

## Series & Parallel Circuits

By

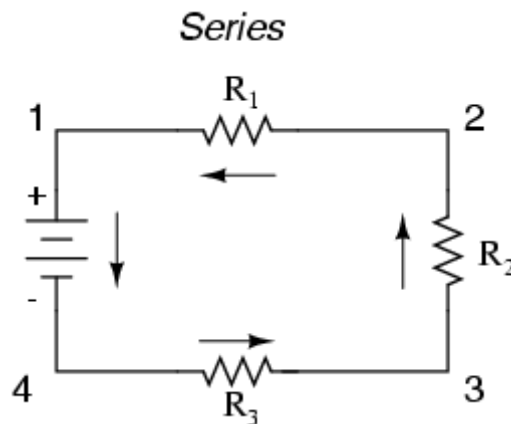
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### Introduction

Every student of physics needs at least a basic understanding of electronic circuits. One of the most important aspects of electronic circuits is the arrangement of circuit elements. In this lab, the circuit element that we will concentrate on is a resistor. There are two types of circuit connections that are involved with this lab, series and parallel.

### Background

We say that circuit elements are in series with each other when each element is connected the next end-to-end. In other words, a series connection allows only one pathway for the current to travel. Current, as you know, is the flow rate of electrons. Below is a picture of a circuit that has three resistors connected in series:



Now let's use what we know about electricity to develop mathematical properties of a series circuit. First, there is only one pathway for the current to travel, and we know that no charge will accumulate on the resistors. This implies that the current through each resistor is of

the same value. Using this property, and applying Ohm's law to each resistor, we come up with the following equations for the above circuit diagram:

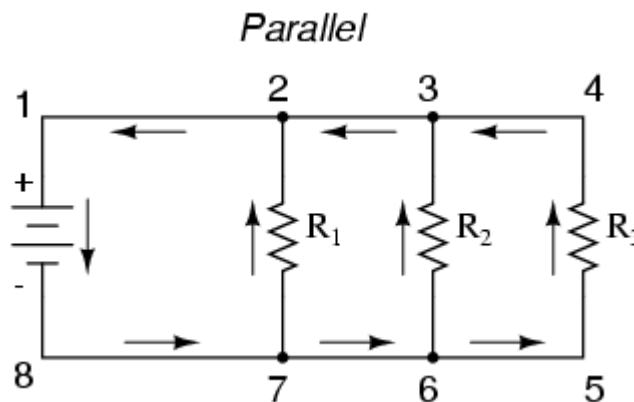
$$V_{total} = V_1 + V_2 + V_3$$

$$I_1 = I_2 = I_3$$

$$R_{total} = R_1 + R_2 + R_3$$

It is important to understand the quantity  $R_{total}$ . This quantity is commonly called the equivalent resistance. Let's say you wanted to reduce the number of resistors in the circuit from three resistors to only one resistor. You would need a resistor whose value is equal to the equivalent resistance ( $R_{total}$ ).

Electrical circuits may be connected in parallel as well as series. In this configuration, there are multiple paths for current to travel, and therefore there are different mathematical properties. We will start with a picture of a parallel configuration as shown below:



Can you see why this circuit is called parallel? If you said because the circuit elements (in this case the circuit elements are resistors) are connected parallel to each other, you are correct. Unlike a series circuit, a parallel circuit allows current to travel in more than one path. You can think of a parallel circuit as a “current-splitter”. Again, we would like to derive some mathematical formulas to represent the total voltage, current and resistance of the circuit. Just by looking at the parallel configuration, can you say something about the voltage drop across each resistor? If you said that they are the same in each element, then you are correct. Let us use this knowledge and Ohm's law to derive some mathematical laws for parallel circuits:

$$V_1 = V_2 = V_3 = V$$

$$I_{total} = I_1 + I_2 + I_3$$

$$I_{total} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = V \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)$$

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

How is all this useful? Let's start to answer this by considering the light bulb experiment of last week. What would happen if instead of one bulb, we used two connected in series? What if they were connected in parallel? Today we'll find out those answers along with others as we examine light bulbs in parallel and series circuits.

## Experimental Procedure

\*For these activities, our switch will simply be the connection of two alligator clips.

On a separate piece of paper, write down EVERY prediction, recorded value, and conclusion made in this lab. It is this separate piece of paper that will be collected at the end of lab. Be sure to label what step is being answered on your paper.

### Part 1. Series Circuit

1. Connect 4 bulbs in sockets in series with a switch, an ammeter, and battery. Place the ammeter between the switch and the two-cell battery. Connect the negative terminal of the ammeter to the negative terminal of the battery.
2. Close the switch. Read and record the amount of current. Open the switch.
3. Reconnect the ammeter between two of the bulbs. Close the switch. Read and record the amount of current. Open the switch.
4. Reconnect the ammeter as in step one.
5. Connect a voltmeter across one of the bulbs. Be sure that the negative terminal of the voltmeter is connected toward the negative terminal of the battery.
6. Close the switch. Read and record the voltage drop. Open the switch.
7. Repeat steps 5 and 6 with the voltmeter connected across two bulbs.

