PHY 152/252

Kirchhoff's Rules – Laboratory 3

OBJECTIVE

The objective of this lab is to build a circuit having two Emfs and five resistors and to use Kirchhoff's Rules to predict the voltage drop across each resistor; to measure the actual voltage drop across each resistor and to compare these values. In effect, the objective is to test Kirchhoff's Rules.

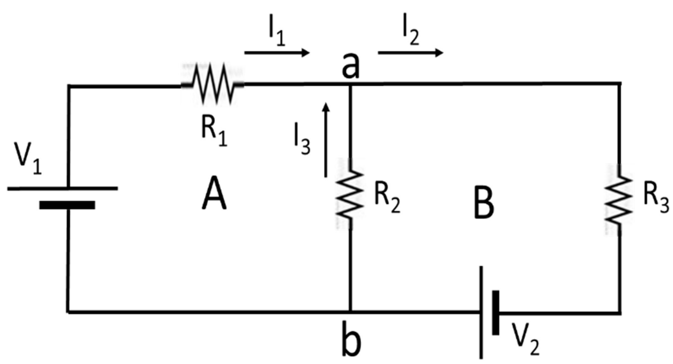
THEORY

Kirchoff's voltage law is based on the conservation of energy and states that the sum of the voltages around a closed loop is equal to zero. Stated another way: KVL (Kirchhoff's Voltage Law) says that the sum of the voltage drops across the resistors is equal to the input voltage of the circuit. Utilizing the principle of KVL gives a method of analyzing various circuits. This method is commonly called mesh analysis.

The rules of mesh analysis are as follows:

1. Define any loops of interest by labeling them, usually with a letter.
2. Choose a starting point in each loop.
3. Choose a current direction for each loop.
4. Following the current from the starting point, add the voltages as you go around the loop using Ohms Law to express the voltage drop across resistors.
5. If you have more than one loop, use the equations from each loop to set up a system of equations. Solve this system to give you a current value.
6. Use the current to get additional information about the circuit as needed; such as the voltage drop across a specific resistor.

Example circuit and mesh equations:



To the left we have a circuit with three resistors and two Emfs. We have divided the circuit into two loops, A and B, and we have assumed current directions for each of the 3 "legs" as shown. We start the mesh analysis at point "a" at the top of the circuit and go around both loops in a clockwise direction. The mesh equations can be written as follows:

The current equation would be:

1) $I_1 + I_3 = I_2$ (point "a" is used for this equation)

KVL around loop A:

2) $+ I_3R_2 + V_1 - I_1R_1 = 0$ (clockwise traveling, starting from "a")

KVL around loop B:

3) $- I_2R_3 + V_2 - I_3R_2 = 0$ (clockwise traveling, starting from "a")

Assuming we know the values of the resistances and the Emfs, these three equations can be solved simultaneously for the three currents. Then the currents can be substituted into the two loop equations to solve for voltage "drops" across all three resistances. If a current solves as a negative value, it simply means that you have chosen the wrong direction for it. But the magnitude for it is still correct.

PROCEDURE

There are two parts to this experiment. You will create a circuit, make and record your measurements, and then you will reverse the polarity of one of the EMF's and repeat the experiment.

Procedure 1: The circuit you will build is shown on the next page. The two EMF's shown are actually one power supply with multiple outputs. We will use the fixed 5 volts output and the variable output. Do not turn on the power supply until your lab instructor has checked your circuit. We will use the blue fixed resistor boxes for our resistors as follows:

R1 = 100 ohms
R2 = 200 ohms
R3 = 100 ohms or 200 ohms as supplied
R4 = 50 ohms
R5 = 50 ohms

To connect to the 5 volts fixed output of the power supply, you will have two pink stranded connector wires (one shorter and one longer). Use your finger to push down on the clip, insert one end of each pink wire into the power supply, and release the clip. Check that the wires are securely fastened. Then use an alligator clip to connect the shorter pink wire to the green wire (see note below).

To make the circuit easy to check, we will all use the same color scheme of connecting wires for each connection as follows:

1. From the positive end of the 5V output to R1	**Pink (see *Note below)**
2. From R1 to R2	**Yellow**
3. From R2 to R3 (plug into the back of the yellow wire)	**White**
4. From R2 to the negative output of the variable power supply	**Blue**
5. From R3 to R5	**Black**
6. From R5 to the positive output of the variable power supply	**Red**
7. From R5 to R4	**Purple**
8. From R4 to the ground end of the 5V output via an alligator clip	**Green to Pink**

We will use the red EXTECH meters as voltmeters. We will only measure voltage in this experiment. The meter will already have a red and a black lead plugged into the proper places.

