Name: ________________________
Partner:________________________
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Ohm's Law and DC Circuits

EQUIPMENT NEEDED:

Circuits Experiment Board | Two D-cell Batteries | Wire leads
Multimeter | 100, 330, 560, 1k, 10k, 100k, 220k Ω resistors

Part 1 Ohm's Law

Purpose

The purpose of this section is to investigate the three variables involved in a mathematical **relationship** known as Ohm's Law.

Procedure

1. Measure the voltage of your battery before you connect anything to it.
   V_B=_______________
2. Choose one of the resistors that you have been given. Using the chart on page 3, decode the resistance value and record that value in the first column of Table 3.1.

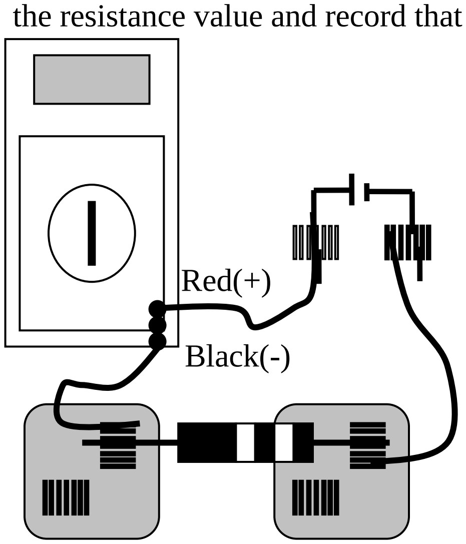


Figure 3.1a

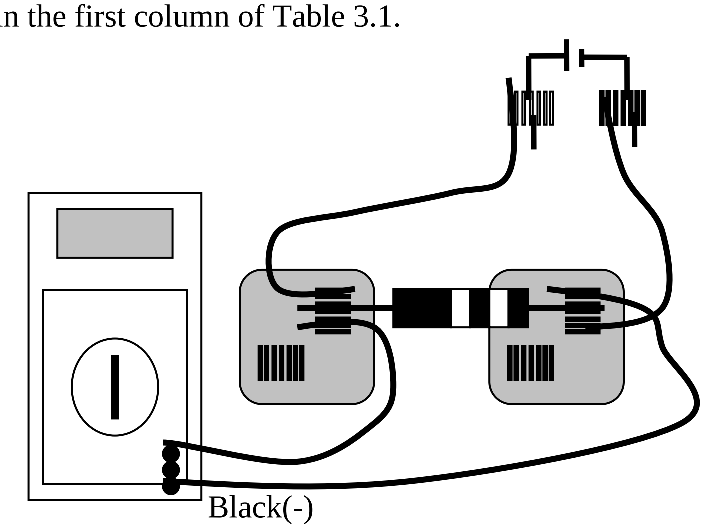


Figure 3.1b

3. **MEASURING CURRENT:** Set the Multimeter to measure current (you may have to move the red lead to the current input on the multimeter). Start with the 200 mA scale. Construct the circuit shown in Figure 3.1a by pressing the leads of the resistor into two of the springs on the Circuits Experiment Board. Complete the circuit by touching the leads of the multimeter to the springs. (Do not poke them into the springs since they get stuck.)

Note that this configuration makes the current flow **through** the meter. This current also flows through the resistor.

4. If the current is much lower than the scale maximum (200 mA) then use a lower scale. (If you are using a 220kΩ resistor, you will need to use the 200μA setting.) Record the current in the 2nd column of Table 3.1.

5. Remove the resistor and select another having a different resistance. Decode its resistance and record the value in Table 3.1. Measure and record the current as in steps 3 and 4. Continue this process until you have measured the current for six different resistors.

6. **MEASURING VOLTAGE:** Follow Figure 3.1b to connect the battery to the first resistor you used in step 2. Change the Multimeter to the 2 VDC scale (change the red lead to the voltage input) and connect the leads as shown in Figure 3.1b. Note that this configuration measures the voltage across the resistor. Record it in Table 3.1.

7. Remove the resistor and select the next one you used in steps 2-4. Record its voltage in Table 3.1

Data Analysis

1. (A) Construct a graph of Current (vertical axis) vs. Resistance using the program Graphical Analysis (See the separate instructions).

   (B) Construct a second graph of Current vs. 1/*R*. Have the program fit the data to the equation
   $y = mx + b$.

