9.2 The Power of Electricity

Electrical power is the rate at which electric potential energy is being transformed. One joule (J) of electric potential energy transformed in one second is one watt (W) of power. Electrical power can be calculated by multiplying voltage and current ($P = VI$). The amount of electrical energy used by a device is its power consumption multiplied by the length of time the device is turned on ($E = Pt$). Since the joule is a very small amount of electrical energy, the kilowatt-hour (kW·h) is used for devices that consume larger amounts of energy.

Words to Know

electrical power
joule
kilowatt-hour
power
power rating
watt

Imagine two cars at the bottom of a very steep hill on a racetrack (Figure 9.12). One car is a well-kept race car whereas the other is an older automobile in a poor state of repair. The old automobile and the race car have exactly the same mass. When the vehicles reach the top of the hill, they will have both gained the same amount of potential energy since they are at the same height. On this particular day, the drivers have a race to the top of the hill. As you might expect, the race car reaches the top of the hill before the old automobile. Both vehicles converted the same amount of energy to reach the top of the hill. What gives the race car the ability to do this work faster?

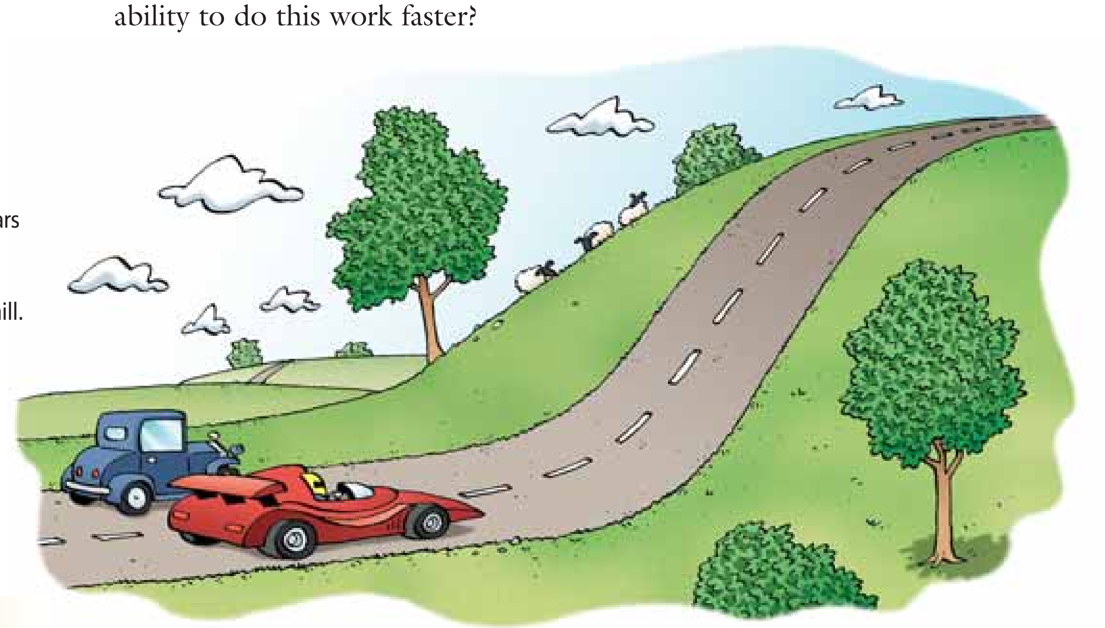


Figure 9.12 Both cars will convert the same amount of energy to reach the top of the hill.

Did You Know?

The amount of electrical energy used to dry your hair with a hair dryer is the same amount of energy needed to lift an average student 1.5 km into the air.

In this section, you will investigate energy and the rate at which it is transferred. In an electric circuit, batteries supply charge with electric potential energy. You can picture this process as the batteries "pushing" the charge "uphill." This electrical energy gets transformed into other forms of energy by loads in the circuit such as resistors and light bulbs. A load that can transform the energy quickly is like the race car in the example above.

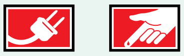
Energy Transformation in Resistors

Find Out ACTIVITY

Teacher Demonstration

In this teacher demonstration, you will compare the rate of energy transfer for three different resistors.

Safety



- Avoid touching resistors while current passes through them and immediately afterward. They can get hot enough to burn you.
- Do not use the power supply to generate voltages greater than 6.0 V.
- Be careful taping the resistor to the glass bulb of the thermometer.

Materials

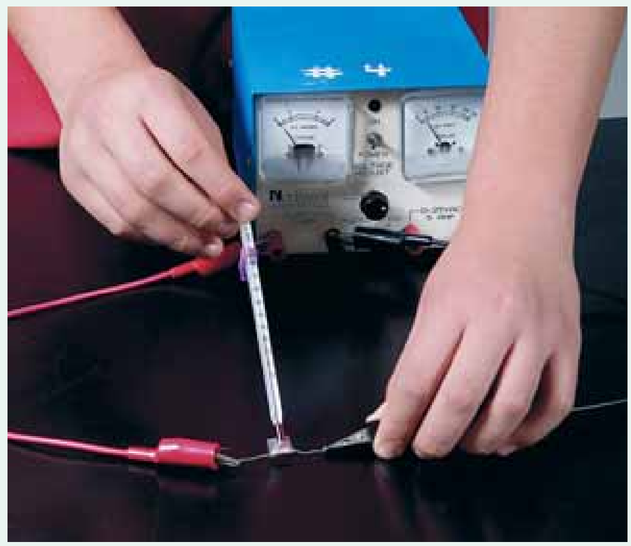
- 3 power supplies
- 3 resistors of different sizes (50 Ω—100 Ω)
- 3 thermometers
- clear adhesive tape
- stopwatch
- connecting wires

What to Do

1. Predict how the size of a resistor affects the amount of heat generated in a circuit. Record your prediction.
2. Copy the following data table in your notebook. Give your data table a title.

	Resistor 1 ______ Ω	Resistor 2 ______ Ω	Resistor 3 _______ Ω
Initial temperature of thermometer (°C)			
Time to increase thermometer temperature by 5.0°C (s)			

3. Using the colour code, determine the resistance of each resistor. Record this value in your data table.
4. Use the adhesive tape to attach each resistor to the bulb of a thermometer. Use one resistor per thermometer, as shown.
5. Note and record the temperature indicated by each thermometer.
6. Connect each resistor to an individual power supply using the connecting wires.
7. Set the power supplies to 6.0 V and start the stopwatch.
8. Record the time for each thermometer to increase its temperature by 5.0°C.
9. Clean up and put away the equipment you have used.



