

SIMPLE DC CIRCUITS

Lab Goals: Use multimeter to measure voltage and current. Measure resistance of series and parallel resistors.

Lab Notebooks: Write descriptions of all of your experiments in your lab notebook. Answer all of the questions about the lab in your notebook also, instead of in the lab writeup.

Apparatus Breadboard, resistors, hookup wires, power supply, multimeter.

Introduction In this first lab, you'll gain invaluable hands-on experience with electrical circuits, which are central to our technological world. Almost every lab employs some kind of circuit, and circuits are critical to all experimental physics.

Circuits

In every circuit you'll encounter, you'll have two things, cause and effect, that you must never confuse. Something flows—the effect—and something causes that thing to flow—the cause.

In an *electrical* circuit, what flows is electricity. That this is really countless tiny particles—electrons—is often not terribly important. What is important is that something carrying **charge** is flowing. You've probably heard about charge already. But all we need know about it is that it can flow from one place to another, carrying energy, and that it has units, coulombs. When charge is the thing flowing, the flowrate, called **current** and given the symbol I , is measured in coulombs per second, which goes by the name amps. And what is needed to cause it to flow? A battery, which establishes not a difference in pressure, but a difference in **potential**. The SI units for potential are volts. Thus,

Effect: Current I , in amps **Cause:** Potential difference ΔV , in volts

Figure 1 depicts an electrical circuit. The solid lines represent hookup wires through which electrical current flows very easily. A battery maintains the flow of electrical current despite the fact that this current also flows through “constrictions”, which in electrical circuits are called **resistors**. Why we should spend so much time studying them is a good question. For now, we simply note that, excepting exotic things like superconductors, electrical resistance is everywhere, and indeed is often the factor governing exactly how much current flows in an electrical circuit.

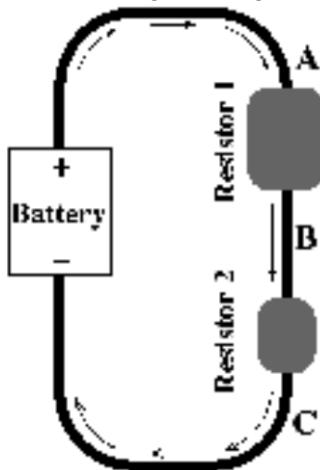


Fig. 1. A simple electrical circuit consisting of 1 battery and 2 resistors.

Measurements

Besides gaining a good feel for the fundamental concepts of circuits—current and potential difference—the other goal of today’s lab is to become comfortable (and good at!) actually measuring them. We usually want to measure the voltage difference between 2 points in a circuit, and the current that flows through a particular branch of a circuit.

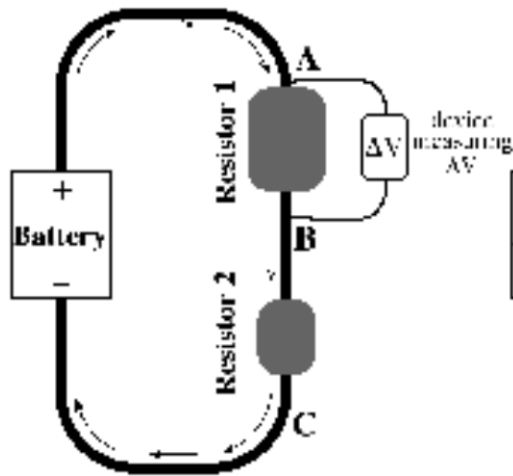


Figure 2a

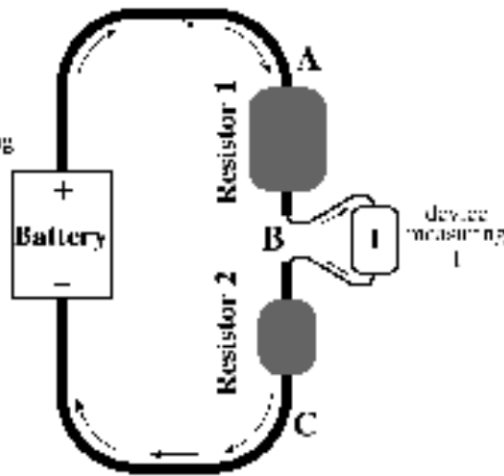


Figure 2b

A device measures the potential difference between points A and B (Fig. 2a) and another device (Fig. 2b) measures the current at point B.

