Athabasca University

PHYS 205 Lab Manual (Lab Information)

Acknowledgment

Athabasca University started employing the physics home lab concept in 1997. Dr. Connors' original versions (v.1.0-1.5 from 1997-2002) of the PHYS 200 Home Lab Guide/Manual were supported by the Office of Learning Technologies (OLT) of Human Resources Development Canada and the Mission Critical Research Fund of Athabasca University.

Since then, the use of home lab manuals has expanded. Athabasca University strives to improve the quality and efficiency of the students' lab experience developing new experiments and introducing new technologies in the lab kits. In addition, we continue to improve the quality of lab manuals by re-editing existing experiments, and producing multimedia content.

The authors gratefully thank, Elaine Goth-Birkigt, Rafael Hakobyan, and Rob Carmichael of Athabasca University Science Lab for their efforts to prepare and maintain the lab kits. Appreciation also extends to the physics tutors Leonid Braverman, Jon Johansson, Fuad Sarajov, Arzu Sardarli, and Bill Scott for their valuable suggestions that helped in developing these laboratory exercises.

Introduction

The lab component provides hands-on empirical experience of the physical concepts covered in the course. The lab experiments are designed to go with the course material to help you connect theory and physical phenomena. All the experiments in this manual can be done at home or in a place of your choice.

The Experiments

The PHYS 205 Lab Manual consists of the following six home labs

Experiment 0: Measurement and Graphical Analysis

This is not a required experiment in this course. It is actually a reading material (taken from the PHYS 204 Lab Manual) aimed to review significant figures and measurement uncertainty and to demonstrate the importance of graphical analysis. In other words, no lab report is expected

After completing this experiment, you should be able to

- explain the meaning of significant figures.

- estimate error propagation resulting from basic mathematical operations.
- generate a 2D graphical representation for a numerical data set.
- calculate and give meaning to the slope and y-intercept of a linear graph.

Experiment 1: Coulomb's Law

Electric charge is a fundamental physical property of matter. Unlike mass, however, the charge carried by a particle can be positive, negative or zero. Charges are found every where and in great abundance. Actually, a normal atom is composed of an equal number of positively charged protons and negatively charged electrons, in addition to neutral (or uncharged) neutrons. In such state, the atom is a neutral particle carrying zero net charge. However, it can turn into a charged particle (or ion) if it loses or gains an electron.

Two objects carrying similar charges (both positive or both negative), exert repulsive forces on each other. Oppositely charged objects, however, attract each other. This electric force becomes stronger when the quantity of charge on either object increases or if the distance between them decreases. In this experiment, you will investigate the relationship between electric force and distance for two charged objects.

After completing this experiment, you should be able to

- state Coulomb's law.
- explain the relation between electric force and separation between two charges.
- demonstrate the charging of a non-conductor material by friction.
- demonstrate repulsion of two objects carrying similar charges.
- perform curve fit to a date set and interpret the fit parameters.

Experiment 2: Ohm's Law and Resistivity

The flow of charges in a conducting wire is referred to as electric current. Numerically, it is equal to the net charge passing through the wire in one second. The voltage drop (or potential difference) across a section of the wire produces the force required to push the charges and generate the current. Thus, increasing the voltage drop generates more current through the wire.

The ability to control currents and voltages in different sections of an electric circuit has many practical applications. A common element of electrical circuits is the resistor, which is available in various resistance values and power-dissipation ratings. Resistors have a resistive material inside them and are often coded with colour bands to indicate resistance value. For many conductors, over a wide range of conditions, the current is directly proportional to the voltage drop. Resistors made of such conductors are called ohmic resistors because they follow Ohm’s law, while those that do not are nonohmic. In the first part of this experiment, you will investigate the relationship between electric potential and current for an ohmic resistor.

A piece of conducting wire also has resistance. However, wires used for connecting different components of an electric circuit are usually made from highly conductive material, such as copper. Therefore, the resistance of these wires can be ignored for most practical purposes. Wires made from material with relatively low conductivity can have significant resistance to the flowing current. For example, the resistance of a piece of nichrome wire is much larger than the resistance of a similar piece made from copper. In the second part of this experiment, you will explore the relation between the resistance of a nichrome conducting wire and its length.

