

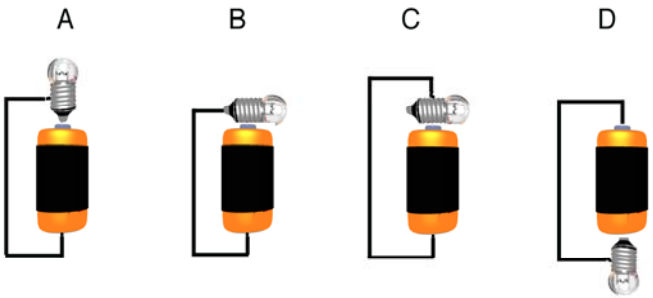
Electric Circuits
Series Circuits

CONCEPT EXPLORATION

In order to get a light bulb to "light up", there must be electrons that flow through the filament of the light bulb. This requires an electric current produced by a complete circuit that creates the flow of electrons through the filament of the light bulb.

Engagement Question

1. Which of the following circuit arrangements would <u>not</u> light up the light bulb? Explain why this arrangement would not light up the light bulb.



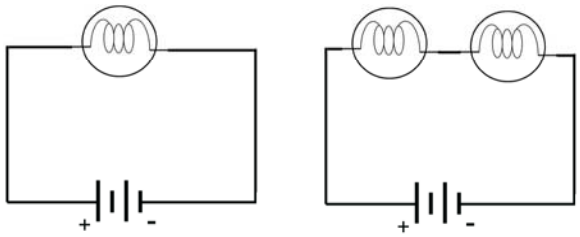
In the last lesson you learned about a simple circuit that consisted of a single light bulb, a battery, and the connections between them. In this lesson you will learn about more complex circuits that have two light bulbs in a "series" arrangement.

The Challenge

You will experiment with a simple series circuit. You should be able to tell how the current behaves as it passes through each light bulb in these simple circuits.

Your Ideas about the Challenge

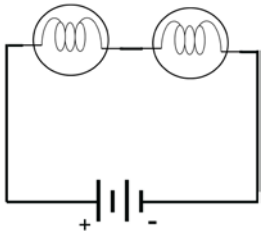
2. How do you think the brightness of each of the bulbs in the second circuit will compare to the brightness of the bulb in the single-bulb circuit seen below? Will all of the bulbs be just as bright or will one or more of the bulbs be brighter than the others. Explain your answer. Assume that identical batteries and light bulbs are used in each circuit.



At each lab station you will find the following:
two light bulbs with bases, a battery, and three wires

The Investigation

a. Using the materials provided, construct the circuit that you see pictured below. Each of the bulbs should light up if you have done this correctly.



b. After you have succeeded in getting both light bulbs to light up, unscrew and remove one of the bulbs in this circuit. Take note of what happens when you do this in question 3.
c. Replace the bulb you removed in part "b" and then unscrew and remove the other bulb. Take note of what happens when you do this in question 4.

3. Describe what happened when you removed the first bulb in your circuit.

4. Describe what happened when you removed the second bulb from your circuit. How did this compare to what happened when you removed the first bulb in your circuit?

5. Based on your observations how do you think the current through each of these bulbs compares? Does one bulb get more current than the other bulb or do they each get the same current?

6. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

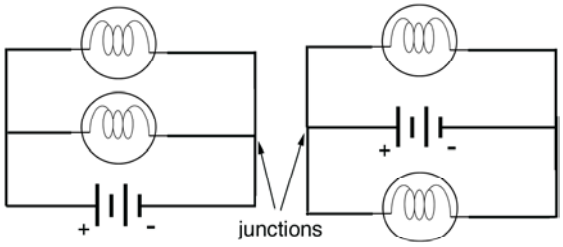
"I think that each of these bulbs split up the current that is running through the wire. The second bulb in the circuit gets the current that is left over from the first bulb in the circuit."

Student B

"I think that each of the two bulbs gets the exact same current. When we removed a bulb from the circuit the other bulb went out. The current that flows through the circuit has only one path to follow and this path goes through both bulbs."

Check your work with your teacher ☐

The circuit that you have constructed is a **series** circuit. There are no junctions between circuit elements that are wired in series. A **junction** is a point in a circuit where the current would divide. Examples of junctions in circuits are seen below.

