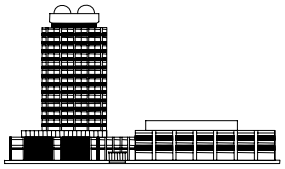
UNIVERSITY OF TORONTO
Department of Physics

First Year Physics Laboratory Manual

PHY110Y and PHY138Y
2007-2008



Department of Physics

1st Year Physics Laboratory

PHY110 Y1Y, PHY138 Y1Y

University of Toronto

Laboratory Outline and Information

September 2007 - April 2008

Welcome! The First Year Physics Laboratory is an essential and required component of both the *Basic Physics* and *Physics for the Life Sciences* courses. In this lab you will have an opportunity to work on interesting, challenging experiments and activities, deepen your understanding of the underlying Physics, and develop your laboratory skills and analysis techniques.

You are left much more to your own initiative in carrying out the experiments than you may have ever been in high school or another university. At the same time you are given many more resources to work with - both in the availability of more sophisticated equipment and in staff to help you. You are strongly encouraged to make good use of your demonstrator, the course coordinators and administrator, and the technological staff. As you become more accustomed to the format and structure of the course, we encourage you to use your imagination and creativity when solving problems. If you discover some aspect of an experiment or activity which really interests you, or come up with some innovative way of doing the analysis, you may, with guidance from your demonstrator, modify the exercises to suit you. We want you to have fun and we'd like to help you make the most of the opportunities in this course.

The course web-site has the most up to date manuals and information:

http://faraday.physics.utoronto.ca/PHY110_138Lab.html

Goals

The main goal of the lab is to give you an appreciation of the essential nature of laboratory exploration in the development of our knowledge about the physical world and the power of the experimentation on which the science of Physics rests. We believe that the only way to develop initiative in the lab is by individual, hands-on experience. You will develop your own solutions to practical problems. The lab is designed to help you develop skills to:

- manipulate equipment with grace and use it to solve practical problems,
- keep complete records, including the display of data in tabular and graphical form,
- analyze data efficiently and accurately, with and without the use of a computer,
- estimate uncertainties in experimental results.

Staff

Here are the names and contact information of some of the people who can help you in the 1st Year Lab this year:

Name	**MP Office**	**Phone**	**Email** (@physics.utoronto.ca)
Professors:			
Jason Harlow (coordinator)	129-A	946-4071	jharlow
Vatche Deyirmenjian	129-B	946-0336	dey
Administrative Assistant:			
April Seeley	129	946-0531	seeley
Technological Staff:			
Larry Avramidis, Phil Scolieri, Rob Smidrovskis	127	978-2957	

Professors and the Administrative Assistant will endeavour to respond to email inquiries from students within 2 days. If you do not receive a reply within this period, please resubmit your question(s) and/or phone (leave a message if necessary). Please note that some servers (such as hotmail) can be unreliable in both sending and receiving messages.

Lab Hours

The two week cycle of Physics labs starts on Tuesday October 9, 2007. You will meet one of the two lab coordinators on the first day of the course and your lab demonstrator at your first lab. Check the notices posted from time to time on the lab information boards by MP125 and MP126 and also the laboratory web page.

Before you come to the lab, you need to obtain:

- The First Year Physics Laboratory Manual 2007-2008 (which you are reading right now!) and the Physics Laboratory Notebook, a bound white notebook in which you will record all your experimental work. They are sold as a package by the University of Toronto Bookstores. Note: The black hardcover Physics Notebook is not acceptable.
- An electronic calculator: Choose one which can calculate statistical functions (mean values, standard deviations, etc. of a set of numbers). It is better if it also provides the values of scientific constants. Bring along the instruction manual for your calculator until you are confident you can use it properly for the statistical calculations.
- A good clear plastic ruler of at least 30 centimetres in length (smaller versions are inadequate), a sharp pencil, and a writing pen. You do not, however, need a lab coat!

Before you come to your first lab you should read this manual.

You will have been assigned to a lab section, P0x0y, where x denotes the day of the week you

have chosen, and y denotes week 1 or 2 of the lab's two week cycle. You will normally attend the lab on alternate weeks on your chosen weekday (one of MTW 2:00-5:00 PM, RF 1:00-4:00 PM, W(night) 6:00-9:00 PM). Monday, October 8, 2007 is a University Holiday. Section P0102 will first meet on Monday, October 22 and have a final session on Monday, December 3.