After completing this experiment, you should be able to

- state and demonstrate Ohm's law.
- discuss the difference between ohmic and non-ohmic resistance.
- explain the difference between resistance and resistivity for a conducting material.
- construct simple electric circuits.
- use appropriate instruments to make voltage and current measurements.
- perform linear fit and interpret the values of slope and y intercept.

Experiment 3: *RC* Circuit

Circuits that are composed of batteries and resistors only produce steady currents and voltages that do not change with time. However, for many practical applications, time-dependent currents and voltages are desired. A circuit involving a resistor and a capacitor connected in series is called an *RC* Circuit. In a closed *RC* circuit, the capacitor goes through a transient period of charging (or discharging). As a result, the flowing current changes gradually from an initial value, when the circuit is closed, to a final steady-state value when the capacitor is fully charged (or discharged). The length of the transient period depends on the capacitor and resistor sizes.

After completing this experiment, you should be able to

- describe the charging process of a capacitor.
- describe the discharging process of a capacitor.
- explain the meaning of exponential growth and decay.
- define the time constant for an RC circuit.
- construct simple RC circuits and demonstrate charging and discharging processes.

Experiment 4: Magnetic Field of a Solenoid

A solenoid is a closely packed helical coil constructed by winding a long conducting wire. The net field inside the solenoid is equal to the vector sum of the magnetic fields generated by each turn of the wire. If a solenoid were infinitely long, we would have an ideal configuration, in which the magnetic field inside the solenoid is uniform and parallel to its axis. A real solenoid, which is of finite length, should be a good approximation of the ideal situation, provided that we avoid making measurements close to the ends.

After completing this experiment, you should be able to

- construct a simple solenoid.
- describe the magnetic field configuration of an ideal solenoid.
- describe the magnetic field configuration of a real solenoid.
- state the relation between current and magnetic field inside a long solenoid.

- make magnetic field measurements using a magnetic field sensor.

Experiment 5: Electric Motor

The electric motor is one of the most important inventions in recent history, with significant impact on modern human culture and lifestyle. Computer hard drives, food mixers, water pumps, washing machines, elevators, and electric trains are all driven by electric motors varying in size, strength, and complexity. However, all are based on the basic principle of a magnetic torque exerted on a current loop.

After completing this experiment, you should be able to

- describe the torque on a current loop placed in a magnetic field.
- construct a simple electric motor.
- explain how a simple electric motor works.
- discuss the effects of magnetic field strength and loop size on the rotation speed of a motor.

Experiment 6: Lab Project

Scientific theories are tested through empirical research, which plays an increasingly important role in many disciplines and professions. Proper experimental investigation, however, requires specific personal and professional skills. To be a good researcher, you should know how to perform a literature review and demonstrate the ability to design and execute an experiment. In addition you need to master the skills of analyzing, presenting, and explaining experimental data.

To give you an opportunity to widen your scope of experimental methodology skills, we are here moving beyond traditional procedures. In this lab, you have the flexibility to choose, design, and perform your own physics experiment. We believe that this project will enhance your critical thinking skills and increase your confidence in performing independent experimental research.

After completing this experiment, you should be able to:

