

# Ohm's Law and Electric Circuits

## Ohm's Law; Series Resistors; Circuits Inside Three- and Four-Terminal Black Boxes

January 2014

Print Your Name

Print Your Partners' Names

### Instructions

Before the lab, read all sections of the *Introduction to Ohm's Law and electric circuits*, and answer the Pre-Lab questions on the last page of this handout. Hand in your answers as you enter the general physics lab.

You will return this handout to the instructor at the end of the lab period.

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## 0. Introduction to Ohm's Law and electric circuits

*Abstract* Concepts that are part of the lab activities

### 0.1 Current

- 0.1.1 Current is the number of coulombs per second flowing out of a power source, past a point on a wire, or through something (light bulb, motor, radio, ...).
- 0.1.2 Current is usually represented by the letter  $I$  in equations.
- 0.1.3 The unit of current is the *ampere*, defined to be *one coulomb per second*.


### 0.2 Ohm's Law

- 0.2.1 Ohm's Law is  $V = IR$ .
  - $V$  is the difference in electric potential (in volts) between two points in a circuit.
  - $I$  is the current flowing along the path between those two points.
- 0.2.2 The meaning of Ohm's Law is that voltage  $V$  is proportional to current  $I$ .
  - $R$  is the proportionality constant between the voltage  $V$  and the current  $I$ .  $R$  is called the *resistance*.
- 0.2.3 The unit of resistance is the *Ohm*, represented by a Greek uppercase omega:  $\Omega$ .

0.2.4 Ohm's Law, the proportionality between voltage and current, is true for many things that conduct current but not for everything. Light bulbs are an example of something that conducts current but does not obey Ohm's Law. If you apply different voltages to a light bulb and measure the light bulb currents, you get different values of the ratio  $V/I$ . This makes it impossible to assign a resistance  $R$  to a light bulb. Things which do have resistance always yield the same  $V/I$  ratio no matter what voltage you apply to it. **Then** it is possible to say that  $V/I = R$  is the resistance, because the ratio is always the same.

0.3 The graphic symbols for things without and with resistance

Wires or things that have little or no resistance are represented by straight lines. The idea behind resistance is that it resists the flow of electrical current, so resistance is represented by a jagged line (which should make you think of a difficult path).

- Wire, or something with little or no resistance: \_\_\_\_\_
- Something with significant resistance: ————————

0.4 Two resistances connected in series

You can connect two things having resistance by joining one of the ends of the first to one of the ends of the second. The result is a new single thing with resistance. This is called a *series* connection, and the resistances of the two separate things combine to make the resistance of the new single thing. This is represented using the graphic symbol for a resistor as shown immediately below.

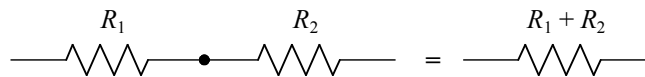


Figure 1 Combining resistors in series

0.5 Current always flows in a closed loop

Electric current flowing out of a power supply or battery must always return to where it started. More precisely, current flowing out of the positive terminal of a power supply or battery must flow back in the negative terminal of the same power supply or battery.

This forces electric current always to flow in closed loops. If the circuit does not contain a continuous closed loop, no electric current can flow.

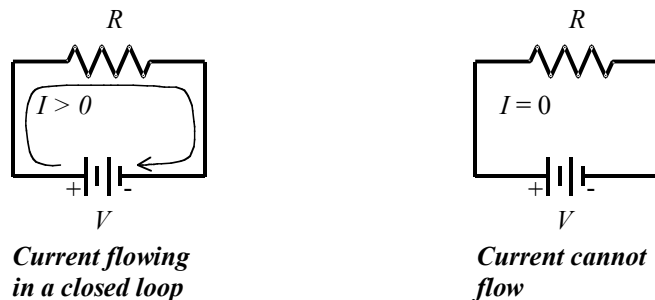


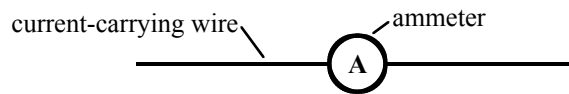
Figure 2 With no closed loop conductive path, as in the circuit on the right, current cannot flow.

