PHY132 Practicals Week 8
Student Guide

Concepts of this Module

- Charging and discharging capacitors
- RC circuits
- Interactions of permanent magnets with other magnets, conductors, insulators, and electric charges.
- Magnetic fields of permanent magnets, current carrying coils, and a current carrying straight wire.

EM-Mod.5 Activity 6 - Capacitors, Batteries, and Light bulbs

Let's do an experiment using capacitors, batteries, and light bulbs to see what happens to the current flowing through a resistor (the bulb) when a capacitor is charged by a battery and then discharged. You are provided with two light bulbs (6V 1W and 6V 3W), two capacitors (0.47 F and 1 F), and a 6 V battery. The capacitors are built using nanotechnology and are called *supercapacitors*; further information appears in the Appendix to this Guide.

A. Connect the 6V 1W light bulb (the elongated one) in series with the 0.47 F capacitor, a switch, and the 6 V battery. Draw a circuit diagram of your setup. Describe what happens when you close the switch.

B. Now, can you make the bulb light up again without the battery in the circuit? Mess around and see what happens. Describe your observations and draw a circuit diagram showing the setup when the bulb lights up without a battery.

C. Repeat parts A and B with a voltmeter across the capacitor. Draw a rough sketch of the voltage across the capacitor as a function of time for both cases.

D. Draw a sketch of the approximate brightness of the bulb as a function of time when it is placed across a charged capacitor without the battery present. Let t = 0 when the bulb is first placed in the circuit with the charged capacitor. Note: You can examine the change in the current is by wiring an ammeter in series with the bulb.

E. Explain what is happening. Is there any evidence that charge is flowing between the plates of the capacitor as it is charged by the battery with the resistor (the bulb) in the circuit, or as it discharges through the resistor? Is there any evidence that charge is not flowing through the capacitor? Hints: (1) You may want to repeat the observations described in parts A and B several times; placing the voltmeter across the capacitor or placing an ammeter in series with the capacitor and bulb in the two circuits you have devised might aid you in your observations. (2) Theoretically, how should the voltage across the capacitor be related to the amount of charge on each of its conductors at any given point in time?

F. What happens when more capacitance is put in the circuit? What happens when more resistance is put in the circuit? You can use the 6V 3W light bulb (the rounded one) in the circuit to get more resistance. Hint: Be careful how you wire the extra capacitance and resistance in the circuit. Does more capacitance result when capacitors are wired in parallel or in series? How should you wire resistors to get more resistance?

EM-Mod.6 -Activity 4

In Electricity and Magnetism Module 1 Activity 1 you may have put an electric charge on a length of sticky tape by suddenly peeling it off the tabletop and hanging it from the cupboard. You may wish to refer to the Student Guide for that Module and/or your lab book to refresh your memory. Repeat that procedure.

1. Does the magnet exert a force on the charged tape? Is there a difference between the North and South poles?
2. You are supplied with an unmagnetised soft iron rod. Does it exert any forces on the charged tape? Are there any differences between the interaction of the tape with magnet and with the metal rod?
3. What can you conclude about the interaction of stationary electric charges with magnetic fields?

EM-Mod.6 - Activity 5

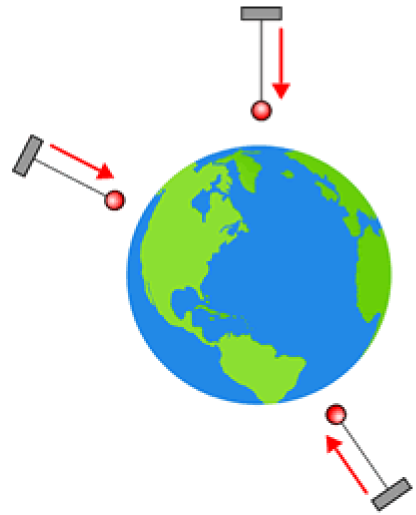
We can describe the fact that the Earth exerts a gravitational force on all objects near it by saying:

1. The Earth creates a *gravitational field* in all regions of space around it.
2. The gravitational field exerts a gravitational force on all objects in the field.

