

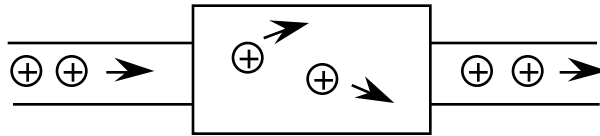
# ECE 109 - THE VERY BASICS - INVESTIGATION 4 LINEAR RESISTORS

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To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

In the last Investigation we found how  $V$  and  $I$  are related in ideal voltage and current sources. The objective of this Investigation is to determine the relationship between  $V$  and  $I$  for linear resistors. As you undoubtedly know linear resistors are simply pieces of material like carbon with wires connected to them as follows

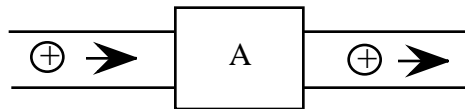


that we represent with the following symbol

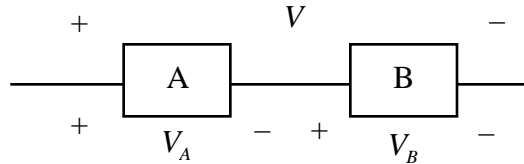


The equivalent positive charges flow easily through the wires but it takes work to push them through the carbon (or other resistive material). As a result, there has to be a nonzero voltage drop across a resistor to get the charges flowing. Be sure to take a look at the **Computer Demos** on Ohm's Law.

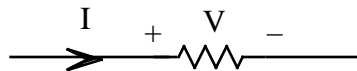
1. We begin with some review problems. Which side is at a higher potential in the following circuit



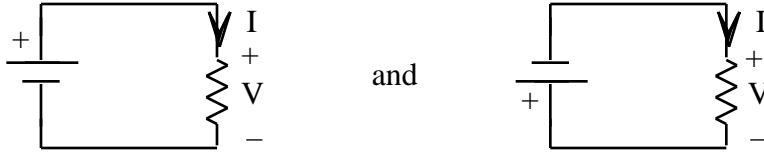
- a. If the equivalent positive charge is transferring energy to A
  - b. If A is transferring energy to the equivalent positive charge
2. Find the voltage  $V$  in the following circuit if  $V_A = 3$  volts and  $V_B = -5$  volts



3. To find out how the voltage  $V$  (in volts) **across** and current  $I$  (in amps) **through** a given resistor as follows



are related we have to do as the first investigators did. We have to go into the lab, connect up different batteries (or voltage sources) as follows

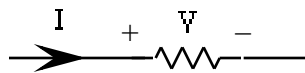


and then measure the corresponding currents  $I$ . Suppose we do this for a **particular** resistor and obtain the following data

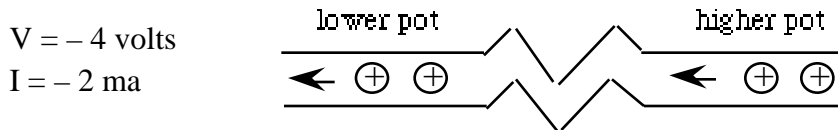
V (volts)	I (ma)
-4	-2
-2	-1
0	0
2	1
4	2

where **ma** is shorthand for milliamp =  $10^{-3}$  amps. Our goal in this problem is to get an equation for  $V$  as a function of  $I$  for **this** particular resistor

- First plot a graph of the data points with  $V$  in **volts** as a function of  $I$  in **amps (not ma)**. Then draw a curve through your data points. Describe your curve
  - Find an equation for your curve with  $V$  (in **volts**) as a function of  $I$  (in **amps**) - an equation like  $V = 1000I$
  - Why would you say that we refer to such resistors as **linear** resistors
  - What does your **model** for this resistor - your equation - predict for the voltage  $V$  when  $I = -2$  ma.
  - What do you predict for  $V$  when  $I = 2.5$  ma
4. The objective of this problem is to see what happens to the energies of equivalent positive charges as they flow through the resistor in Problem (3) with **reference directions** as follows



- First draw pictures like the following



for **each** of the data points in Problem (3) - pictures that show

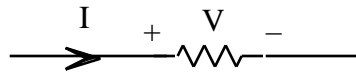
- Which way the equivalent positive charges are flowing and
  - Which node is at the higher and which at the lower potential
- Now make use of your pictures in part (a) to set up a Table that indicates - for each data point - whether the equivalent positive charge flowing through the resistor is going from higher to lower or lower to higher potential.
  - What does your Table in part (b) tell you about the transfer of energy in the resistor - are the equivalent positive charges flowing through this resistor always losing energy, always gaining energy or sometimes gaining and sometimes losing energy.
  - Are your results in part (c) what you expected - are they consistent with your understanding of what's going on inside resistors. Why

5. Now suppose we apply the same voltage  $V$  across two resistors  $R_1$  and  $R_2$  as follows



and obtain the currents  $I_1$  and  $I_2$  as shown. Which resistor would you say has the higher **resistance** - most **resists** the flow of charge when a voltage is applied across its terminals. How can you tell

6. We know from our results in Problem (3) that  $V$  and  $I$  for linear resistors like the following



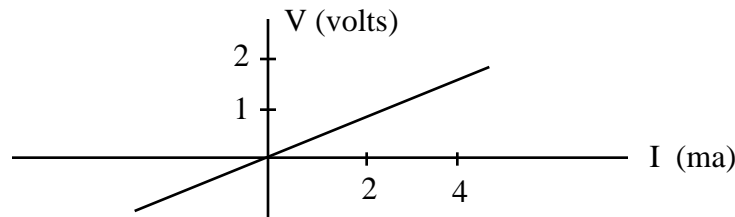
are related by equations like  $V = 1000I$  and  $V = 2000I$  where  $V$  is in *volts* and  $I$  is in *amps*. We refer to the coefficient of  $I$  as the resistor's **resistance**  $R$  with  $V = RI$

