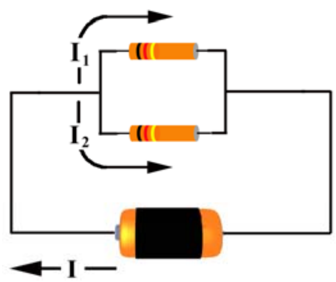
Electric Circuits
Parallel Circuits

CONCEPT EXPLORATION

In the last lesson you learned about a simple circuit that consisted of two light bulbs, a battery, and the connections between them. These were series circuits. Circuit components that are in series receive the same current.

In this lesson you will learn about parallel circuits. Circuit components that are in parallel, have a junction in the circuit between them. This junction causes the current to split. Parallel circuit components usually don't have the same current.

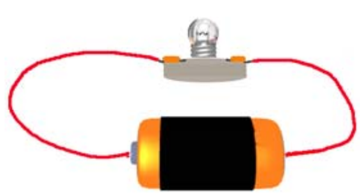
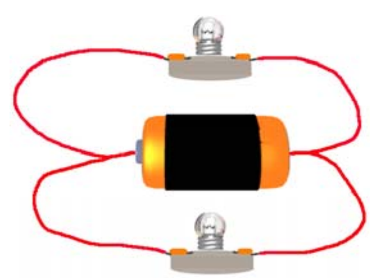
Engagement Question
The resistors seen in the circuit below are in parallel. Take note of the junction that appears between the two resistors. This is where the current "I" splits into "I_1" and I_2".



1. Assuming that the two resistors have equal resistance, describe what you think would happen to the current in the circuit when it reaches the junction in this circuit.

The Challenge
You will experiment with a simple parallel circuit. You should be able to tell how the current behaves as it passes through the junction between each light bulb in these simple circuits. You should also know how the voltage is distributed between circuit components in a parallel circuit.

Your Ideas about the Challenge
Parallel circuits can be arranged in a number of different ways. In every situation there must be a junction (a place where the current splits) between the parallel-circuit components. Shown below is one such arrangement (on the right). The diagram on the left represents a single-bulb circuit.
Assume that each of the lights bulbs, shown in the diagrams below, have equal resistance. Also assume that the batteries have equal voltage.

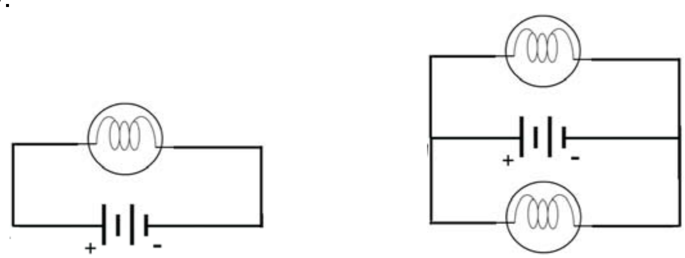
2. How do you think that the brightness of the two bulbs, in the parallel circuit, would compare to each other?

3. How do you think that the brightness of the two bulbs, in the parallel circuit, would compare to the brightness of the single bulb in the single-bulb circuit?

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

The Investigation

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



4. How does the brightness of the two bulbs in the parallel circuit compare? Is one bulb brighter than the other?

5. Do the bulbs in the parallel circuit appear to get the same voltage or do they get different voltage? Explain how you know.

6. How does the brightness of the two bulbs in the parallel circuit compare to the brightness of the single bulb in the single-bulb circuit? Is one bulb significantly brighter than the others?

7. Do the two bulbs in the parallel circuit appear to get the same voltage <u>and</u> current as the single bulb in the single-bulb circuit? Explain how you know.

8. 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.

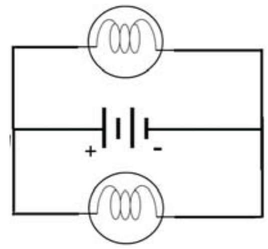
<u>Student A</u>
"Since each of the bulbs in the parallel circuit were just as bright as the bulb in the single-bulb circuit, I think that each of these bulbs gets the same amount of current and the same amount of voltage as the bulb in the single-bulb circuit."