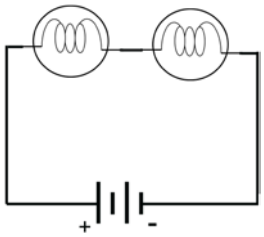


7. There is another junction in each of the two circuits shown in the preceding diagram. Label each of these in that diagram.

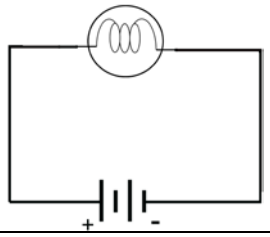
The circuits with the junctions that you see in the preceding diagram are called **parallel** circuits. Circuit elements (such as light bulbs) will have a junction between them if they are in parallel with one another. You will study parallel circuits in the next lesson.

The Investigation (continued)

a. Using the materials provided construct the circuit that you see pictured below. Each of the bulbs should light up if you have done this correctly.



b. After you have succeeded in getting both light bulbs to light up once again, remove one wire and one light bulb from the circuit so that you have a single lit light bulb wired in series with your battery.



8. How did the brightness of each of the bulbs in the series circuit compare to the brightness of the bulb in the single-bulb circuit? Were they as bright, brighter, or not as bright as the bulb in the single-bulb circuit?

9. Based on your observations do you think that the bulbs in the series circuit had more or less electrical current than the bulb in the single-bulb circuit? Explain your answer.

10. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

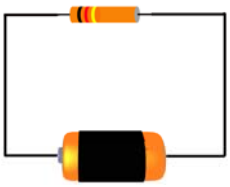
"Since each of the bulbs in the series circuit were dimmer than the bulb in the single-bulb circuit, I think that they didn't get as much current as the bulb in the single-bulb circuit."

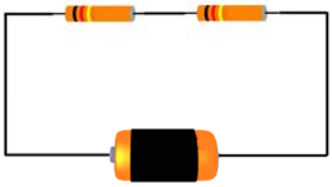
Student B

"I think that the current in the series circuit was about half what it was in the single-bulb circuit. This must be because it is twice as hard to push electrons through two bulbs than it is to push them through one."

Check your work with your teacher ☐

The circuit diagrams shown below represent a single battery that is connected to a single resistor () and a single battery connected to two resistors in series. All of the resistors have the same resistance.





A simple **resistor** is an electronic device that opposes the flow of current in a circuit. They have a fixed resistance value.

11. Which of the two circuits shown above do you think would have the most overall resistance? Explain your answer.

12. How do you think that you could calculate the "total" resistance of the circuit that has the two resistors in series?

13. Evaluate the following student statement about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

"I think that you would have to add the resistance values of the two resistors together in order to determine the total resistance of the circuit. When you have one resistor connected to another resistor, in series, they're both going to oppose the flow of current in the circuit and this would increase the overall resistance in the circuit."

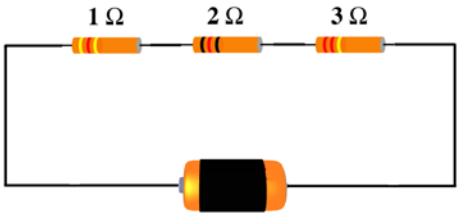
To determine the total resistance of resistors that are connected in series, you add the resistance value of each of the resistors together.

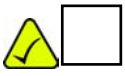


For example, to find the total resistance of 4 resistors connected in series you would add all four of their individual resistance values together.

$$R_{total} = R_1 + R_2 + R_3 + R_4$$

14. What is the total resistance of the circuit that you see pictured below?

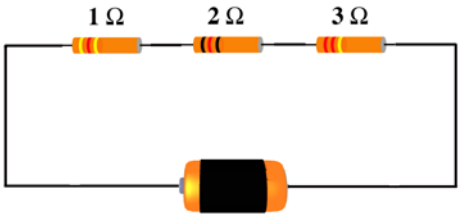


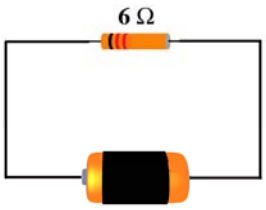
Check your work with your teacher 

CONCEPT DEVELOPMENT

To find the total resistance of any number of resistors in series you just simply add the resistance values of each of the individual resistors together.

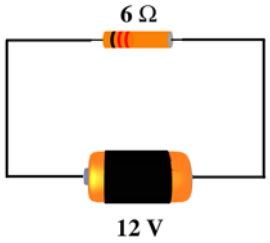
For example: the three-resistor circuit seen below on the left has the same amount of resistance as the single-resistor circuit seen below on the right.





