10 Transferring and transforming energy

A fireworks display is one of the most spectacular energy transformations; you can not only see it but also hear, feel and smell it. When fireworks are ignited, the energy stored in the substances inside them is quickly transformed into movement (kinetic energy), light energy, sound energy and thermal energy (more commonly called heat). Energy that is stored is known as potential energy.

Think about energy

- Which type of energy do you find in chocolate?
- When you drop a tennis ball to the ground, why doesn't it return to its initial height?
- How much electrical energy is wasted as heat by an incandescent light globe?
- How does ceiling insulation keep your house warmer in winter?
- Where does a firefly get the energy to light up?
- How do glow-in-the-dark stickers work?
- How does a didgeridoo player create its unique sound?

In this chapter:

YOUR QUEST

Potential energy and kinetic energy

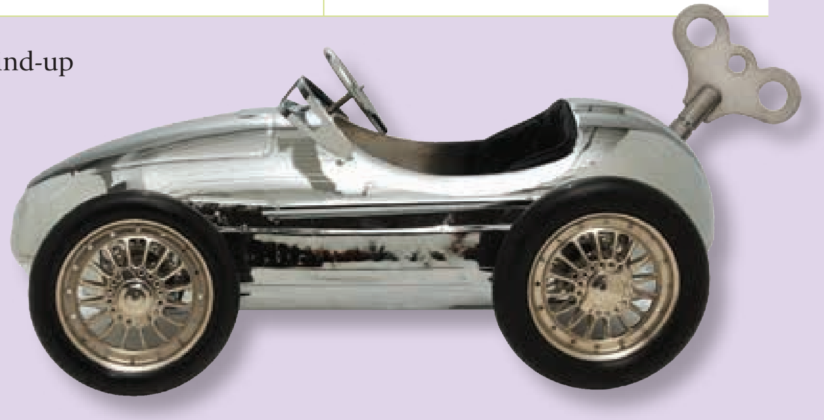
All substances and objects possess **potential energy**. But you can't tell unless something happens to transform the potential energy into a different type of energy. In the case of fireworks it's obvious when they explode. When a diver dives from a platform or diving board, the **kinetic energy** they gain on the way down is transformed from the energy stored in them because of their height above the ground. And the energy stored in the stretched string of a bow is transformed into the kinetic energy of the arrow when it is released.

THINK

1 Copy and complete the table below. One example has been completed for you.

Object	What to do to release the stored energy	Potential energy is usefully transformed into . . .
Torch battery	Switch it on	electrical energy and light energy
Chocolate		
Petrol		
Dynamite		
Olympic diver on platform		
Match		
Stretched elastic band		

2 Answer the following questions about the wind-up toy shown on the right.
(a) Where is the energy stored when it is wound up?
(b) What do you have to do to allow the stored energy to be transformed into different forms?
(c) Name two forms of energy into which the potential energy is transformed.
(d) From where does the energy come that allows the user to wind up the toy?



Matter and energy: Making things happen

Types of energy

Potential energy

(stored energy that, when released, is converted to other forms such as kinetic, sound, heat or light energy)

Gravitational

(potential energy of an object elevated above the ground)

Elastic

(energy stored by an elastic object that is stretched, such as a spring or rubber band)

Chemical

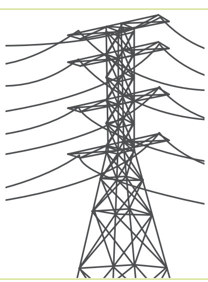
(energy stored in chemicals that, when reacted together such as in burning reactions, release heat, sound or light)

Nuclear

(energy stored in the nucleus of atoms that can release energy slowly, such as in a nuclear reactor, or quickly, such as in a nuclear explosion)

Electrical

(energy supplied to homes by powerlines and available to your appliances via power outlets in the home)



Other types of energy

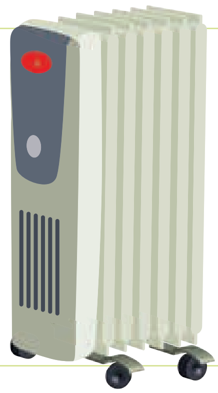
(often converted from potential energy, these are more easily observed by our senses)

Kinetic

(energy possessed by objects that are moving)

Heat

(energy that causes objects to gain temperature)

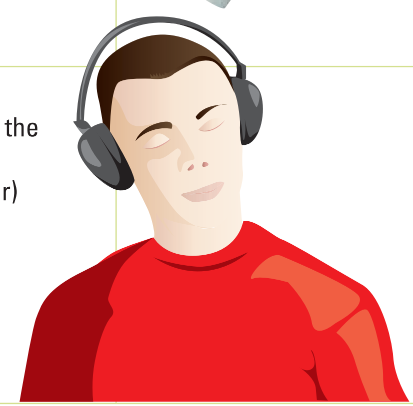


Light

(energy that may be released, for example, when an object is hot or by a nuclear reaction in a star)

Sound

(energy carried by the air in a room and detected by the ear)



What is energy?

Energy is a word that you sometimes use to describe how active you feel. Sometimes you don't seem to have any energy. At other times you feel like you have enough energy to do just about anything. Energy is defined as 'the ability to do work'. That is, it is the ability to make something observable happen.

We know that:

- all things possess energy even if they are not moving
- energy cannot be created or destroyed. This statement is known as the **Law of Conservation of Energy**. It means that the amount of energy in the universe is always the same.
- energy can be transferred to another object (for example, from a cricket bat to a ball) or transformed into a different form (for example, from electrical into sound)
- energy can be stored.

Types of energy

Light energy, sound energy, thermal energy and kinetic energy are all very easily observed. All objects that move have kinetic energy. **Electrical energy** can be seen if there is a spark or a lightning strike, but you

1 At the very top of a jump, the bouncer is momentarily stopped — he has no kinetic energy. But he does have gravitational potential energy due to his height above the trampoline. As the force of gravity pulls the bouncer down, some of his potential energy is transformed into kinetic energy.

2 As the bouncer strikes the trampoline, his kinetic and gravitational potential energy are transferred to the trampoline's surface and springs. The energy is momentarily stored in the springs. It is called elastic potential energy.

3 At this point, the bouncer pushes off the trampoline. The elastic potential energy is transformed back into kinetic energy and some gravitational potential energy.

4 As the bouncer rises again, his kinetic energy is transformed into gravitational potential energy again. At the top of the jump, the bouncer has no kinetic energy, just gravitational potential energy.

Types of energy changes involved in bouncing on a trampoline eBookplus **eLesson**

Energy in disguise
Did you know that all energy is constantly being transformed and transferred from one object to another? There's more going on in your world than meets the eye.

eles-0063

can't see it when it's moving in wires. You become aware of it when it is changed into other forms, for example into light in a fluorescent tube or into sound in an iPhone.

Stored energy is known as potential energy because it has the 'potential' to make something happen. There are several different forms of potential energy, some of which are described in the following examples.

- A ball held above your head has **gravitational potential energy**. This form of energy becomes noticeable when you drop the ball and its stored energy is transformed into kinetic energy.
- A battery contains **chemical energy** but this is not noticeable until the battery is connected in an electric circuit. When that happens the chemical energy is transformed into electrical energy, which in turn is transformed into other types of energy — to make things glow, get hot, produce sounds or move. It is the chemical energy stored in food and drinks that gives you the energy to live and be active. The chemical energy in fuels is transformed to operate cars and other vehicles, keep you warm and generate electricity.
- The **elastic potential energy** stored in a stretched elastic band is released when you let go of one end. The stored energy is transformed into kinetic energy.
- **Nuclear energy** is the energy stored at the centre of atoms, the tiny particles that make up all substances. The energy we receive on Earth from the sun has been transformed from nuclear energy. Under the right conditions, nuclear energy can be transformed into electrical energy in a nuclear power station. Unfortunately it can also be transformed into thermal energy in nuclear weapons.
- Electrical energy can also be stored. For example, if you rub a plastic ruler with a cloth it can become charged. You can't see the stored electrical energy but you can tell it's there when the ruler bends a slow stream of water from a tap.

An unavoidable loss

Every electrical appliance you use, whether powered by batteries or plugged into a power point, converts electrical energy into other forms of energy. Most of that energy is usually converted into useful energy — but some is converted into forms of energy that are wasted or not so useful. But all of the electrical energy is converted — that's the Law of Conservation of Energy in action. The table below shows some examples of energy conversion by electrical appliances. None of the wasted energy is actually lost.

