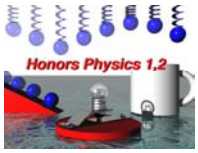


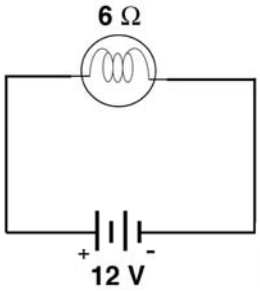
Electric Circuits
Power

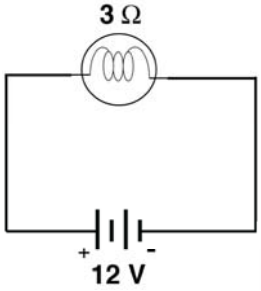
CONCEPT EXPLORATION

In order to get a light bulb to "light up", there must be electrons that flow through the filament of the light bulb. These electrons do work and give up some of their energy as they pass through the resistive filament of the light bulb. Some of this energy is given off as light while the majority of the electron's energy is given off in the form of heat.

Engagement Question

1. Which of the two circuits shown below, do you think would use the most energy in 1 minute? Explain your answer.





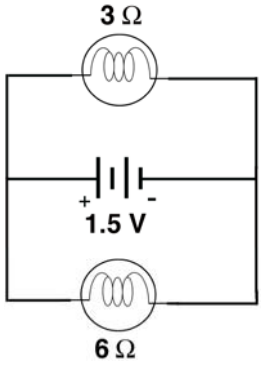
In the previous lessons you learned about simple circuits that consist of light bulbs, a battery, and the connections between them. In this lesson you will learn about another important electrical concept, power.

The Challenge

You will experiment with a simple parallel circuit. You should be able to tell the comparative amount of energy each of the bulbs in the circuit uses based on the brightness of each bulb.

Your Ideas about the Challenge

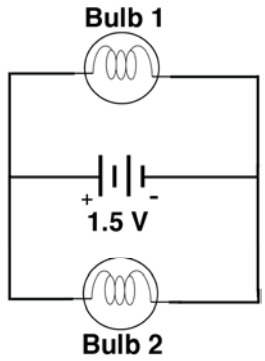
2. How do you think the brightness of the two bulbs in the parallel circuit, shown to the right, will compare? Explain your answer.



At each lab station you will find the following:
two different size light bulbs with bases, a 1.5-Volt battery, an ammeter, and four wires

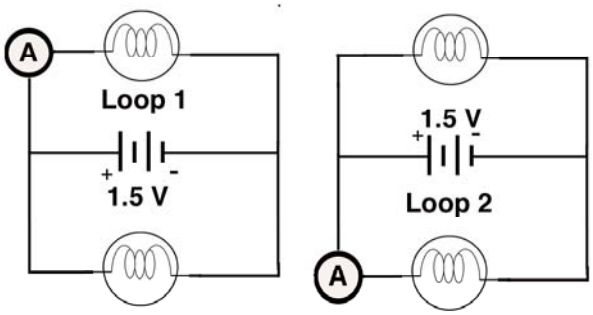
The Investigation

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. Indicate, in the data table that follows, which bulb was the brightest.

c. Use the ammeter to measure the current in each loop of the circuit. Record each of these current readings in the data table that follows.



Data Table

Circuit Bulb	Bulb Brightness (brightest or dimmest?)	Current Reading (A)
1		
2		

3. Which bulb got the most voltage, the brighter bulb or the dimmer bulb? Explain how you know.

4. Which bulb had the most current, the brighter bulb or the dimmer bulb?

5. Calculate the resistance of each bulb. Use the version of Ohm's law solved for resistance: $R = \frac{V}{I}$.

Assume that the battery had a voltage of 1.5 Volts.

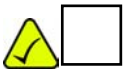
6. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"I think that the brighter bulb used the most energy since it gave off the most light."

Student B

"You're crazy. The bulb that had the greatest resistance must have used up the most energy. Since resistance is a measure of the opposition to the flow of charge, the bulb that opposed the current the most must have used more energy."

Check your work with your teacher 

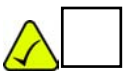
Power is defined as the rate at which energy is used or at which work is done. The bulb that used the most energy in the parallel circuit had the highest power rating.

7. If power is the rate at which energy is used, or the amount of energy used per unit of time, what would the units have to be?

8. What electrical unit has Joules as a part of its derived unit? Show the unit breakdown for this unit.

9. What electrical unit has something to do with the rate of something occurring? Hint: this unit is something per second. Show the unit breakdown for this unit.

10. Take the unit breakdown for the unit that you answered question 8 with and multiply this by the unit breakdown for the unit that you answered question 9 with. Simplify your answer.