Each section is divided into lab groups (with numbers like 1A, 2B, 4C, 5X, etc.), each containing about 16 students per group. Each group has a "demonstrator" who provides supervision, guidance, organization, and assistance throughout the year. Although each demonstrator has a specific group responsibility, all of them are available, along with the lab coordinators, to answer questions from any student in the lab. You will meet your demonstrator on your first lab day.

Important!! Learn the name, office number, telephone extension, and email of your demonstrator, and remember what he or she looks like. Print your demonstrator's name, lab section, and lab group number on the front of your Laboratory Notebook. Print your Faraday computer login and password on the inside cover of your Lab Notebook. Register your account immediately.

Schedule

Students attend the lab on the same weekday on alternate weeks

Lab week	Week of:	Mon 2 - 5	Tue 2 - 5	Wed 2 - 5	Thu 1 - 4	Fri 1 - 4	Wed (eve) 6 - 9	Lab sess.	Topics
2	Sept 10	No labs							
1	Sept 17	No labs							
2	Sept 24	No labs							Individual Study: Error Analysis
1	Oct 1	No labs							Individual Study: Error Analysis
2	Oct 8	*Holiday* P0202	P0302	P0402	-	P5302		1	Module A *Oct 8 is a University Holiday*
		First P0102 lab – Oct 22. Last P0102 lab – Dec 3.							
1	Oct 15	P0101	P0201	P0301	P0401	P0501	-		Module A
2	Oct 22	P0102	P0202	P0302	P0402	-	P5302	2	Module B
1	Oct 29	P0101	P0201	P0301	P0401	P0501	-		Module B
2	Nov 5	P0102	P0202	P0302	P0402	-	P5302	3	Module C
1	Nov 12	P0101	P0201	P0301	P0401	P0501	-		Module C
2	Nov 19	P0102	P0202	P0302	P0402	-	P5302	4	Module D
1	Nov 26	P0101	P0201	P0301	P0401	P0501	-		Module D
1	Jan 7	P0101	P0201	P0301	P0401	P0501	-	5	**PHY110Y and PHY138Y**: 5 weights of free choice experiments for this term
2	Jan 14	P0102	P0202	P0302	P0402	-	P5302		
1	Jan 21	P0101	P0201	P0301	P0401	P0501	-	6	
2	Jan 28	P0102	P0202	P0302	P0402	-	P5302		
1	Feb 4	P0101	P0201	P0301	P0401	P0501	-	7	
2	Feb 11	P0102	P0202	P0302	P0402	-	P5302		
1	Feb 18	**Reading Week - no classes**							
1	Feb 25	P0101	P0201	P0301	P0401	P0501	-	8	
2	Mar 3	P0102	P0202	P0302	P0402	-	P5302		
1	Mar 10	P0101	P0201	P0301	P0401	P0501	-	9	
2	Mar 17	P0102	P0202	P0302	P0402	-	P5302		
1	Mar 24	P0101	P0201	P0301	P0401	P0501	-	10	
2	Mar 31	P0102	P0202	P0302	P0402	-	P5302		

Fall 2007 Semester Deadlines and Procedures

You will find that the core and non-core experiments have their complete guide sheets distributed on-line at: http://faraday.physics.utoronto.ca/IYearLab/Experiments.htm

In the Fall term, you will perform four activities and experiments organized in four 3-hour modules:

Module A	Oct.9 - Oct.22
Module B	Oct.23 - Nov.5
Module C	Nov.6 - Nov.19
Module D	Nov.20 - Dec.3

You are required to attend all four modules in the Fall and will be penalized for unauthorized absences. The penalty will be a zero on the Module work done in the session you did not attend.

All work in the laboratory which is undertaken for credit must be done under the supervision of a lab demonstrator. Your Lab Notebook must stay with your demonstrator when you leave the lab. You may take the Notebook out between the 9th and 10th lab sessions in March and April, 2008, for use when writing your Formal Report. The Notebook must be returned to your demonstrator when you finish the Formal Report, and it becomes the property of the department when you are done the course.