Energy conversion by appliances

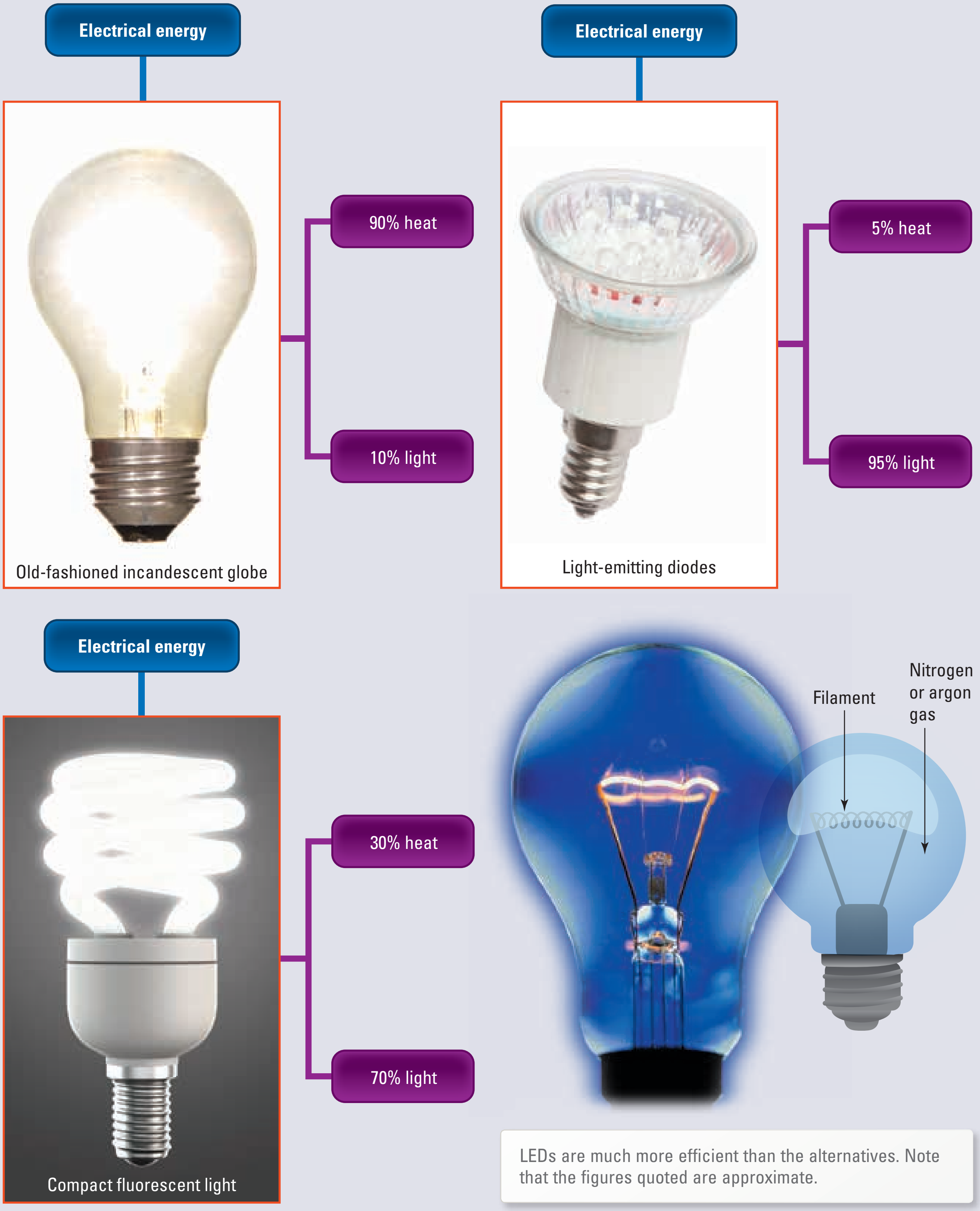
Appliance	Electrical energy usefully converted to . . .	Electrical energy wasted . . .
Microwave oven	thermal energy of food	heating air in the oven, plates and cups etc.
Television	light and sound	heating the television and the surrounding air
Hair dryer	thermal energy and kinetic energy of air	as sound
Electric cooktop	thermal energy of food	as light and heating the surrounding air

This loss of useful energy is also apparent when you step on the brake pedal in a car — not all the energy you transfer to the pedal is used to stop the car. Much of it is lost in the brakes themselves and to the surrounding air as heat. The same applies to using the brakes of a bicycle. Also, when you drop a tennis of cricket ball it never bounces back to its original height because some energy is lost as heat. On a larger scale it is seen in power stations, where the fuel, falling water, solar energy or any other energy source is used to produce electricity; some of the energy of the source is transformed to heat, warming the power equipment, the surrounding air and the water used as coolant. The 'loss' of useful energy is unavoidable.

Some types of lighting waste more energy than others. Old-fashioned incandescent light bulbs convert more energy to wasted heat than to light. They emit light only when the filament inside gets white hot. Fluorescent lights and LEDs (light-emitting diodes) waste very little energy. Almost all of the electrical energy is converted to light, so you use much less energy to produce the same amount of light than you would using an incandescent bulb.

HOW ABOUT THAT!

In old-fashioned incandescent light bulbs, electricity passes through a thin filament in the bulb, causing it to glow white hot. The light is a useful form of energy, but about 90% of the electrical energy is wasted as heat. Compact fluorescent lights (CFLs) offer a more energy-efficient form of lighting, but light-emitting diodes (LEDs) are even more efficient.



LEDs are much more efficient than the alternatives. Note that the figures quoted are approximate.

ONLINE PAGE PROOFS

Efficiency

The **efficiency** of a car, light bulb, gas heater, power station, solar cell or any other energy converter is a measure of its ability to provide useful energy. Efficiency is usually expressed as a percentage. The efficiency of the incandescent light globe pictured on the previous page is 10% because 10% of the total electrical energy input is usefully transformed into light. The efficiency of the compact fluorescent light is 70%, and the LED light is 95% efficient.

The efficiency of every device that uses fossil fuels is very important for the environment and life on Earth. Scientists and automotive engineers are constantly working on methods of reducing fuel consumption by:
- increasing the efficiency of burning petrol and other fossil fuels such as diesel by reducing the amount of energy wasted as heat
- changing the external design of cars to reduce the amount of energy needed to overcome air resistance
- searching for alternative fuels such as ethanol that can be produced from sugar cane and grain crops.

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Australian International Model Solar Challenge
Learn about the exciting annual event where Australian high school students compete by building and racing model cars and boats.
eles-0068

UNDERSTANDING AND INQUIRING

REMEMBER

1 State the Law of Conservation of Energy.

2 Which form of energy is observed when:
(a) an athlete runs
(b) a spring is squashed?

3 List five types of stored energy.

4 Describe the difference between gravitational potential energy and elastic potential energy.

5 Define the efficiency of an energy converter.

6 Outline three of the methods being used by scientists and automotive engineers to reduce the fuel consumption of cars.

THINK

7 Identify four types of energy that are present during a lightning strike.

8 From which type of energy does the sound of a cymbal come?

9 From which two types of energy does the sound of a bass drum come?

10 How can you tell that a high diver has gravitational potential energy?

11 Construct a table similar to the one below and use it to list the useful energy and the wasted energy converted by the following devices.
(a) A torch
(b) A wind-up toy
(c) A pop-up toaster
(d) A gas cooktop
(e) A car engine

Device	Source of energy	Energy usefully converted to . . .	Forms of energy wasted

12 When a tennis ball is bounced on the ground, it never returns to its original height. Does this break the Law of Conservation of Energy? Explain your answer.

13 Outline at least three reasons why efficiency is important for devices that use fossil fuels.

14 Suggest some methods that drivers could use to increase the fuel efficiency of their vehicles.

CREATE

15 Illustrate the energy transfers and transformations of the person on the trampoline shown on page XXX in the form of a flowchart.

16 Create a poster-sized flowchart to show the energy transformations that take place to produce lightning and thunder. (Think first about how the clouds become electrically charged during an electrical storm.)

INVESTIGATE

17 Research and report on the methods used by motor companies to increase the fuel efficiency of their cars since 1975.

18 Are solar-powered cars a realistic alternative to cars that run on fossil fuels or biofuels like ethanol? Find out what scientists, engineers and members of the public have contributed to the design of solar-powered vehicles.

19 Find out the purpose of the Australian International Solar Challenge and how you could become involved in it.

20 Use the **Coaster** interactivity in your eBookPLUS to identify the positions on a roller-coaster ride where the car has more kinetic energy and where it has more gravitational potential energy. **int-0226**

eBookplus

work sheets
10.1 Skateboard flick cards
10.2 Types of energy

Hot moves

If you accidentally touch a hotplate you'll find out quickly — and painfully — that heat travels from warm objects to cooler objects.

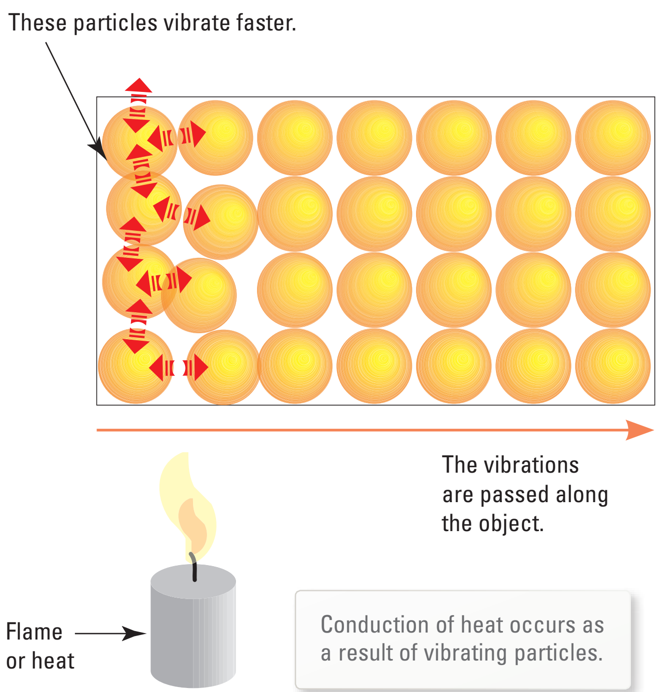
It is the rapid transfer of energy into your hand that causes the pain. Sports people sometimes use ice baths to assist with injury. The body heat is transferred quickly to the cold ice. If you touch something that has the same temperature as your hand, you won't feel any sensation of heat transfer into or away from your hand.

Heat is energy in transit from an object or substance to another object or substance with a lower temperature. Heat can move from one place to another in three different ways — by conduction, convection or radiation.

Conduction

If you've ever picked up a metal spoon that has been left in a hot saucepan of soup you will know that heat moves along the spoon and up to the handle. This is an example of **conduction** of heat. Metals are very good conductors of heat. Like all substances, metals are made up of tiny particles. The particles in all solid substances are vibrating. Of course, you can't see the vibrations because the particles are far too small to see — even with a microscope. When you heat a solid object, its temperature increases. The particles vibrate faster and bump into each other. The vibrations are passed from particle to particle along the object until the whole object is hot.