A convenient definition of the gravitational field is that it is equal in magnitude and direction to the acceleration due to gravity $\vec{g}$ at that point in space. Then the gravitational force exerted on a mass m in the gravitational field is:

$$\vec{F} = m\vec{g}$$

We could measure the direction of the gravitational field by taking a mass hanging from a string and observing in what direction the mass hangs. The figure to the right illustrates.



A compass is a little bar magnet that is free to rotate. In this Activity we will use a simple compass the measure the direction of the *magnetic* field around various objects. The procedure is similar to the one we described for determining the gravitational field. We will use the following standard convention:

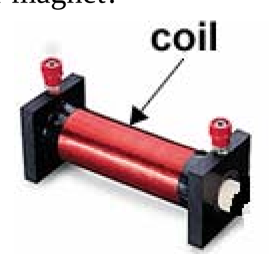
> **The direction of an external magnetic field is parallel to the orientation of the compass, and points from the South to the North direction as marked on the compass.**

All of the fields you will map are sufficiently strong that the Earth's magnetic field is negligible.

Be sure when you are mapping a magnetic field that all other magnets and metals are as far away as possible.

A. Map the magnetic field around one of the bar magnets using the compasses. Use your results to sketch the magnetic field "lines" around the bar magnet. Be sure to include arrows on the lines to indicate the direction of the magnetic field.
B. Place the two bar magnets together, with the North pole of one in contact with the South pole of the other, as shown. Map the magnetic field of the combination and sketch the field lines including the direction of the field. Do you think the field any different from that of a single long bar magnet?

C. In Activities 11 and 12 below you will be using a wire coil, and a plastic plate with a rectangular hole cut in it. Place the coil in the hole. You will place the compasses on the Plexiglas

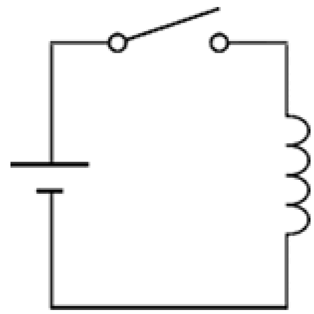


   You will connect the 6V battery to the red sockets on the coil, with a switch to avoid draining the batter.

   The switch you will use is called a *Contact Key*: this type of switch is only on when you hold it down.

The symbol for a coil is shown to the right.

So the circuit diagram of the experiment you will do is:



Use the compasses to map the magnetic field around the coil, and draw field lines including the direction. Compare your results to Parts A and B.

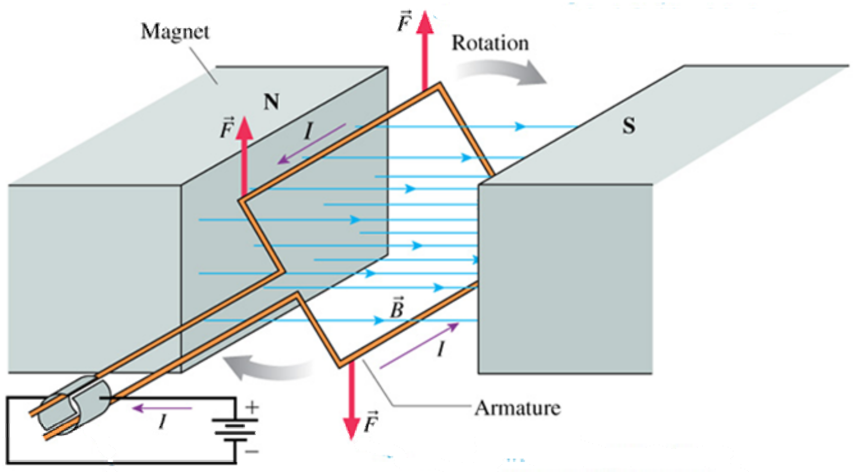
D. In terms of its magnetic field we can model the Earth as a big bar magnet. Is the magnetic North pole located at the geographic North pole (where Santa's workshop is located) or at the geographic South pole (where the penguins live)?