2. For each of your sets of data, calculate the ratio Voltage/Resistance and enter in Table 3.1.

Resistance, Ω	Current, amp	Voltage, volts	Voltage/Resistance

Table 3.1

Discussion

1. (A) From your graphs, what is the **mathematical relationship** between current and resistance? Answer with an equation and define all symbols used in it.

   (B) How *good* was the fit of the equation $y = mx + b$ to your graph of I vs. $1/R$?

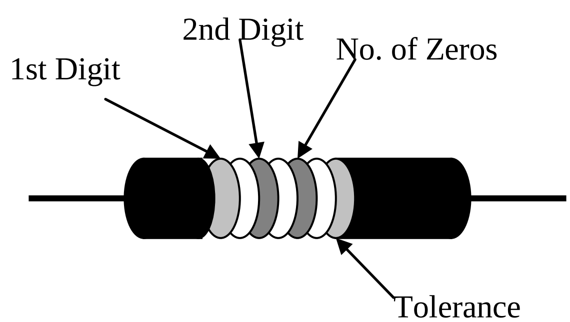
   (C) What is the interpretation of the slope of the graph (i.e., what does m represent)?

2. How do the ratios you calculated above in step 2 of **Data Analysis** compare to the currents you measured? What should the relationship be?

3. Suppose you were given an unknown resistance and you followed the procedures of steps 2 through 6 with the result that you measured 20 mA flowing through the resistor and you measured a voltage of 1.4 volts across it. What is the resistance?

Reference

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9



<u>Fourth Band</u>

None ±20%
Silver ±10%
Gold ±5%
Red ±2%

Tolerance is the range of values the manufacturer allows during the fabrication of the resistors. For the user, this is equivalent to the range of uncertainty about the value represented by the color code.

Example: Suppose the colors are (in order from the end closest to the color bands) are red red orange red. This means the resistance is 22000 ohms plus or minus 2% of 22000 or 22 ± 0.44 kΩ.

Part 2: Resistors in Circuits

Purpose

The purpose of this section is to begin experimenting with the variables that contribute to the operation of an electrical circuit.

Activity 1: Resistors in Parallel and in Series

Procedure

1. Find the three resistors that have values as indicated by their color code; R_1 = 100 Ω, R_2 = 330 Ω, and R_3 = 1000 Ω. Enter their color codes in Table 4.1 below. You will refer to these resistors as #1, #2, and #3, respectively.

2. From the color code, determine the manufacturer's stated resistance of each and enter the value in the column labeled "Coded Resistance" in Table 4.1. Enter the Tolerance value as indicated by the color of the fourth band under "Tolerance".

3. Use your Multimeter to measure the resistance of each resistor and enter these values in Table 4.1.

4. Since we do not know the *real* or *true* value of the resistance, you cannot calculate a percentage error. To compare your measured value with the manufacture's coded value, you should calculate the percentage difference.

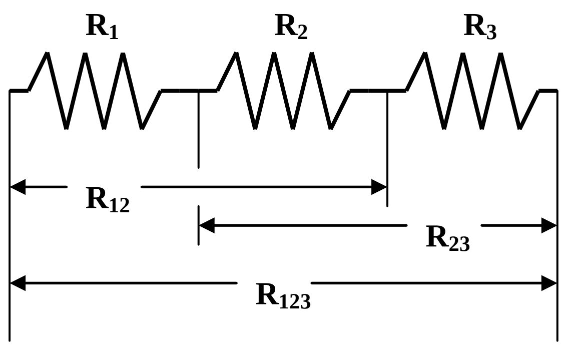
   Percentage Difference = [|measured – coded| / (1/2 (measured + coded))] x 100%

	Colors				Coded	Measured	%	Tolerance
	1st	2nd	3rd	4th	Resistance	Resistance	Difference	
#1					100 Ω			
#2					330 Ω			
#3					1000 Ω			

Table 4.1

5. Connect the three resistors in SERIES, figure 4.1, using the spring clips on the Circuits Experiment Board to connect the leads of the resistors together without bending them. Measure the resistances of the combinations as indicated on the diagram by connecting the leads of the Multimeter to the points at the ends of the arrows.