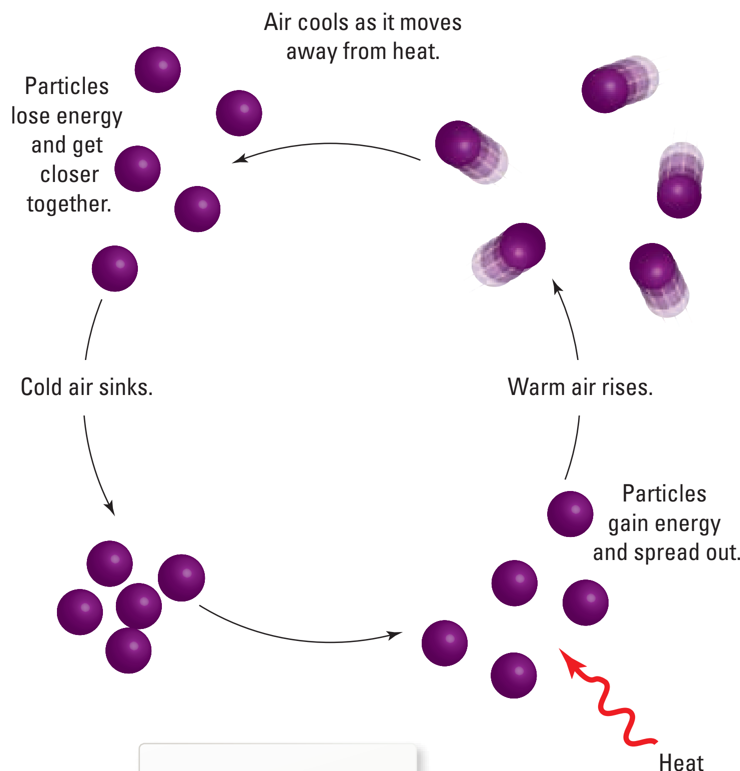
Not all solids conduct heat at the same rate. Metals, for example, are much better conductors than most other solids. Some solid substances are very poor conductors of heat. Glass, wood, rubber and plastic are all poor conductors of heat, and are called **insulators**. Many metal saucepans have a plastic or wooden handle. Suggest a reason for this.



Conduction of heat occurs as a result of vibrating particles.

Convection

The particles that make up solids are close to each other and held together tightly. They can vibrate faster only when heated. However, in liquids and gases the particles are further apart and can move around. So when they are heated, rather than the vibration passing between particles, the particles themselves can move. Heat can travel through liquids and gases by a process called **convection**.



Modelling heat transfer in air by convection

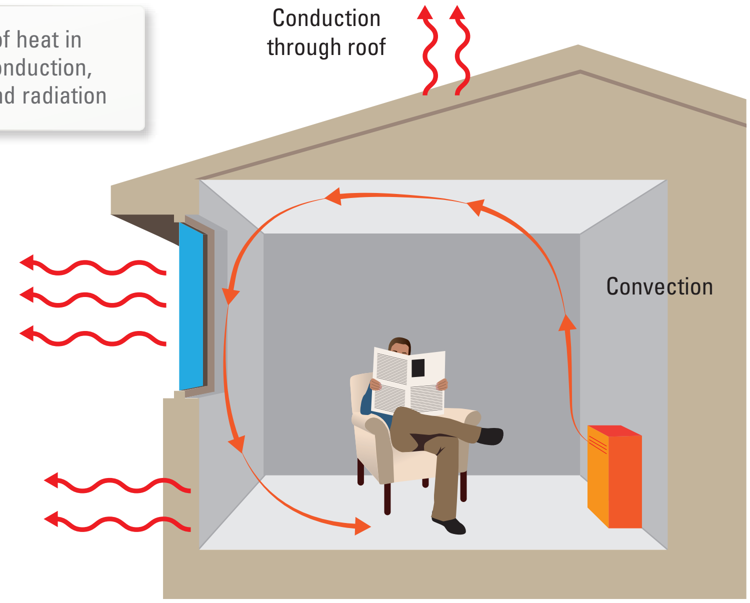
The figure in the right column of the previous page shows how convection takes place. Heat causes the particles of air to gain energy, move faster and spread out. This warmer air is less dense than the air around it, so it rises. As it rises it begins to cool. The particles lose some of the energy gained, slow down and move closer together. This cooler air is denser than the air around it, so it falls. The whole process then starts again, creating a pattern of circulation called a convection current.

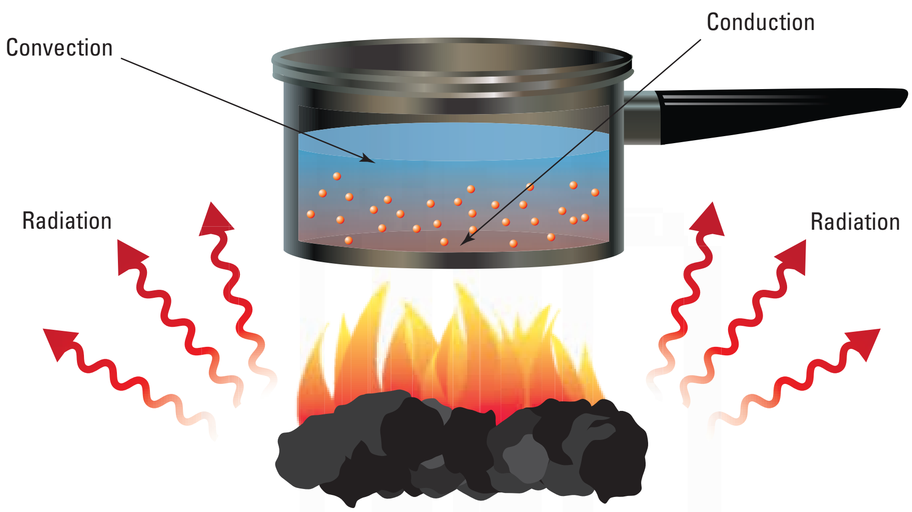
Gas wall heaters create convection currents with the aid of a fan that pushes warm air out near floor level so that it heats the entire room as the air rises.

Radiation

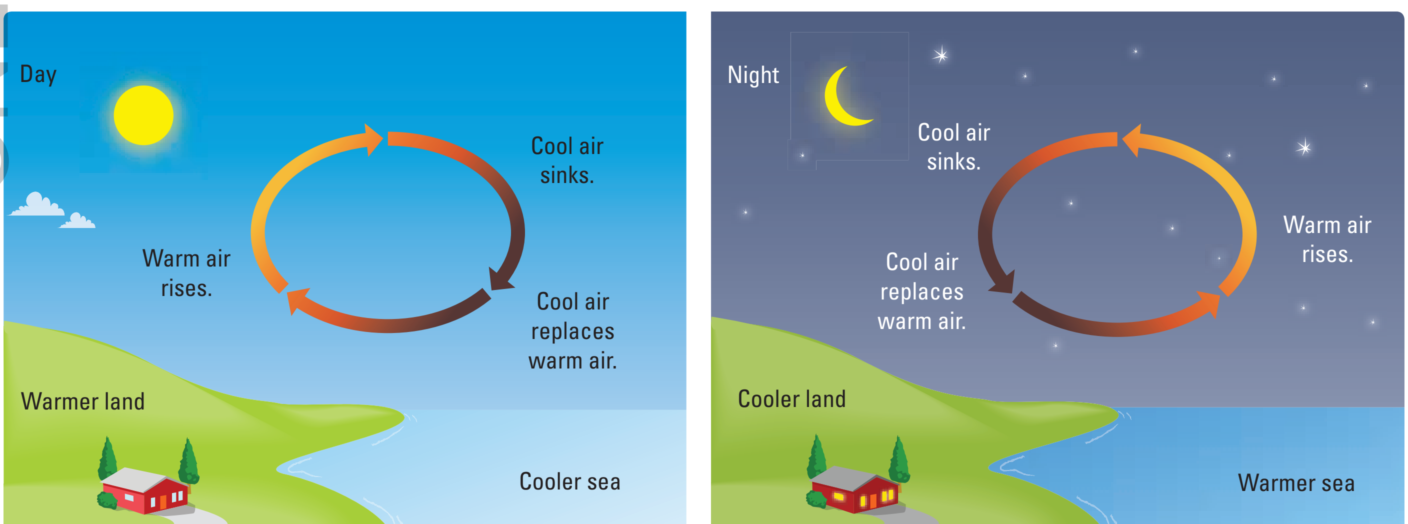
Heat from the sun cannot reach Earth by either conduction or convection because there are not enough particles in space to transfer heat by moving around or passing on vibrations. Heat from the sun reaches Earth by **radiation**. Heat transferred in this way is called **radiant heat**. Heat transfer by radiation is much faster than heat transfer by conduction or convection.