What Did You Find Out?

1. What form of energy is being produced by the resistors?
2. Compare the amount of resistance of the resistors to how quickly each transformed the electrical energy from the power supply.
3. Which of these resistors had the greatest amount of current? Explain your answer.
4. Based on your observations in this experiment, explain the relationship between current and the rate at which energy is transformed by the resistor.

Did You Know?

The power of a car engine is still commonly measured in an older unit for power called "horsepower." James Watt invented this term so he could compare the power of his improved steam engine to the power of a horse, to help him boost sales of his steam engine. One unit of horsepower equals 746 W.

A Matter of Time and Energy

It is obvious that a race car could get to the top of the hill in a much shorter time than an old automobile (Figure 9.13). This is because the race car has more power. **Power** is defined as the rate of change in energy. Power is also the rate at which work is done or energy is transformed. The unit for measuring energy is the **joule** (J), named for the British scientist James Prescott Joule (1818–1889). One joule (J) of energy transformed in one second (s) is called one **watt** (W) of power, in honour of Scottish inventor James Watt (1736–1819).

By the time they reach the top of the hill, both cars have gained the same change in energy since they had the same mass and climbed the same hill. Because the race car could transform its energy faster, it has more power.

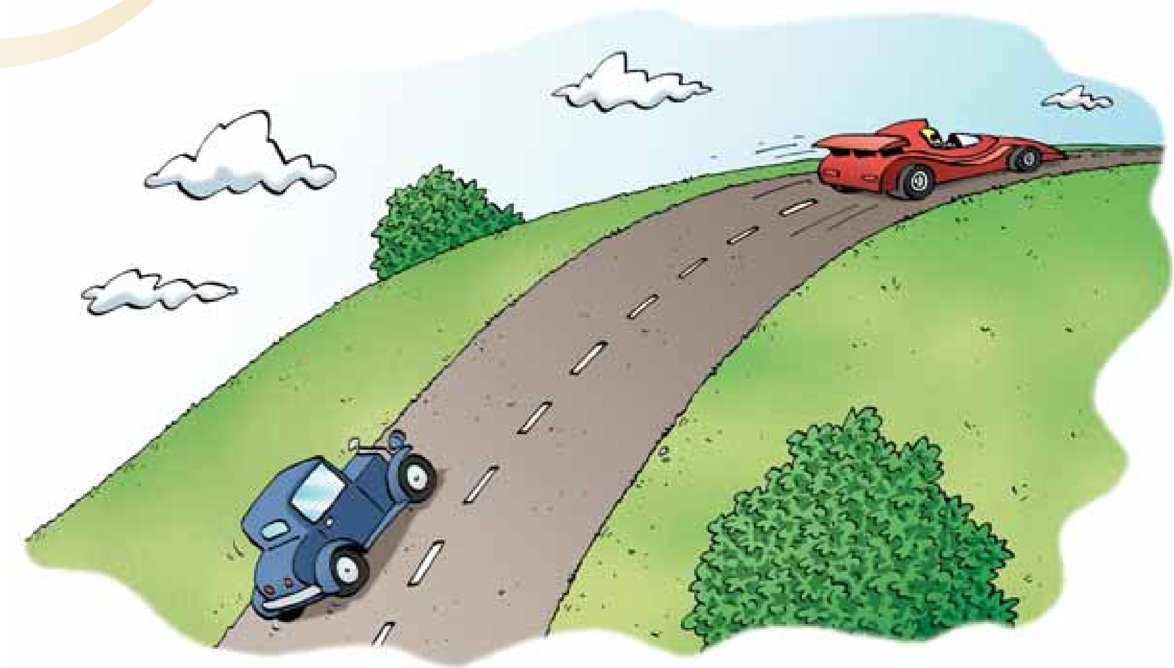


Figure 9.13 The rate of energy transformation is faster in the race car than in the old automobile.

Electrical power is the rate of change in electrical energy. An electrical load changes electrical energy to other forms. The amount of electrical energy changed or transformed on a load per second is the power rating of the load. For example, a 60 W light bulb uses 60 J of electrical energy every second and produces 60 J of heat and light energy (Figure 9.14).

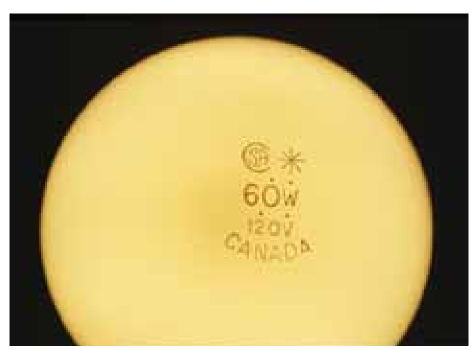


Figure 9.14 A 60 W light bulb converts 60 J of electrical energy into 60 J of light and heat every second.

Calculating Electrical Power

For calculating the power of an electrical device, it is more common to talk about the voltage and current rather than energy and time. You can calculate the power of an electrical device by multiplying voltage and current. In other words, electrical power (P) is the product of voltage (V) and current (I): $P = VI$.

Read the question:

If a 6.0 V battery supplies a current of 2.0 A, what is the power output of the battery?

Use the formula:

$$P = VI$$
$$= (6.0 \text{ V})(2.0 \text{ A})$$
$$= 12 \text{ W}$$

State your answer:

The power output of the battery is 12 W.

Did You Know?

The Gordon M. Shrum generating station, shown on the opening page 304, is the largest hydroelectric station in British Columbia, generating more than 2700 million watts of power.

Practice Problems

Try the following power problems. Show each step in your solution.

1. A flashlight bulb operates on 3.0 V and draws a current of 4.0 A. What is the power of this bulb?
2. A 60 W light bulb is connected to 120 V. What current passes through the light bulb?
3. A voltmeter measures 15 V across a 45 W resistor. What current is passing though the resistor?