At the beginning of the year you will do the Error Analysis Assignment outside the lab sessions. It is available on the course web-site at http://faraday.physics.utoronto.ca/PHY110_138Lab.html

The Error Analysis Assignment Due to your demonstrator at the beginning of your second lab session Oct.23-Nov.5.

Late Error Analysis Assignments will be penalized at the rate of 10% per day of lateness. A fractional number of days will always be rounded *up* to the nearest integer, and the penalty will be applied as a percentage of the unpenalized mark. Assignments more than 10 days late will receive a zero.

Spring 2008 Semester Deadlines and Procedures

In the Spring term, you will complete **5 or 6 weights of free choice experiments**, core or non-core. If you complete 6 weights your mark will be computed using the best 5 out of 6 weights. In order to help you develop the skills required to keep a good Notebook, you will not be allowed to take your Lab Notebook out of the laboratory, except just before the date the Formal Report is due.

While most experiments are worth two weights, talented and/or interested students are urged to consider undertaking one of the three weight experiments, which are more challenging but often more stimulating.

You must have your demonstrator's permission to start any new experiment. Such permission will not normally be given until you have completely finished the previous experiment.

A one weight experiment is designed so that the data-taking stage can be completed within one

three hour period if you work efficiently. However, for most this will be true only if you have spent time beforehand in preparation, and fully understand the purpose and method of approach of the experiment you are about to perform. In particular you should ensure that you can answer all the Preparatory Questions which appear on the guide sheets for each of the core experiments. The lab is open for this preparatory work from 11:00 AM to the beginning of the lab session (1:00 PM or 2:00 PM) , every weekday. Technologists and occasionally demonstrators may be available.

A short **Formal Report** is due to www.turnitin.com by 11:59 PM on Sunday, March 23, 2008. The Formal Report is meant to be written in the style of a scientific journal article. It should be a brief, but concise summary of one of the free choice experiments you have already completed in the Spring Term, using the information you have recorded in your Lab Notebook. It should be no more than 800 words, (approximately 3 pages of double spaced type) and 2 pages of graphs and/or diagrams (marks will be deducted if the report is longer than this!). Note that turnitin.com sometimes overcounts the number of words; the turnitin.com word count must not exceed 1000 words. It must be submitted in electronic format (Word, PDF and several other formats are acceptable) to www.turnitin.com by the deadline, and an identical paper copy must also be submitted to your demonstrator at the beginning of your final lab session Mar.24-Apr.4. Your Notebook must also be turned back to your demonstrator during your final lab session Mar.24-Apr.4. The paper copy may be turned in early if you wish, as can the electronic version. Your name, Student Number, Lab Group and Lab Demonstrator Name must appear clearly on the front of your Formal Report.

Late Formal Reports will be penalized at the rate of 10% per day of lateness. The number of days of lateness will be the maximum of the electronic submission lateness, as based on the turnitin.com time-stamp, and the paper-copy lateness (paper-copy lateness includes late returns of the Notebook). A fractional number of days will always be rounded *up* to the nearest integer, and the penalty will be applied as a percentage of the unpenalized mark. Formal Reports with an electronic or paper lateness of more than 10 days will receive a zero.

The Formal Report will be primarily evaluated on writing style and on the organization and presentation of the material. Good English structure, spelling and grammar are expected, and graphs and diagrams should be clearly labelled.

Marking Scheme and Expectations

A major part of your lab mark will reflect the quality and quantity of work (with quality being of prime importance) which you have accomplished during the scheduled lab session under your demonstrator's supervision. Your final lab mark will be evaluated as follows:

Error Analysis Assignment, Due at the beginning of your second lab session, Oct.23-Nov.5, 2007	10%
Fall Modules A, B, C, D: Notebook Marks	30%
Fall In Lab Mark, Posted in December 2007	10%
Spring 5 Best Free Choice Weights: Notebook Marks	30%
Spring In Lab Mark, Posted in April 2008	10%
Formal Report, Due online Mar. 23, 2008, and in paper format at the beginning of your final lab session, Mar.24 – Apr.4, 2008	10%
Total:	**100%**

Notebook Marks

Immediately after you have finished an experiment, have your demonstrator attest to its completion by signing the last entry in your Notebook. If time permits, your demonstrator will sit down with you and your sub-group at that time to briefly discuss the experiment you have just done. If time is short, this discussion may take place at your next lab session, after marking. Between that lab session and the next, your demonstrator will grade that experiment and give you a mark out of 100. The Fall Module marks will be based not on the entire module, but a randomly chosen (but consistent from group-to-group) set of activities.

