Electrical Power

How do you calculate electrical power?

In this skill sheet you will review the relationship between electrical power and Ohm's law. As you work through the problems, you will practice calculating the power used by common appliances in your home.

During everyday life we hear the word *watt* mentioned in reference to things like light bulbs and electric bills. The watt is the unit that describes the rate at which energy is used by an electrical device. Energy is never created or destroyed, so "used" means it is converted from electrical energy into another form such as light or heat. And since energy is measured in joules, power is measured in joules per second. One joule per second is equal to one watt.

We can calculate the amount of electrical power by an appliance or other electrical component by multiplying the voltage by the current.

$$\text{Current} \times \text{Voltage} = \text{Power, or } P = IV$$

A kilowatt (kWh) is 1,000 watts or 1,000 joules of energy per second. On an electric bill you may have noticed the term kilowatt-hour. A kilowatt-hour means that one kilowatt of power has been used for one hour. To determine the kilowatt-hours of electricity used, multiply the number of kilowatts by the time in hours.

EXAMPLE

You use a 1500 watt hair heater for 3 hours. How many kilowatt-hours of electricity did you use?

Given	**Solution**
The power of the heater is 1500 watts. The heater was used for 3 hours.	$1500 \text{ watts} \times \frac{1 \text{ kilowatt}}{1000 \text{ watts}} = 1.5 \text{ kilowatts}$
Looking for The number of kilowatt-hours.	$1.5 \text{ kilowatts} \times 3 \text{ hours} = 4.5 \text{ kilowatt-hours}$
Relationships kilowatt-hours = kilowatts x hours	You used 4.5 kilowatt-hours of electricity.

PRACTICE

1. Your oven has a power rating of 5000 watts.
   a. How many kilowatts is this?
   b. If the oven is used for 2 hours to bake cookies, how many kilowatt-hours (kWh) are used?
   c. If your town charges $0.15/kWh, what is the cost to use the oven to bake the cookies?
2. You use a 1200-watt hair dryer for 10 minutes each day.
   a. How many minutes do you use the hair dryer in a month? (Assume there are 30 days in the month.)
   b. How many hours do you use the hair dryer in a month?
   c. What is the power of the hair dryer in kilowatts?
   d. How many kilowatt-hours of electricity does the hair dryer use in a month?
   e. If your town charges $0.15/kWh, what is the cost to use the hair dryer for a month?

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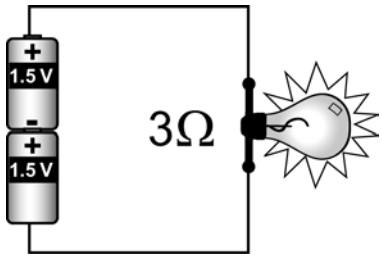
3. Calculate the power rating of a home appliance (in kilowatts) that uses 8 amps of current when plugged into a 120-volt outlet.

4. Calculate the power of a motor that draws a current of 2 A when connected to a 12 volt battery.

5. Your alarm clock is connected to a 120 volt circuit and draws 0.5 A of current.
   a. Calculate the power of the alarm clock in watts.
   b. Convert the power to kilowatts.
   c. Calculate the number of kilowatt-hours of electricity used by the alarm clock if it is left on for one year.
   d. Calculate the cost of using the alarm clock for one year if your town charges $0.15/kWh.

6. Using the formula for power, calculate the amount of current through a 75-watt light bulb that is connected to a 120-volt circuit in your home.

7. The following questions refer to the diagram.



   a. What is the total voltage of the circuit?
   b. What is the current in the circuit?
   c. What is the power of the light bulb?

8. A toaster is plugged into a 120-volt household circuit. It draws 5 amps of current.
   a. What is the resistance of the toaster?
   b. What is the power of the toaster in watts?
   c. What is the power in kilowatts?

9. A clothes dryer in a home has a power of 4,500 watts and runs on a special 220-volt household circuit.
   a. What is the current through the dryer?
   b. What is the resistance of the dryer?
   c. How many kilowatt-hours of electricity are used by the dryer if it is used for 4 hours in one week?
   d. How much does it cost to run the dryer for one year if it is used for 4 hours each week at a cost of $0.15/kWh?

10. A circuit contains a 12-volt battery and two 3-ohm bulbs in series.
    a. Calculate the total resistance of the circuit.
    b. Calculate the current in the circuit.
    c. Calculate the power of each bulb.
    d. Calculate the power supplied by the battery.