The transfer of heat in a house by conduction, convection and radiation





A camp cookout — heat is transferred by radiation, conduction and convection



Sea breezes caused by convection currents

INVESTIGATION 10.1

Moving particles

AIM To model convection currents in a liquid

Materials:

250 mL beaker
single small crystal of potassium permanganate
Bunsen burner and heatproof mat
tripod and gauze mat
tweezers
drinking straw

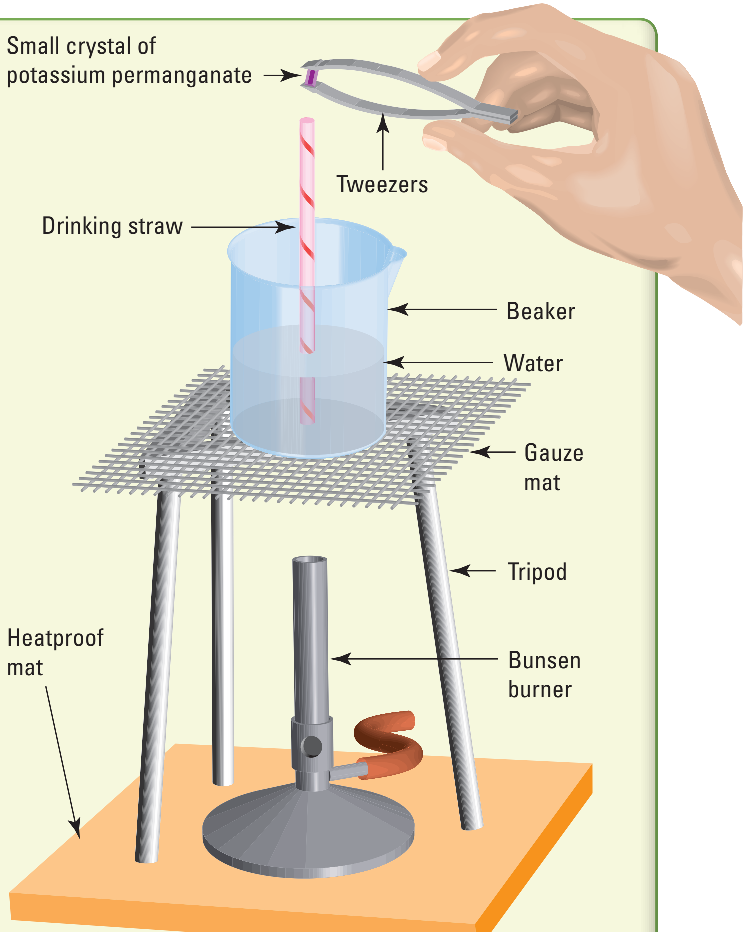
METHOD AND RESULTS

- Fill the beaker with water and place it on a gauze mat and tripod.
- Use the tweezers to drop a crystal of potassium permanganate down the drinking straw into the water at the bottom of the beaker.
- Slowly remove the straw, taking care not to disturb the water.
- Light the Bunsen burner and turn it to a blue flame. Be sure not to disturb the beaker.

1. Draw a diagram to show the movement of colour through the beaker. This will show the currents within the beaker.

DISCUSS AND EXPLAIN

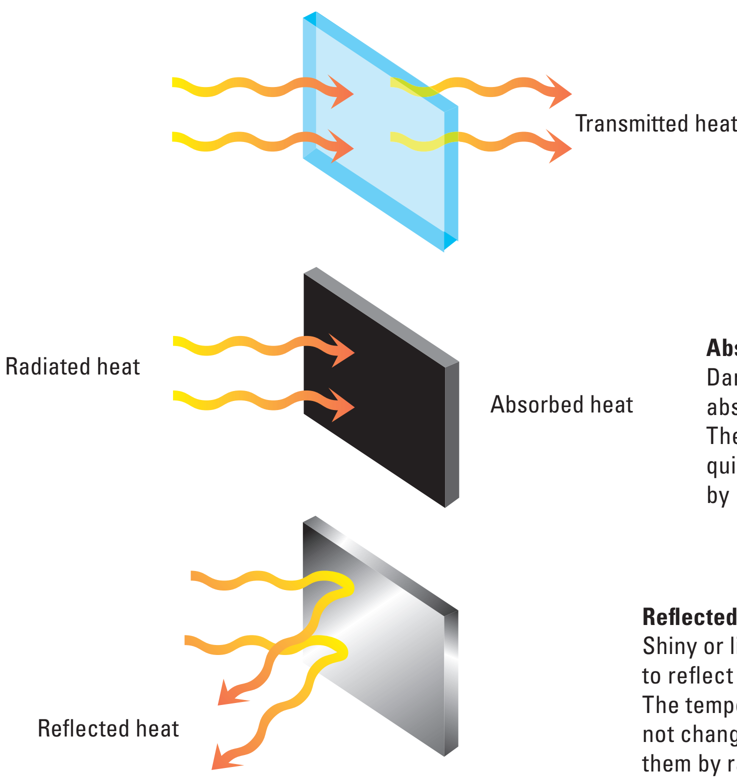
2. Explain why the colour moved in the way it did.
3. Is this experiment successful at modelling convection? Explain why or why not.



Drop the coloured crystal down the drinking straw.

Transmission, absorption and reflection

When radiant heat strikes a surface, it can be **reflected**, **transmitted** or **absorbed**. Most surfaces do all three; some surfaces are better reflectors, others are better absorbers and some transmit more heat. The diagrams on the right show how different surfaces are affected by radiant heat.



Transmitted radiant heat
Clear objects, like glass, allow light and radiant heat to pass through them. The temperature of these objects does not increase quickly when heat reaches them by radiation.

Absorbed radiant heat
Dark-coloured objects tend to absorb light and radiant heat. Their temperatures increase quickly when heat reaches them by radiation.

Reflected radiant heat
Shiny or light-coloured surfaces tend to reflect light and radiant heat away. The temperature of these objects does not change quickly when heat reaches them by radiation.

During cold weather, snakes lie against rocks that have absorbed some heat from the sun. The fast-moving particles in the rocks transfer some of their energy to the snake, warming it up.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Copy and complete the table below.

Type of heat transfer	Describe briefly how heat moves	Substances in which heat moves in this way
Conduction		
Convection		
Radiation		

2 What is an insulator? Name three different materials that can act as insulators.

3 Heat can travel through empty space (for example, between the sun and Earth). How does the heat move?

4 What three things can happen to radiated heat when it arrives at any surface?

THINK

5 Conduction occurs in solid materials like metals but is not an effective way of transferring heat in liquids and gases. Explain why this is so.

6 Draw a diagram similar to the one on the page xxx (top right) to show how air-conditioners push cool air out near the ceiling to create convection currents that cool rooms in hot weather.

7 When you hold a mug of coffee or hot soup, your hands feel warm. How is the heat transferred to your hands? Use a storyboard, cartoon or flowchart to illustrate your response.

8 Would it be hotter to sit in a black or a white car during summer? Why?

INVESTIGATE

9 Compare the advantages and disadvantages of evaporative and refrigerated air-conditioners.

10 How quickly do things cool? The rate at which substances cool is determined by many factors. A cup of hot chocolate will cool more rapidly than the same cup filled with thick vegetable soup. The material in the cup is one variable that affects how quickly cooling takes place. The size of the container, the temperature around the outside of the container, and the type of container are other variables that affect the rate of cooling.

Choose one variable to investigate. All other variables must remain the same so that the test is fair. If, for example, you decide to investigate the effect of the shape of the cup, you must make sure that nothing but the shape changes. The two or three shapes of cup you choose to investigate would need to contain the same amount of liquid, start at the same temperature, be made from the same materials, and be in the same surroundings.

- Write down the aim of your investigation and state your hypothesis.
- List the set of steps that you will follow.
- Decide what equipment is needed and make a list of it.
- Decide how your results will be recorded and draw up any necessary tables.
- Check with your teacher before beginning.
- Use your results to write a conclusion. State whether your hypothesis was supported.

A costly escape

Knowledge of how heat moves from a warm place to a cooler place can help you to save on the energy that is used to heat and cool your home.

Using less energy for heating and cooling also conserves valuable resources such as coal and natural gas that are used to generate electricity.

Staying warm

In winter, heat leaves the inside of a warm, cosy home by conduction, convection and radiation. New homes are designed to reduce heat losses by all three methods. However, there are also measures that occupants can take to reduce heat losses (and the bills that go with them).

Using the sun

The direction that a house faces, positioning of windows and skylights, and the types of trees planted around the house all affect the amount of sunlight and radiated heat that enter a home. **Deciduous** trees planted near north-facing windows allow radiated heat from the sun through in winter but block it out in summer.

Insulation

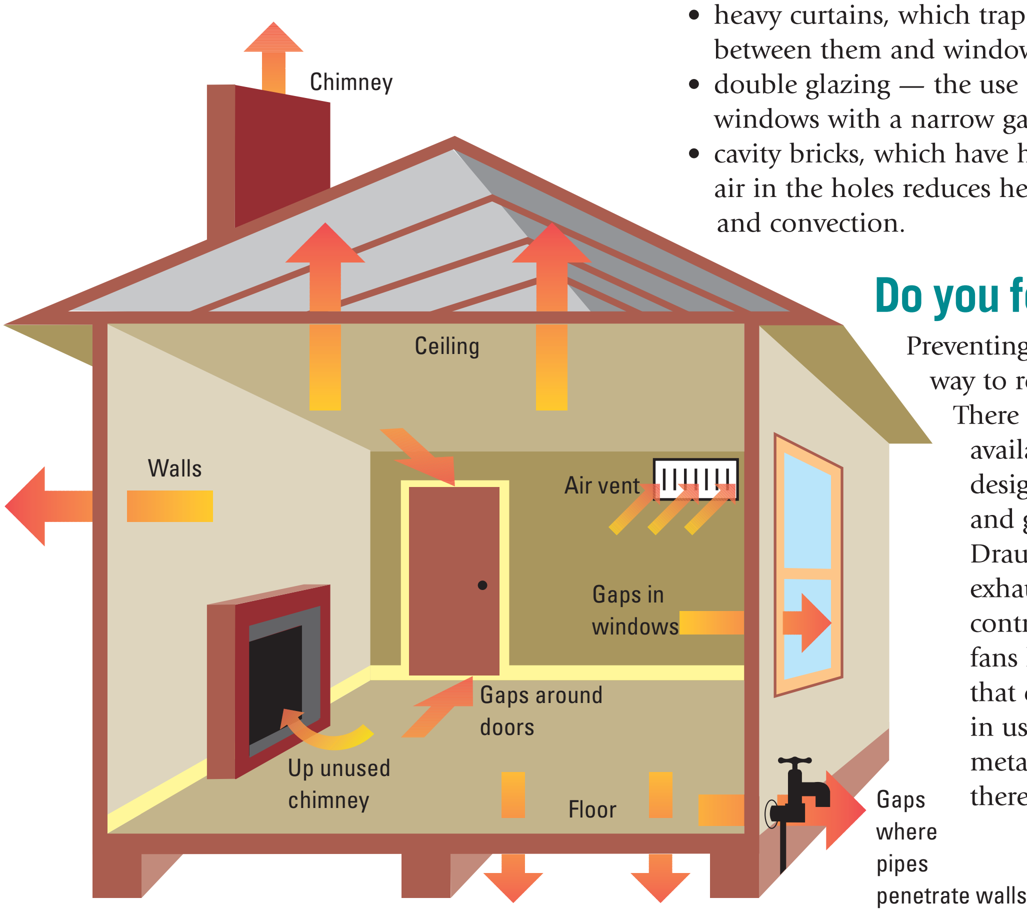
Heat loss by conduction occurs through the ceiling, walls, windows and floor. Since air is a very poor conductor of heat, materials containing air reduce heat loss. However, if the air is free to circulate, it can move away, taking heat with it. The best insulators, therefore, are those that contain air that is restricted from moving. Woollen clothes, birds' feathers and animal fur are all good insulators because they restrict heat loss by both conduction and convection.