Answers

1. 12 W
2. 0.5 A
3. 3.0 A

Power Ratings

You may have noticed that many electrical devices are labelled with their power rating (Figure 9.15). A **power rating** is a measurement of how much electrical energy an electrical device consumes for every second it is in use. You may remember that the definition of power is the rate of change in energy. In other words, 1.0 W is the transfer of 1.0 J of energy every second. This means a 1500 W hair dryer uses 1500 J of electrical energy each second.

Figure 9.15 Light bulbs, hair dryers, and kitchen appliances are labelled with their power ratings.

Suggested Activity

Conduct an Investigation 9-2C on page 327

Calculating Energy Consumption

By using the power rating and the amount of time, you can calculate the amount of electrical energy a particular device consumes. Power (P) is defined as energy transferred (E) per time interval (t). Therefore,

$$P = \frac{E}{t}$$

Since $P = \frac{E}{t}$, to get energy, multiply both sides of this equation by t.

$$Pt = \frac{E\cancel{t}}{\cancel{t}}$$ In this equation, the t's cancel.

Therefore the electrical energy consumed can be calculated by

$E = Pt$ where energy (J) = power (W) × time (s)

The following is an example of how you can use this formula to calculate electrical energy consumption.

Read the question:

How much electrical energy is consumed by a 1200 W hair dryer if it is used for 5.0 min?

Science Skills

Go to Science Skill 13 to learn more about using scientific notation, such as 3.6×10^5.

Use the formula:

Before you begin, make sure your time is in seconds.
5.0 min = 5 × 60 s = 300 s.

$$\begin{aligned} E &= Pt \\ &= (1200\ \text{W})(300\ \text{s}) \\ &= 360\ 000\ \text{Ws} \\ &= 3.6 \times 10^5\ \text{J} \end{aligned}$$

State your answer:

A 1200 W hair dryer consumes 3.6×10^5 J of electrical energy if it is used for 5.0 min.

Practice Problems

Try the following energy consumption problems. Show each step in your solution.

1. How much electrical energy is consumed by a 60 W light bulb if it is left on for 25 min?
2. A 1600 W kettle is turned on for 3.0 min. How much electrical energy does the kettle use in this time?
3. How much electrical energy is consumed by a 100 W light bulb left on for 4.0 h?

Answers

1. 9.0×10^4 J
2. 2.9×10^5 J
3. 1.4×10^6 J

A Larger Unit for Energy

As you can see in the example on the previous page, a 1200 W hair dryer used for only 5.0 min consumes 360 000 J of energy. Could you imagine how many joules of electrical energy are consumed by all the electric devices in your home in one day? In terms of electrical energy, the joule is a very small amount.

$$1.0 \text{ joule} = 1.0 \text{ watt} \times 1.0 \text{ second}$$

You can also use a larger unit of electrical energy. To increase this measurement, power is measured in kilowatts (kW) and time is measured in hours (h). There are 1000 W in 1 kW and 3600 s in 1 h. A **kilowatt-hour** (kW·h) is the product of power in kilowatts and time in hours.

$$1.0 \text{ kilowatt-hour} = 1.0 \text{ kilowatt} \times 1.0 \text{ hour}$$

or

$$1.0 \text{ kW·h} = 1.0 \text{ kW} \times 1.0 \text{ h}$$

Figure 9.16 shows the energy label on an electric appliance. Instead of giving the energy consumption in joules, the kilowatt-hour is used.

Did You Know?

More than 52 billion kW·h of electrical energy is used in British Columbia each year.

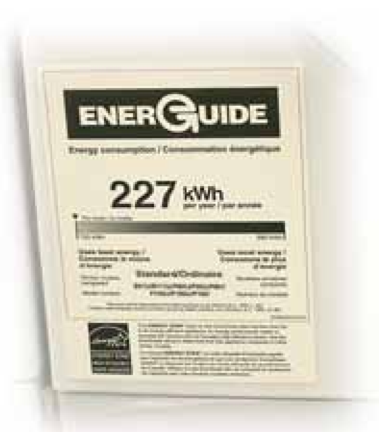


Figure 9.16 The energy label shows the average annual energy consumption in kilowatt-hours.

Paying for Electricity

The power company that supplies electricity to your home keeps track of the electrical energy you consume. Your home probably has a meter similar to the one in Figure 9.17 that monitors your energy consumption. Every time you turn on a load, such as a light bulb, current passes through the meter and turns the dials. An employee of the power company visits your home and reads this meter to determine how much energy has been consumed since the last bill. These meters represent the energy consumed in kilowatt-hours. When you receive your electricity bill, you are charged for each kilowatt-hour of electrical energy you have used.

Figure 9.17 The electricity meter in your home may be similar to this one. The middle disk turns, showing the rate at which electrical energy is being used within the home.

For example, suppose a family uses 1500 kW·h of electrical energy in a given month. If the power company charges 7 cents for every kW·h of energy, how much is the electric bill for the month?

$$\text{cost of energy used} = \frac{\$0.07}{1 \text{ kW·h}} \times 1500 \text{ kW·h} = \$105.00$$

The family will owe the electric company $105.00 for the electrical energy it used.

internet connect

To find out more about reading a home electricity meter, go to **www.bcscience9.ca**.

9-2B The Cost of Electricity

Think About It

In this activity, you will use the power rating and time of use to calculate the energy consumption and cost of operating specific devices.

What to Do

1. Copy the following data table in your notebook. Give your data table a title.

Appliance	Power (W)	Time of Use Each Day (h)	Energy (kW·h)	Cost (cents)	Cost (dollars)
Television	200	2.0			
Stereo	80	1.5			
Kitchen stove	12 000	2.0			
Microwave	1 400	0.5			
Bedroom light	100	4.0			

2. Calculate the energy consumed, in kilowatt-hours, by each of the appliances. Be sure to change the power in watts to kilowatts.
3. Using the cost of electricity as 7 cents per kilowatt-hour, calculate the daily cost of each appliance in cents and in dollars.

What Did You Find Out?

1. Which appliance had the greatest daily cost?
2. Considering all the electrical devices in your home, state which ones you think would have the greatest daily cost.

Explore More

Hydroelectric dams are usually located great distances from the cities and communities they serve. Therefore, electrical energy must be transmitted through many kilometres of power lines. The power company transmits this energy at extremely high voltages. Find out the risks and benefits of transmitting electricity at high voltage. Begin your research at **www.bcscience9.ca.**

Electrical Surges

Surges of electric charge are brief increases in voltage to tens of thousands of volts and can occur through household wiring, telephone lines, and coaxial cable. Electrical surges can be caused by lightning, by turning on or off large electrical appliances, or by a local power company transferring large amounts of energy into or out of the power grid. An electrical surge protector absorbs some of the electrical surge and then diverts the rest to the ground (Figure 9.18).