Your best marks from 5 weights of experiments from the Spring term will be used to give a Spring Experiment Mark. In order to encourage you to attempt experiments which are not core, a bonus of 3 marks will be added to your experiment mark (i.e. 3 out of 100) for each non-core experiment you complete in the Spring term. This offer is conditional on there being sufficient apparatus available to meet the demand, so talk to your demonstrator early!

At the end of the guide sheets for the core experiments, there is a set of Preparatory Questions. These questions are designed to assist you in understanding and preparing for the experiment. Some provide pointers to the theoretical background. You may need to consult your textbook or the References listed at the beginning of the guide sheets. Other questions give you indications of the experimental procedures. For these you will need to develop some familiarity with the equipment. The answers to these questions should be an integral part of your preparation.

Write your answers to the Preparatory Questions on a piece of paper and submit it to your demonstrator at the beginning of each new experiment you undertake. These answers also may be pasted or stapled into your Notebook. Also, graphs of data produced by a computer program such as that on Faraday may also be pasted or stapled into your Notebook. No other materials from outside the lab may be added to your Notebook! The rest should be written by you in pen during lab time.

When marking your Notebook, your demonstrator will be looking at your performance in the following categories:

- data displayed as it was taken, in well-labelled tables
- errors in data indicated
- graphs titled, with both axes correctly labelled
- correct units used throughout
- discussion of the quality of the measurements
- data self-consistent
- graphs and diagrams used appropriately
- calculations clearly indicated
- correct and intelligent use of error analysis
- evidence of good organization and experimental procedures
- sufficient description to make clear exactly what was done
- an overall impression of careful and accurate work, well understood, with "reasonable" measurements, errors, and results
- indications of limitations of the experimental method, with comments on possible extensions

In Lab Mark

During each lab session throughout the course, your demonstrator will be observing how you perform in the lab on an ongoing basis. Once in the Fall term and once in the Spring term, your demonstrator will assign a mark based on this ongoing observation.

Criteria for In Lab Mark Criteria for arriving at the In Lab Mark overlap to a great extent with those for the Experiment Mark. The In Lab Mark is meant to provide a more general overview of your work, with particular focus on your experimental ability. In arriving at this mark, your demonstrator will take into account your preparedness, the way you approach and organize your experimentation, your efficiency in planning and setting up the experiment, evidence of graceful handling of instruments and equipment, and your care in taking data. Also considered will be your ability to estimate errors (rather than calculating each one exactly), your ability to distinguish the essential from the inessential, the way you work with your sub-group, your willingness to try something, to make a mistake, and to learn from it, and how often you seek advice and ask questions. A student who never asks questions may leave the impression of being disinterested.

Percentage	Letter Grade	Grade Definitions
80-100	A	**Excellent** Strong evidence of original thinking and creativity; excellent organization; capacity to analyze and synthesize; superior grasp of subject matter with sound critical evaluations; evidence of extensive knowledge base.
70-79	B	**Good** Evidence of grasp of subject matter, some evidence of critical capacity and analytic ability; good understanding of relevant issues; evidence of familiarity with literature.
60-69	C	**Adequate** Student who is profiting from his/her university experience; understanding of the subject matter; ability to develop solutions to simple problems in the material.
50-59	D	**Marginal** Some evidence of familiarity with subject matter and some evidence that critical and analytic skills have been developed.
0-49	F	**Wholly Inadequate** Little evidence of even superficial understanding of subject matter; weakness in critical and analytic skills; with limited or irrelevant use of literature.

Teamwork

You will be performing your experiments with others in the laboratory. You and your sub-group will work together to take data. We fully expect that you will jointly take the data and do all parts of the experiment. We also fully expect that you will discuss the problems of the experiment and your analysis together, thus sharing each other's experience in problem solving. However, we also expect that you will do your own independent analysis and write-up of the experiment. It is

expected that sub-group members will not copy each other's descriptions of procedure or conclusions in their Lab Notebooks.

