

Experiment 18

Ohm's Law

Advance Reading:

Openstax- University Physics-Vol 2
Chapter 9, section 9-3 to 9-5.

Equipment:

1 universal circuit board
1 1-15 volt power supply
2 DMMs with leads
1 150 Ω resistor
1 330 Ω resistor
1 560 Ω resistor
1 jumper (i.e., shunt)
1 14 volt light bulb and socket 2 wire leads

Objective:

The object of this lab is to examine the relationship called Ohm's Law by determining the current versus potential relationship of resistors and a light bulb. Additionally, students will be introduced to the resistor color code.

Theory:

In the Electric Fields and Potential experiment the notion that the electric field inside a conductor is zero was examined. *This statement is true only if the conductor is in static equilibrium.* In this experiment there is a nonzero electric field inside the conductor (i.e., a wire) and the charges are not in equilibrium and there is a current.

A current density J (defined as current per unit area with units of amperes per meter squared) and an electric field are established in a conductor whenever a potential difference is maintained (across a conductor). In some materials the current density is proportional to the electric field E and

$$J = \sigma E \quad \text{Eq. 18-1}$$

where the constant of proportionality σ is called the conductivity of the conductor.

Materials that obey Eq. 18-1 are said to follow Ohm's Law. This definition implies that the *conductivity is independent of the electric field producing the current.*

The resistance R is defined as the ratio of potential difference ΔV across a conductor to the current I in the conductor:

$$R = \frac{\Delta V}{I} = \frac{V}{I} \quad \text{Eq-18-2}$$

The relationship above is the *definition of resistance* and is often called Ohm's Law but technically that is incorrect. See text.

The definition of resistance (i.e., Eq-18-2) will be examined in this lab and it states that the current I that flows in a circuit is directly proportional to the voltage V across the resistance R of the circuit, or in mathematical form:

$$I = \frac{V}{R} \quad \text{Eq. 18-3}$$

Materials that obey Ohm's Law exhibit a simple (i.e., linear) relationship between E and J (or V and I) are said to be ohmic. Resistors are ohmic devices. Materials that do not obey Ohm's Law are said to be nonohmic (i.e., do not exhibit a simple [linear] relationship between V and I). Light bulbs and diodes are said to be nonohmic. See question 5

In this lab, the current flow through a resistor will be measured when the voltage across the resistors is varied and from these data, the resistance is determined. The current is measured using a DMM (on the ammeter setting).

Ammeters are connected so that the current is through them (see Fig. 18-1). An ideal ammeter would have a resistance of zero so that it had no effect on the current. In reality ammeters have some resistance. On the other hand, the ideal voltmeter (the DMM in this case) has an infinite resistance. (approximately $10^7 \Omega$ for your DMM) This keeps the voltmeter from becoming an alternate path of current flow around the circuit element being measured.

The potential difference will be measured with the Digital multimeter, as in the Electric Field experiment. Voltmeters are connected in parallel to resistive elements in the circuit so that it measures the potential difference on each side of the element. The ideal voltmeter has an infinite resistance so that no amount of current is through the voltmeter (real voltmeters have a 'high' resistance).

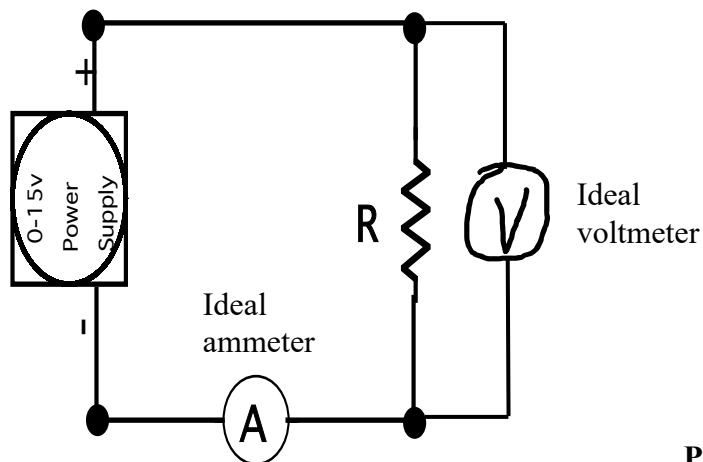


Figure 18-1

Resistor Color Code

There is a color coding scheme used to identify the value of the resistance of a resistor. The first two color bands give the first two digits in the resistance value. The third band gives the multiplier for the first two in powers of ten. The last color is the tolerance. For example, a resistor that has two red bands and a black multiplier band, has a

Color	Number	Multiplier
Black	0	10^0
Brown	1	10^1
Red	2	10^2
Orange	3	10^3
Yellow	4	10^4
Green	5	10^5
Blue	6	10^6
Violet	7	10^7
Gray	8	10^8
White	9	10^9
<u>Tolerance</u>		
Gold	5%	
Silver	10%	
no band	20%	

Figure 18-3

resistance of 22Ω . The figures below give the color code.