## 0.6 Ammeters

0.6.1 An ammeter is an instrument that measures the rate at which electric charge flows through a wire in amperes, which are the same as coulombs per second. An ammeter also tells the direction the current flows.

0.6.2 The only way the ammeters used in our labs can know how much current flows through a wire is if the wire's current actually flows through the ammeter. If you had a single wire and wanted to know the current flowing through it, you would have to cut the wire and connect the two cut ends of the wire to the ammeter so that the current passes through the ammeter.

0.6.3 Measurements in electric circuits do not require you to cut wires, but you do have to arrange the circuit connections so that the current you want to measure is diverted to flow through your ammeter. In a circuit diagram, the connection looks as shown in Figure 3.



*Figure 3 An ammeter connected to measure the electric current flowing through a wire*

0.6.4 Of the two places on the ammeter where you connect a wire (to measure the current flowing through it), one will be named **ground** (sometimes abbreviated to **GND** or indicated with a ground symbol:  $\equiv$ ). If the current flows out of the ammeter's ground terminal after flowing in the other terminal, the ammeter identifies the current as positive. If the current flows into the ground terminal and out of the other terminal, the ammeter identifies the current as negative. That is how you can tell which direction the current is flowing.

## 0.7 Voltmeters

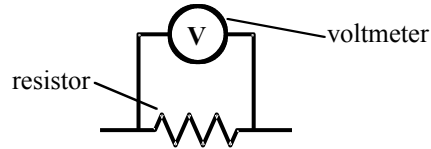
0.7.1 In a circuit with resistors and batteries, an electron in the wire sees some places as higher than others – and harder to get to – while an electron will see other places as lower than others – and getting to those low places is easy, like rolling down a hill. However, there is no way a human can look at a circuit and immediately see which points in the circuit look high and which points in the circuit look low from an electron's perspective. Those high and low places (to an electron) are there even if the circuit is completely flat on the table.

0.7.2 One thing is usually easy for a human to see. To electrons, batteries and power supplies look like escalators, moving electrons uphill, from the low places to the high places. You can look at a battery and see which terminal is + and which is -. To an electron, the + terminal is low (because negative electrons are attracted to positive) and the - terminal is high. Since batteries pull electrons in at the + terminal (the low end) and push them out the - terminal (the high end), batteries act like electron escalators.

0.7.3 Elsewhere in circuits, which places are high and which places are low is not immediately obvious to human eyes. That is why humans use voltmeters. To use a voltmeter, you touch its two terminals to two different points in a circuit. The voltmeter compares the two points, determines which is high and which is low, and tells you what

the height difference is in *volts*, that being the measure of height that the electrons respond to. (Height in volts has to do with electric forces and has nothing to do with height in meters from which things fall due to the gravity force. Different forces have different measures of height, but it is the same idea in both cases.)

0.7.4 Using a voltmeter to measure the voltage difference between different parts of a circuit requires you to touch the two voltmeter terminals to the two different parts of the circuit. Figure 4 shows how a voltage measurement looks in a circuit diagram.



**Figure 4** Using a voltmeter to determine the voltage ("height") difference between two ends of a resistor

0.7.5 The voltmeter reads out the difference in height between the two points it touches in volts. If the voltage is positive, the ground terminal of the voltmeter touches the circuit point that is – from an electron's point of view – higher than the other point. If the voltage is negative, the ground terminal touches the high point. This is confusing because it means a circuit point with a positive voltage is *lower* than the comparison point. The confusion is due to the fact that everyone talks about electricity as if it were a flow of positive particles moving from + to –, in spite of the fact that it really is a flow of negative particles moving from – to +.