You may talk about experimental data with other persons in your group. You will receive a zero final lab grade if you copy another person's work or invent data.

Make-ups

Students are expected to attend all scheduled lab sessions. However, if you have a documented reason (backed up by a note from a physician or your College Registrar and reported to your demonstrator) lab time may be made up at other hours. If you have to do a make up lab, the following rules apply:

1. You must arrange in advance with your demonstrator a time for a make-up period, three hours or less in length.
2. You must see your demonstrator immediately prior to starting work in the lab and have him/her initial your Lab Notebook.
3. Your demonstrator, or an alternate appointed by your demonstrator*, must visit you in the lab at least once, and preferably several times during the make-up period. Without this visit you cannot receive credit for work done in the lab.
4. You must see your demonstrator, or alternate*, when the make-up period is over, so that he or she can sign your Notebook in the usual way.

*Note: Only one of the lab coordinators or demonstrators may sign make-up work. Signatures from the lab technologists are not acceptable.

General Procedures in the Laboratory

Your Laboratory Notebook will serve as an ongoing record of your work in the lab. Lab Notebooks should be used for ALL data, ALL "rough work", and an account (note form is acceptable) of what you are actually doing, written as you actually do it (as opposed to recollections made after the fact). Detailed essays on your procedure are not required. You will not be allowed to take your Lab Notebook out of the laboratory. The collection of your data and the write up in your Notebook must be done during your regular lab hours. However, in the Spring Semester, the analysis of your data, including graphical analysis or error calculations can be done outside your regular lab session, if you so wish. Data entered and backed-up into one of your files on the lab computer are also available thereafter for similar analysis. An example of a top-quality Laboratory Notebook can be found at:
http://www.upscale.utoronto.ca/PVB/Harrison/AzumaBook/Azuma.html.

Your Lab Notebook Record

Recording data is a vital part of experimentation. Everything you do in the lab should be recorded in your Lab Notebook while you are doing the experiment and no entries are to be done in the Notebook outside lab hours. A good lab book is a minute-by-minute record of your work in the lab. It should contain everything you do, all of your rough calculations or preliminary measurements, full details of any error calculations, any comments, records of success or failure, etc., should appear in its pages. If you do use additional scraps of paper, you risk having marks

taken off. ALSO, there is no point in copying information that is already contained in the guide sheets. Nor is there any point in writing elegant descriptions or detailed essays on your procedure. Note form is quite sufficient, as long as it is complete and comprehensible to your demonstrator and fairly describes what you are doing as you do it. Please be neat! Notebooks are marked, in part, on the basis of completeness.

Important! Every student will receive an Experiment Mark based on individual work. Every student will have to submit his or her own Notebook for marking.

Do not write in pencil since it is not permanent. You will see that the lab book has numbered pages and a title page so that it is possible to follow the logic and sequence of the recorded work, experiment-by-experiment. Enter the title of the experiments you do in the List of Experiments, along with starting and completion dates. Computer or hand-drawn graphs can be inserted beside your description of your experiment.

However, it is not permissible to add any additional pieces of paper which have descriptive writing, data, or calculations. Penalties will be imposed for the use of loose paper for data taking or calculations. All of your work should be entered and appear in your Lab Notebook.

It is good practice to keep the record of the experiment on facing pages and any rough work, doodles, or scribbles on the back pages (labeled "Rough Work"). Of course, if you need to, you can design additional data tables or draw rough graphs on the other pages to suit the needs of the moment.

Please note: Apart from the data tables and graphs described above, and the preparatory questions, no other pages and no other information can be stuck into your Lab Notebook.

Each report should contain a clear statement of the purpose of the experiment you are about to do, preferably near the beginning. If you do not know the purpose, it is unlikely that you will do a good experiment!

Most workers doing research in experimental science find that a diary format works best. Write down what was done immediately after it was done in the order that it was done. This is the form that we recommend in this lab. Diary format means that each set of data will have a date and time on it and the record is written in the order in which a procedure, calculation, or inspiration actually occurred. As your Lab Notebook is a diary that moves forward in time, DO NOT leave blank pages to be filled in later. When you complete all your data, finish all the calculations, comments, and conclusions as soon as possible, and definitely before you start writing anything for the next experiment.