Figure 9.18 An electrical surge protector

Reading Check

1. Define power.
2. How are power (P), voltage (V), and current (I) related?
3. What does a power rating of 40 W mean in terms of energy and time?
4. What is the formula that relates energy consumption (E) to power (P) and time (t)?
5. What unit of energy is commonly used when dealing with large quantities of energy?

9-2C A Current View of Power

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

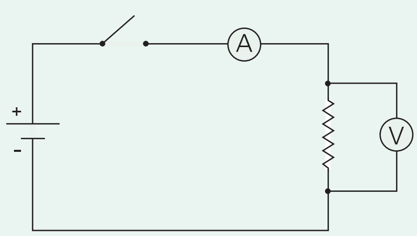
- Predicting
- Measuring
- Controlling variables
- Evaluating information

Safety

- If any of the resistors or wires become hot, open the switch immediately.

Materials

- 3 resistors of different sizes (100 Ω–1000 Ω)
- 1.5 V cell
- ammeter
- voltmeter
- switch
- connecting wires



Science Skills

Go to Science Skill 11 to learn more about using an ammeter and a voltmeter.

The light bulbs you use in your home are resistors that change electrical energy into both heat and light energy. A 60 W light bulb has a different resistance than a 100 W light bulb. In this activity, you will measure the voltage and current of a circuit in order to calculate the power of different resistors.

Question

What is the relationship of resistance, current, and power?

Procedure

Part 1 Measuring Voltage and Current

1. Copy the following data table in your notebook. Give your data table a title.

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

2. Using the colour code, determine the value of each resistor. Record these values in your data table.
3. Using one resistor, set up the circuit shown in the diagram.
4. Close the switch and measure the current and voltage for your first resistor. Record these values in your data table. If your ammeter is measuring in milliamperes, be sure to convert the current to amperes.
5. Open the switch, and replace resistor 1 with resistor 2. Repeat step 4.
6. Open the switch, and replace resistor 2 with your final resistor. Repeat step 4.
7. Clean up and put away the equipment you have used.

Part 2 Calculating Power

8. Using the equation $P = VI$, calculate the power for each resistor.

Analyze

1. Compare the voltage across each of your three resistors.
2. Compare the current through each resistor.
3. Which resistor had the greatest power?
4. In one or two sentences, relate power, resistance, and current.

Conclude and Apply

1. Given what you have learned in this investigation, would a 60 W or 100 W light bulb have more resistance? Explain your answer.

Career Connect

Electrician

Travelling, meeting new people and troubleshooting problems: these are the things that make Clint Tomma's job exciting. As an electrician from Chase, British Columbia, Clint finds that every job is different and brings new challenges. The electrical concepts may be the same, but no two jobs are the same.

Q. What is a typical job for an electrician?

A. I do a lot of residential work, so one morning I may fix a furnace, and in the afternoon I may work on a broken pump. I may wire a new house or work in some of the bigger commercial properties that have more sophisticated electrical systems. Some of the new systems are computer based, which poses new challenges, such as programming controls for motors, lighting, heating, and cooling.

Q. How long does it take to wire a new house?

A. It depends on the size of the house, but generally one person can put in service and "rough in" the electrical wiring within about four days. When we rough in a house, we install all the wiring before the walls are dry walled. We install all of the boxes for the light fixtures, switches, phone lines, and whatever else is specified by the builder. These boxes are connected back to the power panel, and then the rest of the wiring is installed for the house. Once the drywall is in place, we put in the light fixtures, switches, and receptacles. When you wire a new house, you need at least 600 m of 14/2 wire and at least another 100 m of other wire. The electrical service provided for a house is usually 240/120 V.

Q. What do you need to know about circuits, current, and voltage to do your job?

A. You need a really good knowledge of circuits to be an electrician. Most housing projects are done in parallel. Residential properties are 240 V, and commercial properties range from 600 V to 25 000 V. A lot of the circuitry is for amperes, so you have to look at what kind of material you are using. Appliances all have a rating in watts, and you have to do a calculation for wattage, voltage, and amperes (watts = amperes × volts).

Q. What training do you need to be an electrician?

A. You need high school graduation with English 12 and Math 12. Then you do either a 6-month Electrical Trade course or you can work for an electrical contractor and go to school for 10 weeks each year for four years. I took a 6-month training course at Thompson Rivers University.

Q. What is the most challenging part of your job?

A. The most challenging part of the job is also the most exciting part: troubleshooting. When I go to a job, I never know what the problem will be or how I am going to solve it.

Clint Tomma

Questions

1. How much wire goes into wiring a new house?
2. What is the main type of circuit used in houses?
3. What training do you need to become an electrician?

Check Your Understanding

Checking Concepts

1. What do we call the rate at which energy is transformed?
2. State one unit for energy and one unit for power.
3. What is another name for joules per second?
4. In which unit are large amounts of energy measured?
5. How many joules is 1 kW·h equal to?
6. State the relationship of energy (E), power (P), and time (t).

Understanding Key Ideas

7. Two identical batteries are connected to different circuits. Explain how it is possible for the batteries to supply different amounts of power.
8. Explain how two loads can consume the same amount of electrical energy but have different power ratings.
9. What is the power rating of a light bulb if 3.0 A flow through it when connected to a 15 V battery?
10. How much electrical energy, in joules, does a 40 W light bulb consume in 15 min?
11. (a) A 1600 W hair dryer is used for 15 min. How much electrical energy, in kW·h, did the hair dryer consume during this time?
    (b) If the cost of electricity is 7 cents/kW·h, how much did it cost to use the hair dryer?
12. In a set amount of time, a battery supplies 25 J of energy to an electric circuit that includes two different loads. One of the loads produces 10 J of heat energy during this time interval. How much heat energy is produced by the second load in this time? Explain your answer.

Pause and Reflect

Throughout British Columbia, there are stations where electrical energy is generated from other forms of energy such as at the Brilliant Dam on the Columbia River and the Burrard Power Station in Port Moody. Why are such stations often referred to as *power* stations?

