PHY132 Practicals Day 6
Student Guide

Summer 2009

Concepts of this Module

- Introducing current and voltage
- Simple circuits
- Circuit diagrams

Background

When water flows through a garden hose, we can characterize the rate of flow as the volume of water passing any cross section of the hose per time. Units for this flow could be m^3/s. Similarly, for a conducting wire electric charge can flow down the wire. We call the rate of flow of electric charge the *current*, which is the charge Q passing a cross section of the wire per time *t*. In SI units this is C/s. 1 C/s is also called an *ampere*, A. Conventionally the current is given the symbol *I* or *i*, so the definition of current is:

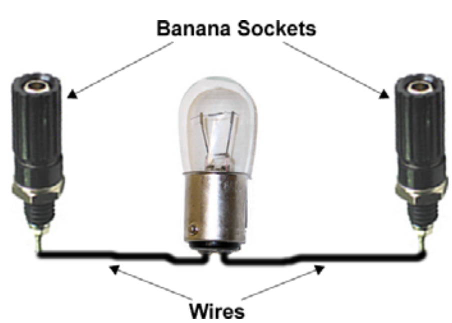
$$I \equiv \frac{\Delta Q}{\Delta t}$$

In order for water to flow in a hose a source of pressure is required. Similarly, for a current to flow in a wire a source of *voltage* is required. Common voltage sources are batteries, electric generators, and power supplies. In this Module we will be using a battery.

The Activities

Note: the battery you will be using in the Activities is filled with acid. Do not lay it on its side or turn it upside down.

Electricity and Magnetism Module 2, Activity 1

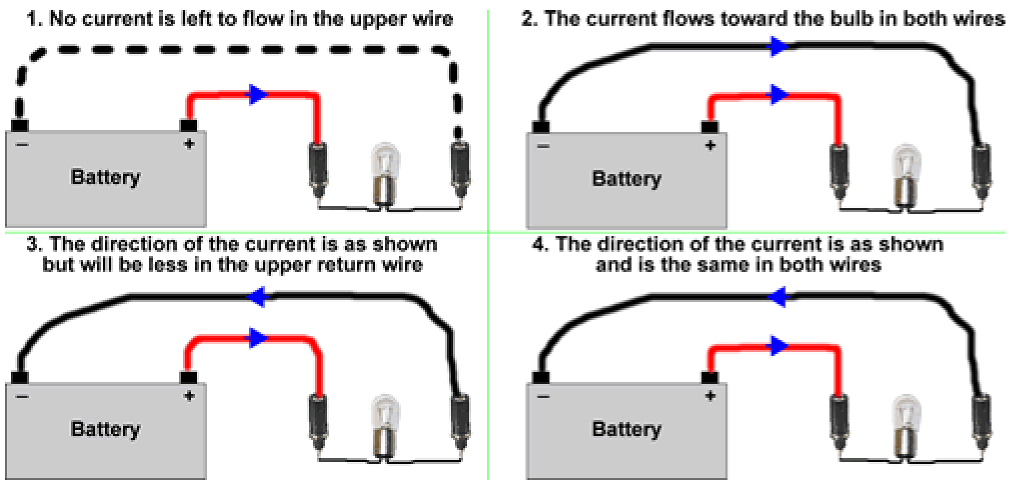


Mounted on a plastic frame is a light bulb and two *banana sockets*. On the bottom of the light bulb are two metal contacts which are connected to wires. The other ends of the wires are connected to the banana sockets, which are a convenient way to attach wires with a corresponding plug. The figure on the previous page shows the bulb, wires and sockets.

The figure to the right traces the conductors from the banana sockets through the light bulb. If you are viewing this in color, the conductors are in red.

A. Examine the mounted light bulb and identify the parts that are indicated in the above figures. Connect a wire from each terminal of the battery to each of the banana sockets. The light bulb should light. It is good practice to use a red wire to connect to the red terminal of the battery marked **+**, and a black wire to connect to the black terminal of the battery marked **-**.

B. Here are four possible models for how the current flows in the wires when the light bulb is lit:



Which case is most correct? Why?