**0.7.6 To make it less confusing, pretend – along with everyone else – that electricity is a flow of positive particles. Then a positive voltage reading means the ground terminal of the voltmeter is touching the lower point and the other terminal is touching the higher point, from the positive particle's point of view. Conversely, a negative voltage means it is the ground terminal that is touching the high point.**

## 0.8 DC and AC

0.8.1 Electric current that always flows in one direction is called *DC*, for *direct current*. Current that keeps changing directions is called *AC*, for *alternating current*. Ammeters and voltmeters can measure current and voltage for both kinds of current, but you have to tell the meter which kind of current it is measuring before you do the measurement.

0.8.2 On the big rotary switch that determines what the meter will measure, you will see either A–, A~, V–, V~ or  $\overline{A}$ ,  $\tilde{A}$ ,  $\overline{V}$ ,  $\tilde{V}$ . The symbols with wiggly lines indicate AC, and the symbols with straight lines indicate DC. Thus, either A~ or  $\tilde{A}$  might be used to indicate the AC ammeter function, and similarly either V– or  $\overline{V}$  might be used to indicate DC voltmeter function.

0.8.3 In this lab, all currents are DC, so you will never use the meters to measure AC current or voltage.

## 1. Activity #1: Instructor demonstrates circuit building for Activity #2

**Equipment:** Computer with MS Excel  
DC ammeter set for 2.0 or 3.0 amperes DC  
DC voltmeter set for 20 or 30 volts DC  
DC power supply (0 to at least 5 volts at 0.5 amperes)  
Unknown resistors *A*, *B*, and *C* mounted for banana plug connection  
See the picture of the three resistors mounted on a small box, below.  
Banana plug wires (each group gets their own from the common supply)

1.1 The instructor does the following as a demonstration.

1.1.1 Ignoring the voltmeter, build the main current loop in Figure 5 (power supply, resistor, ammeter).

1.1.2 Add the voltmeter.

1.1.3 Set the voltmeter scale to 20 V DC or 30 V DC, whichever the voltmeter has, and turn the meter on.

1.1.4 Set the ammeter scale to 2 A DC or 3 A DC, whichever the ammeter has, and turn the meter on.



1.2 After verifying that everyone understands building the circuit, the instructor disassembles the circuit and turns off the meters.

1.3 The Lab instructor mentions the importance of not exceeding 6 V from the power supply. This is so the resistors do not overheat.

## 2. Activity #2: Ohm's Law

*Abstract* An experimental demonstration of Ohm's Law

2.1 Verify that the power supply, the voltmeter, and the ammeter are turned off.

2.2 Obtain banana plug wires as needed from the rack mounted on the wall.

2.3 Using resistor *A* on the resistor board, construct the circuit shown in Figure 5. The following steps will help.

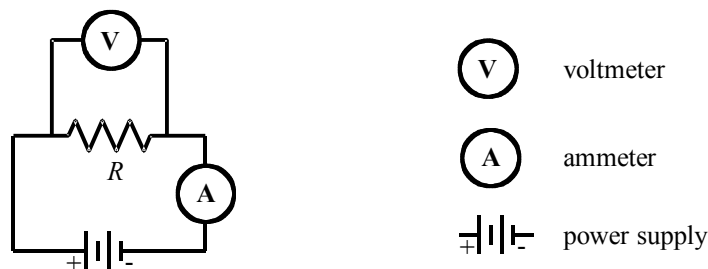


Figure 5 The circuit to build for Activity #2

2.3.1 Ignoring, for the moment, the voltmeter, connect the power supply, resistor, and ammeter in series, with the black lead from the ammeter connected to the – terminal

(which is black) of the power supply. When done, these three components and their connecting leads should form a closed loop. As a check, see if you can start with the + terminal of the power supply and trace a path around the loop that passes first through the resistor and then through the ammeter and back to the – terminal of the power supply.