Some ways in which insulation is used in the home include:

- ceiling insulation such as fibreglass batts and loose rockwool that can be blown in. These materials contain pockets of air that provide insulation, and reduce the loss of warm air from the roof by convection.
- cavity wall insulation, a foam that can be sprayed in between the inside and outside walls
- heavy curtains, which trap a still layer of air between them and windows
- double glazing — the use of two sheets of glass in windows with a narrow gap of air between them
- cavity bricks, which have holes in them. The still air in the holes reduces heat loss by conduction and convection.

Do you feel a draught?

Preventing draughts is the easiest way to reduce heat loss in winter. There are many products available from hardware stores designed to seal small cracks and gaps to stop draughts. Draughts from chimneys and exhaust fans are difficult to control, but some exhaust fans have automatic shutters that close when the fan is not in use. Chimneys may have a metal plate to seal off air when there is no fire alight.



Heat can escape from many different places.

INVESTIGATION 10.2

Investigating insulators

AIM To investigate the insulating ability of a range of materials

Materials:

6 empty soft drink cans
6 thermometers
newspaper
woollen cloth
cottonwool
polystyrene foam and sticky tape, or foam drink can holder
foam rubber
hot water
measuring cylinder
sticky tape (to tape on the materials)

METHOD AND RESULTS

(a) Plain (b) Newspaper (a few layers) (c) Woollen cloth (d) Cotton-wool (e) Foam drink can holder (f) Foam rubber

- Surround each can except one with a different material.
- Copy the table below into your workbook and use it to record your measurements.
- Measure out and pour 100 mL of hot water into each of the cans.
- Measure the temperature of the water in each can. Repeat the measurement of temperature every 5 minutes for 20 minutes.

Investigating insulators

Temperature of water in cans (°C)

	Time (minutes)				
Can covering	**0**	**5**	**10**	**15**	**20**
None					
Newspaper					
Woollen cloth					
Cottonwool					
Foam can holder					
Foam rubber					

1 Draw a bar graph that will allow you to compare the drop in temperature of the water in the cans after 20 minutes.

DISCUSS AND EXPLAIN

2 Which covering appears to be the most effective insulator?
3 Which one or more of the three methods of heat transfer does the most effective insulator reduce?
4 Use your data to suggest a good container for a mug of hot chocolate.
5 Why was one can left without a covering?
6 Are your conclusions reliable? Discuss the difficulties encountered in making sure that the comparison of insulators was fair.

Radiation

A warm house radiates heat in all directions. Heat loss by radiation can be reduced with shiny foil that reflects radiated heat. Foil can be added to insulation in the ceiling and is also used in external walls.

UNDERSTANDING AND INQUIRING

REMEMBER

1 What property makes a material a good insulator?
2 Installing insulation in the ceiling reduces which method (or methods) of heat transfer?
3 What is the cheapest way of reducing heat losses from your home in cold weather?

THINK

4 Foil placed in ceilings and walls is often referred to as 'insulation'. Is this term appropriate? Explain your answer.
5 What are convection currents? Draw a diagram to show how they move heat around a room.
6 Homes with central heating that are built on concrete slabs have heating ducts in the ceiling because they cannot be installed in the floor.
   (a) What is the disadvantage in having ducts in the ceiling?
   (b) Suggest a way of overcoming this disadvantage.
7 Loose clothing is recommended on hot days as it allows body heat to escape. Explain why loose clothing is better than close-fitting clothing for this purpose.

INVESTIGATE

8 What features of a thermos flask reduce heat loss by:
   (a) conduction
   (b) convection
   (c) radiation?

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work sheet 10.3 A costly escape

Light energy

Like all stars, the sun changes some of the energy stored inside it into light energy. A burning candle converts some of the chemical energy stored in wax into light energy. Some living things are also able to change chemical energy stored in their bodies into light energy.

Without light from the sun, the world would be in darkness. Plants would not grow and no other life on Earth would exist. However, light makes up only a very small fraction of the energy that comes to us from the sun.

Light travels through space at about 300 000 kilometres per second, taking almost 10 minutes to get here.

Each of the light sources shown here is luminous.

Sources of light

The sun is not the only source of light. Any objects or substances that give off their own light are said to be **luminous**. Examples of some other sources of light are shown on the right.

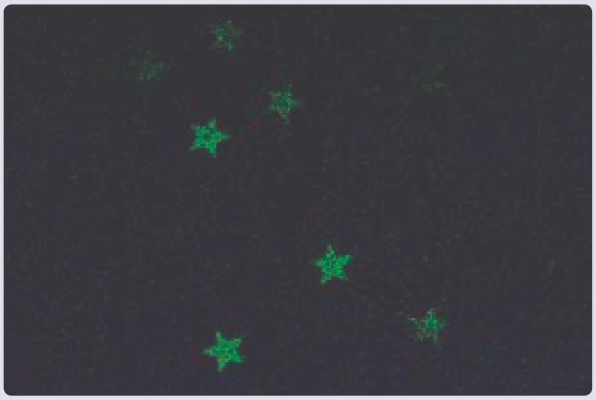
Most of the light sources shown are **incandescent**. They emit light because they are hot. The sun and all other stars, light bulbs and flames are incandescent. Other sources, such as fluorescent tubes, the paint on the hands and numerals of clocks and watches, fireflies, glow-worms and some deep-sea fish, emit light without getting hot — they are not incandescent. Living things that emit light without heat are referred to as **bioluminescent**.

Most things that you see are not luminous. We see **non-luminous** objects because light from luminous objects is reflected from them. They do not emit their own light. Light from luminous objects, such as the sun, light globes or fluorescent tubes, strikes them and is reflected into your eyes. The moon is not a luminous object. Its surface reflects light from the sun.

The firefly's light energy comes from a chemical reaction that takes place in its abdomen.

HOW ABOUT THAT!

Glow-in-the-dark stickers are made with a chemical called phosphor, which absorbs light energy. Phosphor then slowly releases this extra energy as a single colour — usually green. Because the light energy is released more slowly than it is absorbed, the sticker releases green light for quite a long time. This process is called phosphorescence.



The angler fish, living in darkness about 4000 metres below the ocean surface, uses a luminous lure to attract its prey.

The deep black sea

Light from the surface does not reach deep below the ocean. From a depth of about 1000 metres downwards, the ocean is in complete darkness. Imagine the problems the fish that live there have in finding food. Some deep-sea fish swim closer to the surface to get their food, but others spend all of their time in the dark. The angler fish wiggles a luminous lure to attract its prey. The viperfish uses bioluminescent lights in its open mouth to entice prey directly into its stomach. The black dragonfish produces red light from a spot just beneath its eye. This allows the dragonfish to see its prey without being seen itself, as most of its prey can't see red light.

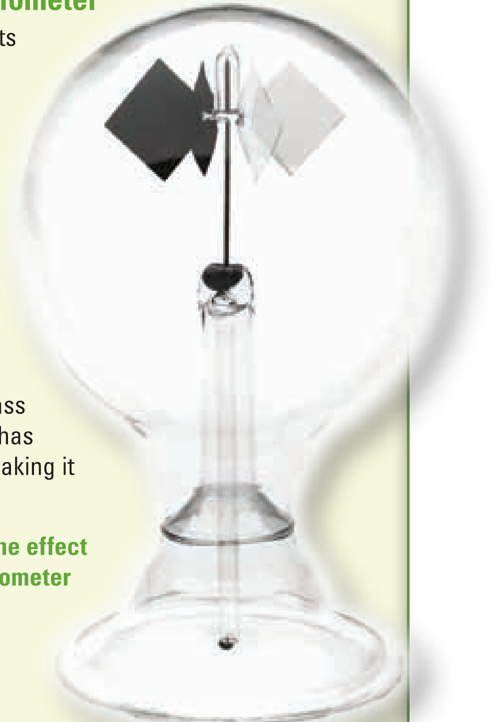
Seeing the light

Light is not normally visible between its source and any surface that it strikes. You can see a beam of light only if there are small particles in its path. The light is then **scattered** in many directions by the particles, some of it reaching your eye.

INVESTIGATION 10.3

Observing a radiometer

A radiometer consists of four vanes, each of which is black on one side and silver on the other. The vanes are balanced on a vertical support so that they can turn with very little friction. The mechanism is encased inside a glass bulb from which air has been pumped out, making it almost a vacuum.



