretical physics education. Seize the opportunity to learn in a *practical* setting.
- **Practical Experience.** Learn how to do practical things such as analyzing real data in a laboratory setting where the situation is frequently less than ideal. Experimental physics, much like life itself, rarely goes according to plan.
- **Communication.** "In science, it is important to be right. But (perhaps) it is more important to be interesting." Wise words from a renowned theorist. The point being made is that all scientists share their data and ideas, but only those who present their work *clearly* and in an *interesting* manner gain recognition (and reap the rewards). Learn the art of telling a good story by writing a *scientific journal article* as opposed to a lab report. Learn how to make an oral presentation *clear* and *interesting* so that the audience pays attention and learns from you.

The instructors intend to provide an interesting and enjoyable learning environment. We hope that you will become an active student willing to learn new concepts and develop experimental skills. Above all else, we want you to communicate with us. Feel free to ask for assistance in the laboratory or engage the instructors in a discussion of the theoretical physics involved in your experiment - we are here to make this as profitable of an experience as possible.

Laboratory Notebooks

In order to emphasize the importance of maintaining complete records of ones experimental work, a laboratory notebook is essential. Lab books provide a detailed history of an experiment so that those who come after you may follow your progress, and so you will have information available when preparing your written articles. It will also be an element in evaluating your performance in the laboratory once the course has been completed. By no means will we be marking neatness or organization, we just want to see appropriate content.

Oral Presentations

Good researchers must have the ability to communicate their results effectively. Giving a short 10 minute talk (as required here) can often be more difficult than giving a longer presentation since you must cover so much in what always seems an inadequate amount of time. Speaking quickly may shorten the talk but is very ineffective. It is much better to identify the essential things that need to be said in order for the results to be understood and appreciated by your audience. e.g. the principles of an experiment and the scientific motivation as opposed to a detailed mathematical derivation You should explain the physics behind an experiment through diagrams, heuristics and the occasional (if necessary) equation. For reference, we provide you with key guidelines that should be considered when designing an oral presentation.

- NEVER present long mathematical derivations.
- Use diagrams and pictures to explain difficult concepts
- Make sure all text such as axis labels lables and titles are large enough to be seen by someone at the back of the room. The font should be considerably larger than normal text on a written page (24 point is about right).
- Pace your presentation such that you use about one slide per minute.
- Slides should not contain a large amount of text, rather you should provide the explanations.
- In such a short talk lead up to single conclusion that can be drawn from the work.

Further instructions and an example will be available on the web site before the first oral presentation. **All oral presentations must be with Power Point. You must submit the presentation by email to one of the TA's the day before the presentations are scheduled.**

Written Reports

An unfortunate truth about undergraduate science education is that there is negligible emphasis placed upon developing good writing skills. Too often science students are pressured to produce large quantities quickly, but little feedback is provided concerning the quality of the writing. It is hoped that Physics 409 will help rectify this situation.

Submission of Formal Reports

In order to ensure that good writing habits develop and to prepare you for writing scientific journal articles or technical reports, the editing process shall be embedded within the course curriculum. The process will involve submitting laboratory reports twice - on the first draft we will provide general comments which will help you avoid making any serious errors on the second draft. We believe that this process is much more beneficial than the conventional process of just submitting reports and receiving a grade. Furthermore, the overall process is meant to emulate the use of referees in the submission of research papers to major scientific journals. The following procedure will be followed when submitting laboratory reports;

1. WRITE A ROUGH DRAFT - Writing a rough draft will often make the job easier and will result in a superior final product.
2. Prepare and Submit First Draft - Submit the finished product by the specified date. **You must use LATEX to prepare the drafts and final reports** The final product should be in **PORTABLE DOCUMENT FORMAT (.PDF) file and is to be e-mailed to both Rob and the TA responsible for marking it. We will not accept hard copies or any other file formats. In most cases we will print a hardcopy and provide comments. Beware the first draft has a much bigger impact on your final mark than the weighting it is given in the marking scheme. If you do not take advantage of submitting a first draft you will almost certainly do poorly on the final report.**
3. Modify and Submit final report by email. The final report should have addressed all the concerns or problems identified from the first draft.

At the end of the procedure, we will return a marking scheme based on both the draft and final report.

Formal Report Style

Physics 409 will emphasize periodical style writing (clear, concise, and relatively short), as opposed to thesis style writing (extremely detailed, relatively long). The only format acceptable is that of the Physical Review family of journals. A documented journal article template and any necessary software will be put on the website when required.

One particular aspect that we would like to emphasize is the presentation of graphics. Graphs should be labelled clearly and a caption should be provided to tell the reader explicitly what it is they should be concluding from the graph. Much of this is under your control, however we ask that you recognize that many graphing packages place severe limitations upon what you can accomplish. **In particular, we will not accept graphs generated from Microsoft Excel.** Please choose more appropriate software for generating graphics.

A Note Concerning Mathematica. It is a powerful PC/UNIX based number crunching package, but it typically produces horrible graphics. We endorse the use of Mathematica when performing data analysis and will accept Mathematica generated graphs, provided you take the time to learn how to label and scale these graphs appropriately, as the default options make a mess. We will provide a Mathematica fitting and graphing tutorial prior to the submission of the first paper.