Check your work with your teacher 

A joule per second has a special name. It is called a **Watt** (W). This unit is named for James Watt who was a mechanical engineer who worked with horses in the 18th century. He actually invented an alternative unit of power, the horsepower. It takes 746 Watts to equal one horsepower (hp).
Since a Watt is a joule per second it can be broken down even further.

$$1\ \mathrm{W} = 1\frac{\mathrm{J}}{\mathrm{s}} = 1\frac{\mathrm{N}\cdot\mathrm{m}}{\mathrm{s}} = 1\frac{\mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}^2}\cdot\mathrm{m}}{\mathrm{s}} = 1\mathrm{kg}\frac{\mathrm{m}^2}{\mathrm{s}^3}$$

Since Watts are a fairly complex unit it is recommended that you simply remember that a Watt is equal to a Joule per second.

Electricity is sold in units called kilowatt-hours. A kilowatt-hour is the number of kilowatts that are used multiplied by the number of hours in which these kilowatts were used.

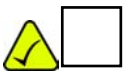
11. How many watts are there in a kilowatt? How many Joules/second are there in a kilowatt?

12. How many seconds are there in an hour?

If you multiply the number of Joules/second in a kilowatt by the number of seconds in an hour you will know how many units a kilowatt-hour is, as well as what the unit actually represents.

13. Multiply the number of Joules/second in a kilowatt by the number of seconds in an hour. Be sure to include the units and to correctly label your answer.

14. What does a kilowatt-hour actually measure?

Check your work with your teacher 

Electric Circuits
Power

CONCEPT DEVELOPMENT

Power is the rate at which energy is used or it is the rate at which work is done. It can also be considered to be the rate at which heat is dissipated across a resistive device in a circuit. The units of power are Watts. A Watt (W) is equal to a Joule per second (J/s).

Engagement Questions

1. What two electrical units did you multiply together to get a Joule per second? See questions 8 and 9 in the exploration lesson.

2. What two electrical concepts do these two units correspond to? What do these two units measure?

The basic equation that can be used to calculate electrical power is shown below.

Power = Current x Voltage

P = IV

There are two variations of this basic power equation that can be derived by combining this basic equation with Ohm's law.

Since current can be expressed as the ratio between the voltage and the resistance of a circuit component ($I = V/R$), this expression can be substituted for I in the basic power equation as you see below.

$$P = IV$$

$$P = \left(\frac{V}{R}\right)V = \frac{V^2}{R}$$

Another form of the electrical power equation can be derived by substituting the expression IR, ($V = IR$), for the voltage (V) in the basic power equation. This can be seen below.

$$P = IV$$

$$P = I(IR) = I^2R$$

The Challenge

You will construct a parallel circuit that consists of two different sized light bulbs in parallel with the same battery. You will take both current and voltage measurements in order to determine the power rating of each light bulb. You will then calculate how much energy each bulb uses in a given amount of time.

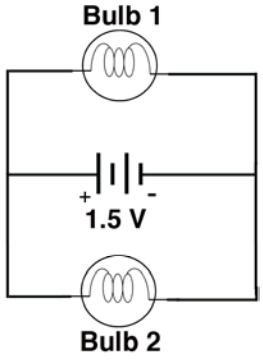
Your Ideas about the Challenge

3. Do you think that a Watt is a big or a small unit of power? Explain your answer.

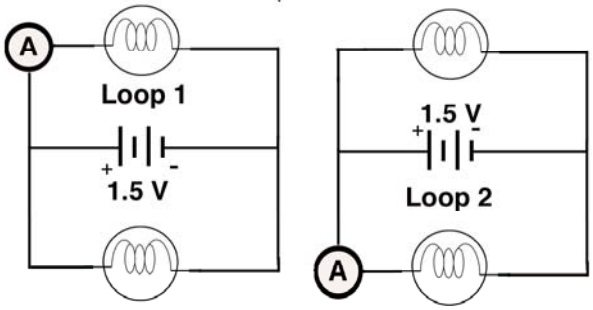
At each lab station you will find the following:
two different size light bulbs with bases, a 1.5-Volt battery, an ammeter, and four wires

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. Use the ammeter to measure the current in each loop of the circuit. Record each of these current readings in the data table that follows.



c. Measure the voltage across each of the light bulbs while they are lit. Record each of these voltage readings in the data table that follows.

Data Table

Circuit Bulb	Current Reading (A)	Voltage Reading (V)
1		
2		

4. Calculate the power rating for each of the light bulbs by using the basic power equation (P = IV). Show all of your calculations including the units and label your answers appropriately.

Bulb 1 Power	Bulb 2 Power

Power is the rate at which energy is used. This can be seen in the power equation that you see below.

$$\text{Power} = \frac{\text{energy}}{\text{time}}$$

If you solve the equation seen above for energy you get the equation: energy = Power x time.