AIM **To observe the effect of sunlight on a radiometer**

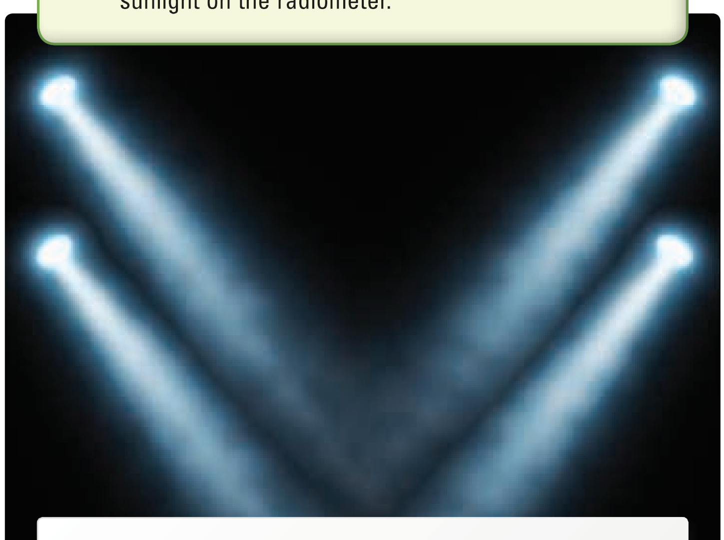
Materials:
radiometer

METHOD AND RESULTS

1. Put the radiometer in direct sunlight. Record your observations.
2. Put it in the shade. Record your observations again.

DISCUSS AND EXPLAIN

3. What effect does sunlight have on a radiometer?
4. How does this experiment demonstrate that sunlight is a form of energy?
5. Research a scientific theory to explain the effect of sunlight on the radiometer.



Light beams are visible only when there are particles in the air to scatter the light into your eyes. Light from a spotlight can be seen if there is smoke or fog in the air.

INVESTIGATION 10.4

Seeing the light

AIM To observe and explain the scattering of light

Materials:

moderately dark room
torch or projector
matches or a well-used chalk duster

METHOD

- Shine the torch or projector on a nearby wall.
- Now hit the chalk duster with your hand, or light and blow out a match, so that chalk dust or smoke falls between the light source and the wall.

DISCUSS AND EXPLAIN

1 Can you see the light beam between the light source and the wall without the chalk dust or smoke?

2 What changes when the chalk dust or smoke is present?

3 Explain what happens to the light from the source to make it visible.

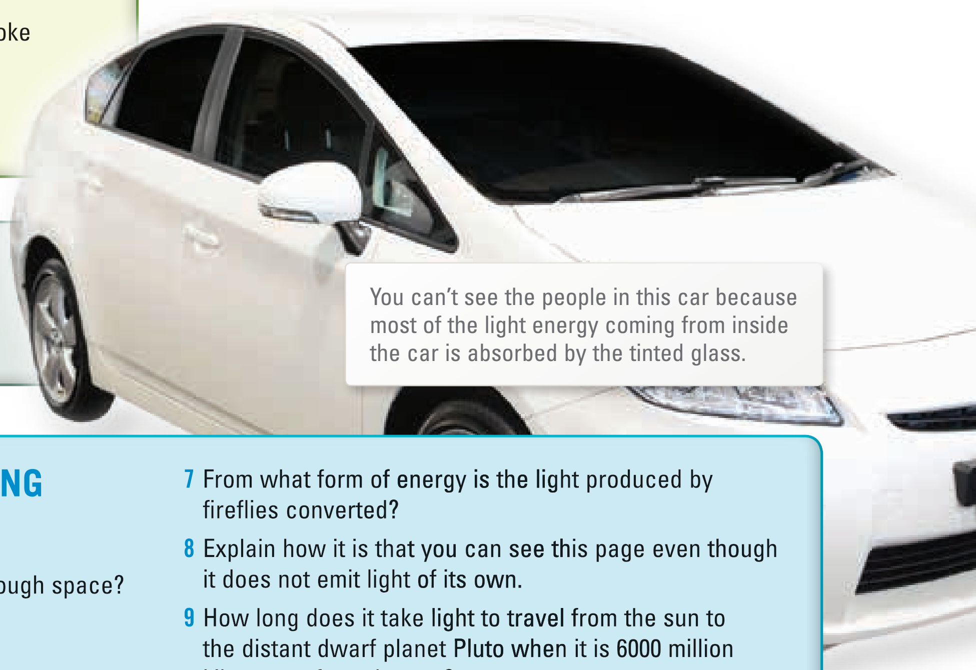
WHAT DOES IT MEAN?

The word *absorb* comes from the Latin word *sorbere*, meaning 'to suck in'.

Meeting new substances

When light energy travels from one substance to another, three things can happen to it.

1 It can be transmitted; that is, the light energy can travel through the substance. For example, light is transmitted through clear glass.
2 It can be absorbed; that is, the light energy can be transferred to particles inside the substance. For example, the tinted glass in many cars contains a substance that absorbs some of the light energy passing through it.
3 It can be reflected from the surface of the substance or reflected (scattered) by small particles inside the substance. For example, light is reflected from opaque objects like a piece of wood and scattered by particles of water in fog. This is how you are able to see them.



You can't see the people in this car because most of the light energy coming from inside the car is absorbed by the tinted glass.

UNDERSTANDING AND INQUIRING

REMEMBER

1 What is light and how fast does it travel through space?
2 (a) What does 'incandescent' mean?
(b) List two examples of light sources that are incandescent.
(c) List two examples of light sources that are not incandescent.
3 Why do you see the beam of light from a torch if it is foggy?
4 Describe what can happen to light energy travelling through the air when it meets a new substance.

THINK

5 Which of the following objects are luminous?
(a) The sun
(b) The moon
(c) The stars
(d) A burning candle
(e) This page
6 Apart from light, what other form of energy comes to Earth from the sun?
7 From what form of energy is the light produced by fireflies converted?
8 Explain how it is that you can see this page even though it does not emit light of its own.
9 How long does it take light to travel from the sun to the distant dwarf planet Pluto when it is 6000 million kilometres from the sun?
10 When light energy meets the surface of your sunglasses, what is the evidence that some of it has been:
(a) transmitted
(b) reflected
(c) absorbed?

INVESTIGATE

11 Find out how the energy that reaches the Earth is produced by the sun.
12 Research and report on an animal that produces light by bioluminescence.

eBook*plus* work sheet 10.4 Light energy

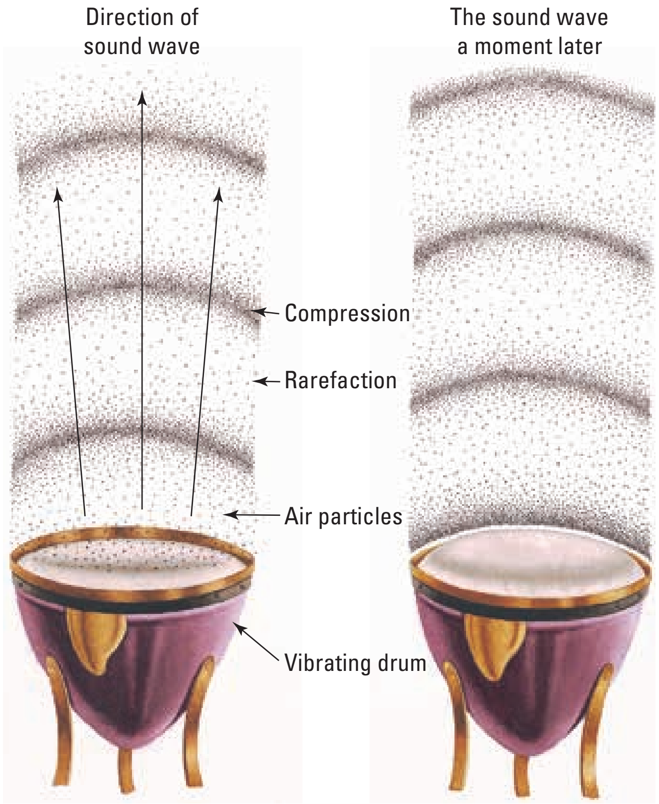
Sound energy

Humans and other animals rely heavily on sound energy to communicate with each other. You can use your voice, whistle or tap something to make a sound. How else can you make a sound?

Good vibrations

All sounds are caused by **vibrations**. When you speak or sing, the vocal cords in your throat vibrate. You can feel the vibrations if you put your hand over the front of your throat. When you strike a drum, the up and down movements of the drum skin cause the air around the drum to vibrate. When the drum skin moves down, the air particles near it are pulled back, spreading them out. A fraction of a second later the drum skin moves back up, squeezing the air particles together.

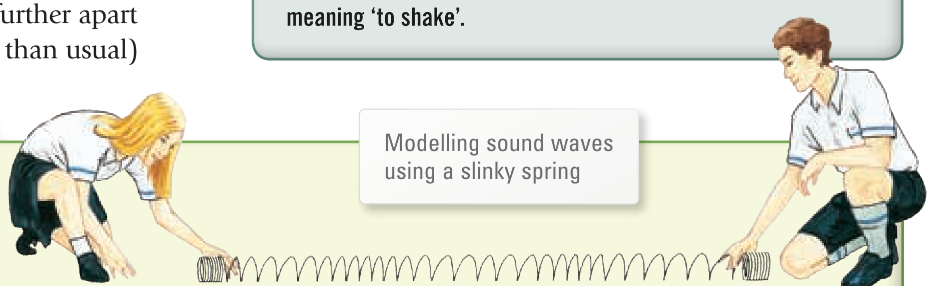
The energy of the air particles is transferred to nearby air particles, causing them to vibrate as well. This creates a moving series of **compressions** (air particles closer together than usual) and **rarefactions** (air particles further apart than usual)



Sound waves consist of a series of vibrating air particles.