Figure 4.1 Series



R_{12} = ____________________

R_{23} = ____________________

R_{123} = ___________________

6. Construct PARALLEL combinations of resistors, first using two resistors at a time to make R_{12}, R_{23}, and R_{13}, and then using all three for R_{123}. Measure and record the resistances.

Parallel

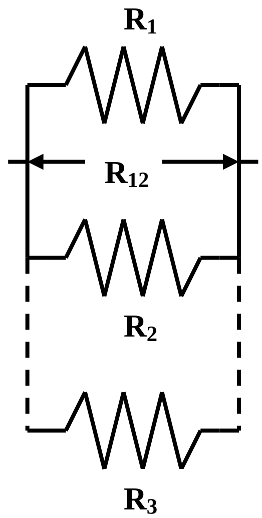


Figure 4.2

R_{12} = ____________________

R_{23} = ____________________

R_{13} = ____________________

R_{123} = ____________________

Activity 1 Discussion

1. How do the % differences you calculated for your resistors compare with the manufacture's tolerances?

____

____

2. What is the apparent rule for combining resistances in series? In parallel? Cite evidence from your data to support your conclusions.

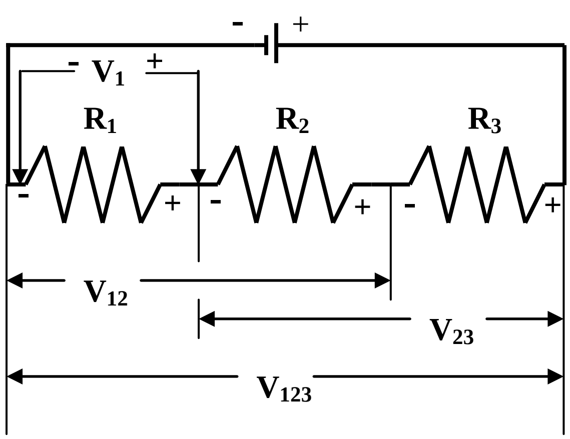
Activity 2: Measuring Voltages and Currents within Circuits

Procedure

1. Select the three unequal resistors $R_1 = 100\ \Omega$, $R_2 = 330\ \Omega$, and $R_3 = 1000\ \Omega$.

2. Connect the three resistors into the **series** circuit shown below, using the springs to hold the leads of the resistors together without bending them. Connect the D-cell to the series of resistors. Note which end is connected to the negative and which is connected to the positive terminals.

3. Set the Multimeter to measure dc voltage on an appropriate range of sensitivity. Measure the voltages across the individual resistors and then across the combinations of resistors. Be careful to observe the polarity of the leads (red is +, black is -). Record your readings below. When you measure resistances, <u>be sure to disconnect the battery from the circuit</u>. (The resistances should agree with the measurements you made in Activity 1.)



R_1 = ____________	**V_1 =** ____________
R_2 = ____________	**V_2 =** ____________
R_3 = ____________	**V_3 =** ____________
R_{12} = ____________	**V_{12} =** ____________
R_{23} = ____________	**V_{23} =** ____________
R_{123} = ____________	**V_{123} =** ____________

Figure 4.3 Series

4. Now connect the **parallel** circuit of figure 4.4, *using all three resistors*. Set the multimeter to measure current. Measure the total current provided from the battery, and the current through each resistor by breaking the circuit and inserting the multimeter into each position indicated in Figure 4.5. Recall that in order to measure current, the multimeter must be in series so that current flows through the meter. Also measure and record the indicated voltages.