Lab hours

The laboratory will be open 13h00→17h00 on Monday, Wednesday and Thursday. However you are urged to attend the weekly departmental colloqium at 16:00 on Thursdays since it provides an excellent opportunity to learn about current research topics in physics.

Marking

Oral Presentation, Experiment 1	15
Draft Report for Experiment 1	5
Final Report for Experiment 1	25
Lab Performance and notebook for Exp. 1	5
Oral Presentation, Experiment 2	15
Draft Report for Experiment 2	5
Final Report for Experiment 2	25
Lab Peformance and notebook for Exp. 2	5
TOTAL	100

For marking of the *DRAFT reports* we will use the following scheme:
Name:
Experiment:

Component	Criterion	0	1	2
Abstract	*Clear Purpose, Key Results*			
Introduction	*Motivation for Experiment, Background*			
	Clear Objectives			
Theory	*Concise Description of Theory*			
Experimental Methods	*Description of Apparatus*			
	Procedures			
Results and Analysis	*Data Quality*			
	Data Presentation			
	Analysis and Interpretation			
Conclusions	*Summary of Experiment, Results*			

0 = POOR   1 = FAIR   2 = GOOD: see comments on report

For the marking of final report we employ the following scheme:

Written Work Evaluation

Component	Criterion	Weight	Draft	final
Abstract	*Clear Purpose*	5		
	Key Results	5		
Introduction	*Background and Motivation for Experiment*	6		
	Clear statement about what follows and key results	3		
Theory	*Concise Description of Theory*	6		
Experimental Methods	*Description of Apparatus*	10		
	Procedures	5		
Results and Analysis	*Data Quality*	10		
	Data Presentation	15		
	Appropriate Error Estimates	5		
	Analysis and Interpretation	15		
Conclusions	*Summary of Results and/or Conclusions*	10		
References	*Adequate Documentation*	5		
Adjustments				
TOTALS		100		

For the marking of oral presentations, we use the following scheme:

Oral Presentation Evalulation

Component	Criterion	Weight	Mark
Delivery	*Clear and Audible*	3	
Visual Aids	*Legible Overheads*	3	
Content	*Clear Purpose*	3	
	Clear Explanation	3	
Time	*Not Exceeding 10 Minutes*	3	
TOTALS		15	

Late Policy for Written Work

As you are a fourth year physics student, we will trust your time management skills. We also understand that you do have other courses and lives to lead, and so there will be times when you may not be able to meet a particular deadline. Therefore, if you have serious problems with meeting any deadline, please speak to one of the instructors. Unfortunately there is no flexibility in the oral presentations since the rooms have to booked in advance. Also, it has proven necessary in the past to invoke a late policy. The late penalty will be 5% per day for all written work.

Computer Facilities

The Physics 409 laboratory has a variety of computing facilities available for your use. There are two WYSE terminals connected to the Physics server, three computers on carts with IEEE-488 bus interfaces and one computer on a cart with a pulse height analyzer. A colour printer is also available for your use (very handy for preparing presentation slides). All of these computers are connected to the Phys409 intranet and to the Hebb building backbone. All PCs have X-Win and SSH/SFTP software for interfacing with the Physics server. If you have to log into one of our PCs, then enter 'P409' as the user and 'p409' as the password.

Experiment Manuals

To conserve some paper, we have chosen not to print a copy of the entire Physics 409 manual for each student. This document is becoming rather lengthy and is in the process of being rewritten. Rather, you will be supplied with a copy of the manual for only those experiments that you choose to study. Please return these manuals at the end of an experiment, or ask the instructors if you would like your own copy. In some cases the experiments are new or have recently been upgraded. and thus there is no up to date manual.In these cases we will provide you with a previous students report on the experiment and other background information you might need.

You will notice that some of the manuals prepared in LaTeX are rather lengthy. These are experiments which have been deemed particularly suitable for advanced undergraduate students and great efforts have been made to explain the theory and logic behind them. However, these manuals do not provide you with a written recipe for performing an experiment. Rather, the intention is to supply you with sufficient knowledge for you to make rational choices on how to study a physical phenomenon.

Brief Description of Available Experiments

The following are meant to give you some guidance in choosing which experiments you would like to perform this semester. Please ask for a complete experiment manual if you want more details.

- **Electromagnetic Skin Depth of Metals**
  A fundamental picture of electron conduction in normal metals is presented and then compared to theory. The experiment involves driving screening currents in a metal cylinder by applying a magnetic field and then measuring the attenuation of the field. This experiment should be considered essential for those who wish to study condensed matter physics.

- **X-Ray Diffraction**
  The AMPEL X-ray diffraction facility is available for student use under supervision. This is an opportunity to learn about a very important materials science diagnostic tool with a world class instrument. The theory of diffraction by crystalline and polycrystalline samples is developed. There is some flexibility in what structures are studied. This experiment will involve sessions at times other than normal Physics 409 laboratory periods. Please book experiment time with the teaching assistant.