But here is something both convenient and dangerous! The **multimeter** we use is capable of functioning as a potential difference measuring device or a current measuring device. However, it can't do both at the same time, and if you use it in the wrong mode, you blow it out! The simple guidelines follow. *Your lab instructors will have scant patience for failure to pay them the proper attention.* Refer to them as often as you need to *throughout the summer!*

Using the Multimeter (sometimes called a DVM for Digital Voltmeter, although our meter can also measure current)

1. Leads

To use the multimeter, hookup wires must be inserted in two of its jacks, usually the $V\Omega mA$ jack and the COM jack. *Never use the 10A jack unless you are specifically instructed to do so!* Hookup wires themselves aren't positive or negative—whether their plastic insulation is red or black is immaterial. But at least while you're learning, it's best to use a red wire in the $V\Omega mA$ jack and a black one in the COM. These wires we refer to as **leads**.

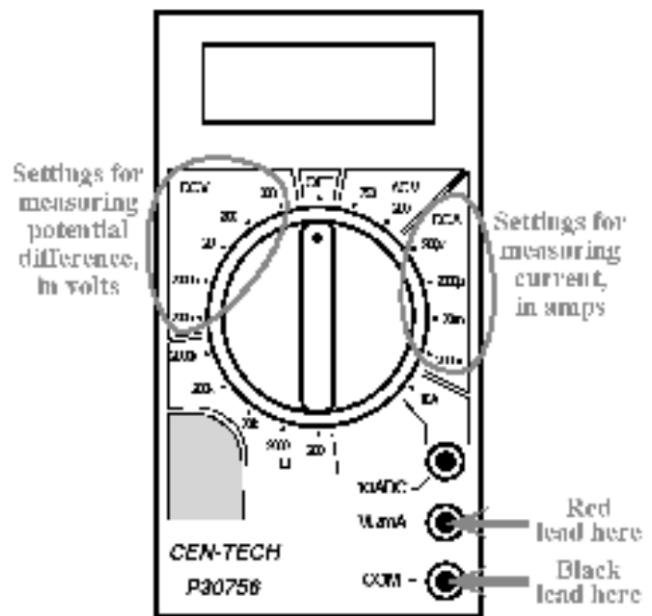


Figure 3: The Multimeter

2. Choosing a Scale

Before each and every measurement you make, before attaching either of the multimeter leads to any portion of the circuit, you must “choose the proper scale” on the multimeter as follows:

To measure potential difference ΔV , in volts

Choose the scale by turning the rotary switch to one of the settings in the DCV (direct-current volts) portion of its dial. A setting of, say, 20 means it can read potential differences as high as 20 volts. If you choose a scale smaller than values you'll actually encounter, you may blow out the meter. On the other hand, choosing a scale orders of magnitude *larger* than values you'll encounter often gives poor precision. At least early in the summer, you'll be guided on choosing the proper voltage scale.

With the proper scale chosen, you're ready to place the other ends of the leads at the two points in the circuit whose potential difference you wish to measure.

Note: When the multimeter reads a *positive* value, it means that the $V\Omega mA$ jack is at higher potential than the COM jack; when it reads negative, $V\Omega mA$ is at lower potential than COM.