If you knew that there was a 12-V battery being used in the original circuit you could calculate what the current was in each of these circuits. Since each of the three resistors gets the same current and together they act like a single 6-Ω resistor, you could use Ohm's law to determine the current that they receive.

Engagement Question



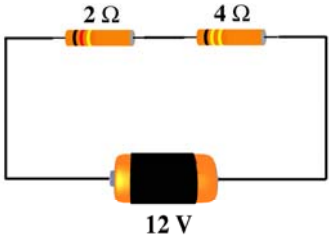
1. What would be the current in the circuit seen above? Be sure to use appropriate units and to label your answer appropriately.

The Challenge

You will experiment with a simple series circuit. You will measure the voltage of the voltage supply as well as the voltage that is dropped across each resistor. From this data you should be able to determine the relationship between the voltage that is available from the voltage supply and the voltage that each resistor in a series circuit receives.

Your Ideas about the Challenge

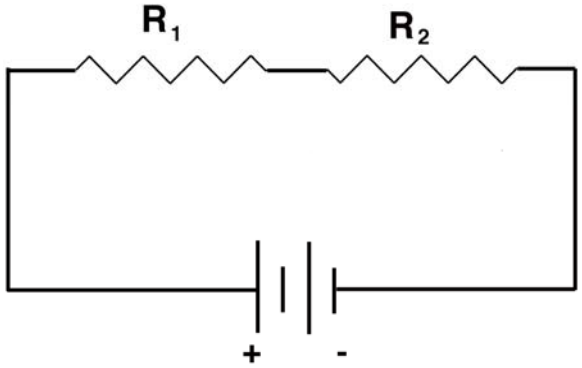
2. How much voltage do you think each of the two resistors, seen in the diagram below, receive? Do they both get 12 volts or do they split up the 12 volts somehow?



At each lab station you will find the following:
two resistors, a voltage supply, a voltmeter, and three wires

The Investigation

a. Using the materials provided construct the circuit that you see pictured below.



b. Measure the voltage (be sure to take positive readings) across the voltage supply and each of the resistors. Record these measurements in the data table that you see below.

Data Table

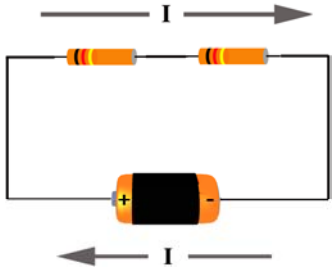
Voltage Supply voltage measurement (V)	First Resistor voltage measurement (V)	Second Resistor voltage measurement (V)

3. Is there a relationship between the voltage that you measured across the voltage supply and the voltages that you measured across each of the resistors? If so, describe this relationship.

The mathematical technique that you use to determine the total resistance of resistors in series can be used to show a relationship between the voltage supplied by a voltage supply and the voltage that is used by each of the resistors in a series circuit.

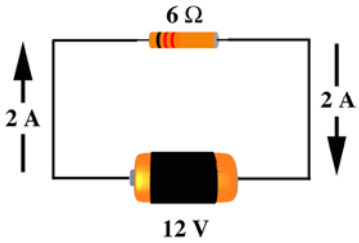
To determine the total resistance of two resistors connected in series you add their resistances together.	$R_{total} = R_1 + R_2$
Solving Ohm's law for resistance gives you the following expression.	$R = \frac{V}{I}$
By substituting each of the voltage/current ratios for each of the corresponding resistances seen in the total resistance expression, you get the equation that you see to the right.	$\frac{V_{total}}{I_{total}} = \frac{V_1}{I_1} + \frac{V_2}{I_2}$
The total current (I_{total}) is equal to the current that goes through each resistor (I_1 and I_2).	$I_{total} = I_1 = I_2$
Multiplying through by the equal currents gives the following relationship between the voltages across the battery (V_{total}) and the voltage across the two resistors ($V_1 + V_2$).	$V_{total} = V_1 + V_2$

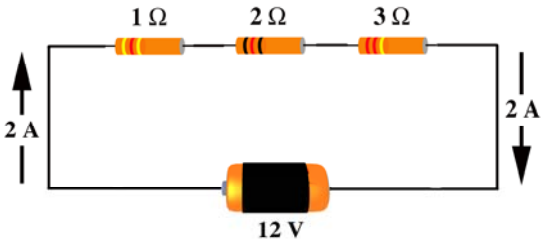
The last mathematical equation can be summarized in what is known as Kirchoff's loop rule. Gustav Kirchoff was a 19th century scientist who stated that the sum of the voltages around any closed loop in a circuit is zero.