<u>Student B</u>
"That's crazy, the current and the voltage has to split as it enters the junction between the two bulbs in the parallel circuit. The parallel bulbs must have been getting half the voltage and half the current as the single bulb."

Check your work with your teacher ☐

The Investigation (continued)

a. Disassemble the single-bulb circuit.



b. With both bulbs lit in the parallel circuit, unscrew and remove one of the bulbs. Take note of what happens when you do this in question 9.

c. Replace the bulb you removed in part "b" and then unscrew and remove the other bulb. Also take note of what happens when you do this in question 9.

9. Did the brightness of the other bulb in the circuit change much when you removed either of the bulbs?

10. Based on your observations, do you think that each of the bulbs in the parallel circuit get the same current or do they each get there own separate current? Explain your answer.

11. 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.

<u>Student A</u>

"Since each of the bulbs in the parallel circuit remained lit when you removed the other bulb, they must be getting their own separate current."

<u>Student B</u>

"If you apply Kirchoff's "loop" rule to the parallel circuit you will see that there are two separate loops. The battery is connected to just one of the light bulbs in each loop. That would mean that each of the light bulbs would be getting the full voltage from the battery."

Check your work with your teacher

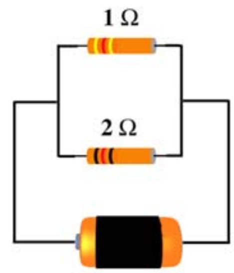
Electric Circuits
Parallel Circuits

CONCEPT DEVELOPMENT

Circuit components that are in parallel get the same amount of voltage.

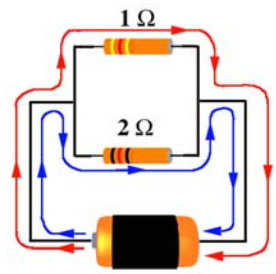
You can use Kirchoff's loop rule to show how this works.

The circuit diagram, shown to the right, represents a 1-Ω resistor in parallel with a 2- Ω resistor. They are both connected to the same battery.

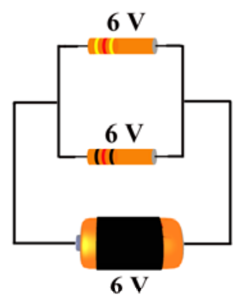


There are two complete-loop paths that can be traced around this circuit, that pass through the battery.

The total voltage, that is available from the battery in this circuit, is used by each of the resistors in this circuit.

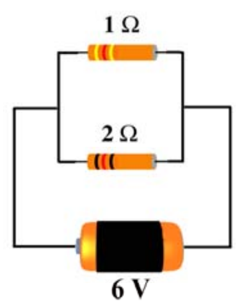


If the battery has 6 Volts, then all 6 Volts would be available to each of the resistors in this circuit no matter what the resistance value is for each of the resistors.



Engagement Question

1. Calculate the current that would pass through each of the resistors shown in the circuit to the right.

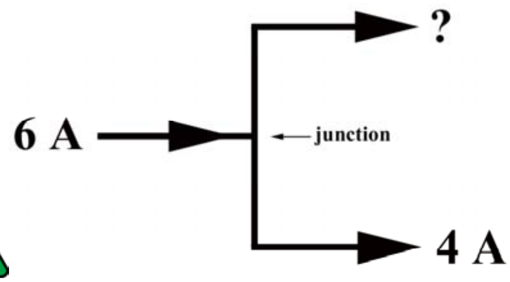


The Challenge

You will measure the current in different segments of a parallel circuit in order to show how the current behaves when it enters and leaves a junction in a circuit.

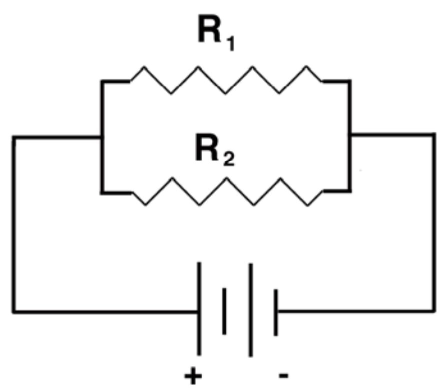
Your Ideas about the Challenge
The diagram shown below represents 6 Amps of current flowing into a junction.