- Verify that the units of  $R$  are volts/amp
  - How does increasing the size of the resistance  $R$  affect  $I$  for a given  $V$
  - Make use of your result in part (b) to explain why we call the coefficient of  $I$  the *resistance* of the resistor.
7. Engineers and scientists usually use the term **ohm** (  $\Omega$  ) instead of the more cumbersome volts/amp with

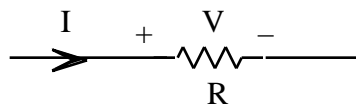
$$1 \text{ ohm} = \frac{1 \text{ volt}}{\text{amp}}$$

when specifying resistances. We also make use of the shorthand  $1K$  for  $1000$  . Now express the resistances of the following resistors in volts/amp as well as ohms

- A resistor characterized by  $V = 4000I$
- A resistor characterized by the following curve (Be sure to note that the current on this graph is in milliamps)

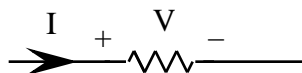


8. Find the current  $I$  in the following circuit

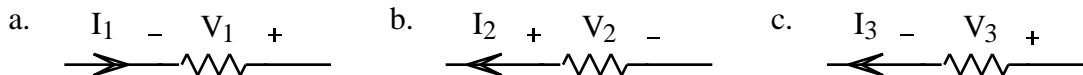


if the resistance  $R = 1K$  ohms and the voltage  $V$  is

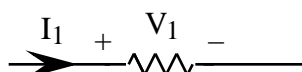
- $V = 2$  volts
  - $V = -2$  volts
9. Up to now the reference directions of our resistors have all been **associated reference directions** - reference directions with the current reference arrow pointing from the plus to the minus of the voltage reference direction as follows



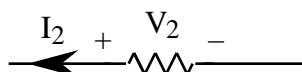
**Memorize** this definition. Then make use of it to determine which of the following resistors have associated reference directions and which do not



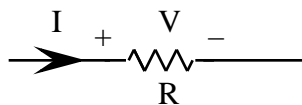
10. Suppose Engineer 1 measures  $V_1 = 3$  volts and  $I_1 = 2$  ma for a resistor with associated reference directions as follows



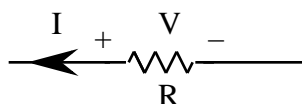
Then what will Engineer 2 measure for the same resistor if the reference directions are not associated as follows



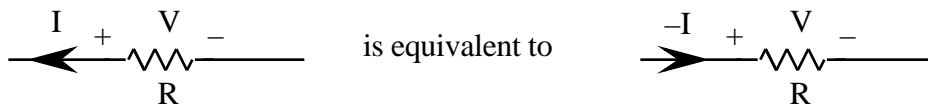
11. Now whenever we go into a lab and measure  $V$  and  $I$  of a resistor with *associated* reference directions as follows



we always find that  $V = RI$ . The objective of this problem is to find the relationship between  $V$  and  $I$  when the reference directions are *not associated* like the following

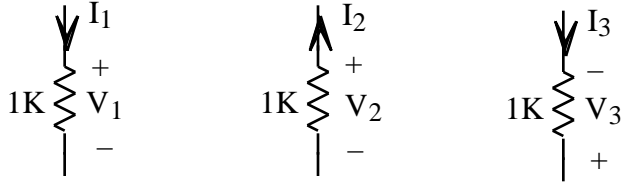


The trick is to make use of the fact that non-associated reference directions can be turned around to make them associated as follows



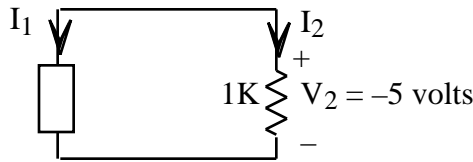
Make use of this equivalence to find  $V$  as a function of  $I$  for this resistor.

12. Generalizing on the result of Problem (11) we have that whenever the reference directions of a resistor are associated then  $V = RI$  but when they're not associated then  $V = -RI$ . **Memorize** this result. Then make use of it to express each of the following voltages in terms of the corresponding currents

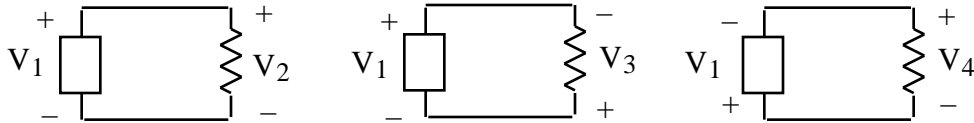


13. Now as you surely know  $V = RI$  is known as **Ohm's Law**. What was Ohm assuming about the reference directions of  $V$  and  $I$  when he wrote Ohm's Law.

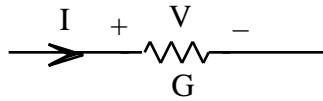
14. Find  $I_1$  and  $I_2$  in the following circuit



15. Find the voltage drops  $V_2$ ,  $V_3$  and  $V_4$  across each of the following resistors assuming the wires are ideal with no voltage drops and  $V_1 = 5$  volts



16. When we take our equation  $V = RI$  for a linear resistor as follows



and solve for  $I$  we obtain  $I = (1/R)V = GV$  where  $G = 1/R$  is defined to be the **conductance** of the resistor. Conductance is measured in **siemens S** with 1 siemen = 1/ohm. Find the current through the resistor above with  $V = 5$  volts and conductance  $G = 10^{-3} S$

17. Math Review: Sketch  $V = \frac{R}{1000 + R}$  for  $R > 0$