

Voltage, Current, and Resistance in a DC Circuit

Introduction

We define an object's resistance as $R = V/I$ where

V = voltage across the object (the difference in voltage of the conductors connected to the two ends of the object),

I = electric current passing through the object.,

This equation can be used to compute R for any sort of circuit element. But for most types of circuit elements, a different R value would be measured for every different current (I) passing through the element. If R remains constant as V and I are varied then V is linearly related to I , $V = IR$. Such objects obey Ohm's law and are referred to as being "linear" or "ohmic". If R does not remain constant as V and I are varied it is "nonlinear".

Outcomes

When you have finished the activities in this experiment, you will have:

- a) measured the resistance of a resistor and a diode.
- b) measured the DC current through each device as a function of the potential across it and plotted the data to obtain the I - V characteristic curve.
- c) become familiar with using a multimeter to measure voltages, currents, and resistances.

In the following lab you will make similar measurements for an AC circuit.

Procedure

An object designed solely to provide resistance is called a resistor. Resistors are typically carbon cylinders with a plastic shell painted with colored lines. Diodes are made of a semiconductor material and will have a single line at one end of its shell. Get a resistor and diode from the instructor.

A. Resistance Measurements: DC

To use your multimeter to measure resistance, turn the function dial to Ω (or ohms). Connect the resistor to the ohmmeter (multimeter set to measure resistance), this

is usually done by plugging wires into the “ Ω ” and “COM” (Common) sockets of the multimeter and connecting those wires to the two ends of the resistor. Set the ohmmeter to the lowest setting that does not overflow the meter and record the value. Reverse the resistor so that the meter now measures the resistance to current flow in the opposite direction, record the value.

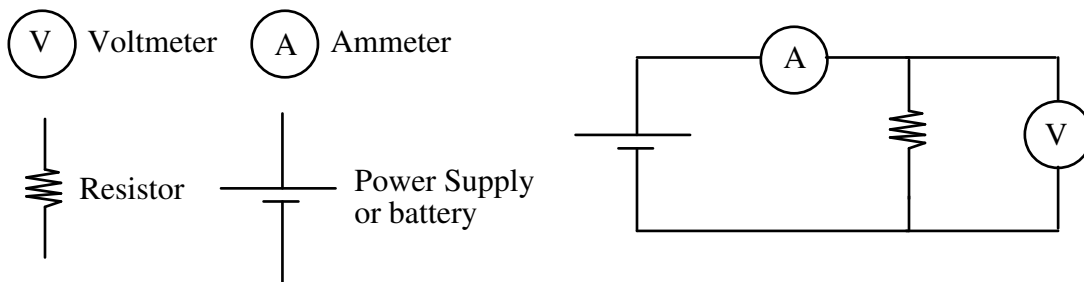
Replace the resistor with the diode and repeat the measurements, except measure the diode’s resistance using all the different ohmmeter scales.

Question 1: Which device is reversible, i.e., its resistance is independent of the direction of the current? Which device has a resistance that is dependent on the current direction?

Question 2: What is the nominal value of the resistance of the carbon resistor and its tolerance as specified by its color code? Does your measured value and the nominal value agree within the tolerance specified by the color code? See the table at the end of the lab instructions to interpret color codes.

B. Voltage and Current Measurements: DC

In order to determine whether a resistor is a linear or nonlinear electrical device you will study the resistor in an electrical circuit. Connect the circuit shown here:



The connecting lines represent wires.

Power Supply

Don’t turn on the power supply until everything is prepared. The power supply has three separate output pairs; output A, output B, and a fixed 5-volt output. There is a switch near the top of the power supply which lets you choose whether output A or B is enabled (you can use either but not both simultaneously). These two are variable outputs, the size of the voltage is controlled with the dials on the right-hand side of the power

supply. The other two dials control the maximum current that is permitted to flow through the outputs. If the “overload” light comes on, try turning up the current dial. If the overload light stays on, you have probably connected your circuit incorrectly and have a short-circuit.

The 5-volt output always puts out the same voltage. Although it says 2 A above this output, that does not mean that it always puts out a current of 2 amps. Instead that is the maximum current that can flow through this output and if the current is larger the overload light will come on (and you will definitely have a short-circuit). The 5 volt output can be used simultaneously with the A or B output (it can be used by two different groups or a single team needing more than one voltage source).

A wire should connect the positive (red) output socket of the power supply to the positive input socket of the ammeter (usually designated ‘+’ or ‘A’). Another wire will connect the negative (black) socket of the power supply to one end of the resistor.

Ammeter

The ammeter will have its positive connection connected to the power supply as above. It should also have a connection between its ground socket (often labeled ‘GND’ or ‘COM’ or ‘-’) and the resistor. It is good technique to start with the ammeter on its highest setting and later reducing the setting. This protects against problems like blown fuses. Ultimately you want get a current reading on the most sensitive scale possible. This is a DC circuit, do not use an AC ammeter or an AC setting on a multimeter.

Resistor

The ends of the resistor should already be connected, one to the power supply and the other to the ammeter.