C. You are supplied with a *clamp meter*, which measures the current in a wire that goes between the jaws of the clamp. Appendix 1 describes how to use this meter. Use the meter to measure the current in one place along one of the wires. As you slightly move the position of the clamp the measured current will change a bit. Quantify this by guessing the error ΔI to one significant figure.[1]

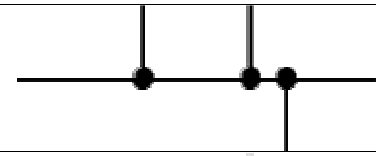
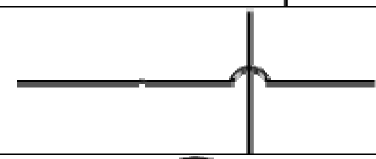
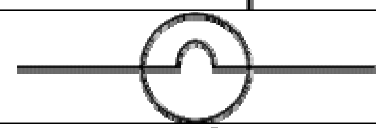
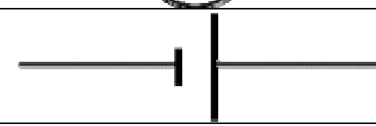
D. Use the clamp meter to check your prediction of Part B. Were you correct?

Please disconnect all the wires and turn off the meter when you are done with this Activity.

[1] Although one can carefully repeat the measurements of the current and calculate the standard deviation to get a value for ΔI, that will not be necessary here. This is a general principle: do things the simple way first. If you later discover that you need a more careful determination you can always go back and do so.

Electricity and Magnetism Module 2, Activity 2

Instead of drawing a picture of an electric circuit, we can schematically represent it with a *circuit diagram*. Here are a few elements of circuit diagrams.

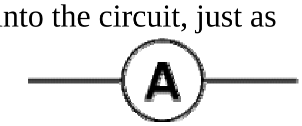
Wire	
Wires that are joined	
Wires that are not joined	
Light Bulb	
Battery	

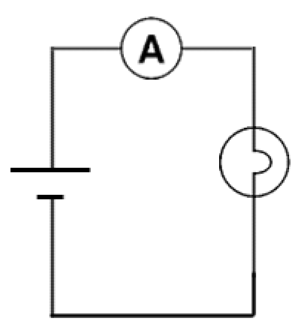
For the Battery, the positive terminal is on the right and the negative terminal is on the left. Here is a mnemonic for remembering this: a **+** symbol has more line in it than **–**, and the longer line of the battery is the + terminal.

Draw a circuit diagram of the circuit of Activity 1.

Electricity and Magnetism Module 2, Activity 5

Meters that measure currents are called *ammeters*. Conventional ammeters, as opposed to the clamp meter you used in Activity 1, must be inserted in series into the circuit, just as the single switch was inserted into the circuit in Parts A and B of Activity 4. The circuit diagram symbol for a conventional ammeter is shown to the right.





Here is the circuit diagram for using a conventional ammeter to measure the current in a wire of the same setup you investigated in Activity 1.

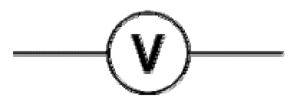
You are supplied with *multimeters* which can be used as conventional ammeters. Details on how to do this are in Appendix 2.A.

Wire the circuit and measure the current in the wire. Check your measurement using the clamp meter. Do they give the same results for the magnitude and direction of the current? How do the values compare to the results of Part D of Activity 1?

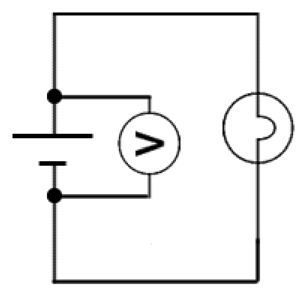
Please disconnect all wires from all the circuit elements and turn off the meters when you have completed this Activity.

Electricity and Magnetism Module 2, Activity 6

Voltmeters measure voltages of, say, batteries. The circuit symbol for a voltmeter is shown to the right.



Voltmeters are typically wired in *parallel*. So the circuit diagram that measures the voltage of the battery while the light bulb is being lit is shown to the right.



