10 Energy

LEARNING SEQUENCE

10.1 Overview

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10.1.1 Introduction

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 (potential energy) 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.

FIGURE 10.1 Fireworks are a spectacular display of energy transformation.

on Resources

Video eLessons Energy transformations (eles-2677)

Watch the video of energy transformations to visualise the conversion between potential energy and kinetic energy as an object moves along a rollercoaster.

10.1.2 Think about energy

1. Which type of energy do you find in chocolate?
2. When you drop a tennis ball to the ground, why doesn't it return to its initial height?
3. How much electrical energy is wasted as heat by an incandescent light globe?
4. How does ceiling insulation keep your house warmer in winter?
5. How do glow-in-the-dark stickers work?
6. Why does your image look different in a mirror?
7. How is a rainbow formed?
8. What creates the unique sound when a didgeridoo is played?

10.1.3 Science inquiry

Potential energy and kinetic energy

All substances and objects possess **potential energy**, but until it is transformed into other types of energy you will not be able to see it. For example the energy stored in fireworks only becomes apparent when it explodes, transferring the stored energy into light, heat and sound. When a diver dives from a platform or diving board, the energy stored in them because of their height above the ground is transformed to **kinetic energy** they gain on the way down. The energy stored in the stretched string of a bow is transformed into the kinetic energy of the arrow when it is released.

potential energy energy that has the potential to do work and so the energy is 'stored', such as gravitational energy, elastic energy and chemical energy

kinetic energy energy due to the motion of an object

FIGURE 10.2 Potential energy is all around us. Examples include elastic potential energy in bows and the gravitational potential energy we transform into kinetic energy when we dive off a diving board.

1. Complete table given. One example has been completed for you.

TABLE Releasing and transforming energy of different objects

Object	What to do to release the stored energy	Potential energy is 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.
   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?

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eWorkbooks Topic 10 (ewbk-5158)
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10.2 Different forms of energy

LEARNING INTENTION

At the end of this subtopic you will be able to describe the different forms that energy can take, and be able to classify them as potential energy or kinetic energy.

10.2.1 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 (e.g. from a cricket bat to a ball) or transformed into a different form (e.g. from electrical into sound)
- energy can be stored.

The SI unit of energy is the joule (J).

10.2.2 Types of energy

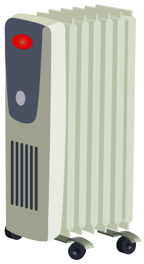
All forms of energy can be classified as either potential energy or kinetic energy. Potential energy is the energy related to position. Kinetic energy is the energy of a moving object.

Many forms of kinetic energy, such as light, sound and thermal energy are very easily observed. Potential energy has the 'potential' to make something happen, so is not easily observed until it is transformed into another type of energy.

Law of Conservation of Energy
a law that states that energy cannot be created or destroyed

TABLE 10.1 Types of energy

Potential energy (stored energy that, when released, is converted to forms of kinetic energy)	**Kinetic energy (often converted from potential energy, these are more easily observed by our senses)**
Gravitational (potential energy of an object elevated above the ground) 	Kinetic (energy possessed by objects that are moving) 

Elastic (energy stored by an elastic object that is stretched, such as a spring or rubber band) 	Heat (energy that causes objects to gain temperature) 
Chemical (energy stored in chemicals that is released as heat, sound, light or other forms of energy in a chemical reaction) 	Light (energy that may be released, for example when an object is hot or by a nuclear reaction in a star)
Nuclear (energy stored in the nucleus of atoms that can be released slowly, such as in a nuclear reactor, or quickly, such as in a nuclear explosion) 	Sound (energy carried by vibrating particles and detected by the ear) 
Electrical (energy provided by the movement of electrons or build-up of electric charge.) 	Magnetic (energy stored in magnets or metals placed in a magnetic field) 

10.2.3 Potential energy

Potential energy is the energy associated with the position of an object. Potential energy can be a result of stretching or squashing an object, lifting an object above the ground, or keeping unlike charges apart.

FIGURE 10.4 Types of potential energy

Potential energy

- Gravitational
- Elastic
- Chemical
- Electrical
- Magnetic
- Nuclear

FIGURE 10.3 Gravitational energy is converted into kinetic energy when we fall.