2. If 4 A of current flows into the bottom segment of this circuit section, how many amps do you think flow into the top segment?

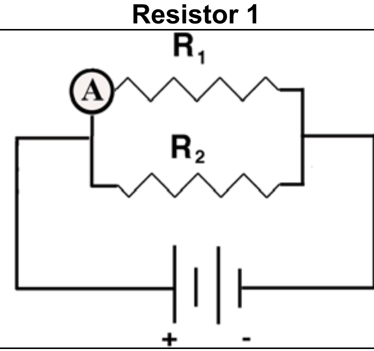
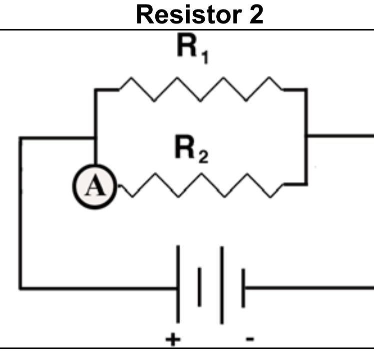


At each lab station you will find the following:
two resistors, a voltage supply, an ammeter with two probes, and four wires

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



b. Measure the current in this circuit (be sure to take positive readings), at each location indicated by the diagrams shown below. Record these measurements in the data table that follows.

Battery	Resistor 1	Resistor 2
		

Data

Measurement Location	Battery	Resistor 1	Resistor 2
Current Measurement (A)			

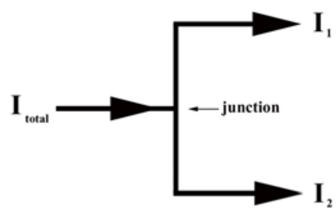
3. Do you see a relationship between the current that flows through the battery and the currents that flow through the two resistors? If so, describe this relationship.

4. 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.
"If you multiply the currents that pass through the two resistors you get the current that passes through the battery."

Check your work with your teacher

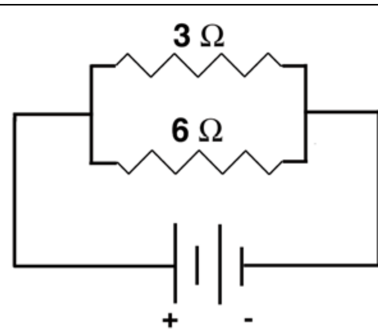
Kirchoff's junction rule states that the sum of currents that enter a junction in a circuit is equal to the sum of the currents that leave that junction. In other words the current that flows into a junction must be equal to the current that flows out of that junction.

What if you were trying to tell the current that flows through a battery in a parallel circuit. If you could determine the total resistance of the parallel circuit then you could determine the "total" current by using the version of Ohm's law solved for current (I): $I = \dfrac{V}{R}$.



The total current that flows in a parallel circuit is equal to the sum of the currents that flow into the branches in the circuit.	$I_{total} = I_1 + I_2$
Substituting the corresponding ratios of voltage and resistance for each current in the preceding equation gives you the equation that you see to the right.	$\dfrac{V_{total}}{R_{total}} = \dfrac{V_1}{R_1} + \dfrac{V_2}{R_2}$
According to Kirchoff's loop rule the total voltage (V_{total}) is equal to the voltages applied across each of the resistors (V_1 and V_2).	$V_{total} = V_1 = V_2$
If you multiply the 2nd equation through by the total voltage you get the following expression.	$\dfrac{1}{R_{total}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

In order to determine the total resistance of a pair of parallel resistors you must add the reciprocal values of each of the two resistors together. You must then take the reciprocal of this value.
For example, the total resistance of the resistors shown below can be found by doing the calculations seen in the table that follows.