8. Predict what will happen to the voltage drop if the voltmeter is connected across all three bulbs. Repeat steps 5 and 6 with the voltmeter connected across all three bulbs.
9. Remove one of the bulbs from its socket without disconnecting the socket. Remove the voltmeter. Close the switch. Record the ammeter reading. Open the switch.
10. Reconnect the circuit, so that, there are only two bulbs, and sockets in series with the ammeter, switch, and battery. Record the current value and voltage (IR) drop across the circuit. Open the switch.

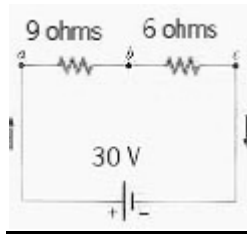
Students, this concludes our first activity. Now, let's discuss what took place.

**Part2.** *Parallel Circuits*

1. Connect 4 flashlight bulbs in parallel sockets.
2. Connect battery, a switch, and an ammeter in series. Place this in series with the 4 sockets. Be sure, that the negative terminal of the ammeter is toward the negative terminal of the battery.
3. Close the switch. Read and record the current value. Notice how bright the bulbs are. Open the switch.
4. Without disconnecting the socket, remove one bulb. Close the switch. Record the current value. Compare the brightness of the remaining bulbs to their brightness before. Open the switch. Replace the bulb.
5. Reconnect the ammeter in series with one of the bulbs. Predict how the current will compare to the previous reading.
6. Test your prediction by closing the switch. Record the current and open the switch.
7. Remove a bulb in a different branch from the ammeter. Close the switch. Read and record the current value. Open the switch.
8. Connect a voltmeter across one socket. Close the switch. Read the meter, and record the voltage. Open the switch. Repeat for each of the other sockets.

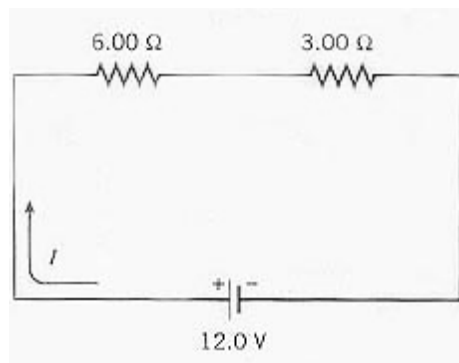
## Analysis

1a.



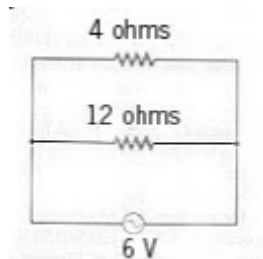
Calculate the current ( $i$ ) of the circuit. What's the equivalent resistance of the circuit?

1b.



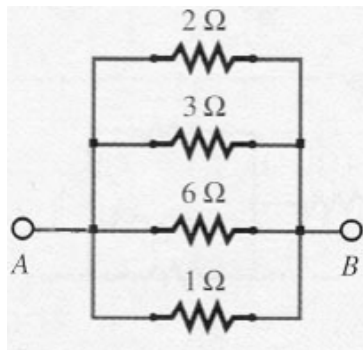
What's the current here? What's the equivalent resistance of the circuit?

2a.



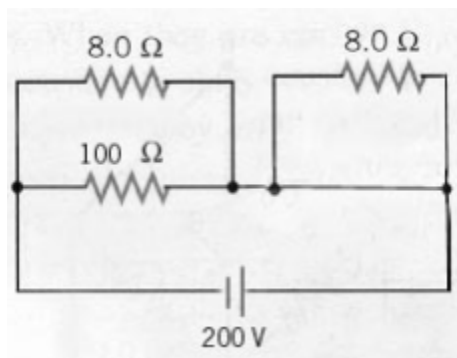
Calculate the current ( $i$ ) of the circuit. What's the equivalent resistance of the circuit?

2b.



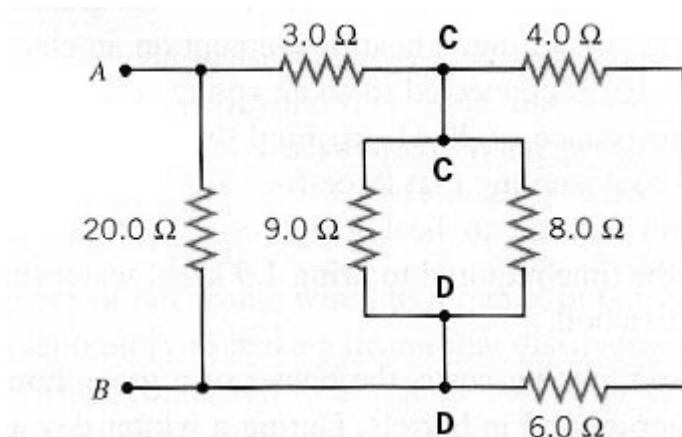
What's the equivalent resistance between A and B?

3.



What is the current through the 100ohm resistor?  
 What is the equivalent resistance of the parallel section?  
 What is the total current in the circuit?

4.



What is the total resistance between Points A and B?