**Datasheet for Ohm's Law Activities –**

<b>Activity #2</b>		Resistor A							
	I (amps) (x)	V (volts) (y)							
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
			Ω						
	Resistance of A (from linear fit)								
	Ω stands for "ohms," the unit of resistance								
<hr/>									
<b>Activity #3</b>									
<b>RA</b>		volts VA		amps IA					Ω RA (= VA/IA)
<b>RB</b>		volts VB		amps IB					Ω RB (= VB/IB)
<b>RC</b>		volts VC		amps IC					Ω RC (= VC/IC)
<hr/>									
<b>Activity #4</b>									
		volts VTOTAL (from meter)		volts V'A (from meter)					
		amps ITOTAL (from meter)		volts V'B (from meter)					
		Ω RTOTAL (= VTOTAL/ITOTAL)		volts V'C (from meter)					
		Ω RA+RB+RC (= RTOTAL?)		volts V'A+V'B+V'C (= VTOTAL?)					
		% discrepancy (total R's)		% discrepancy (total V's)					

2.3.2 Now connect the voltmeter leads, one lead to each end of the resistor, with the black lead from the voltmeter connected to the resistor at the same place as the red lead of the ammeter.

2.3.3 Set the voltmeter scale to 20 V DC or 30 V DC.

2.3.4 Set the ammeter scale to 2 A DC or 3 A DC.

2.3.5 Have your instructor check your circuit. S/he will initial here \_\_\_\_\_  
when the circuit is correct.

Instructor's Initials

2.4 Turn on the voltmeter and the ammeter.

2.5 Turn the voltage control knob of the power supply down to zero, and then turn on the power supply.

2.6 Turn the voltage up to about 0.5 volts, as displayed on the voltmeter. **Never read voltage or current from the meters on the power supply**, because those meters are only approximately correct. **Always use the voltmeter and the ammeter.**

2.7 If the voltmeter and the ammeter both show positive readings, they are connected properly. If not, turn the power off and reverse the connections to whichever meter is reading negative.

2.8 Record, in the datasheet on page 6 of this handout, values of current and voltage for values of voltage 0.5 V, 1.0 V, 1.5 V, ..., 5.0 V. The voltage values for which you record the measurements need not be exactly those in this list, but they should be near. Record the exact values given by the meters – not the nominal values from the list – in the datasheet.

**Do not  
exceed  
6 volts**

2.9 Make an MS Excel spreadsheet, and graph your data.

2.9.1 Refer to the **Activity #2** section of the sample MS Excel datasheet (on the previous page of this handout) to see what your spreadsheet should look like.

2.9.2  $I$  (current in amperes) is on the  $x$ -axis;  $V$  (voltage in volts) is on the  $y$ -axis

2.9.3 If any of the data do not fall on a straight line through the origin, re-do the measurement.

2.9.4 Add a straight line fit to the plot (Excel calls it a Trendline). On the **Options** tab:

- Check the box "Set intercept = 0."
- Check the box "Display equation on chart."

2.10 Edit the equation, replacing  $y$  by  $V$  (for voltage) and  $x$  by  $I$  (for current).

2.11 Print a copy of the spreadsheet and graph for everyone in your group.

2.12 Write the slope of the straight line fit in the box labeled "Resistance of  $A$  (from linear fit)" in the Datasheet where you recorded your current and voltage data.

***Q 1 Have you verified Ohm's Law for resistor  $A$ ? If you think you have, do you think it was a good, convincing verification?***

### 3. Activity #3: The resistance of three individual resistors

3.1 Without changing the circuit (so that resistor  $A$  is still connected to the power supply), set the power supply to some intermediate voltage (say, somewhere around 2 V or 3 V), enter the

voltage and current values into the appropriate place under Activity #3 in the Datasheet on page 6, and use a hand calculator to calculate the resistance of resistor  $A$ .