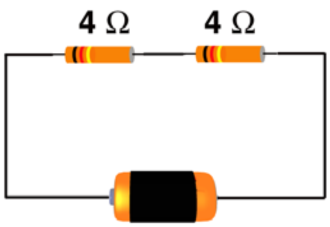
Apply the equation: $\dfrac{1}{R_{total}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$	$\dfrac{1}{R_{total}} = \dfrac{1}{3\,\Omega} + \dfrac{1}{6\,\Omega}$
Adding the equivalent fractions found on the right side of the equation gives you the equation seen to the right.	$\dfrac{4}{12\,\Omega} + \dfrac{2}{12\,\Omega}$
Reduced the sum of the fractions gives you the value seen to the right.	$\dfrac{4}{12\,\Omega} + \dfrac{2}{12\,\Omega} = \dfrac{6}{12\,\Omega} = \dfrac{1}{2\Omega}$
The reciprocal of the total resistance is equal to 1/2Ω.	$\dfrac{1}{R_{total}} = \dfrac{1}{2\,\Omega}$
Taking the reciprocal of the last values will give you the	

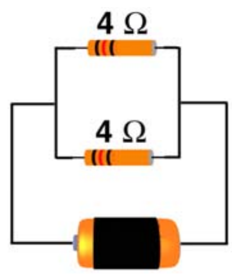
total resistance (R_{total}).	$R_{total} = 2\ \Omega$

5. What appears to happen to the total resistance of a circuit when the resistors are connected in parallel? Does the total resistance seem to be larger or smaller than the value of the individual resistors in the circuit?

6. How does the total resistance of a circuit compare to the individual resistance of the resistors when the resistors are connected in series? Is the total resistance of series resistors larger or smaller than the individual resistance of the resistors? Explain how you know.

Two circuits use the same size battery and two equal size resistors. One circuit is a series circuit and the other circuit is a parallel circuit.





7. Which circuit has the largest total resistance? Show your calculations and be sure to use the appropriate units.

8. Which circuit has the largest total current? Explain how you know.

9. 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.
"If you connect circuit components in parallel the current is much greater than if you connect the same components in series. Series circuits have a lot more total resistance than parallel circuits."

Check your work with your teacher ☐

Electric Circuits
Parallel Circuits

CONCEPT REFINEMENT

Review

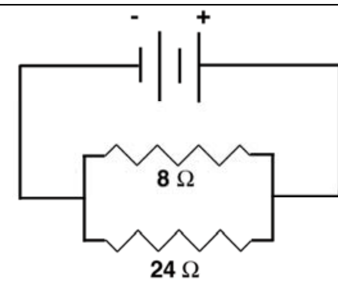
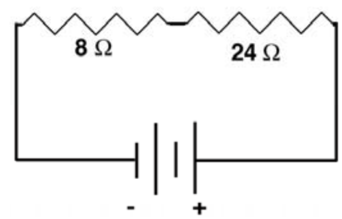
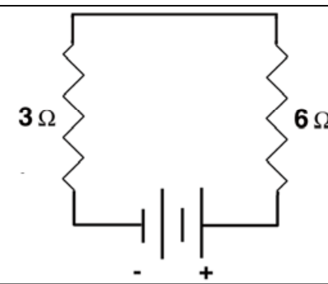
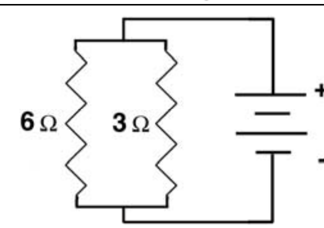
Parallel circuit components get the same voltage. If they have different resistance values then they will have different currents.

In order to calculate the total resistance of parallel resistors you add the reciprocals of the resistances. You then take the reciprocal of the sum of the reciprocals.

The table below summarizes the electrical concepts that apply for both series and parallel circuit components. *Assume that the components that are connected have different resistance values.*

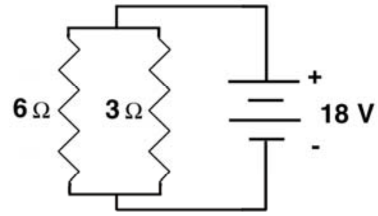
Electrical Concept	**Series Components**	**Parallel Components**
Voltage	Different	Same
Current	Same	Different
Total resistance	$R_{total} = R_1 + R_2 + \ldots + R_n$	$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$

Calculate the total resistance of the following four circuits. Be sure to show your calculations and to label everything with the appropriate units.