Gravitational potential energy

Gravitational potential energy is the result of gravity. All objects are attracted to the Earth; the heavier the object and the further the object is from Earth, the stronger the attraction.

When an object is lifted above the ground or moved away from the Earth's surface, it has the potential to fall back to the Earth's surface as soon as it is released, hence it is said to have gravitational potential energy. The heavier the object and the further it is from Earth, the more gravitational potential energy it has.

Elastic potential energy

When the shape of an object is changed, it gains or loses elastic potential energy. A good example of this is a sling shot. When the rubber band is pulled back, it gains elastic potential energy. The more the band is stretched, the more elastic potential energy it gains. While the rubber band is held stretched, it maintains its elastic potential energy that has the potential to make something happen as soon as it is released.

FIGURE 10.5 The stretched rubber in a slingshot stores elastic potential energy.

Chemical potential energy

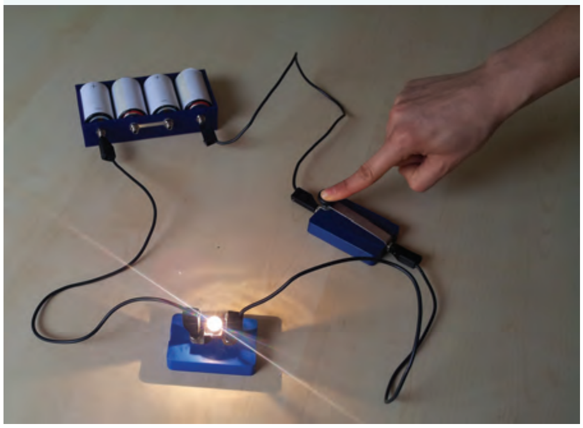
An object is said to have chemical potential energy when the chemicals inside it have the potential to react and make something happen. One example of this is a battery. When the two terminals of a battery are connected, a chemical reaction takes place that results in the flow of electricity. Another example is the chemical energy in food and drinks. When eaten or drunk, food and drink release their stored chemical energy to our body so that we have energy to do things.

FIGURE 10.6 The chemical potential energy in foods and drinks is converted into the energy that we use to power our muscles.

Electrical potential energy

All substances are made up of positive and negative charges. When opposite charges are separated, they are said to have electrical potential energy, because as soon as they are released they are attracted together again. As the charges come together again, they release their electrical potential energy into other forms of energy. If this takes place in an electrical circuit, the stored electrical potential energy is released to the connecting wires and components of the circuit, such as a light globe.

FIGURE 10.7 Electric potential energy causes electricity to flow through the circuit shown, providing power to the light.



Magnetic potential energy

Magnetic fields provide another form of potential energy, called magnetic potential energy. It is easy to understand magnetic potential by playing around with some magnets. If you hold two magnets so that they are attracted to each other you will feel the pull of the magnets attempting to reach each other. If released the magnetic potential energy will cause them to accelerate together.

Nuclear potential energy

The energy stored in the nucleus of atoms is called nuclear potential energy, because if the nuclei can be made to split or combine, a huge amount of energy has the potential to be released. There are four types of nuclear reactions that can take place: **fission, fusion, nuclear decay** and **transmutation**. Fission involves splitting a heavy nucleus into two or more smaller nuclei, releasing a huge amount of energy in the process. Fusion involves two or more lighter nuclei coming together to make one heavier nucleus. Nuclear decay involves an unstable **isotope** of a particular **element** spontaneously transforming into a new element. Transmutation refers to when an element is bombarded with high energy neutrons in an attempt to convert it to another element.

fission the process whereby a large nucleus splits into smaller fragments releasing large amounts of energy

fusion the process whereby two small nuclei combine to form a larger nuclei releasing large amounts of energy

nuclear decay the spontaneous decay of unstable nuclei to a new nucleus

transmutation the process whereby a nucleus is bombarded with high energy neutrons in an attempt to convert it to another element

isotope atoms of the same element that differ in the number of neutrons in the nucleus

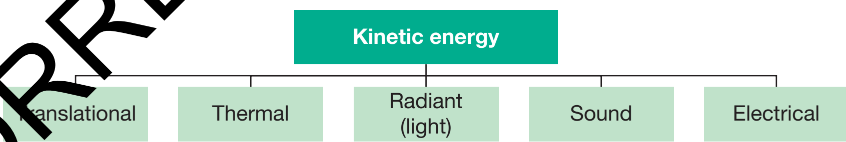
element pure substance made up of only one type of atom

FIGURE 10.8 The amount of nuclear potential energy that is released in nuclear reactions is so large it causes enormous explosion like this one.

