Using a Digital Multimeter

In this course we will frequently use a *digital multimeter* to measure the voltage, current and resistance of *circuit elements*, such as batteries, resistors, and bulbs. While these instructions are specific to the *Metex M-3800 Digital Multimeter* shown in **Figure 1**, the basic concepts apply to any multimeter.

1. Multimeter settings:

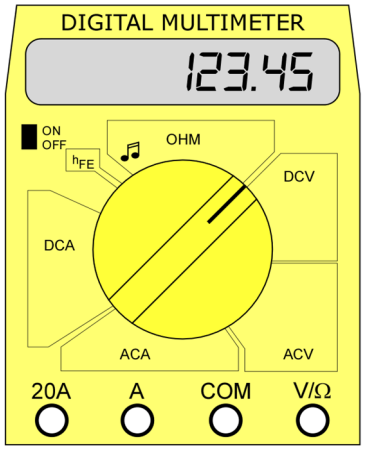

Figure 1: A digital multimeter

The front of the multimeter is divided into six sections; the large knob in the center allows you to choose the type of measurement and voltage (DC – *direct current*, or AC – *alternating current*) to be used. The meter setting chosen should always be recorded in your report. The sections are as follows, clockwise from the top:

- **OHM**: This range of settings allows the multimeter to be used as an *ohmmeter* to measure the resistance of a circuit element. The scale settings range from 200 Ω (*ohms*) to 20 MΩ (*megohms*).
  - The setting with a musical note (♫) above it will provide an audible tone when the resistance of an element is less than 30 Ω. *This setting will not be used in this course*.
- **DCV**: This range of settings allows the multimeter to be used as a *voltmeter* to measure *direct current* voltages. A voltmeter measures the difference in electric potential (voltage) *across* a circuit element. The batteries in a flashlight are DC voltage sources. The scale settings range from 200 *mV* (*millivolts*) to 1000 *V* (*volts*).
- **ACV**: Another voltmeter setting, this is used to measure *alternating current* voltages. A standard electrical wall outlet is an AC voltage source. The scale settings range from 200 *mV* to 700 *V*.
- **ACA**: These settings allow the multimeter to be used as an *ammeter* to measure the flow of current through an AC circuit. The scale settings range from 200 *μA* (*microamperes*) to 2 *A* (*amperes*).
- **DCA**: Another ammeter setting, this is used to measure current through DC circuits. The scale settings range from 200 μA to 2 A.
- **h_{FE}**: This position is used to measure transistors. *This setting will not be used in this course*.

2. Changing the scale and precision of measurement:

The range of settings determines the maximum quantity that can be measured. For example, setting the direct current voltage (DCV) to 20 means that the meter can measure a *maximum* of 20 volts of direct current. If you were to measure the voltage of a 1.5-volt, AA flashlight battery, you could set the knob to 2, 20, 200 or 1000, but not to 200 *m* (millivolts). You will note that as you increase the scale the precision of the measurement will decrease – fewer significant figures after the decimal point will be displayed. Unless otherwise specified, always use the lowest range setting that will allow you to make the measurement with the most precision.

3. The number '1' appears on the left side of the meter display. What does that mean?

A measurement of 1 unit (e.g. 1 *volt*, 1 *ohm*, etc.) will produce '1' on the right side of the meter display (**Figure 2a**). The meaning of '1' on the *left* side of the display (**Figure 2b**) depends on how the multimeter is being used:

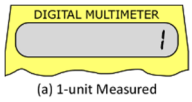

Figure 2: Display difference between (a) measuring 1 *unit* and (b) range overload.

- If you are measuring voltage or current, '1' on the left side of the display means the measurement exceeds the maximum value set by the scale; simply turn the knob to a higher range setting until you can record a measurement. For example, if you were again measuring the voltage across the 1.5-volt, AA flashlight battery, choosing the 200 *m* (*200 millivolt*) setting will produce '1' on the left side of the display. Increasing the setting to 2 volts (or higher) will allow you to properly measure the voltage. *No units are associated with this range-overload warning*.
- If you are measuring resistance (OHM mode), '1' on the left side of the display means that you have an *open circuit*. This means that you do not have a continuous path for current to flow through the circuit.