1.	
2.	
3.	
4.	

Check your work with your teacher

Perform the following calculations using the last circuit you worked with on the preceding page (4). The battery has 18 Volts.



5. Calculate the current that passes through the battery.

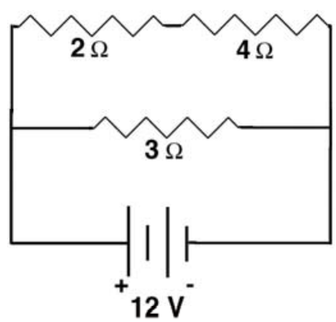
6. How many volts does the 3-Ω resistor get? How many volts does the 6-Ω resistor get? Explain how you know.

7. Calculate the current that passes through the 3-Ω resistor.

8. Calculate the current that passes through the 6-Ω resistor.

Check your work with your teacher

The circuit seen below has two resistors in series with one resistor in parallel. Answer the following question with respect to this circuit.

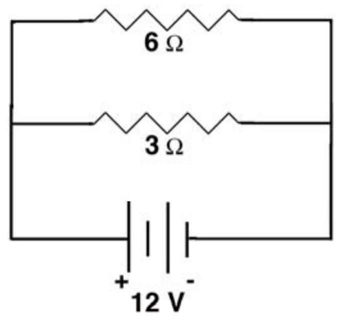


9. How many volts does the 3-Ω resistor get? Explain how you know.

10. Calculate the current that passes through the 3-Ω resistor.

11. Calculate the total resistance of the series pair.

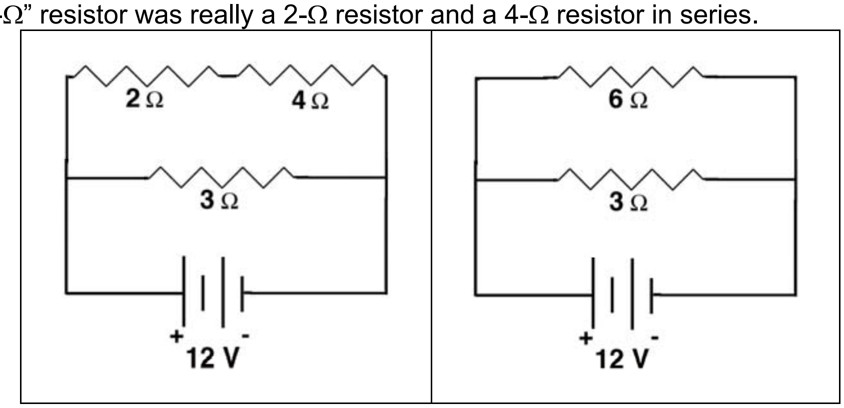
You can replace the series pair of resistors with a single resistor that has the equivalent resistance of the two series resistors acting together. The original circuit that you were given then reduces to the form that you see below. This is called **circuit reduction**.



12. How many volts would the 6-Ω resistor, shown in the circuit above, receive?

13. Calculate the current that passes through the "6-Ω" resistor mentioned in the previous question.

Remember that the "6-Ω" resistor was really a 2-Ω resistor and a 4-Ω resistor in series.

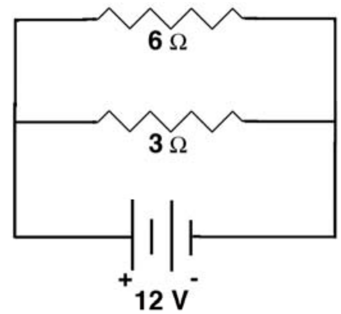


14. What current would pass through the original two resistors in series (the 2-Ω resistor and the 4-Ω resistor)? Hint: resistors in series have the same current.