The current, in the circuit seen above, goes around the circuit loop in the clockwise direction. As you pass through the battery, in this circuit loop, the voltage increases. The voltage in the battery would be the total voltage available (V_{total}). As the current passes through each of the resistors it loses (drops) voltage. The voltage increase, from the battery, is equal to the sum of the voltage drops across the resistors ($V_{total} = V_1 + V_2$). Therefore the sum of the voltages as you complete a loop around this circuit is equal to zero.

We determined that the total current in each of the circuits seen below (see question 1) was 2 A.





Each of the three resistors gets 2 A of current. You can use this information along with Ohm's law to determine the voltage drop across each of the resistors seen above in the diagram on the right.

4. Calculate the voltage drop across each of the three resistors. Be sure to use appropriate units and to label your answer appropriately.

Resistance (Ω)	Current (A)	Voltage (V)
1 Ω	2 A	
2 Ω	2 A	
3 Ω	2 A	

5. What is the sum of the voltage drops across the three resistors?

6. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"The biggest resistor dropped the most voltage and the smallest resistor dropped the least. I think that the greater the resistance of a resistor, the more energy the resistor will use."

Student B

"The sum of the voltages for the three resistors was equal to the voltage supplied by the battery. The resistors must somehow double the available voltage in a circuit since they match the voltage of the battery."

Check your work with your teacher ☐

CONCEPT REFINEMENT

Review

Resistors that are in series get the same current.
Resistors in series "split up" the voltage that is available in a circuit. In other words the sum of the voltages dropped across two resistors in series is equal to the total voltage that is available to them.

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

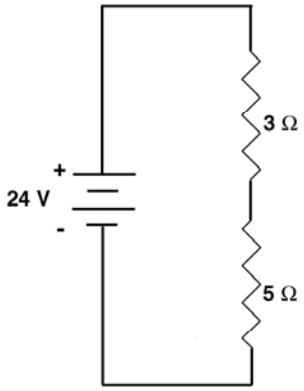
To calculate the total resistance of two (or more) resistors in series you just add the resistances together.

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

The circuit seen below consists of a 24-V voltage supply connected in series to a 3-Ω resistor and a 5-Ω resistor.

1. Calculate the total resistance of this circuit. Be sure to use appropriate units.

2. Calculate the amount of current that flows through this circuit. Be sure to use appropriate units.



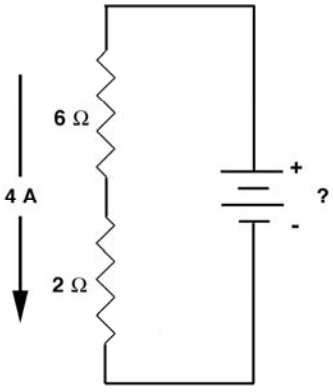
3. Calculate the voltage drop across the 3-Ω resistor.

4. Calculate the voltage drop across the 5- Ω resistor.

The circuit seen below has a current of 4 Amperes flowing through a 6-Ω resistor in series with a 2- Ω resistor.

5. Calculate the voltage drop across the 6-Ω resistor.

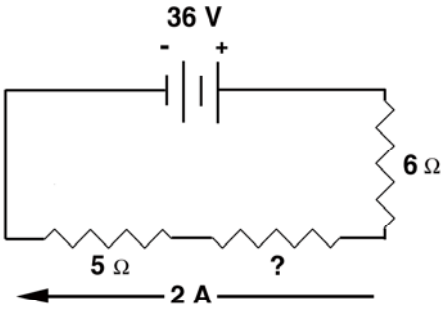
6. Calculate the voltage drop across the 2-Ω resistor.



7. What must be the voltage of the battery in this circuit?

The circuit seen below has 2 Amperes of current flowing through three resistors in series. One of the known resistors is a 5-Ω resistor and the other is a 6- Ω resistor. There is a 36 Volt voltage supply in this circuit.

8. Calculate the total resistance of this circuit.



9. Calculate the resistance of the unknown resistor.