11. A circuit contains a 12-volt battery and two 3-ohm bulbs in parallel.
    a. What is the voltage across each branch?
    b. Calculate the current in each branch.
    c. Calculate the power of each bulb.
    d. Calculate the total current in the circuit.
    e. Calculate the power supplied by the battery.

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Series Circuits

READ

In a series circuit, current follows only one path from the positive end of the battery toward the negative end. The total resistance of a series circuit is equal to the sum of the individual resistances. The amount of energy used by a series circuit must equal the energy supplied by the battery. In this way, electrical circuits follow the law of conservation of energy. Understanding these facts will help you solve problems that deal with series circuits.

To answer the questions in the practice section, you will have to use Ohm's law. Remember that:

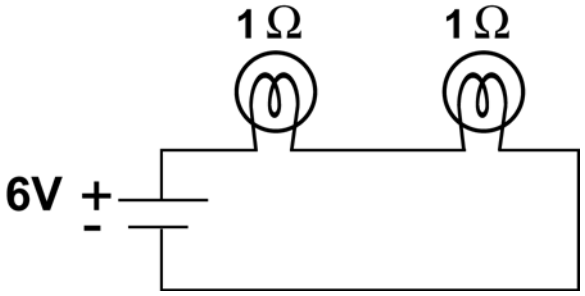
$$\text{Current (amps)} = \frac{\text{Voltage (volts)}}{\text{Resistance (ohms)}}$$

Some questions ask you to calculate a *voltage drop*. We often say that each resistor (or light bulb) creates a separate voltage drop. As current flows along a series circuit, each resistor uses up some energy. As a result, the voltage gets lower after each resistor. If you know the current in the circuit and the resistance of a particular resistor, you can calculate the voltage drop using Ohm's law.

$$\text{Voltage drop across resistor (volts)} = \text{Current through resistor (amps)} \times \text{Resistance of one resistor (ohms)}$$

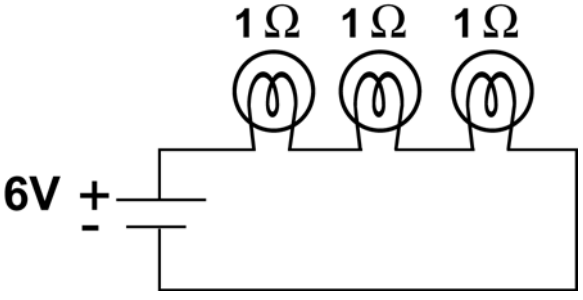
PRACTICE

1. Use the series circuit pictured to the right to answer questions (a)-(e).



   a. What is the total voltage across the bulbs?
   b. What is the total resistance of the circuit?
   c. What is the current in the circuit?
   d. What is the voltage drop across each light bulb? (Remember that voltage drop is calculated by multiplying current in the circuit by the resistance of a particular resistor: $V = IR$.)
   e. Draw the path of the current on the diagram.

2. Use the series circuit pictured to the right to answer questions (a)-(e).



   a. What is the total voltage across the bulbs?
   b. What is the total resistance of the circuit?
   c. What is the current in the circuit?
   d. What is the voltage drop across each light bulb?
   e. Draw the path of the current on the diagram.

3. What happens to the current in a series circuit as more light bulbs are added? Why?

4. What happens to the brightness of each bulb in a series circuit as additional bulbs are added? Why?

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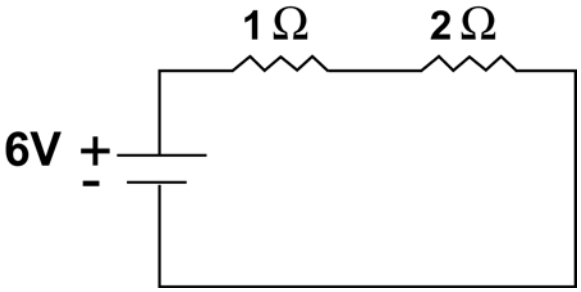
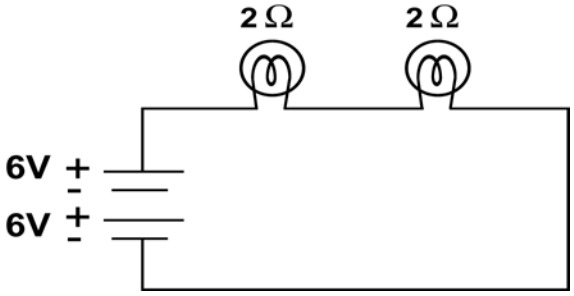
5. Use the series circuit pictured to the right to answer questions (a), (b), and (c).