Course Concepts ***EM-Mod.6, Activity 9 [If you have time]***

The force exerted on a moving charge is given by:

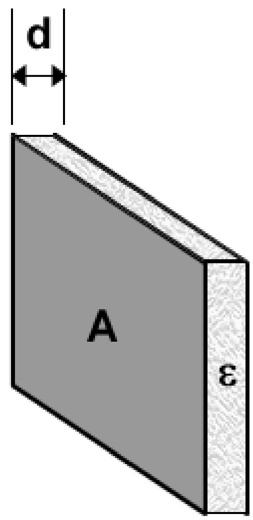
$$\vec{F} = q\,\vec{v} \times \vec{B} \qquad (1)$$

A. The direction of this force is always perpendicular to the velocity of the charge. Can this force ever do work on the charge?
B. Here is a figure of a typical electric motor:



A current in the loop experiences the forces shown due to the magnet. Eqn. 1 describes the forces. Is this fact consistent with your answer to Part A? Do motors do work? Explain.

Appendix – Supercapacitors



For a parallel plate capacitor with each plate having a surface area *A*, the plates separated by a distance *d*, and the space between the plates filled with a dielectric of constant ε, the capacitance *C* is:

$$C = \varepsilon \frac{A}{d}$$

So there are three ways to increase the capacitance:

1. Use a dielectric with a higher constant.
2. Increase the surface area of the plates
3. Decrease the distance between the plates.

If the space between the plates is air and the plates are separated by 1 mm, then a 1 Farad capacitor must have a plate surface area of about 10^8 m^2. For square plates this means the plates must be 10 km × 10 km.

Supercapacitors use *nanotechnology* to achieve extremely high effective surface areas. Often highly porous carbon is used, which can achieve effective areas of as much as 2000 m^2 per gram. Although the basic idea was known as early as 1957, it is only since the mid-1990’s that advances in material science have led to reliable inexpensive supercapacitors.

Over time chemical redox reactions can occur on the electrodes which will degrade performance, and some manufacturers minimize this effect by making the two electrodes somewhat differently. Thus supercapacitors have their two terminals marked to indicate which is positive and which is negative. Some other more conventional capacitors, such as electrolytic types, also have a polarity. Using the correct polarity for supercapacitors extends their life somewhat but is not terribly important for our purposes. Electrolytic capacitors can explode if they are wired incorrectly.

This Guide was written in December 2007 by Kimberly Strong, Dept. of Physics, Univ. of Toronto. The Appendix was written by David M. Harrison, Dept. of Physics, Univ of Toronto in February 2008.

The EM-Mod.5 activities are based on Randall D. Knight, **Student Workbook** (Pearson, 2004) and Priscilla W. Laws, **Workshop Physics Activity Guide, Module 4: Electricity and Magnetism** (John Wiley & Sons, 2004).

The EM-Mod.6 Guide Sheet was written by David M. Harrison, Dept. of Physics, Univ. of Toronto in January 2008. EM-Mod.6 Activity 4 is from Lillian McDermott et al, **Tutorial in Introductory Physics**, Magnets and Magnetic Fields I.B, (Prentice-Hall, 2002), pg. 113. Parts of EM-Mod.6 Activity 5 are similar to Priscilla W. Laws et al., **Workshop Activity Guide**, Module 4, Unit 28, (John Wiley, 2004), pg. 725.

The figure of the electric motor is slightly modified from Fig. 32.48 of Randall D. Knight, **Physics for Scientists and Engineers** (Pearson, 2004).

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slight revisions for PHY132 Spring 2009 semester by Jason Harlow
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