WHAT DOES IT MEAN?

The word *vibration* comes from the Latin word *vibrare*, meaning 'to shake'.



Modelling sound waves using a slinky spring

INVESTIGATION 10.5

Modelling sound waves

AIM To model sound waves on a slinky

Materials:
slinky spring

METHOD

- Pull the slinky spring from both ends to stretch it a couple of metres along the floor.
- Create vibrations at one end of the slinky by moving the coils in and out.
- Watch the series of compressions and rarefactions travel to the opposite end and reflect back.

DISCUSS AND EXPLAIN

1. Describe how your model is similar to real sound waves.
2. Describe how your model is different from real sound waves.

HOW ABOUT THAT!

During a thunderstorm, the flash of lightning and the crash of thunder occur only a tiny fraction of a second apart. So why do you always hear thunder one or more seconds after you see the lightning? The answer lies in one of the differences between sound and light. Sound energy travels through the air at a speed of about 340 m/s. Light energy travels through air at a speed of 300 000 km/s. The delay between seeing lightning and hearing thunder is about 3 seconds for each kilometre that you are away from the lightning.

that move away from the source of the sound. These moving compressions and rarefactions are what we know as **sound waves**. If enough energy is transferred to the vibrating air, the sound waves reach your eardrum and you hear sound.

The highness or lowness of a sound is called its **pitch**. The faster an object vibrates, the higher the pitch of the sound it makes. A short string vibrates faster than a long one and so has a higher pitch. When you blow across the top of a straw, the air inside it vibrates. If the straw is shorter, the air inside vibrates faster, producing a higher pitched sound.

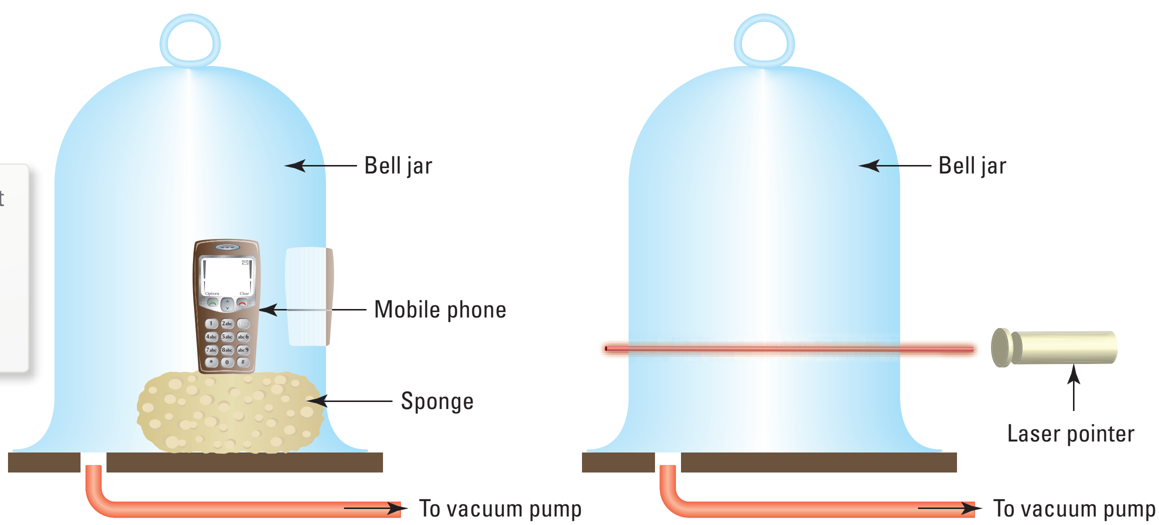
The need for air

When a mobile phone rings in a bell jar, the sound can be heard clearly. But if the air inside is sucked out by a vacuum pump, the sound can't be heard. Sound energy cannot travel through empty space — it can travel only by making particles vibrate. In empty space there are no particles to vibrate. Light energy, unlike sound, can travel through empty space. It doesn't need particles. So you can still see the ringing phone in the bell jar, even if you can't hear it.

Making it louder

If you pluck a stretched guitar string while it is not attached to a guitar, it vibrates but makes very little sound. If you strike a stretched drum skin while it is not attached to the drum, it makes very little noise. Even your own vocal cords make very little noise while they are vibrating. In each of these cases, a vibration is needed to create the sound but an enclosed region of air is needed to make the sound louder.

The air inside the body of an acoustic guitar is set vibrating by the strings. The air inside a drum vibrates when the drum skin is struck. The vibrating air inside your throat and mouth makes the sound created by your vocal cords loud enough to be heard.



Sound energy cannot travel through empty space. Sound waves require a medium to travel through; light does not.

INVESTIGATION 10.6

Vibrations and pitch

AIM **To investigate the relationship between the size of a vibrating object and pitch of the sound it produces**

Materials:

ruler
scissors
small beaker
2 straws
spatula
large beaker

METHOD AND RESULTS

- Hold a ruler over the edge of a table so that one end is firmly pushed down. Flick the overhanging end of the ruler.
- Move the ruler so that more of it is over the edge of the table and flick it again.

1. How does the sound change as the vibrating part of the ruler is made longer?

- Cut one straw into two so that one part is twice as long as the other part. Place the top of the uncut straw lightly against your bottom lip and blow gently across the opening. Listen to the sound made.
- Blow across the two shorter (cut) pieces of straw in the same way and listen to the sounds.

2. How does the sound change as the straws get shorter?

- Tap the side of a small beaker gently with a spatula and listen to the sound. Do the same with a larger beaker.

3. How does the sound of the large beaker compare with the sound of the smaller one?

DISCUSS AND EXPLAIN

4. How would you change each of the following to make a higher pitched sound?
   (a) The length of a vibrating strip of wood
   (b) The length of a tube of air
   (c) The size of a cymbal

INVESTIGATION 10.7

Making it louder

AIM **To explore methods of increasing the loudness of sound**

Materials:

guitar
guitar string
tuning fork

METHOD AND RESULTS

- Pluck a stretched guitar string. Listen to the sound it makes.
- Pluck a similar string attached to a guitar.

1. How does the sound of a plucked string change when it is attached to a guitar?

- Strike a tuning fork on the sole of your shoe and listen to the sound it makes. While it is still vibrating, place the base of the fork on a solid table surface.

2. How does the sound change when the tuning fork is placed on the table?

DISCUSS AND EXPLAIN

3. Explain why the sound changes in each case.

The sounds of music

How do musical instruments produce sound? The energy comes from the person playing the instrument — but what does the instrument do to convert that energy into sound?

With an acoustic guitar, the vibrations are made by plucking the strings. The air around the sound hole vibrates, causing the air inside the body of the guitar to vibrate. In an electric guitar, a microphone or pick-up detects the vibrating air and an amplifier is used to make the sound louder. The pitch of the sound made by a guitar is increased by shortening the strings using your fingers, tightening the strings or using lighter strings.

A saxophone's vibrations are first made when air is blown across a thin wooden reed. The air inside the saxophone then vibrates, making a loud sound. The pitch can be changed by using keys to open or close holes. When all the holes are closed, the saxophone contains a long column of air, producing a low-pitched sound. As holes are opened, the length of the air column becomes shorter, and the pitch increases.

The didgeridoo is a wind instrument that has no holes to change the length of the column of vibrating air. The player blows into the instrument using loosely vibrating lips to control how quickly the air inside vibrates.

Sounding great

Like light, sound energy can be transmitted, reflected or absorbed when it meets a new substance.

- All materials transmit some sound, some better than others. That's why you can sometimes hear conversations from the other side of a wall.
- Sound is reflected from hard substances like the tiles in your bathroom. Each note that you sing in the shower lasts longer because it is reflected over and over again from hard surfaces. This effect is called **reverberation**.
- Soft materials, like curtains and carpet, absorb much more sound than walls of plaster or tiles.

INVESTIGATION 10.8

Making music

AIM **To explore the ways in which musical instruments make sound**

Materials:
a small selection of musical instruments

METHOD

- If musical instruments are available in your classroom, have someone demonstrate how they work.
- Look at the musical instruments illustrated below.

DISCUSS AND EXPLAIN

1. For each instrument, write down:
   (a) what the player does to make the instrument work
   (b) what vibrates to make musical sounds.
2. What do all of the musical instruments have in common about the way they make sound? What differences are there in how they make sound?

Concert halls are designed to control the transmission, reflection and absorption of sound. For example, the timber in the panelling on the ceiling and walls of the concert hall in the Melbourne Recital Centre was selected because it minimises reflection and reverberation. In the Melbourne Concert Hall, Hamer Hall, heavy curtains behind the audience can be closed to increase the amount of sound absorbed.

The Elisabeth Murdoch Hall at the Melbourne Recital Centre

UNDERSTANDING AND INQUIRING

REMEMBER

1 What is the cause of all sounds?

2 When compared with air particles in a silent room, how are the particles in compressions and rarefactions different?

3 Explain why sound can't travel through empty space.

4 If you blow across the top of a straw, a sound is made. How could you increase the pitch of the sound? How do we know, without taking any measurements, that light travels through air faster than sound?

5 Which vibrates more quickly — a long string or a short string made of the same material?

6 Describe what can happen to sound energy travelling through the air when it meets a new substance.

7 Which types of surfaces cause reverberation?

THINK

8 Is sound energy a form of kinetic energy? Explain your answer.

9 Explain why the mobile phone in the bell jar needed to be sitting on a sponge when the air was removed.

10 Imagine that light energy couldn't travel through empty space. What would you observe if the air was removed from a bell jar containing a ringing mobile phone?