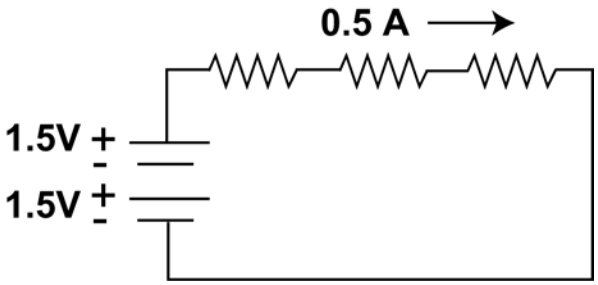
   a. What is the total resistance of the circuit?
   b. What is the current in the circuit?
   c. What is the voltage drop across each resistor?

6. Use the series circuit pictured to the right to answer questions (a)-(e).



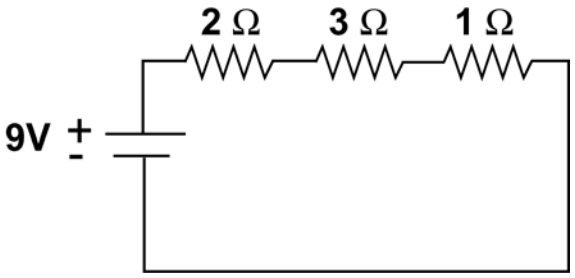
   a. What is the total voltage of the circuit?
   b. What is the total resistance of the circuit?
   c. What is the current in the circuit?
   d. What is the voltage drop across each light bulb?
   e. Draw the path of the current on the diagram.

7. Use the series circuit pictured right to answer questions (a), (b), and (c). Consider each resistor equal to all others.



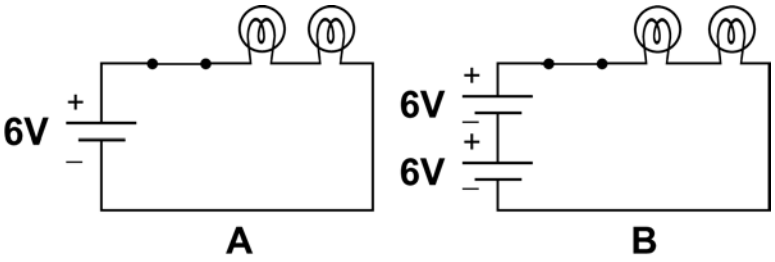
   a. What is the resistance of each resistor?
   b. What is the voltage drop across each resistor?
   c. On the diagram, show the amount of voltage in the circuit before and after each resistor.

8. Use the series circuit pictured right to answer questions (a) - (d).



   a. What is the total resistance of the circuit?
   b. What is the current in the circuit?
   c. What is the voltage drop across each resistor?
   d. What is the sum of the voltage drops across the three resistors? What do you notice about this sum?

9. Use the diagram to the right to answer questions (a), (b), and (c).



   a. How much current would be measured in each circuit if each light bulb has a resistance of 6 ohms?
   b. How much current would be measured in each circuit if each light bulb has a resistance of 12 ohms?
   c. What happens to the amount of current in a series circuit as the number of batteries increases?

Parallel Circuits

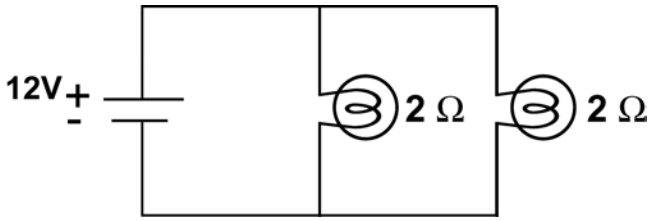
READ

A parallel circuit has at least one point where the circuit divides, creating more than one path for current. Each path is called a branch. The current through a branch is called branch current. If current flows into a branch in a circuit, the same amount of current must flow out again, This rule is known as **Kirchoff's current law**.

Because each branch in a parallel circuit has its own path to the battery, the voltage across each branch is equal to the battery's voltage. If you know the resistance and voltage of a branch you can calculate the current with Ohm's Law ($I=V/R$).