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated how circuits are designed to control the transfer of electrical energy. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 12 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Series Circuits
2. Parallel Circuits
3. Power
4. The Cost of Electricity

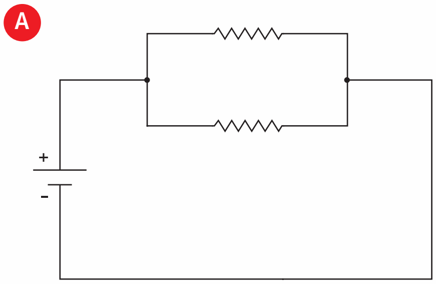
Checking Concepts

1. In terms of the number of pathways, what is the difference between a series circuit and a parallel circuit?
2. Two resistors are connected in series. How does the current through the second resistor compare to the current through the first resistor?
3. A 6.0 V battery is connected to three resistors connected in series. What is the total voltage lost on the three resistors?
4. Complete each of the following sentences in your notebook, using "increases," "does not change," or "decreases."
   (a) Adding a resistor in series ___________ the total resistance of the circuit.
   (b) Adding a resistor in parallel __________ the total resistance of the circuit.
5. Two resistors are connected in parallel. How does the voltage on one resistor compare to the voltage on the second resistor?
6. (a) A current entering a junction point branches into two pathways. Describe the relationship between the current entering the junction point and the total current in the two pathways that leave the junction point.
   (b) If the two pathways have different resistances, will the current in each pathway be the same?
7. (a) State the definition of power.
   (b) What unit is used to measure power?
8. State the relationship of power (P), voltage (V), and current (I).
9. (a) What two units are used for measuring electrical energy?
   (b) Which unit is larger?
10. What is the definition of power in terms of energy and time?

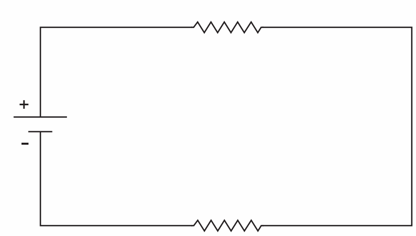
Understanding Key Ideas

11. A battery and two light bulbs are all connected in series.
    (a) What happens to the second light bulb if the first one "burns out"?
    (b) Would the result be the same if the bulbs were connected in parallel? Explain.
12. Give a non-electric example of a real life situation that represents:
    (a) a series circuit
    (b) a parallel circuit
13. For each circuit below, state if the resistors are connected in series or parallel. Give a reason for your answer.

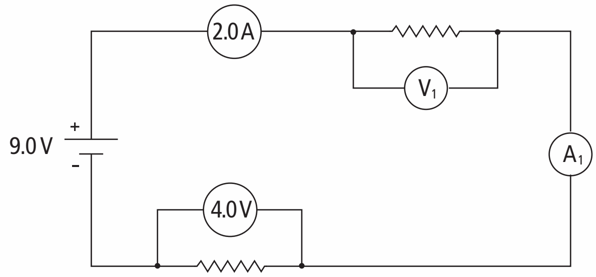
A



B

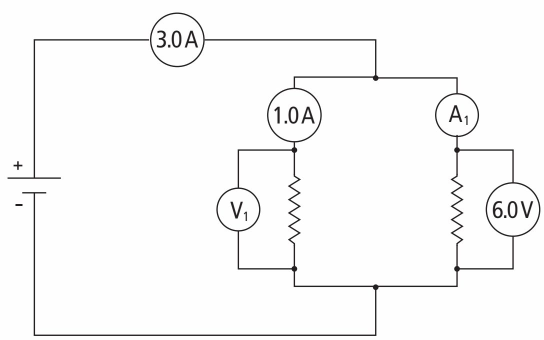


14. In the circuit shown below, what would be the readings on the voltmeter V_1, and the ammeter A_1?



15. A battery is connected to a resistor and the current leaving the battery is measured. What would happen to the current leaving the same battery if another resistor is:
(a) connected in series with the original resistor? Explain your answer.
(b) connected in parallel with the original resistor? Explain your answer.

16. In the circuit shown below, what would be the reading on the voltmeter V_1 and the ammeter A_1?

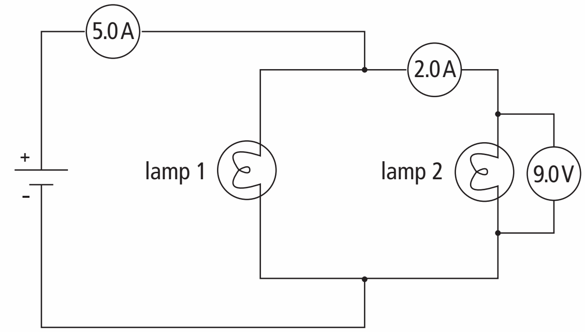


17. A light bulb is connected to 120 V and uses 1.2 A. What is the power rating of this bulb?

18. What is the current through a 1200 W hair dryer if it is connected to 120 V?

19. A 0.20 A current passes through a 450 Ω resistor. Calculate the electric power "lost" in this resistor. (**Hint:** Use Ohm's law to find the voltage.)

20. Find the power rating of each lamp in the circuit below.



21. List the following device usages in order of highest consumption of energy to lowest consumption of energy.

Device	Power Rating	Time
Hair dryer	600 W	15 min
Light bulb	60 W	4 h
Microwave oven	700 W	5 min

22. If the electric company charges 7 cents for every kW·h of energy, calculate how much it costs for each of the following:
(a) 5.0 kW stove used for 2.0 h
(b) 200 W water heater used for 8.0 h

Pause and Reflect

A battery supplies 6.0 W of power when connected to two resistors in series. The same two resistors are then connected in parallel to the same battery. The battery now supplies 24 W of power. Why is there a difference in power?