11 How would you expect a carpeted classroom to sound compared with one with a hard vinyl floor? Give reasons for the differences.

12 How are different notes played on:
(a) a single string of a guitar?
(b) a recorder?
(c) a xylophone?

13 Complete the gaps in the following table.

Musical instrument	What vibrates first?	What makes the sound louder?
Guitar	Plucked string	Air inside guitar
Trumpet	Player's lips	
Drum		Air inside drum
Saxophone		Air inside saxophone
	String hit by hammers	Air inside instrument

CREATE AND EXPLAIN

14 Make a string telephone. You will need about five metres of string and two open and empty cans. Punch a small hole in the bottom of each can. Thread the string through each hole and tie a knot to keep the string in place. Hold the cans far enough apart so that the string is tight. Talk into the can at one end while your partner listens at the other end.
(a) How does the sound travel from one can to the other?
(b) Does the sound change if you make the string tighter or looser?
(c) Would a string telephone work without the cans? Why are the cans used?

INVESTIGATE

15 Find out more about the following careers that involve using and understanding sound energy.
(a) Audiologist
(b) Acoustic engineer
(c) Audio engineer

STUDY CHECKLIST

ENERGY TRANSFERS AND TRANSFORMATIONS

- ☐ define the term 'energy'
- ☐ identify bodies that possess kinetic energy because of their motion
- ☐ define potential energy as stored energy
- ☐ differentiate between gravitational, chemical and elastic potential energy
- ☐ outline examples of transformations from potential and kinetic energy into other forms of energy
- ☐ recognise that heat energy is always produced as a by-product of energy transfers
- ☐ use flow diagrams to illustrate changes between different forms of energy

HEAT, LIGHT AND SOUND ENERGY

- ☐ define heat as energy in transit from one object or substance to another object or substance with a lower temperature
- ☐ describe and compare the transfer of heat by conduction, convection and radiation
- ☐ differentiate between luminous and non-luminous objects
- ☐ relate the ability to see non-luminous objects to the scattering and reflection of light
- ☐ describe sound as a series of vibrating air particles
- ☐ recognise that heat, light and sound energy can be transmitted, reflected or absorbed

SCIENCE AS A HUMAN ENDEAVOUR

- ☐ explain how the unwanted transfer of heat can be decreased to reduce the amount of energy needed for home heating, cooling and lighting
- ☐ describe the energy transformations involved in playing a variety of musical instruments
- ☐ investigate how energy efficiency can reduce energy consumption
- ☐ investigate the development of more energy-efficient motor vehicles

eBookplus DIGITAL RESOURCES

ANSWERS for this chapter can be found online in your eBookPLUS.

Online section

This section of the chapter can be found online in your eBookPLUS.

10.6 Thinking tools: Matrixes and Venn diagrams (eBookplus ONLINE ONLY)

Individual pathways

Activity 10.1	Activity 10.2	Activity 10.3
Transferring and transforming energy	Investigating energy	Analysing energy
doc-6093	doc-6094	doc-6095

FOCUS activity

Access more details about focus activities for this chapter in your eBookPLUS. doc-10560

eLessons

Energy in disguise

Did you know that all energy is constantly being transformed and transferred from one object to another? This eLesson helps you to discover that there's more going on in your world than meets the eye as you learn about the different types of energy and the laws that govern them. A worksheet is attached to further your understanding.

Searchlight ID: eles-0063

Australian International Model Solar Challenge

Learn about the exciting annual event where Australian high school students compete by building and racing model cars and boats.

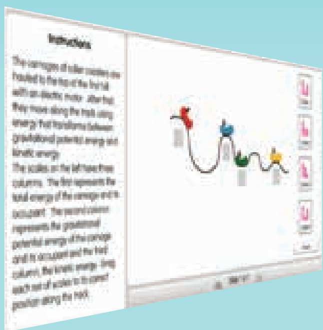
Searchlight IN: eles-0068

Interactivity

Coaster

This interactivity helps you apply your knowledge of energy to an amusement ride. Identify the positions in a roller-coaster ride where the car would have more kinetic energy and where it would have more gravitational energy. Instant feedback is provided.

Searchlight ID: int-0226



LOOKING BACK

1 Replace each of the following descriptions with a single word.
(a) Energy associated with all moving objects
(b) Energy that is stored
(c) The form of energy that causes an object to have a high temperature
(d) The form of energy stored in a battery that is not connected to anything
(e) The source of most of the Earth's light

2 Explain why the amount of energy in the universe never changes.

3 Describe an example of an object that has:
(a) elastic potential energy
(b) gravitational potential energy.

4 Draw a flowchart to illustrate the energy transformations that take place:
(a) after you switch on a torch
(b) when a firecracker is lit
(c) when a ball rolls down a hill and then up another hill.

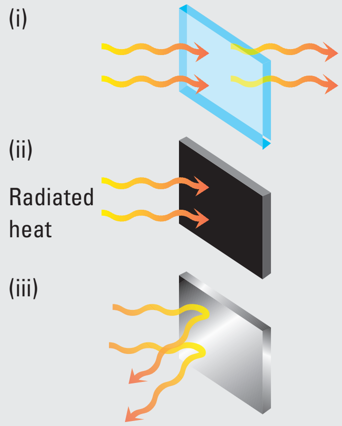
5 When a kettle of water is boiled on a gas cooktop, not all of the energy stored in the gas is used to heat the water. Where does the rest of the energy go?

6 Explain why it is not possible for an energy converter like a battery or car to have an efficiency of 100%.

7 Explain how fibreglass batts are able to reduce the loss of heat through the ceiling by both conduction and convection.

8 Heat moves from regions of high temperature to regions of low temperature by conduction, convection or radiation. In which of these three ways is heat most likely to be transferred:
(a) from a frying pan to an egg being fried
(b) from the sun to the planets of the solar system
(c) through water in a saucepan on a hotplate or gas burner
(d) through a metal spoon being used to stir hot soup
(e) from a very hot and bright light globe near the ceiling to your body directly beneath?

9 Each of the diagrams on the right shows radiated heat falling on a solid object. Which diagram shows heat being:
(a) absorbed
(b) reflected
(c) transmitted?



10 Explain how your body keeps its core temperature at 37 °C even when the air temperature is greater than this.

11 Explain how you are able to see an object like a tree even though it doesn't produce its own light energy.

12 Make a list of as many luminous objects as you can.

13 Why is it incorrect to describe fluorescent lights as incandescent?

14 You can't normally see the beam of light coming from a car headlight. However you can see the beams if there is fog or smoke in the air. How does the fog or smoke make a difference?

15 When a sound is made, what happens to the particles in the regions of the air nearby that are called:
(a) compressions
(b) rarefactions?

16 When an object making sound vibrates faster, what happens to the pitch of the sound?

17 When you sing in the shower the sound of your voice reverberates.
(a) What happens to sound energy to cause reverberation?
(b) Why don't you observe reverberation when you sing in a room with carpet and soft curtains?
(c) In some outdoor places, if you speak loudly you can hear an echo. For example, you might say 'hello' and a second or two later you hear the word 'hello' again. Explain how an echo is different from a reverberation.

18 Explain what is wrong with this cartoon.

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work sheet — 10.5 Energy: Puzzles

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Going green

SEARCHLIGHT ID: PRO-0093

Scenario

As the supply of fossil fuels dwindles, cities become more crowded and human-caused global warming becomes an unavoidable reality, an increasing number of people are opting for a more self-sufficient lifestyle. To meet this need, an increasing number of architecture and building firms specialise in the design and construction of energy-efficient houses that are able to exist off the electricity grid indefinitely because they use electricity generation systems that meet all of the household's needs using renewable energy sources.

You and your team at Sustainable Housing Solutions have been approached by a potential client who wants to build a series of sustainable eco-tourist cottages in remote locations across the country. To see whether your company should be awarded the lucrative contract to oversee the work on the whole chain of cottages, the client has asked you to make a presentation detailing how you would make one of these cottages as energy efficient and self-sustaining as possible. You can place this trial cottage anywhere in the country for your presentation purposes, provided that it is at least 100 km away from any town with a population greater than 5000 people. Other criteria must also be met as follows:

- All of the cottages will have the same layout and will be constructed of mud bricks and have tiled roofs (you will be given a copy of the plan). While you can change the orientation and location of the cottage, you cannot change the design or these construction materials.
- Each cottage must have the following appliances: refrigerator, washing machine, stove, microwave, TV set, DVD player and stereo system. Smaller appliances such as toasters, shavers, hairdryers and computers may occasionally be used by guests as well.
- The cottages must be cool in summer and warm in winter; the client is not opposed to the idea of a reverse-cycle air-conditioner or fans.
- There must be sufficient lighting to be able to read in every room.
- The cottages will not be attached to the national electricity grid — all of the electricity needs of each cottage must be met using a renewable energy source in its area. (Water will be provided from rainwater tanks and septic tanks will take care of the sewage.)

Your task

Your team will prepare and deliver a report for the client that provides the following information:

- The best location to place the trial cottage (keeping in mind that it can be placed somewhere close to a source of renewable energy)
- Suggestions as to how the cottage can be made as energy efficient as possible
- A detailed estimate of how much electricity will need to be generated to power the cottage and run appliances
- A justified recommendation as to which renewable energy system should be used to generate that amount of electricity and how it would be supplied to the trial cottage
- An estimate of how much the energy system will cost, using costs for similar systems available on the internet as a guideline.

The report will take the form of an oral presentation with visuals (which may include PowerPoint slides and models). The presentation should be between six and eight minutes long.

Process

Open the ProjectsPLUS application for this chapter located in your eBookPLUS. Watch the introductory video lesson and then click the 'Start Project' button to set up your project group. You can complete this project individually or invite other members of your class to form a group. Save your settings and the project will be launched.