Plagiarism (representing the work of past students, current students, or any other person as your own) and invention (reporting imaginary data) are serious academic offences. If done in the "outside" world, they often produce serious setbacks for science, not to mention lawsuits! In the university setting, plagiarism or invention will result in disciplinary measures such as setting your final lab mark to zero which means that you would lose the lab portion of your final course mark. Disciplinary measures are referred to the Dean of your Faculty and they may remain on your record. Repeated offences can lead to expulsion from the University. Laboratory work done without your demonstrator's knowledge will not be marked. You will receive a zero final lab grade if you copy another person's work or invent data.

If you legitimately copy part of some published work in your lab book, you must cite that work, quoting the author, title, date, etc. Copying published work with proper citations is not

plagiarism. Also, you may talk about experimental data with other persons in your group.

A typical lab session

1. Prepare ahead of time. Download the write-up off the lab web-site, and answer any preparatory questions on pieces of paper that can later be added to your Notebook.
2. Arrive on time, check-in with your demonstrator, and pick up your Lab Notebook.
3. Find your apparatus. This is particularly important in the Spring when you have free choice of experiments, which are located all over the North Wing of MP.
4. Enter the Experiment Title, Apparatus Number, and **Date** in your Lab Notebook.
5. Take data, entering it directly into your Lab Notebook along with a brief description of your procedures. Make rough plots of the data as you go along. Do your calculating, error estimates, and graph plotting. Use the computer when appropriate.
6. Be prepared to answer questions from your demonstrator or the lab coordinators who will drop by from time to time. Search them out with your own questions.
7. Complete as much of your write-up as possible.
8. At the end of the lab period, check-out with your demonstrator. Ensure that he/she initials your book at the end and leave your book with him/her. If it is the Spring term and you have completed an experiment, discuss the next experiment with your demonstrator.

FARADAY Accounts – Using the computers for data fitting

There is a lab computer, called Faraday, which has student terminals in MP125, MP126, and MP257. Faraday offers a variety of programs including facilities for curve fitting, experiment checking, report writing, and informational material giving lab equipment specifications. You will receive an account and instructions for logging on early in the term. Record your account information in your Lab Notebook. We suggest that you try out the lab computer as soon as is convenient in order to accustom yourself to this facility.

You access the programs on the computer through a series of menus. The system is set up to be easily usable by people with no prior experience with computers. There is ample information available on what to do if things do not work for you. Obtain this information by typing “help” on the computer. There is also a printed copy of this computer help information available at the Resource Centre. We encourage you to start using the computer early in the term.

You will find that the computer is an enormous aid to your work in the lab. By far the most used feature is the least-squares fit of your data to a polynomial function (linear, quadratic, cubic, etc.), since almost any hypothesis concerning the data from the First Year Lab experiments can be expressed as a polynomial. Here are a few tips:

- Use single, lower-case letters to define your variables, for example, p, v, etc.
- Enter data in the raw form. The computer will do any required calculations. For example, suppose you have measured values of a pressure, which you have called p, and need to plot $1/p$. Don't calculate $1/p$. The computer will do it for you.

- If the error in a given variable is a constant, or a simple function of the variables such as $0.05/p^2$, you do not need to enter it into your data set. The computer will do the calculation for you.
- Once you have entered your data, backup the file immediately. Follow the menu.

Caution: There are types of work for which computer assistance is not appropriate. An important part of your learning this year should be the development of judgment about when and when not to seek assistance from the computer.

If you have any difficulties with or questions about the computer, contact the lab coordinators or send a message to them via email.

Mathematical Expressions on Faraday:

x*y (multiplication), x/y (division), 1/x (inverse), x^n (polynomial x^n), Sqrt[x] (square root), Log[x] (natural logarithm base e), Exp[x] (exponential e^x), Log[10,x] (logarithm base 10), Cos[x] (cosine), ArcSin[x] (inverse sine), Abs[x] (absolute value)

Examples 4*(x+Sin[x^2]) 0.5*Log[10,x^2+4*x]