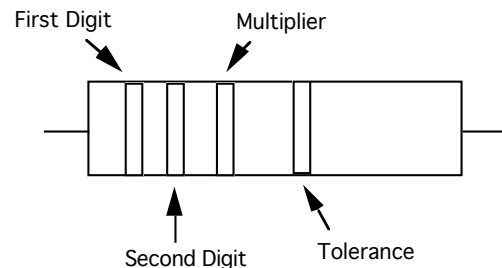


Figure 18-2

Procedure:

1. Make a simple series circuit with the 150Ω (as shown in fig. 18-1), using the power supply, milliammeter (DMM), shunt, and wire leads. **Have the circuit approved by your instructor before turning anything on.**

CAUTION: NEVER HOOK AN AMMETER IN PARALLEL WITH A POWER SUPPLY. IT HAS A RESISTANCE CLOSE TO ZERO AND COULD BE DAMAGED or blow a fuse.

2. Plug in the power supply and adjust the voltage until the DMM reads a one-volt potential difference across the resistor. Using the 2nd DMM measure the current. Set DMM on 200 milliamp setting.

3. Increase the voltage in one-volt increments up to 10 volts, measuring the current through the resistor at each voltage level. Record all values of current I in amperes and voltage V in volts.

4. Repeat this procedure for the 330 Ω and 560 Ω resistors.

5. Graph I vs. V and plot a best-fit line for each of the resistors on the same graph. Calculate the slope of each line. From these slopes, obtain the value of the resistances R for the resistors. Be sure to label each of the slopes appropriately.

6. Measure the resistance of each resistor using the ohmmeter function of the DMM. Do this by placing the input wires in the correct holes on the DMM and turning the dial to the ohms (Ω) position. The DMM provides a potential difference between the leads and measures the amount of current through the resistance. Be sure and write down color code values, including tolerances. (see figure 18-2).

7. Replace the resistors with the light bulb and repeat step 3 (except for light bulb use 0.2-volts increments up to one volt and then one-volt increments up to 10 volts). Plot a graph of I vs. V for the light bulb, **only this time curve fit the data using a ‘power fit’ curve.**

Questions/Conclusions:

1. a) Which of the resistors (used in this experiment) dissipated energy (as heat) at a higher rate (**use the current at 10 volts from lab data**). Use $P = VI$. Show calculation.

b) How many of the resistor in part a) would it take to emit as much heat as a 100-watt light bulb. Show work.

2. In the field of engineering a ‘water model’ is often used to explain electricity, with **pressure replacing potential** and **volumetric flow rate replacing current**. Answer the following: *Explain all answers and/or show all work.*

a) What is volumetric flow rate and what are its units in both SI and English units?

From Bernoulli eq. we know the **velocity** v of a leak in a hole in the bottom of a tank of **height h** is given (**only**) by $v = \sqrt{2gh}$.

b) If you triple the hole diameter (of a leak) in a tank (with a constant level, h) what happens to the **volumetric flow rate and the velocity** of the leak? Explain your answer.

Helpful hints- $\text{area} = \pi \cdot \text{radius}^2$ and volumetric flowrate is equal to velocity * area.

c) Based upon your answer above what happen to **amount of current flowing** in a wire at a **constant voltage** if you triple the diameter of the wire?

3. The electric company charges its customers for each **kilowatt*hour** used.

a) What’s the difference between a kilowatt and kilowatt hour?

b) **What SI quantity** do you pay the power company (i.e., the ‘electric company’) for? Is the term “power company” a correct term?

4. Based upon your plot, if you were asked why is a light bulb nonohmic, what would you say?

What happens to the resistance of a light bulb as the filament gets brighter? Explain your answer (using observations from your plot).