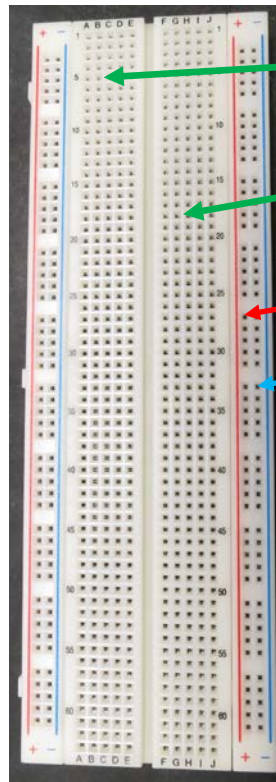
To measure current I , in amps

Turn the rotary switch to one of the settings in the DCA (direct-current amps) portion of its dial. A setting of, say, 20m allows it to read currents as high as 20 milliamps (2000 μ would be 2000 microamps). The same guidelines about the size of the scale apply here, but note that *it's much easier to blow out the meter when measuring current, so be doubly sure you've chosen the proper scale before attaching it to the circuit you're testing.*

With the proper scale chosen, you're ready to measure current. But remember that, while in measuring potential difference the device just sits outside with its “fingers” at two points, to directly measure the flow of current, it really becomes part of the circuit, with all the current it's supposed to measure passing through it. Thus, you'll need to “break the circuit” (cf. Fig. 4b) where you wish to measure the current, and send it through the multimeter leads.

Note: When the multimeter reads a *positive* value, it means that current is flowing into the $V\Omega mA$ jack and out the COM jack; when it reads negative, current flows out the $V\Omega mA$ jack.

How to Use a Breadboard



Horizontal Pins

All of the pins in a single horizontal row labeled ABCDE are connected together.

Similarly, all of the pins in a single horizontal row labeled FGHIJ are connected together.

The pins in one horizontal row are not connected to the row either above or below.

Also, pins ABCDE are not connected to pins FGHIJ, so that an integrated circuit with 2 rows of pins (called a dual inline package, or DIP) can be inserted in the middle of the breadboard, and you can make connections to the pins on each side of the chip.

Vertical Pins

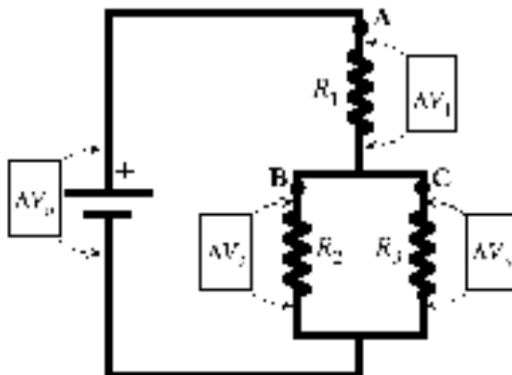
The pins in each vertical row down the length of the bread board are all connected. All of the pins next to a red line are connected, as are all of the pins next to a blue line. The vertical pins on the left and right sides of the board are not connected together, however.

It is often convenient to use the pins in one red row to connect circuit elements to the +V supply, to use the pins in one blue row to connect elements to the -V supply, and to use the pins in the second blue row to connect elements to ground. Each row of pins could then be called a power bus.

Lab Exercises

We are going to use a power supply and $1\text{k}\Omega$ resistors to make several circuits on a breadboard. Turn the power supply voltage to 10V for this series of experiments.

1. Connect one resistor to the power supply. Measure the voltage across the resistor. Also measure the current through the resistor. Check that Ohm's Law ($V=IR$) works.
2. Connect 2 resistors in series to the power supply. Measure the voltage across each resistor. Measure the current through the resistors. Again confirm Ohm's Law for each resistor.
3. Connect 2 resistors in parallel to the power supply. Measure the voltage across the resistors. Measure the current through each resistor. Again confirm Ohm's Law for each resistor.
4. Now wire up the following circuit:



Measure the voltages across all pairs of points as indicated. Use Ohm's law to determine the current through each resistor. Check that all of the voltages add up to zero if you go around the loop. (This is one of Kirchhoff's Laws.) Check that the currents coming into a node add up to those leaving the node. (This is the other Kirchhoff's Law.)

5. Design a more complicated circuit with more resistors and build it. Measure all of the voltages, and calculate all of the currents.