4. Why is there a battery symbol on the display?

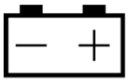

Figure 3: Low battery symbol.

A battery symbol (**Figure 3**) may briefly appear in the lower left corner of the meter display when the multimeter is turned on. If the symbol stays on or flickers, the battery is running low; bring it to your instructor for immediate replacement. A low battery will produce inaccurate measurements.

5. Connecting measuring leads (wires) to the multimeter:

The connection of measuring leads to the multimeter depends upon the intended measurements. There are four ports for connecting wires at the bottom of the multimeter. *It is important to note that you will only have wires plugged into two multimeter ports at any one time!* The ports are labeled as follows:

- **V/Ω**: This is referred to as the positive terminal of the voltmeter/ohmmeter. When using the multimeter as a voltmeter or ohmmeter, the red wire gets plugged into this port. Note that in DC circuits, red color implies the positive terminal, black color the negative (or ground). These colors don't apply to AC circuits, but we will retain the convention to make the analysis clearer.
- **COM**: This is the common ground, or negative terminal of the meter. Typically, a black wire is inserted in this port when using the multimeter as a voltmeter, ammeter, or ohmmeter. You will *always* have a wire plugged into this port, no matter the meter setting.
- **A**: When using the multimeter as an *ammeter*, the red wire typically gets plugged into this port. When measuring the current through a DC circuit, be sure to observe the polarity of the voltage source so that you get the correct sign for the direction of the current.
- **20A**: This port will not be used in this course; it is used for measuring very high currents, and there is no fuse protecting the meter. *Never* insert a wire in this port; you risk damaging the meter and the circuit!

The examples on the next page will show the proper method of connecting the multimeter to your circuit when it is used for various measurements.

Example 1 – Measuring voltage or resistance:

When the multimeter is used as a voltmeter or an ohmmeter, you will insert *two* wires into the meter: one in the **COM** port, the other in the **V/Ω** port, as shown in **Figures 4** and **5** below. Turn the knob to the appropriate setting and voltage type before touching the circuit element. **Figure 4** shows the voltage measured across a 9-volt battery. Note the orientation of the meter wires with respect to the positive and negative terminals of the battery; reversing the meter wires will produce a negative voltage reading. **Figure 5** shows the resistance measurement of a bulb; note that the meter wires are connected in the same manner.

The meter is connected *in parallel* to the circuit element when functioning as a voltmeter or ohmmeter (Parallel circuits will be examined in a future experiment). A high internal resistance when used as a voltmeter or ohmmeter prevents current from passing through the meter.

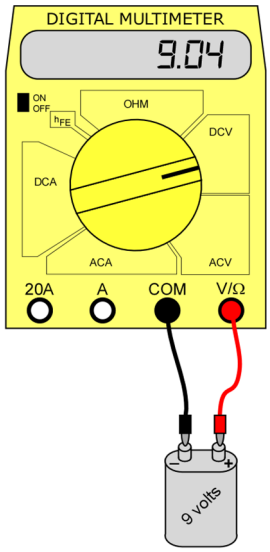

Figure 4: Measuring voltage across a battery.

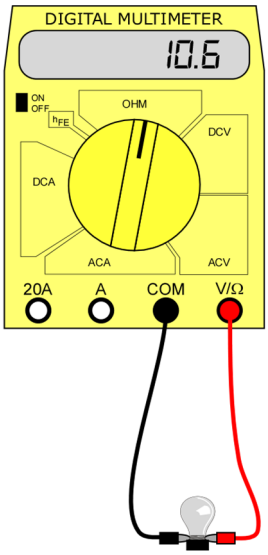

Figure 5: Measuring the resistance of a bulb.