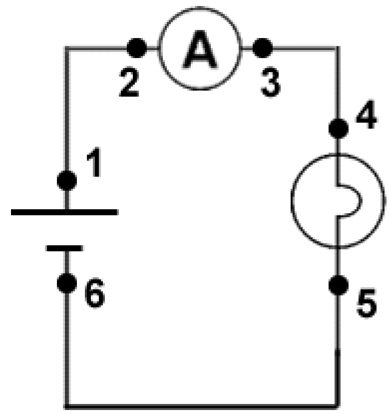
Instructions on how to use a multimeter as a voltmeter are given in Appendix 2.B. Use a multimeter to measure the voltage of the battery. The rated voltage is written on the front of the battery. How do the two values compare?

Disconnect the battery from the circuit and use the voltmeter to measure its voltage. How does it compare with the voltage when it was in the circuit?

Please disconnect all wires from all the circuit elements and turn off the meter when you have completed this Activity.

[***STOP!*** Please go back and take a second look at what you have recorded in your notebook for the mandatory activities. Is there anything missing? Can anything be improved? Does your TA have advice on what you might be able to do better? Please do not attempt this "If you have time" activity until you feel confident that the other activities are completed to the best of your ability, and you have obtained permission from one of your TAs.]

Course Concepts *If you have time: Electricity and Magnetism Module 2, Activity 7*



Rewire the circuit that lights the light bulb with the ammeter in the circuit again. In the circuit diagram to the right we have indicated a number of points in the circuit. Use the voltmeter to measure the voltage difference between **1** and **2**, **2** and **3**, **1** and **3**, **4** and **5**, etc. If the meter reads a very small voltage difference between two points, you should decrease the scale of the reading by rotating the upper knob: when the scale is too small the meter will read **-1**; in this case increase the scale of the reading.

Do you see a pattern? What is the voltage "drop" across the light bulb? What about across the ammeter? One of the wires? Summarise your findings. Can you explain them? Why did we use the word "drop" above?

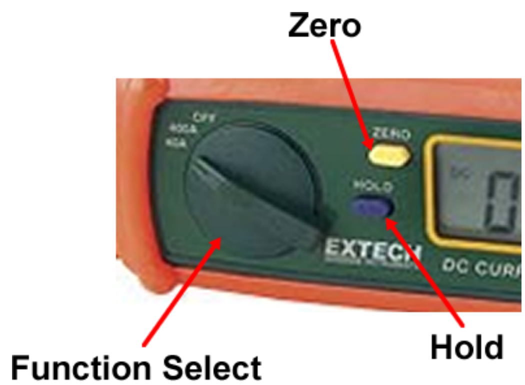
Please disconnect all wires from all the circuit elements and turn off the meters when you have completed this Activity.

Appendix 1 – The Clamp Meter

A *clamp meter* measures the current in a wire that passes through the jaws of the circular clamp. For now we will treat how the meter does this as "magic"; in a later Module we will return to investigate how it works.

The jaws may be separated by pressing on the **Clamp Opening Handle**.

When the current is flowing in the direction shown, the reading will be positive; if the current is flowing in the opposite direction to that shown the reading will be negative. There is a small arrow on the inside of the jaws of the clamp indicating the current direction shown in the figure.



Here is a close-up of the controls of the meter. The **Function Select** knob has three positions:

1. **Off**
2. **400A**
3. **40A**

We will be using the **40A** function.

After turning the meter on it must be zeroed.

1. Place the meter close to the part of the wire whose current will be measured and orient the meter as it will be when it is clamped around the wire.
2. Press **ZERO**: The display will read ***ZERO***.
3. Press on the **Clamp Opening Handle** to separate the jaws of the clamp, place the clamp around the wire, and release the handle.

The meter will now read the current in the wire in *amperes*.

To measure the current at a different location or with the meter at a different orientation:

1. Move the meter close to where it will do the new measurement, oriented as it will be when clamped around the wire.
2. Press on **ZERO**; the display will no longer read ***ZERO***.
3. Press the **ZERO** button again: the display will read ***ZERO***.
4. Clamp the meter around the wire and read the current on the display.