Voltmeter

The positive socket of the voltmeter (often labeled ‘V’ or ‘V-Ω’ or ‘+’) should be connected to the resistor (right next to the connection from the ammeter). The ground socket from the voltmeter should be connected to the resistor’s other end. Make sure the meter is set to measure DC volts. An oscilloscope could be used as the voltmeter if insufficient multimeters are available.

Resistors have power ratings, a typical value is ½-watt, this means it may dissipate ½ watt or less for long periods of time. Higher powers may cause it to smoke

and burn. The maximum voltage across the resistor can be calculated for this maximum power:

$$P = \frac{V^2}{R} \quad \text{so} \quad V_{\max} = \sqrt{P_{\max} R}$$

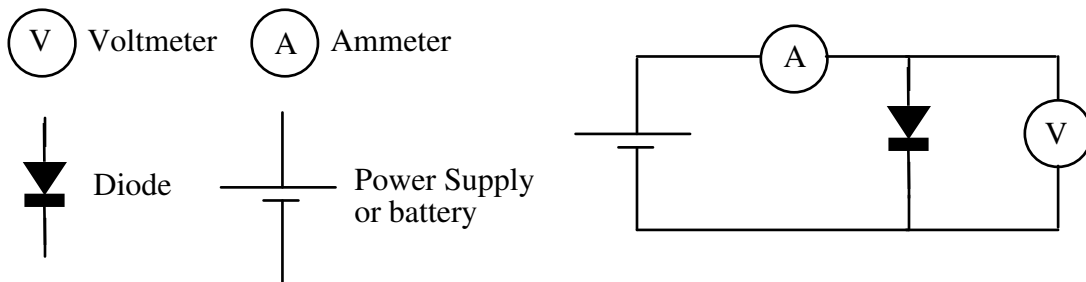
If $P_{\max} = \frac{1}{2} \text{W}$ and $R = 100 \Omega$, then $V_{\max} = 7.1 \text{V}$. Do not exceed the maximum voltage with your resistor.

When you have the circuit properly connected (have the instructor check your circuit if you are unsure), turn on all devices. Measure the current I and the voltage V for three settings of the power supply. Reverse the current through the resistor by disconnecting it, rotating it 180° , and reconnecting it to the circuit; then repeat your measurements. Label these reversed current and voltage values as negative. Note: $1 \text{ mA} = 0.001 \text{ A}$

Plot the current I through the resistor versus the voltage V across it. Place the origin at the center of the graph paper in order to plot positive and negative values.

Question 3: Does your graph suggest that the resistor is a linear device? Discuss. Draw a best-fit straight line through the data points (force the line to pass through the origin since we know $I=0$ when $V=0$) and calculate the slope. Determine the resistance from the slope. [Hint: $I = (1/R)V$]

To study a semiconductor diode, connect the circuit shown here. The arrow or band on the diode indicates the direction of easy current flow (low resistance), usually called the “forward direction”.



CAUTION: Obtain the maximum current rating of the diode from your instructor and do not exceed it; to do so would damage the diode.

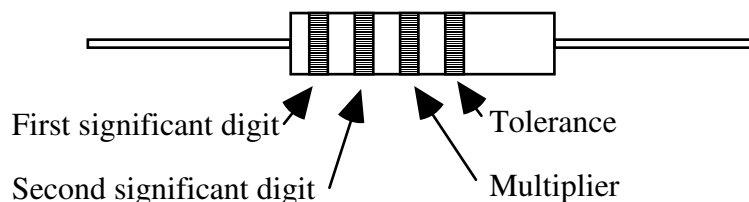
Collect six data points of I and V values for the diode, only collect data with the diode forward-biased. Plot your data.

Question 4: Does the graph suggest that the diode is a linear device? Discuss.

Resistors and Color Coding

Color Code

A common type of resistor used in electronic circuits is made of compressed carbon sealed in a ceramic coating. The resistance value in units of ohms is coded on the resistor by bands of color.



<u>Digit</u>	<u>Color</u>	<u>Multiplier</u>	<u>Color</u>	<u>Tolerance</u>
0	Black	1	Black	20%
1	Brown	10	No color	20%
2	Red	100	Silver	10%
3	Orange	1000	Gold	5%
4	Yellow	10 000		
5	Green	100 000		
6	Blue	1 000 000		
7	Violet	10^7		
8	Gray	10^8		
9	White	10^9		
	Gold	0.1		
	Silver	0.01		

The first two colored bands give the significant figures in the resistance (a value from 1 to 99). The third band gives the multiplier for the figure determined using the first two bands. The fourth band gives the tolerance or uncertainty, it indicates to what precision the resistor has been manufactured.

Examples

$$\text{Red - Yellow - Green} = 24 \times 10^5 \Omega \pm 20\% = 2.4 \text{ M}\Omega \pm 20\%$$

$$\text{Green - Black - Gold - Gold} = 50 \times 10^{-1} \Omega \pm 5\% = 5 \Omega \pm 5\%$$

$$\text{Brown - White - Red - Silver} = 19 \times 10^2 \Omega \pm 10\% = 1.9 \text{ k}\Omega \pm 10\%$$

$$\text{Brown - Black - Red - Silver} = 10 \times 10^2 \Omega \pm 10\% = 1000 \Omega \pm 10\%$$