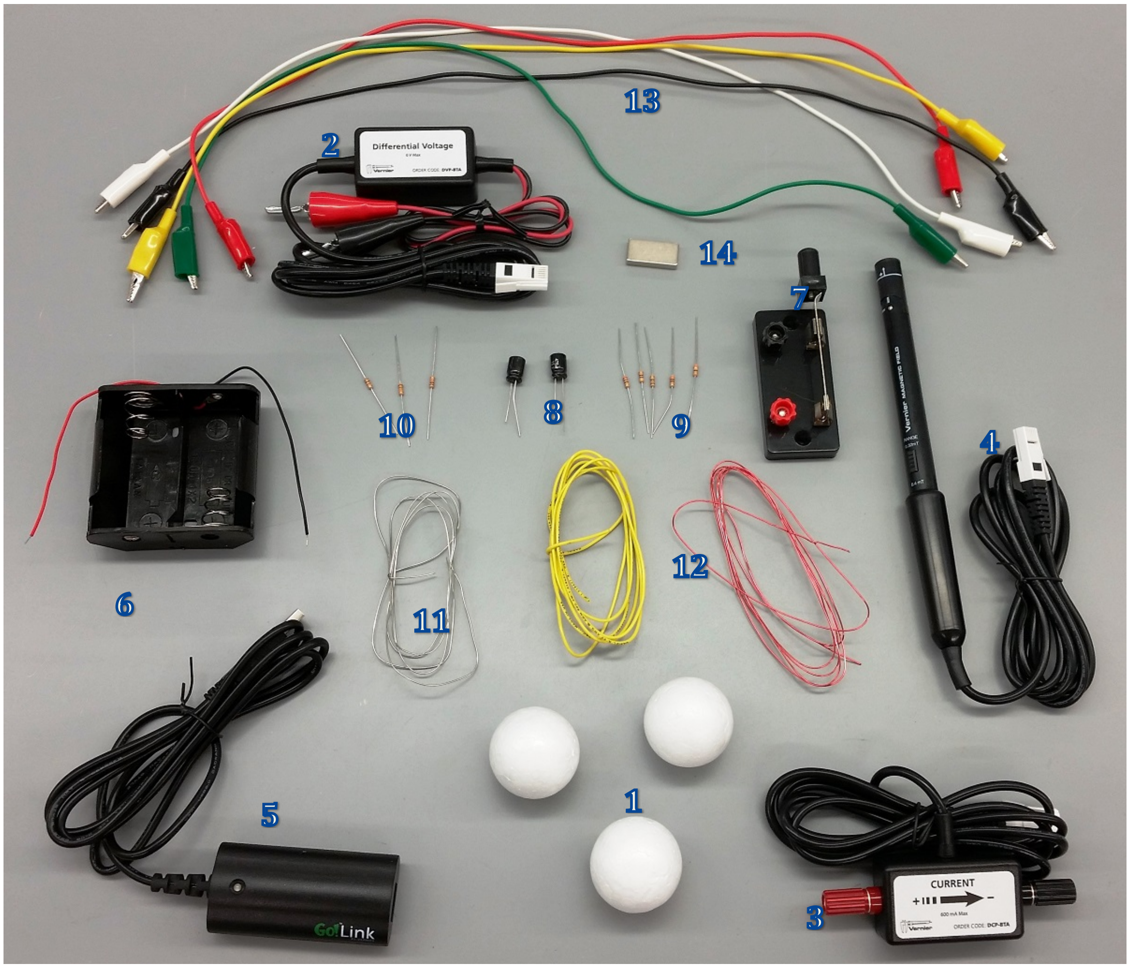
- demonstrate literature review process.
- list a number of learning outcomes from your experiment.

Hardware and Software

To perform the lab experiments in this manual, you will need to provide a digital camera and a computer with a USB port. These will be required for the collection and analysis of experimental data, and for the preparation of the lab reports. You will also need the Logger Pro software from Vernier Software & Technology. This is an interface program that allows you to display the measurements of connected probes and sensors, and to save collected data. The program can also be used for data analysis.

Lab Kit

Part of the material and equipment required for the experiments in this manual are packaged in a kit form, which can be borrowed from the Athabasca University (AU) Science Lab. The PHYS 205 lab kit should contain the items listed below. You are expected to provide additional material in the form of common household items.



Lab Kit Contents

1. Two styrofoam balls (plus one spare)
2. Differential voltage probe
3. Current probe
4. Magnetic field sensor
5. Go!Link connection
6. D-size battery holder
7. Circuit switch
8. Capacitor (470μF)
9. Five resistors (values 15Ω to 50Ω)
10. Three resistors (values 5kΩ to 15kΩ)
11. Nichrome wire (about 1m long)
12. Enameled (or insulated) copper wire (about 1.5m long)
13. Five connection wires
14. Permanent magnet

When you are ready to perform the experiments, please request your lab kit from the AU Science Lab by completing the Lab Request Form. The lab kit will be mailed to you shortly after you request it. If the demand for the kits is high, you may be placed on a waiting list. The kit you receive should contain a card for return postage. Note that only those enrolled in the course may borrow a lab kit.

Evaluation

You are expected to perform six experiments according to the guidelines presented in this manual, and prepare a lab report (or a video presentation when appropriate) for each experiment. All reports (or videos) should be submitted to your tutor for assessment. The lab component counts for 20% of the total course mark, divided among the six experiments as follows.

