Using a Digital Multimeter

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

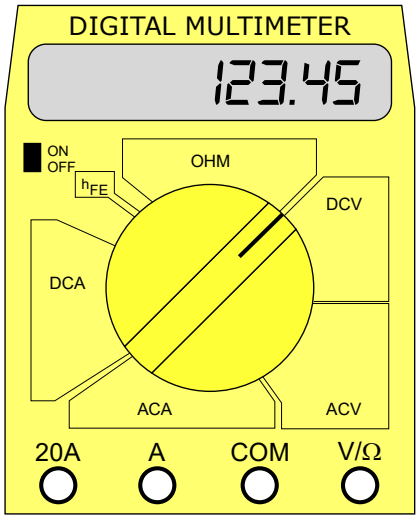


Figure 1

1. Multimeter settings:

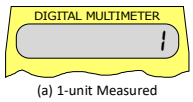
The front of the multimeter is divided into six sections; the large knob in the center allows you to choose the type of measurement and voltage (DC – direct current, or AC – alternating current) to be used. The meter setting chosen should always be recorded in your report. The sections are as follows, 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 component. The scale settings range from 200 Ω (*ohms*) to 20 *M*Ω (*megohms*). There is also a setting with a musical note above it; this setting will provide an audible tone when the resistance of a component is less than 30 Ω.
- **DCV**: This range of settings allows the multimeter to be used as a *voltmeter*, specifically to measure *direct current* voltages. A voltmeter measures the difference in electric potential (voltage) *across* a circuit component. The batteries in your car and in a flashlight are DC voltage sources. The scale settings range from 200 *mV* (*millivolts*) to 1000 *V* (*volts*).
- **ACV**: Another voltmeter setting, this time measuring *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 a circuit, specifically AC current. The scale settings range from 200 *μA* (*microamperes*) to 2 *A* (*amperes*).
- **DCA**: Another ammeter setting, this time measuring direct current. The scale settings range from 200 μA to 2 A.
- **h_{FE}**: This position is used to measure transistors. You will not be using this setting in this course.

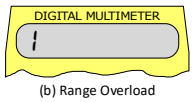
2. Changing the measurement scale:

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. Note that as you increase the scale the precision of the measurement will decrease – fewer significant figures will be displayed. Therefore it is good practice to always use the lowest range setting that will still allow you to make the measurement.

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



(a) 1-unit Measured



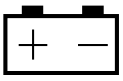
(b) Range Overload

Figure 2

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:

- 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?



The battery symbol at right appears momentarily in the lower left corner of the meter display when the multimeter is first 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:

- **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.
- **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.
- **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 or 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 Figure 3 below. Turn the knob to the appropriate setting and voltage type before touching the circuit component (e.g. a battery or resistor). In Figure 3, the voltage across a 9-volt battery is being measured. 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. The meter wires will be connected in the same manner to measure the resistance of a circuit component.

When functioning as a voltmeter or ohmmeter, the meter has a high internal resistance, and is connected *in parallel* to the circuit component, touching both sides to record the measurement.

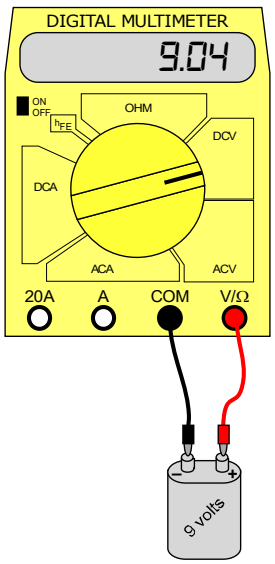


Figure 3

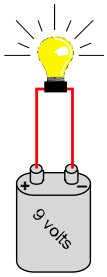


Figure 4

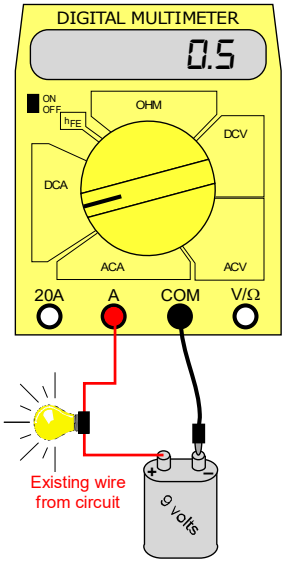


Figure 5

Example 2 – Measuring the current through a circuit:

Figure 4 shows a simple circuit consisting of a battery and a bulb. Configuring the multimeter as an ammeter will allow you to measure the current through this circuit. Do this by inserting *only one* wire into the meter; Figure 5 shows a third wire in the **COM** port. Using a single wire in the meter reminds you that you have to open the circuit up and insert the free wire into the **A** port. In Figure 5, a black meter wire is connected to the **COM** port, and touches the negative battery terminal; the red wire was disconnected from battery and connected to the **A** port (note that the battery polarity in Figures 4 and 5 has been reversed from Figure 3 in order to simplify the picture!).

The ammeter has a very low internal resistance, and is connected *in series* with your circuit components to measure the flow of current through them, without disturbing the current. It is for this reason that it is *very important* that the ammeter is connected correctly to the circuit. Since it has a lower resistance than the circuit components, you might create a short circuit and blow a fuse if the ammeter is connected incorrectly!

Exercise – Using the multimeter to measure voltages:

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. The instructions below follow the conventional use of a black wire in the "COM" port, and a red wire in the "V/Ω" port, but you should check the color of the wires connected to your meter.

a. *Measure the voltage of a 9-volt battery:* Set the multimeter to the "20 DCV" setting so that the meter will measure DC voltage. Touch the red meter wire to the positive terminal of the battery, the black meter wire to the negative terminal and record the value (see Figure 3). Reverse the wires on the battery (red to negative terminal, black to positive), record the measured value and note the difference. (*Note*: you'll be measuring a used battery, so the measured voltage may be lower than expected!)

b. 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!)

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

d. *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, recording the measured value.

e. *Gently* drag the tip of the red meter wire around the conducting paper surface. What happens to the measured voltage as you get closer to each screw head?

f. *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? State your prediction, then adjust the voltmeter and record the measurement.

g. What happens when you switch the wires on the screw heads? Which DC voltage settings can you use on the multimeter when connected across both screw heads?

h. **University Physics (Phys152) only** – *Measure the voltage from an AC outlet:* Insert the *AC-to-banana plug* adapter into the AC outlet on the lab bench power panel. Set the multimeter to the "700 ACV" setting so that you can measure AC voltage. Plug each meter wire into the adapter, and record your measurement.

   Caution: Never put any other wire in the adapter. *Always* plug wires into the meter first, then the adapter (or any other power supply). Likewise unplug the wires from the adapter (or power supply) first, then the meter. Never leave wires dangling from any power supply! Remove the adapter from the AC outlet when finished. And always disconnect wires by pulling on their 'boot', never the wire itself.