3.2 Repeat these measurements and the resistance calculation for resistors  $B$  and  $C$  on the resistance board.

3.3 The values you just obtained for the resistances of the three resistors will be used in Activity #4.

**4. Activity #4: Resistance and voltage in a series combination of resistances**

4.1 Turn off the power supply.

4.2 Construct the circuit in Figure 6.

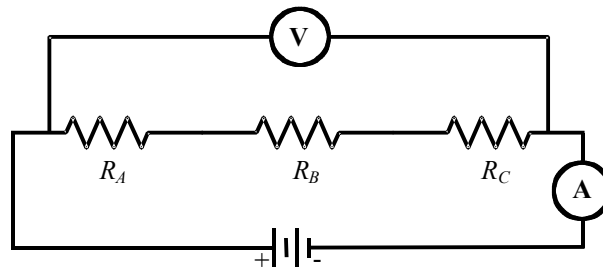


Figure 6 The circuit to build for Activity #4

4.3 Turn on the power supply, and set its voltage to about 5 V.

4.4 Record the actual voltage and current meter readings in the spaces for  $V_{TOTAL}$  and  $I_{TOTAL}$  in the appropriate part of the Datasheet for Activity #4.

4.5 Use a calculator to calculate  $R_{TOTAL}$ , and enter its value in the appropriate place in the Datasheet.

4.6 Leaving the power supply turned on at the same voltage as above, and without disconnecting the resistors or the ammeter, do the following.

4.6.1 Disconnect the voltmeter from the circuit.

4.6.2 Connect the voltmeter so that it reads the voltage across resistor  $A$ .

4.6.3 Record the voltage across  $A$  in the place for  $V'_A$  in the Datasheet for Activity #4.

4.6.4 Repeat the voltage measurement for resistors  $B$  and  $C$ , and record those values in the Datasheet as  $V'_B$  and  $V'_C$ .

4.7 Complete the remaining entries in the part of the Datasheet for Activity #4.

Percent discrepancies are calculated as follows.

$$\% \text{ discrepancy} = \frac{(\text{Value 1}) - (\text{Value 2})}{(\text{Average Value})} \times 100\% \quad \text{The result may be either positive or negative.}$$

where  $\text{Average Value} = \frac{1}{2} (\text{Value 1} + \text{Value 2})$ .

4.8 At this point, please return your banana plug wires to their rack. *Thanks!*



4.9 Assume you are given three resistors having resistances of  $15\ \Omega$ ,  $23\ \Omega$ , and  $42\ \Omega$ . The resistors are connected in series, and the series circuit is connected to a power supply. The current flowing through the circuit is  $I = 0.225\ \text{A}$ . Work with your lab partners to answer the following questions.

*Q 2 Draw the circuit. Have your lab instructor check your drawing.*

*Q 3 The current  $I$  flows through all three resistors. Use Ohm's Law,  $V = IR$ , to find the voltage across each resistor.*

*Q 4 What is the voltage of the power supply? Show your calculation.*

### 5. Activity #5: Electric circuits with the three-terminal black box

*Activity #5 is practice for Activity #6. Your instructor will help you if necessary with Activity #5, but when doing Activity #6 you are on your own.*

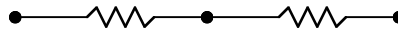
**Equipment:** DMM to measure resistance  
(Use the DMM's  $200\ \Omega$  or  $300\ \Omega$  scale)  
Three terminal black box (see picture)  
Paper  
Pencil or pen



5.1 Preliminary: Everybody does the following

- 5.1.1 Get out a pen or pencil and a sheet of notebook paper, to be used as scratch paper for this lab.
- 5.1.2 Have your lab instructor explain how to use the Digital MultiMeter (DMM, for short) to measure resistance and to check continuity.

5.2 Locate your three terminal box. See the diagram to the right. The three-terminal box has three terminals colored red, green, and blue. There is also an identification number written on the box.

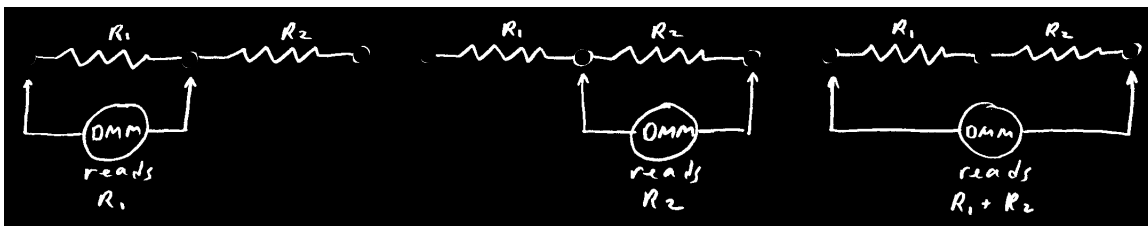


**Figure 7** The circuit inside the three-terminal black box. The problem is to determine the values of the resistors and the color to assign to each connection point (indicated above by a dot).