Unit Summary

7 Static charge is produced by electron transfer.

- Static charge is electric charge that is held in one place. (7.1)
- An atom or material becomes charged when electrons transfer into it or out of it. (7.1)
- Insulators keep charges in one place, whereas conductors allow charges to move more easily. (7.1)
- Like charges repel. Opposite charges attract. Neutral objects are attracted to charged objects. (7.2)
- Electric force is a force at a distance. Electric force can be increased by increasing the amount of charge on objects and by decreasing the distance between charged objects. (7.2)

8 Ohm's law describes the relationship of current, voltage, and resistance.

- Unlike charges gain electric potential energy when they are moved farther apart. (8.1)
- Voltage (potential difference) is the change in potential energy per coulomb of charge. (8.1)
- Electrical energy depends on the amount of charge and the voltage. (8.1)
- Current electricity is the continuous flow of charge in a complete circuit. (8.2)
- Ohm's law states that the electrical resistance of the circuit is the ratio of the voltage to the current. (8.3)

9 Circuits are designed to control the transfer of electrical energy.

- The current is the same in each part of a series circuit, and each load uses a portion of the same voltage. (9.1)
- The current in each part of a parallel circuit depends on the resistance of that path. (9.1)
- When resistors are placed in series, the total resistance of the circuit increases. When resistors are placed in parallel, the total resistance decreases. (9.1)
- Electric power ($P = VI$) is the rate at which electric potential energy is transformed. (9.2)
- Power consumption multiplied by time of use equals the amount of electrical energy used by a device. (9.2)

Key Terms

- acetate
- coulomb
- electric force
- electrons
- static charge
- Van de Graaff generator

Key Terms

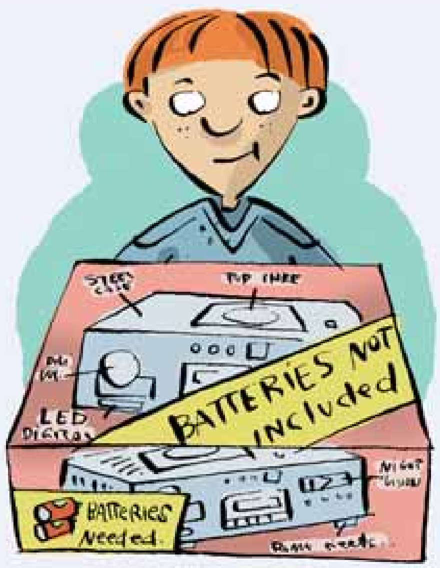
- amperes
- electric current
- energy
- ohm
- Ohm's law
- resistance
- volt
- voltage

Key Terms

- joule
- kilowatt-hour
- parallel circuit
- power
- series circuit

Finding the Best Battery

As you remove your new electronic device from its packing, you read "Batteries Not Included." The store stocks three different brands of the battery size you need. Which brand will produce the most electrical energy?



Problem

In this project, you will work in groups to determine which brand of battery supplies the most electrical energy.

Safety

- If any wires become hot, disconnect the circuit immediately.

Suggested Materials

- 3 brands of one battery type, such as C, D, AA, or AAA
- identical bulbs
- voltmeters
- ammeters
- stopwatches
- connecting wires
- switches

Criteria

- Draw a circuit diagram for your set-up.
- Construct a circuit from a circuit diagram.
- Collect data for voltage, current, and time.
- Calculate power.
- Graph your data.

Procedure

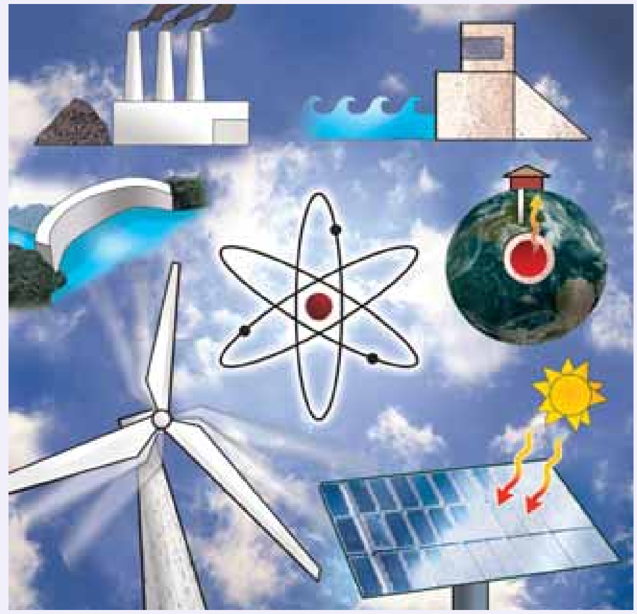
1. With your group, design a circuit that has one battery connected to two or three bulbs in parallel. Include an ammeter to measure the current leaving the battery, a voltmeter to measure the voltage across the battery, and a switch.
2. Draw a circuit diagram for your group's design. Have your teacher approve your circuit design.
3. Create a data table to record your data for each brand of battery.
4. Have each member of the group construct the approved circuit using one of the three batteries. Close the switch and measure the initial voltage and current. Record these values for time = 0.
5. At consistent time intervals, record the voltage and current. Continue these measurements until the bulbs are no longer lit.
6. Disconnect your circuit. Clean up and put away the equipment you have used.
7. For each set of data, calculate the power provided by the battery ($P = VI$).

Report Out

1. Construct a graph of power vs. time. Plot your data for each brand of battery on the same graph. For each battery, connect your data points with a smooth line.
2. The area below the graph line is proportional to the energy produced by the battery ($E = Pt$). Analyze your graph, and state which brand of battery produced the most energy.

Generating Electrical Energy

In this investigation, you will choose a source of energy and research the methods used to convert the energy source into electricity.



Background

Over the last 100 years, British Columbia has continually increased its dependence on electricity. Growth in population, technology, and industry has put a strain on our ability to safely generate enough affordable electricity. Scientists have been researching different methods of generating electrical energy to find methods that are safe and affordable. The most common forms of generating electricity include the following.

Energy Source	Description
Hydroelectric	Dams are built on rivers to convert gravitational potential energy into electricity. Currently, 80 percent of British Columbia's electricity is hydroelectric.
Thermal	Coal or natural gas is burned to convert thermal energy into electricity.
Geothermal	Earth's heat is used to produce electricity.
Nuclear	Nuclear reactors convert nuclear energy into electricity.
Wind	Air movement is converted into electricity by windmills.
Wave/tidal	The motion of the ocean is used to produce electricity.
Solar	Solar panels are used to convert the Sun's energy to electricity.