- **Thermal Noise**
  Thermal noise is present in all electrical circuits and thus places limits on sensitivity of any instrument or device. In this experiment you strive to understand the properties of thermal noise. Measurements of thermal noise across a series of resistors allows one to measure Boltzman's constant k_B.

- **Pulsed Nuclear Magnetic Resonance**
  The fundamentals of NMR such as spin precession and spin-lattice relaxation are understood. Measurements of the relaxation times are made in water and liquid glycerin. This experiment is particularly recommended for those who wish to study condensed matter physics or medical physics.

- **Magnetic Resonance Imaging in 1 Dimension**
  Using the principles of NMR, a theoretical framework for imaging along a one dimensional axis is developed. Practical considerations of signal processing are used to determine appropriate experimental parameters and a specially designed sample is imaged. It is necessary that the student at least read and understand the Pulsed Nuclear Magnetic Resonance experiment prior to attempting this experiment. This experiment uses the same apparatus as the one for NMR.

- **Chaotic Rhythms of a Dripping Faucet**
  This experiment introduces the student to the field of nonlinear dynamics using a relatively simple phenomenon - water dripping through an orifice. The period between drops can become chaotic if the system is driven correctly.

- **Muon Lifetime**
  The muon is one of the fundamental particles of nature. It is similar to the electron in that it has no discernable structure but its mass is about 200 times heavier. TRIUMF produces intense beams of muons for use in condensed matter physics and particle physics. Muons are also produced naturally in the upper atmosphere through nuclear reactions with energetic cosmic rays striking the earth. In this experiment such cosmic ray muons are stopped in a large scintillator The decay of the muon into an electron and two neutrinos is measured with a second scintillator. The student sets up some simple electronics designed to measure the muon lifetime.

- **Photoelectric Effect**
  The student carries out the classic experiment which Einstein explained by invoking the quantum nature of radiation. A metal cathode is held at a fixed potential and then subjected to monochromatic light. By varying the potential and measuring the resulting electrical discharge from the cathode, one can measure the energy of the work potential of the metal and determine a fundamental constant of nature, $\frac{h}{e}$.

- **Atomic Energy States (Frank-Hertz)**
  Measurement of the first excited state of mercury is made using an electron bombardment technique developed by Frank and Hertz. This is another classic experiment which helped formulate our current understanding of the atom.

- **Electron Spin Resonance**
  This is an introduction to the methods of ESR using frequency domain spectroscopy. A DC magnetic field produces an Zeeman energy splitting between the electron spin levels in a solid. An alternating transverse field induces a transition between the energy levels of the electron when the frequency of the AC magnetic field is matched to the Larmor frequency of the electron. The resulting resonance is broadened due to interactions with the solid. This experiment will be of special interest to those who wish to study condensed matter physics.

- **The Magnetization of a High Temperature Superconductor**
  In this experiment one measures the Meissner effect of a high temperature superconductor YBCO ($YBa_2Cu_3O_{7-\delta}$) using an AC magnetic susceptometer. This experiment involves cryogenics, thermometry,

vacuum techniques. and small signal detection. Although high Tc superconductivity was discovered in 1987 there is still no microscopic theory for how these fascintating materials work.

- **Positron Emission Tomography**
  Positron emmission tomography (PET) is a powerful way to track radioisotopes. It is used extensively to monitor metabolic function in the humans. In this expeirment one will explore the main principle of PET–when a positron annihilates with an electron the resulting two gamma rays are emitted back to back. If one detects both gamma rays with position sensitive detectors then the annihilation event must have occured on a line connecting the two detectors. Using this principle one sets up a simple apparatus to create an image of a point source.

- **Speed of Light**
  In this experiment the speed of light is measured by detecting the annihilation radiation from a positron source. Fast plastic scintillators are used to resolve the time difference between the two gamma rays to within 500 ps. By moving the source with respect to the detectors one can measure the speed of light.

- **Gamma Ray Scattering**
  One uses a high resolution gamma ray spectrometer to measure the total cross section for gamma ray scattering from the atom as a function of both the gamma ray energy and charge of the nucleus. This experiment is most relevent to those in medical physics and particle and nuclear physics.

- **Optical Measurement of the the Band Gap in GaAs**
  Electrons in an isolated atom are localized and have sharp well-defined energy levels. In a crsytalline solid where the atoms are interacting the electrons are delocalized while the energy levels disperse into broad energy bands with many fascinating and useful properties. The bandgap refers to the energy difference between the highest fully occupied energy band and the lowest unoccupied energy band. The whole electronics industry is based on this generic feature of solids. In this experiment you measure of the bandgap in GaAs using a white light source and an optical spectrometer. If you are interested in condensed matter physics you should try this.

Important Note

You will need to find a partner ASAP. Please email me at kiefl@triumf.ca later today or tommorrow your partner's name, his email address and a list of your first, second and third choices for the first experiment. Also it would help if you would indicate what area in physics you and your partner are most interested in. (e.g. condensed matter, particle, medical etc). There is limited amount of equipment so experiments will be assigned on a first come first serve basis.