- 5.2.1 Inside the three-terminal box, two resistors are connected as shown in Figure 7.
- 5.2.2 The values of the two resistors are unknown, but they are all near even multiples of  $10\ \Omega$ .
- 5.2.3 The dots at the ends of the resistors represent the terminals on the box. Which dot is red is unknown. Similarly for the other terminals.

5.3 Your task is to deduce the values of the resistors and how they are connected to the terminals. Merely having the right answer is insufficient; *you must conclusively prove you are right.*

5.3.1 Your only tools are the DMM (to measure resistance) and the fact that if resistors with resistance  $R_1$  and  $R_2$  are connected in series, the series connection has a resistance of  $R_1 + R_2$  ohms. See Figure 8.



**Figure 8** The resistance of a series connection is the sum of the individual resistances

5.3.2 You are done when you can draw the circuit inside the box with the correct resistor values and with the terminals correctly labeled by their colors. Here is an example of what a complete answer would look like.



*This is what a typical complete answer looks like.*

5.3.3 You must make all possible measurements and verify that they agree with the circuit you think is in the box. Otherwise you have not conclusively proved your circuit is actually the one inside the box.

5.4 In the empty space below ...

5.4.1 Write the identification number of your four-terminal black box in the space provided.

5.4.2 Draw the circuit inside your three terminal box, identifying the terminals by their colors, red, green, blue, and labeling all resistors by their resistances, rounded to the nearest 10  $\Omega$ .

5.4.3 List all measurements you made and their results. *Example* red to green = 120  $\Omega$ .

	Box Number =
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### 6. Activity #6: Electric circuits with the four-terminal black box

*You and your lab partners are on your own while you do this activity.*

- Equipment:** Ohmmeter (200 or 300  $\Omega$  scale)  
*Optional* Continuity checker (beeps to indicate continuity)  
Four terminal black box with a break in the circuit (see picture)  
Paper  
Pencil or pen

6.1 Locate your four terminal box. See the diagram to the right.

6.1.1 The four-terminal box has four terminals colored red, green, blue, and black arranged in a square pattern.

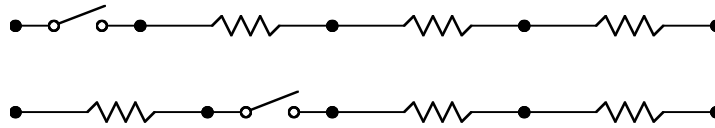
6.1.2 In addition, there are three terminals colored red, blue, and green in a straight line under a silver terminal.

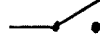
6.1.3 Inside the four-terminal box is one of the two circuits in Figure 9.

6.1.4 The break in the circuit (see the caption to Figure 9) can be fixed by connecting the silver terminal to one of the bottom three red, blue, or green terminals (under the silver terminal). Only one of the three possible connections will actually fix the break.



6.1.5 Once the break in the circuit is fixed, the box is just like the box of *Activity #5* but with three resistors in series instead of two resistors in series.





**Figure 9** Inside the four-terminal black box is one of these two circuits. The switch symbol, , represents a break in the circuit, through which electric current cannot flow.

6.2 Your task is to determine (1) which of the three colored terminals under the silver terminal must be connected to the silver terminal to fix the break in the circuit, (2) the values of the resistors, (3) how the resistors are connected to the terminals, and (4) where in the circuit the break is located. Merely having the right answer is insufficient; *you must conclusively prove you are right*.