Find Out More

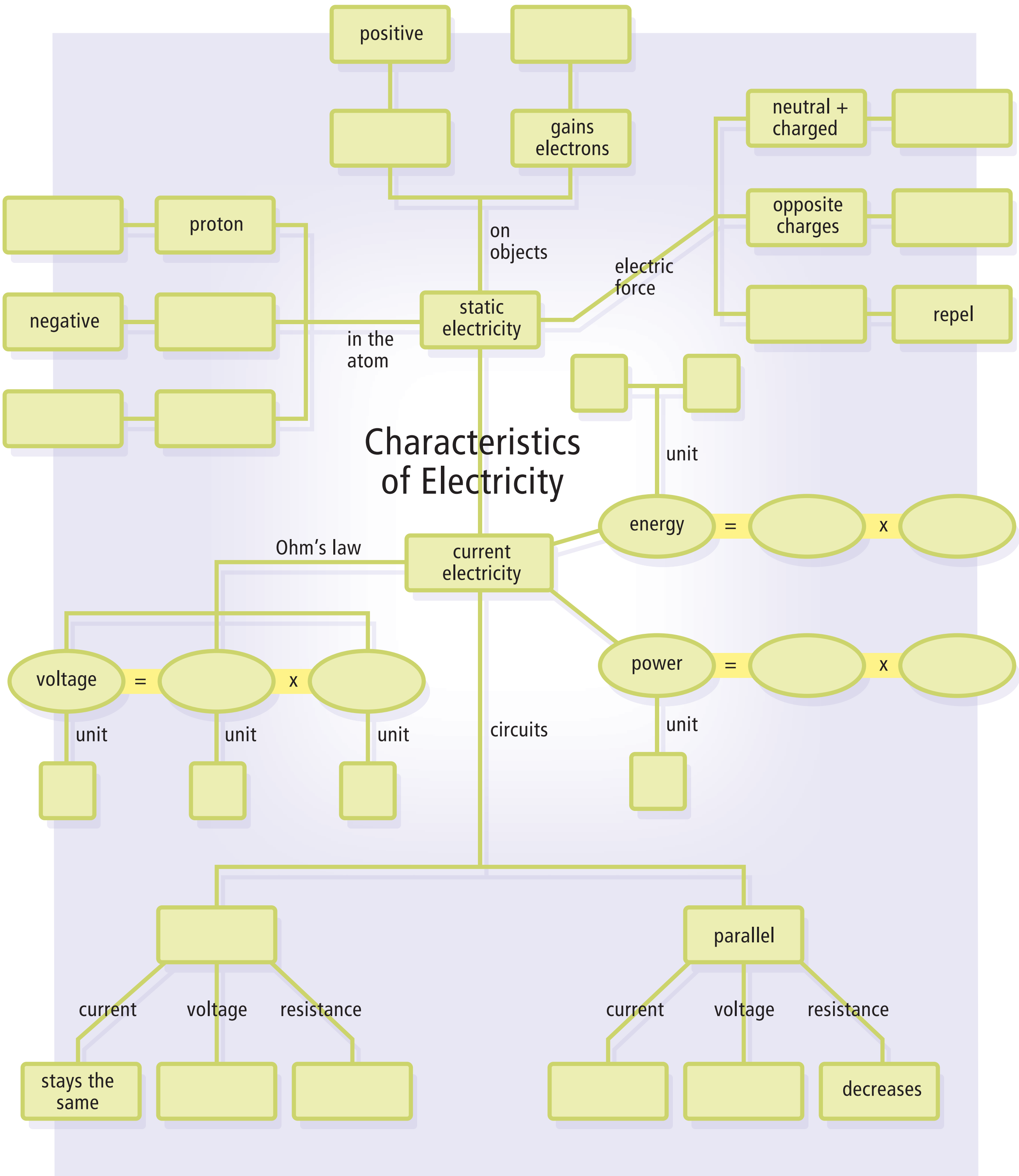
Choose one source of energy from the table. Use the Internet, encyclopedias, books, or other sources to research how the energy source is converted into electricity. You can start your search at **www.bcscience9.ca**.

Report Out

1. Create a poster to display the results of your research. Your poster could include information about:
   - method(s) used to convert your energy source to electricity
   - effects on the environment
   - cost
   - dependability
2. Take part in a "town hall" debate in which you promote your source of energy to a small community on the coast of British Columbia that will soon be expanding and needs a new energy source.

Visualizing Key Ideas

1. Copy the concept map about the characteristics of electricity into your notebook. Complete the map.



Using Key Terms

2. In your notebook, state whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) If an object is neutral, it has no positive and negative charges.
   (b) When an object is charged positive, it has gained protons.
   (c) Grounding an object is allowing charge to flow into Earth.
   (d) An insulator does not allow charge to move easily.
   (e) The load in a circuit converts electrical energy into other forms of energy,
   (f) The battery in a circuit is the source of electric current.
   (g) Resistors slow down the flow of current.
   (h) In a series circuit, the potential difference of the source is equal to the potential difference across each load.
   (i) In a parallel circuit, the current entering the junction point equals the current leaving the junction point.

Checking Concepts

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3. (a) What is the name of the device used for detecting static charge?
   (b) How does this device indicate the presence of a static charge?
4. What two names are given to oppositely charged objects?
5. (a) Which two parts of the atom have a charge?
   (b) What is the charge on each of these parts?
6. What is the charge on an object after it is grounded?
7. What particle is transferred when a neutral object is charged?
8. (a) Give two examples of materials that are electrical conductors.
   (b) Give two examples of materials that are electrical insulators.
9. State the three laws of static charge.

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10. Define voltage in terms of electric potential energy and charge.
11. What is the difference between kinetic energy and potential energy?
12. State what each of the following meters is designed to measure:
    (a) voltmeter
    (b) ammeter
    (c) ohmmeter
13. What is the difference between static electricity and current electricity?
14. Contrast conventional current and electron flow.
15. What happens to the electrical energy when a charge passes through a resistor?
16. State Ohm's law in terms of voltage, current, and resistance.
17. Describe the purpose of the coloured bands on a resistor.

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18. What is the difference between a series circuit and a parallel circuit?
19. Use the words "same," "different," "increases," and "decreases" to complete the following table.

	Series	Parallel
Current in every part of the circuit		
Voltage across different size resistors in the circuit		
Total resistance when a resistor is added		

20. In any complete circuit, how does the voltage supplied by the battery compare to the sum of the voltages lost on each resistor?
21. If 4.0 A of current enters the junction point of a parallel circuit, how much total current must leave that junction point?
22. State the relationship of power, voltage, and current.