If it is difficult to see the display because of the orientation of the meter:

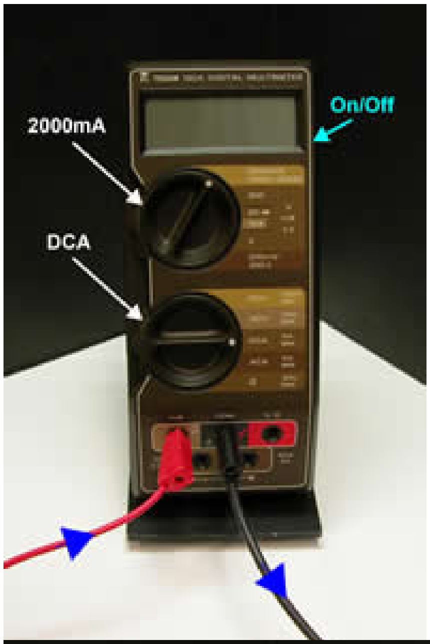
1. Press on the **HOLD** button. This will cause the reading to be held and the display will read ***HOLD***.
2. Remove the meter and read the current on the display.
3. Press on the **HOLD** button to return the meter to normal operation. The display will no longer read ***HOLD***.

Appendix 2 – The Multimeter

This module uses multimeters, which are devices capable of a number of different electrical measurements. With the flexibility of this instrument comes a price: at first glance there is a bewildering array of controls and inputs. This Appendix will guide you through this complexity to learn how to use the meter to measure currents and voltages.

Just as for the clamp meter, for now we will treat how the instrument actually works as “magic”.

2.A – Measuring Currents



The figure shows the multimeter configured to measure currents. Not visible in the photograph is the On/Off Switch, which is on the right side of the meter.

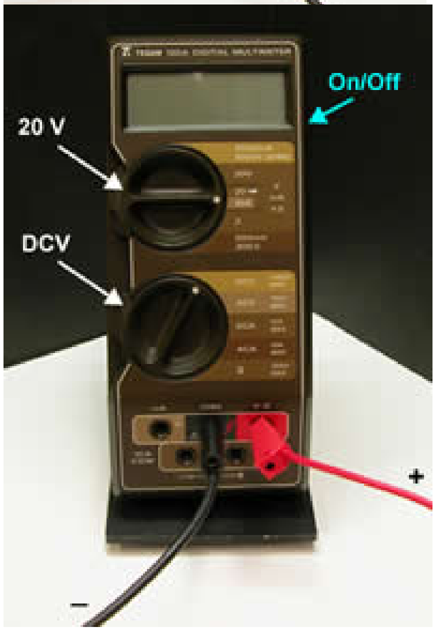
The upper knob controls the scale of the readings, and should be set to the shown **2000mA** position.

The lower knob selects the type of measurement that the meter will do, and should be set to the shown **DCA** position. DCA stands for DC Amps.

The wires are connected to the terminals as shown, which are labeled **mA** and **COM**. COM stands for Common. Note that the meter reads current in milliamperes, *mA*, while the clamp meter reads in amperes.

When the direction of the current in the wires is as shown, the meter will read a positive current. If the current is going in the opposite direction to that shown the meter will show a negative value.

2.B – Measuring Voltages



Here is the meter configured to read voltages. Not visible in the photograph is the On/Off Switch, which is on the right side of the meter.

The upper knob controls the scale of the readings, and should be set to the shown **20V** position.

The lower knob selects the type of measurement that the meter will do, and should be set to the shown **DCV** position. DCV stands for DC Volts.

The wires are connected to the terminals as shown, which are labeled **COM** and **V-Ω**. COM stands for Common, and the V stands for Volts.

If the wire connected to the **V-Ω** terminal of the meter is connected to the **+** terminal of the battery the meter will read a positive voltage; if it is connected to the **–** terminal the reading will be negative. If you are viewing this in color, this is the red wire in the photograph.

Last revision to this write-up: July 8, 2009 by Jason Harlow.

The Electricity and Magnetism Module 2 Student Guide Sheet was written by David M. Harrison, Dept. of Physics, Univ. of Toronto in November 2007. Activity 1 draws on material from Priscilla W. Laws et al., **Workshop Activity Guide**, Module 4, Unit 22.6, (John Wiley, 2004), pg. 604.