5. Calculate how many Joules of energy each of the two bulbs will use in one minute. Be sure to carry through all of your units in your calculations and to label your answer appropriately.

Bulb 1 Energy in One Minute	Bulb 2 Energy in One Minute

A kilowatt-hour is equal to 3,600,000 Joules.

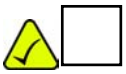
6. Calculate what fraction of a kilowatt-hour each of your two bulbs used in one minute. Show all of your calculations.

Bulb 1 (fraction of a kilowatt-hour)	Bulb 2 (fraction of a kilowatt-hour)

A kilowatt-hour typically costs about $0.10.

7. Calculate the cost of the energy that each of your light bulbs used in one minute. Show all of your calculations and label your answer appropriately.

Bulb 1 cost per minute	Bulb 2 cost per minute

Check your work with your teacher 

CONCEPT REFINEMENT

Review

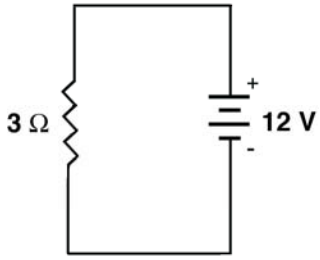
Power is the rate at which work is done or at which energy is used. The different power equations are all shown in the table below.

Current and Voltage	Voltage and Resistance	Current and Resistance	Energy Used per Time
$P = IV$	$P = \frac{V^2}{R}$	$P = I^2R$	$P = \frac{\text{energy}}{\text{time}}$

Which equation you use depends on what information you have available to you and what you are investigating.

You will use all of the power equations in the following exercises.

1. How many volts does the 3-Ω resistor, shown in the circuit diagram to the right, receive? Explain how you know.



2. Calculate the amount of power that this resistor uses. Be sure to show all of your calculations and to label your answer appropriately.

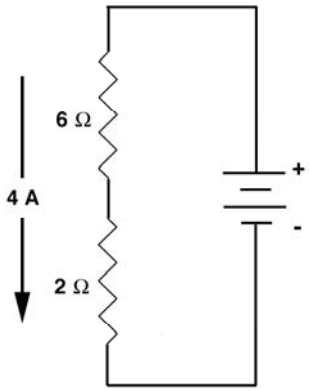
3. How much energy does this resistor use each second? Explain how you know.

4. How much energy would this resistor use in 10 minutes? Be sure to show all of your calculations and to label your answer appropriately.

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 power that is used by the 6-Ω resistor.

6. Calculate the power that is used by the 2-Ω resistor.



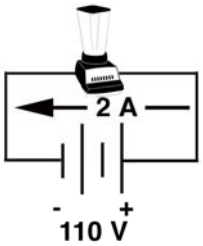
7. What is the total resistance of this circuit?

8. If you treat the two resistors shown in this circuit as a single resistance, what would be the power used by this single resistor.

Check your work with your teacher ☐

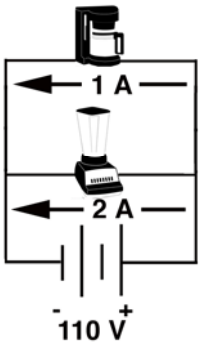
A blender is switched on in an electrical circuit in a kitchen. There are 2 Amps of current flowing through this blender while it is being used. In all of the calculations that follow, be sure to use the appropriate units and to label your answer with the appropriate units.

9. Calculate the power used by the blender in this circuit.



While the blender is still running a coffee maker is switched on. The coffee maker draws 1 Amp of current.

10. Calculate the power used by the coffee maker.

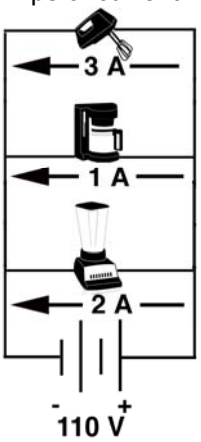


11. How much current must be coming from the 110-V voltage source?

12. Calculate the power that is being delivered from the voltage supply.

While the blender and the coffee maker continue to run a mixer is switched on. The mixer draws 3 Amps of current.

13. Calculate the power used by the mixer.



14. How much current must be coming from the 110-V voltage source now?

15. Calculate the power that is being delivered from the voltage supply at this time.

16. As more appliances are switched on in this parallel circuit, what happens to the current delivered by the voltage supply? Does the current increase or decrease?

17. As more appliances are switched on in this parallel circuit, what happens to the power delivered by the voltage supply? Does the power increase or decrease?

18. What is the relationship between the power that is supplied by the voltage supply and the individual power requirements of each of the appliances?

Check your work with your teacher ☐