23. Two light bulbs, a 60 W bulb and a 100 W bulb, are left on for the same amount of time. Which bulb consumes more energy?
24. The joule (J) is a unit used for measuring energy. What energy unit is used when the amount of energy is large?
25. State the relationship of energy, power, and time.

Understanding Key Ideas

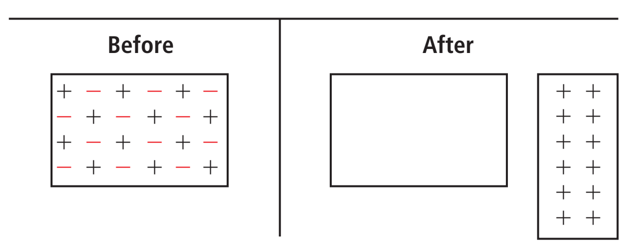
26. Explain the cause of lightning.
27. Explain why a charged balloon sticks to the wall.
28. Using a charged rod and an electroscope, explain how you can determine if an object is a conductor.
29. Suppose that you rub a piece of plastic on your sweater and it gains a charge. Describe how you could use a negatively charged acetate strip to determine the charge on this piece of plastic.
30. Two charged objects are placed 10 cm apart. Describe two ways of increasing the electric force between these two charged objects.
31. Explain, using the motion of electrons, the difference between charging by conduction and charging by induction.
32. Describe two ways to increase the current in a circuit.
33. When a battery is connected to a complete circuit, electrons flow throughout the circuit instantaneously. Explain.
34. A resistor is connected to a battery and a 4.0 A current leaves the battery. The resistor is now replaced by a new resistor with half the resistance. How much current will now leave the battery?
35. Explain why household wiring is constructed in parallel instead of in series.
36. Two identical light bulbs are connected to a battery in a series circuit.
    (a) What will happen to the brightness of the second bulb if the first bulb is unscrewed?
    (b) Would this result be the same if the bulbs were connected in parallel? Explain.
37. A string of 12 identical holiday lights is connected in series. If this string is plugged into a 120 V source, what is the voltage across each light?

Thinking Critically

38. A charged object is brought near a pile of puffed rice cereal. Some pieces of the cereal are attracted to the charged object, but as soon as they contact the charged object they fly off in all directions. Explain this observation.
39. You are caught in a thunderstorm while playing golf. Your caddy suggests that you either keep playing or stand under a tree. Do you think these are good ideas? Give reasons for your answer.
40. Two wires can be placed across the terminals of a battery. One wire has a high resistance, whereas the other has a low resistance.
    (a) Which wire will produce heat energy at a faster rate?
    (b) Why?

Developing Skills

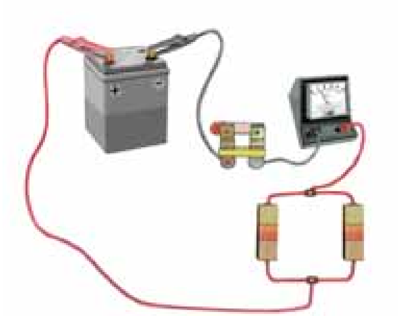
41. Copy the following diagram into your notebook. Place positive (+) and negative (−) signs in the blank object to demonstrate the induced charge distribution.



42. Draw a circuit diagram for each of the following circuits.

A

B

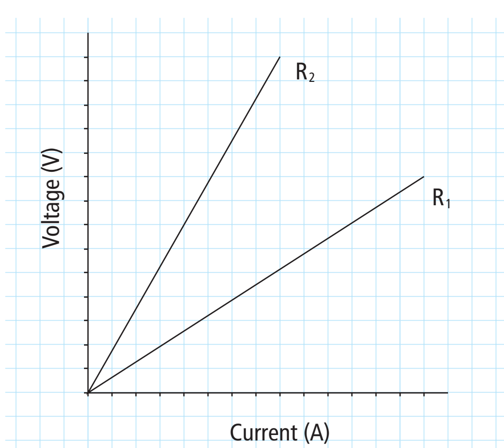


43. A 2.0 A current flows through a 220 Ω resistor. What is the voltage across this resistor?

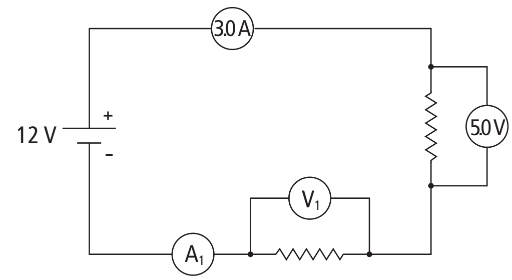
44. A circuit takes 0.45 A of current from a 9.0 V battery. What is the resistance of this circuit?

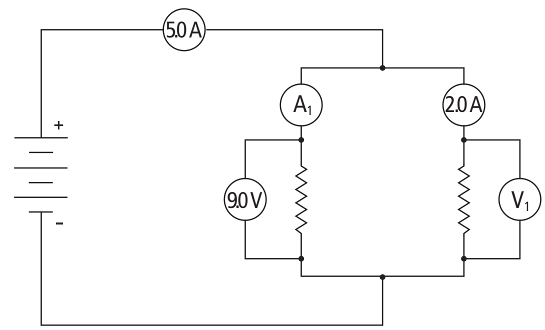
45. A 18 MΩ resistor is connected to 120 kV high power lines. What is the current, in milliamperes (mA) through this resistor?

46. Two different resistors, R_1 and R_2, are connected to various batteries, and the current is measured. The data for each resistor are plotted on the graph below. Which resistor has the largest resistance? Explain.



47. Determine the voltage V_1 and the current A_1 in each of the following circuits.





48. A circuit draws a current of 25 mA from a 12 V battery. What is the power output of this battery?

49. A 1400 W toaster oven is used for 30 min.
   (a) Find the amount of energy consumed by this toaster oven. Give your answer in:
      (i) joules (J)
      (ii) kilowatt hours (kW•h)
   (b) If the electric company charges 7 cents for every kW•h of energy, how much did it cost to operate the toaster oven in (a)?

Pause and Reflect

In less than 300 years, our understanding of electricity has progressed from creating a static charge by friction to the design of powerful computers. What have you learned in this unit that has helped you better understand the importance of electricity in your life?