Experiments	**Overall Mark**
Experiment 1	3%
Experiment 2	3%
Experiment 3	3%
Experiment 4	3%
Experiment 5	3%
Experiment 6	5%
Total 20 %	**100%**

It is important to accumulate a total lab average of at least 50% to pass the course. If you have lab credit from another institution, you may wish to inquire about transfer of lab credit. Such transfer and any evaluation associated with it are entirely at the discretion of Athabasca University. You will be required to submit original lab materials, done by you, for evaluation. Please contact the Course Coordinator before submitting any such materials.

Lab Report

The lab report is an effective way of communicating empirical results. There is little point in doing a successful experiment if you cannot effectively communicate your findings to others. The lab report serves several purposes and gives an organized framework for recording your procedures and results. *Although some students may have encountered laboratory reports before and may feel that there is a standard format for them, this is not entirely true*. However, make sure to include the following sections.

1. **Cover Page** -- This is the first page of the report, which should include:

    - PHYS 205 - Lab Manual version 1.0
    - experiment's title
    - your name and student ID
    - tutor's name
    - date

2. **Theory** -- Here, provide the relevant theoretical background including all formulas needed for the analysis. Make sure you define the different quantities and symbols that you have used in your report.

3. **Procedure** -- In this section, explain your steps in performing the experiment. Use your own words to provide enough detail so that the reader could reproduce your procedure.

4. **Pictures** -- Include clear and sufficient pictures of your setup, taken at different stages of your procedure.

5. **Collected data** -- Organize and present raw data collected in the experiment. For large quantities of data generated by automatic collection, a one-page sample should be sufficient. No calculations or analysis should be included in this section of the report.

6. **Analysis and discussion** -- This is a very important section of your lab report. You are expected to give clear and detailed analysis of your data, as described in the manual. Make sure to include sample calculations, especially for new calculated columns in data tables. You may need to produce graphs and perform appropriate fits using the Logger Pro software. Errors in the observations may have a bearing on your analysis, so you should discuss their role here.

7. **Questions** -- At the end of the lab, you may find a question related to the experiment. Provide a detailed answer (or solution) to this question.

8. **Conclusion** -- Present a brief summary of your findings in the experiment, including the final numerical results.

9. **References and Citations** -- This section should include a complete list of all the sources (books, journal articles, websites, and so on) used in preparing the lab report. In addition, you are expected to cite any information taken from external sources. You do not need to cite this Lab Manual, but it must be listed as a reference. *Failing to credit the source of your information could be considered an act of plagiarism*.

In marking the lab report, each of the nine sections above carries a specific weight, as shown in the table below. Note the small differences in this regard between the first four experiments and the last two.

	Lab 1-4	Lab 5-6
Cover Page	5%	5%
Theory	10%	10%
Procedure	10%	10%
Pictures	10%	10%
Data	10%	10%
Analysis and discussion	30%	30%
Questions	10%	-
Conclusion	10%	10%
References and citation	5%	15%

Video Presentation

In Experiments 5 and 6 you have the option not to submit a formal lab report. Instead, you may decide to prepare a short video presentation. In your video, you should introduce the theory, show the procedure, present your findings, and discuss the results. The evaluation criteria for a video is similar to that for a written lab report.

The video should be concise and less than five minutes long. You may want to properly edit longer videos before submitting them for evaluation. Also, when shooting your video, there should be a piece of paper placed beside your project that clearly displays the following information:

- PHYS 205 - Lab Manual version 1.0
- Title of experiment
- Your name
- Date

You can submit your video by making it available for download on a (preferably password-protected) dropbox, ftp or website.

Lab Safety

Appropriate care should be taken with moving objects and other potentially hazardous situations and materials, such as sharp objects. No materials or equipment used are to be connected to electrical power outlets. Use only low-voltage batteries as instructed. The level of risk involved in doing these labs is comparable to that of day-to-day activities. Care has been taken to avoid suggesting activities which produce hazards.

It is your decision to proceed with any experiment, and in making that decision you control your own situation and assume any risks involved. *It is your responsibility to act in a responsible manner to avoid hazard to yourself or members of the public*. The authors, Athabasca University, or any equipment supplier cannot be held liable for the consequences of any action undertaken in association with these laboratory exercises. If you do not believe you can perform these labs safely, please withdraw from the course.