6.3 Your tools are the following.

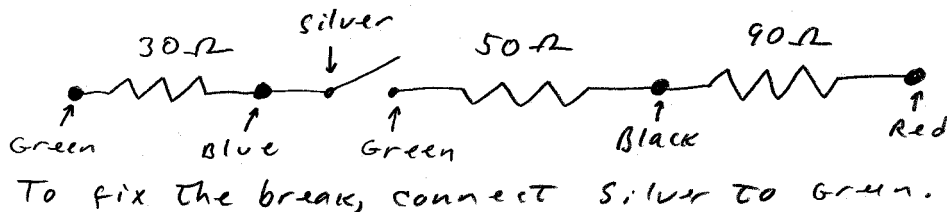
6.3.1 A DMM, optionally with an audible continuity check, so that the DMM beeps when current can flow through the circuit

6.3.2 A banana plug wire, to connect from one of the bottom three colored terminals to the silver terminal, in order to fix the break

6.3.3 The facts that a broken circuit () blocks the flow of current and prevents the DMM continuity checker from beeping, but an unbroken circuit () permits the flow of current and causes the DMM continuity checker to beep.

6.3.4 The fact that if resistors with resistance  $R_1$  and  $R_2$  are connected in series, the series connection has a resistance of  $R_1 + R_2$  ohms (recall Figure 8 in *Activity #5*).

6.4 You are done when you can fix the break in the circuit and when you can draw the circuit inside the box showing where the break in the circuit is, with resistors correctly labeled with their resistance values and with the box terminals correctly labeled. Here is an example of what a complete answer would look like.



*This is what a typical complete answer looks like.*

6.5 Rather than trying to determine the entire box circuit right from the beginning, break the task into the following sub-tasks, and do each in the order given here.

6.5.1 Determine how to fix the break in the circuit. You can do this using only the DMM's audible continuity checker (if it has one – otherwise just check resistances).

6.5.2 After the break is fixed, determine the arrangement and value of each of the three resistors and the colors of the terminals connected to each resistor. This is like *Activity #5*.

6.5.3 Determine the location of the switch in the circuit.

*For full credit you must have both the correct circuit and also a complete proof — based on measurements — that the circuit is correct. A correct circuit which is not conclusively proved to be correct does not get full credit.*

6.6 In the empty space below ...

6.6.1 Write the identification number of your four-terminal black box in the space provided.

6.6.2 Draw the circuit inside your four terminal box, showing the break in the circuit, identifying all terminals by their colors; labeling all resistors by their resistances, rounded to the nearest  $10 \Omega$ ; and showing the color that the silver terminal connects to in order to fix the break in the circuit.

6.6.3 List all measurements you made and their results. The first example below is from fixing the break in the circuit. The second example is from determining the resistors and the way they are connected in the circuit.

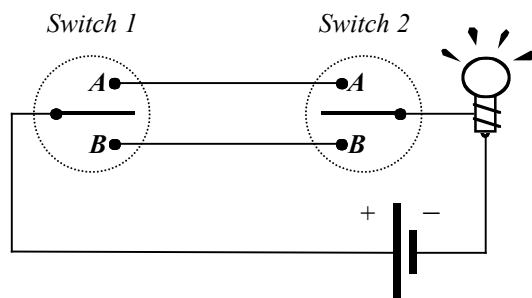
*Example* Connect silver to red: DMM says green and black are unconnected  
*Example* Measured resistance of black to blue: DMM says  $90 \Omega$

	Box Number =
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### 7. Activity #7: Questions

The questions in this activity can be answered by using the fact that electric current will flow only when there is an unbroken conductive loop for it to follow.