*Note: You will have one long and one short pink length of stranded wire. The short length runs from the ground (negative) of the 5 volt fixed output of the power supply to R4 via an alligator clip and the green lead. The longer length pink wire runs from the 5 volt .positive output directly to R1. To make this connection, loosen one of the yellow posts on the 100 ohm blue resistor box, insert the longer curved end of this pink lead under this post and tighten.

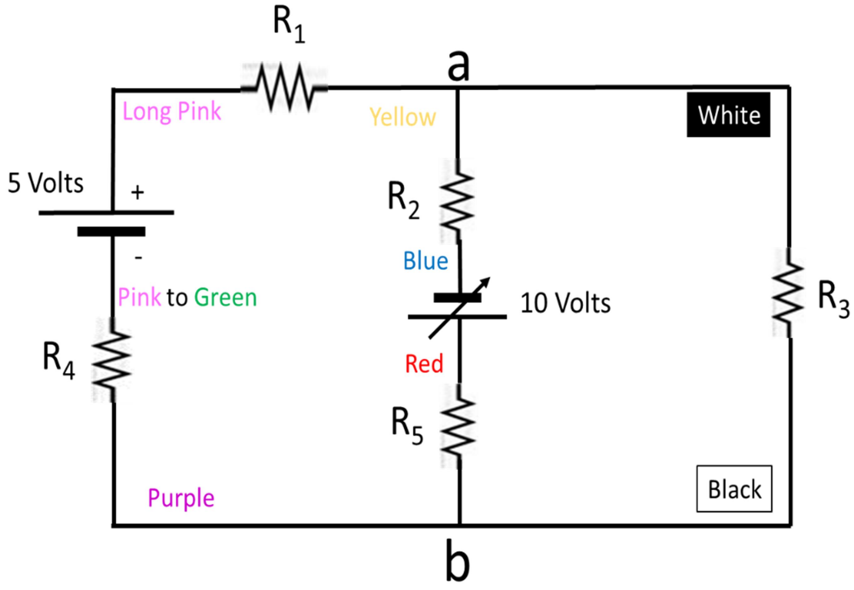
When your circuit is declared correct, turn the large knob on the Extech meter to the VDC position, turn on the power supply and adjust the variable voltage to exactly 10 volts. Use the Extech meter to check this voltage. Adjust as needed. Also use the EXTECH meter to verify that the 5 volt output is, indeed, 5 volts. If it's not, record what it actually is and use that value in your calculations. Then use the Extech meter to measure the voltage difference across each of the 5 resistors to within 0.1 volts. Note carefully the polarity of these voltages; that is, which end of each resistor is at the higher voltage. Indicate this polarity on your circuit schematics in your report (see below).

When measuring voltages, plug the red and black meter leads from the meter into the back of the stackable plugs. If one of the plugs is not stackable, note that these plugs all have "side holes" into which a banana jack will fit.

Procedure 2: When all five of the voltages have been measured and recorded in Procedure 1, turn the power supply off, reverse the polarity of the 10 volt variable output (simply unplug the blue and red wires, swap them, and re-plug them). Since no harm can come from this operation, you do not need the instructor to re-check your circuit. Therefore, turn the power supply on again and measure the voltage differences across the 5 resistors again. They should be different. Record these values in a separate table from the first part (see below).

CALCULATIONS AND THE REPORT

As part of your report, create two five-row, six-column tables. The columns of these tables should be: labeled: R#, Ohms, Current (theor), Volts (theor), Volts (actual), and percent difference. Next, use Kirchhoff's Rules to calculate the theoretical current through each resistor, use Ohm's Law to calculate the theoretical voltage across each resistor, and insert those values into the tables. Finally, place in the tables the measured voltage drops, and calculate a percent difference between the actual and theoretical values of each voltage drop across each resistor. Explain percentage differences greater than 5%. Before you leave lab, calculate the theoretical values of these ten voltage drops to make certain that you understand the process and that your values are approximately correct.



In your report, show all work leading to the theoretical voltage drop across each resistor. It is not required that this calculation work be typed, but it should be written neatly on a separate unlined worksheet which is clearly labeled "Kirchhoff's Calculations." Make two hand-sketches of the circuit above on your worksheet (one for each 10 volt polarity direction); include all resistor values, current values, and voltage polarities on your sketches, and use arrows to indicate your assumed current directions. Do all of this to make it easier for the lab instructor to follow your Kirchhoff calculations.