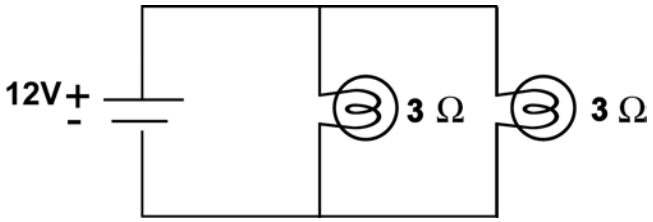
PRACTICE 1

1. Use the parallel circuit pictured right to answer questions (a) - (d).



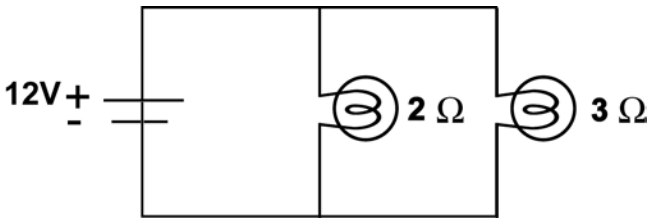
   a. What is the voltage across each bulb?
   b. What is the current in each branch?
   c. What is the total current provided by the battery?
   d. Use the total current and the total voltage to calculate the total resistance of the circuit.

2. Use the parallel circuit pictured right to answer questions (a) - (d).



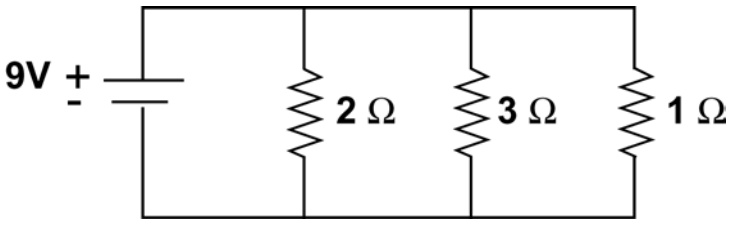
   a. What is the voltage across each bulb?
   b. What is the current in each branch?
   c. What is the total current provided by the battery?
   d. Use the total current and the total voltage to calculate the total resistance of the circuit.

3. Use the parallel circuit pictured right to answer questions (a) - (d).



   a. What is the voltage across each resistor?
   b. What is the current in each branch?
   c. What is the total current provided by the batteries?
   d. Use the total current and the total voltage to calculate the total resistance of the circuit.

4. Use the parallel circuit pictured right to answer questions (a) - (c).



   a. What is the voltage across each resistor?
   b. What is the current in each branch?
   c. What is the total current provided by the battery?

PRACTICE 112m = 4 sec 14.2

READ

In part (d) of problems 1, 2, and 3, you calculated the total resistance of each circuit. This required you to first find the current in each branch. Then you found the total current and used Ohm's law to calculate the total resistance. Another way to find the total resistance of two parallel resistors is to use the formula shown below.

$$R_{total} = \frac{R_1 \times R_2}{R_1 + R_2}$$

EXAMPLE

Calculate the total resistance of a circuit containing two 6 ohm resistors.

Given The circuit contains two 6 Ω resistors in parallel.	**Solution** $R_{total} = \frac{6\ \Omega \times 6\ \Omega}{6\ \Omega + 6\ \Omega}$ $R_{total} = 3\ \Omega$ The total resistance is 3 ohms.
Looking for The total resistance of the circuit.	
Relationships $R_{total} = \frac{R_1 \times R_2}{R_1 + R_2}$	

PRACTICE 2

1. Calculate the total resistance of a circuit containing each of the following combinations of resistors.
   a. Two 8 Ω resistors in parallel
   b. Two 12 Ω resistors in parallel
   c. A 4 Ω resistor and an 8 Ω resistor in parallel
   d. A 12 Ω resistor and a 3 Ω resistor in parallel
2. To find the total resistance of three resistors A, B, and C in parallel, first use the formula to find the total of resistors A and B. Then use the formula again to combine resistor C with the total of A and B. Use this method to find the total resistance of a circuit containing each of the following combinations of resistors
   a. Three 8 Ω resistors in parallel
   b. Two 6 Ω resistors and a 2 Ω resistor in parallel
   c. A 1 Ω, a 2 Ω, and a 3 Ω resistor in parallel