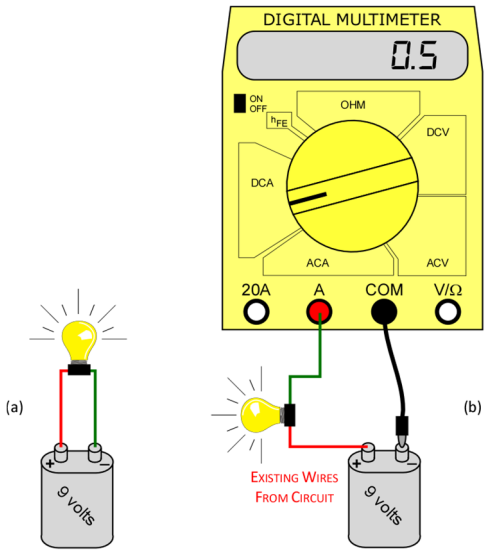

Figure 6: (a) A bulb connected to a battery. (b) Measuring current through the bulb.

Example 2 – Measuring the current through a circuit:

Figure 6a shows a simple circuit consisting of a bulb connected to a battery with two wires (red and green in the figure). Measure the current through this circuit by setting the multimeter to an ammeter (**Figure 6b**): Turn the multimeter knob to the appropriate setting and place a *third* wire into the **COM** port. Disconnect the (green) wire from the battery and insert its free end into the **A** port. (Note that the battery polarity in **Figures 6** has been reversed from **Figure 4** to simplify the picture!)

The ammeter has a very low internal resistance and is connected *in series* (examined in a future experiment) with your circuit elements to measure the flow of current through them, without disturbing the current. Therefore, it is *very important* that the ammeter is connected correctly to the circuit. Since it has a lower resistance than the circuit elements, you might create a short circuit and blow a fuse if the ammeter is connected incorrectly!

Exercise – Using the multimeter as a voltmeter:

This series of voltage measurements will allow you to familiarize yourself with the basic operation of the multimeter as a voltmeter and should be performed before the dipole potential field experiment. *Record your measurements, observations, and answers to the questions in your report.* The instructions below follow the conventional use of a black wire in the "COM" port, and a red wire in the "V/Ω" port of the meter, so you should be consistent with your measurements.

a. Disconnect the long black wire from the green connector on the lab bench power panel.

b. *Measuring the voltage of a 9-volt battery:* Set the multimeter to the "20 DCV" setting so that the meter will measure DC voltage. As shown in **Figure 4**, touch the red meter wire to the positive terminal of the battery, the black meter wire to the negative terminal and record the voltage.

c. Reverse the wires on the battery (red to negative terminal, black to positive), record the measured value. How is this result different than that measured in part (a)? (*Note*: you will be measuring a used battery, so the measured voltage might be lower than expected!)

d. *Change measurement precision*: Switch the meter wires on the 9-V battery again (red wire to the positive terminal) and change the multimeter to the "2 DCV" setting. Explain why you get this reading on the multimeter (***Hint*: read step 3 on page 2!**)

e. With the meter wires still connected to the battery, change the multimeter to the "200 DCV", and then the "1000 DCV" settings. Record the voltage measurement at each setting, and briefly explain how each setting affects the measured value.

f. *Measure the voltage of each screw head on the conducting sheet:* Set the multimeter to the "20 DCV" setting. Plug the black meter wire into the green (ground) connector on the lab bench power panel. Touch the red meter wire to each screw head in turn and record each voltage.

g. *Measure the voltage across both screw heads:* If you were to connect the multimeter across both screw heads (black wire on the left screw, red wire on the right), what do you think will be the measured voltage? Record your prediction and then set the voltmeter to an appropriate setting and record your measurement. *Try several voltmeter settings to be sure that you are measuring the voltage correctly.*

h. Describe what happens when you switch the wires on the screw heads.

Safety Note: Always connect wires into the meter first and then into a power supply. Likewise unplug wires from the power supply first and then the meter. Never leave wires dangling from any power supply! Always disconnect wires by pulling on their 'boot', never on the wire itself.