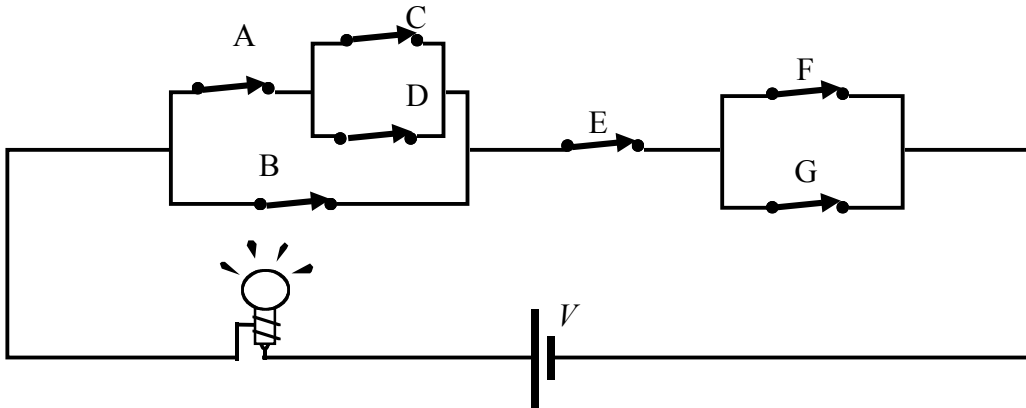
7.1 The drawing to the right shows a circuit in which a light bulb is connected to the household AC voltage via two switches *Switch 1* and *Switch 2*. The horizontal bar inside each switch can be swung either upward, to touch terminal *A*, or downward, to touch terminal *B*.



**Q 5** When Switch 1 is touching terminal A, which position of Switch 2, A or B, turns the light on?

**Q 6** When Switch 1 is touching terminal B, which position of Switch 2, A or B, turns the light on?

7.2 The figure below shows an electric circuit in which a light bulb is connected to a voltage source  $V$  through a network of switches. The switches are labeled A, B, C, D, E, F, and G. For the bulb to light up, electric current must flow in one of the wires connected to the bulb and out the other wire. The circuit is shown with all switches closed and the light bulb shining brightly.



**Q 7** Which switches, if opened while leaving all other switches closed, will immediately make the light go off?

***Q 8 Which pairs of switches, if opened together while leaving all other switches closed, will make the light go off?***

***Q 9 What is the largest number of switches which can be opened while still leaving the bulb turned on, and which switches are these?***

**8. When you are finished ...**

8.1 Make sure

8.1.1 The Datasheet on page 6 is completely filled in.

8.1.2 All questions are answered.

8.1.3 All banana plug wires have been put away.

8.2 Attach the following to this handout:

8.2.1 The spreadsheet and graph from Activity #2 (printed in paragraph 2.11)

8.3 Hand them in.

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## Pre-Lab Questions

**Print Your Name**

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Read the *Introduction* to this handout, and answer the following questions before you come to General Physics Lab. Write your answers directly on this page. When you enter the lab, tear off this page and hand it in.

1. What is the definition of electric current?
2. If something that obeys Ohm's Law allows a current of 2.4 amperes to pass through it when a voltage of 52 volts is applied to it, what is its resistance? Show your calculation, and append the correct units to your answer.
3. How, in a circuit diagram, does one indicate wires and things that have no resistance?
4. How, in a circuit diagram, does one indicate something that has resistance to the flow of electricity.
5. How does current always flow?
6. A  $5\ \Omega$  resistor and a  $12\ \Omega$  resistor are connected in series. Draw the circuit.
7. What is the total resistance of the  $5\ \Omega$  and  $12\ \Omega$  resistors when they are connected in series?
8. What is the largest power supply voltage you can use with resistors *A*, *B*, and *C*? (See paragraph 2.8 on page 7.)

*Continued on the next page ...*

9. In all the circuits in this lab handout, the ammeter is connected to be part of the closed loop around which current flows. Why? [See section 0.6.]

10. In all the circuits in this lab handout, the voltmeter is never part of the closed loop around which current flows. Instead, the voltmeter is always connected to the two ends of something else (usually a resistor) that *is* part of the closed loop. Why? [See section 0.7.]

11. Write the symbols found on meters that indicate AC and DC current and voltage.

12. Resistors have a resistance but light bulbs do not. What is the difference between a resistor and a light bulb that makes it impossible to assign a resistance to a light bulb?