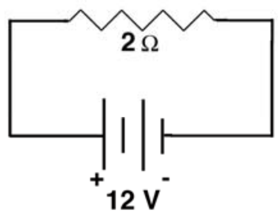
15. Calculate the voltage that the 2-Ω resistor would receive. Hint: V = IR

16. Calculate the voltage that the 4-Ω resistor would receive.

17. Calculate the total resistance of this circuit. Remember that the series resistors can be reduced to a single resistance as seen in the circuit below.



The original circuit can be reduced to the form that you see below.

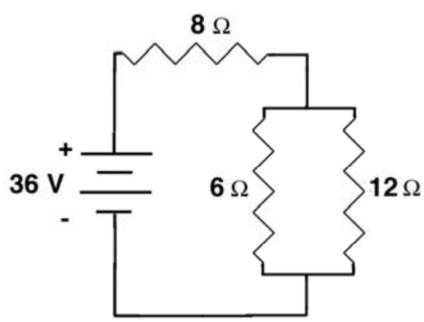


18. Calculate the current that passes through the battery.

19. Is there a relationship between the current that passes through the battery and the current that splits at each of the two junctions in this circuit? If so, explain what it is.

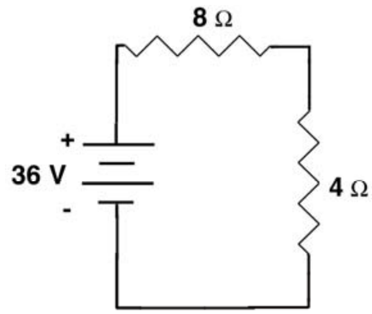
Check your work with your teacher

The circuit that you see below has two resistors in parallel with one resistor in series. Answer the following questions concerning this circuit.



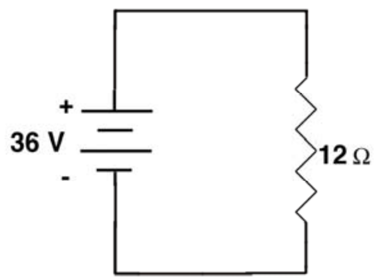
20. What is the total resistance of the parallel pair of resistors?

Once you have determined the resistance of the parallel pair of resistors you can replace this pair with a single resistor that has the total resistance of the two resistors in parallel. This is another example of circuit reduction.



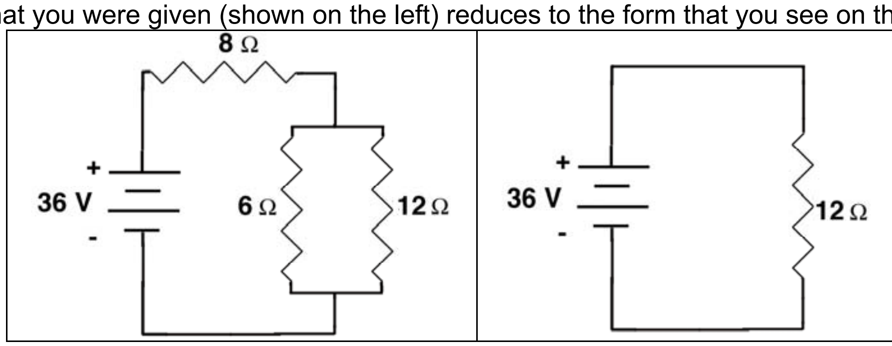
21. What is the total resistance of the two resistors shown in the circuit above?

The original circuit will reduce even further to the form that you see below.



22. Calculate the current for the circuit that you see above. This would be the current that passes through the battery.

The original circuit that you were given (shown on the left) reduces to the form that you see on the right.



23. What must be the current that passes through the 8-Ω resistor? Hint: this resistor is in series with the battery.

24. How many volts does the 8-Ω resistor get? Hint: V = IR

25. How many volts does each of the parallel resistors get? Hint: parallel resistors get the same voltage <u>and</u> try tracing complete paths around the circuit that pass through the battery.

26. Calculate the current that passes through the 6-Ω resistor.

27. Calculate the current that passes through the 12-Ω resistor.

28. Of the parallel resistors, which resistor gets the most current? How much more current does this resistor get than the other parallel resistor?

Check your work with your teacher ☐