Parallel

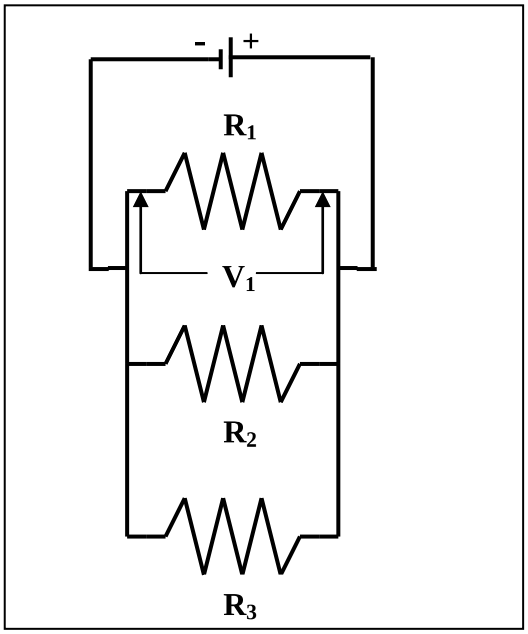


Figure 4.4

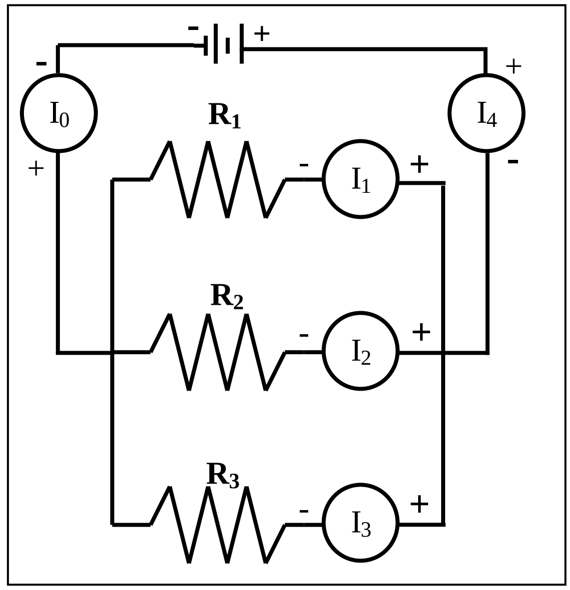


Figure 4.5

I_0 = ____________

R_1 = ____________ **I_1** = ____________ **V_1** = ____________

R_2 = ____________ **I_2** = ____________ **V_2** = ____________

R_3 = ____________ **I_3** = ____________ **V_3** = ____________

R_{123} = ___________ **I_4** = ____________ **V_{123}** = ___________

Activity 2 Discussion

1. According to the data you recorded in the Table with Figure 4.3, what is the pattern for how voltage gets distributed in a series circuit of resistors?

____

____

Do your results confirm Kirchhoff's Loop rule? (Is the voltage rise due to the battery equal to the sum of the voltage drops across the resistors?) Show your work.

____

2. Is there any relationship between the size of the resistance and the size of the voltage across it for resistors in a series circuit?

____

____

3. Utilizing the data you recorded in Figure 4.5, what is the pattern for how current gets distributed in a parallel circuit of resistors?

____

____

Do your results confirm Kirchhoff's Junction (or Node) rule? (Is the current from the battery equal to the sum of the currents through the resistors?) Show your work.

____

4. Is there any relationship between the size of the resistance and the size of the current through it for resistors in a parallel circuit?

____

____

5. For each resistor in Figure 4.5, compare the product of current times resistance to the measured value of the voltage across the resistor. How should these compare?

____

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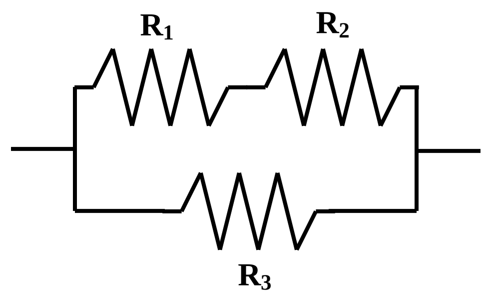
HOMEWORK ASSIGNMENT

Show your work clearly.

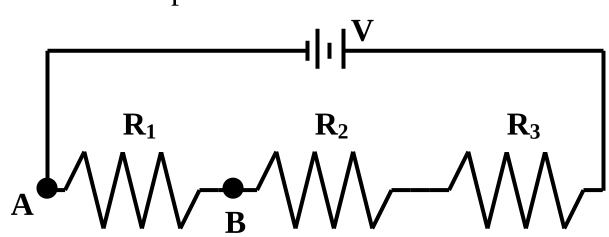
1. Calculate the equivalent (total) resistance of this combination of resistances.

   R_1 = 100 kΩ
   R_2 = 200 kΩ
   R_3 = 300 kΩ



2. In the circuit shown, calculate the voltage difference between points A and B.

   Where V = 30 volts
   R_1 = 250 Ω
   R_2 = 300 Ω
   R_3 = 350 Ω



3. Find the total current supplied by the battery.

   Where V = 30 volts
   R_1 = 250 Ω
   R_2 = 300 Ω
   R_3 = 350 Ω