10.2.4 Kinetic energy

Kinetic energy exists in many different forms. All kinetic energy involves movement, whether it be movement of objects that we see every day, the vibration of particles as thermal energy or other forms such as sound, light or electrical energy.

FIGURE 10.9 Types of kinetic energy



Translational kinetic energy

An object that is moving has translational kinetic energy. The heavier an object and the faster it travels, the more translational kinetic energy it possesses. There are some obvious examples of translational kinetic energy, such as a person walking, a ball rolling, or a car driving, but some forms of kinetic energy are less obvious.

FIGURE 10.10 The blades in wind turbines contain large amounts of translational kinetic energy when they rotate.

Thermal energy

Thermal energy is more commonly known as heat, although more specifically, heat is defined as the transfer of thermal energy, which flows from hotter objects to cooler objects. Thermal energy the result of the movement of atoms, molecules or ions within a solid, liquid or gas. Thermal energy transfer can occur as a result of the movement of atoms, molecules or ions within a solid, liquid or gas. This type of transfer is a form of kinetic energy because it requires the movement of particles. However, thermal energy can also occur as a result of radiation, even without the presence of particles, such as between the Sun and the Earth, and in outer space. We experience heating when thermal energy is transferred into our body from an object or substance with a higher temperature. Cooling is experienced when thermal energy is transferred out of your body to an object or substance with a lower temperature. If you touch a cold object with your hand, such as an ice block, thermal energy moves from your hand to the ice block. If you touch a hot object, such as a pan on the stove, thermal energy moves from the pan to your hand.

FIGURE 10.11 When you touch a cold object you transfer thermal energy to it, heating it slightly.

Radiant energy

Radiant energy is the energy of **electromagnetic waves**. The light that we can see with our eyes are electromagnetic waves with particular frequencies in the **visible spectrum**, which is only one part of a broader **electromagnetic spectrum**. Not all light can be seen with our eyes. Examples of radiant energy include light from the Sun, light bulbs, lamps, torches and flames, x-rays, radio waves and microwaves. Radiant energy is classified as a form of kinetic energy as waves (and/or particles) carry radiation from one source to another.

FIGURE 10.12 Hot objects release radiant energy in the form of light.

electromagnetic waves waves of electromagnetic radiation, light being just one example

visible spectrum different colours that combine to make up white light; they are separated in rainbows

electromagnetic spectrum complete range of wavelengths of energy radiated as electric and magnetic fields

Sound energy

Sound involves the vibration of particles in the air, or another medium. It is therefore a form of kinetic energy. A sound source, such as an instrument or our voice, vibrates, causing the nearby particles in the air to vibrate. We are able to hear some sounds because our ear can detect the vibration of particles and send a message to our brain which tells us the type of sound we are hearing.

FIGURE 10.13 The strings on a guitar vibrate, sending sound waves through the air.

Electrical energy

Electrical energy can be a form of both potential energy and kinetic energy. When electric charges are moving through a circuit, it is a form of kinetic energy called electricity. Electricity is used to power most of your favourite devices, such as your television, your smart phone and your computer. When electric charges are separated they possess potential energy that will be converted into other forms once it reaches a critical amount. An example of this is in lightning, whereby a charge imbalance builds up to the point where it is cannot be sustained, leading to a lightning strike that converts the electric potential energy into thermal energy, light and sound.

FIGURE 10.14 Electrical energy powers all electrical devices such as this tablet.

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Video eLesson Energy in disguise (eles-0063)

assess on Additional automatically marked question sets

10.2 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 7	Questions 2, 6, 8	Questions 5, 9, 10

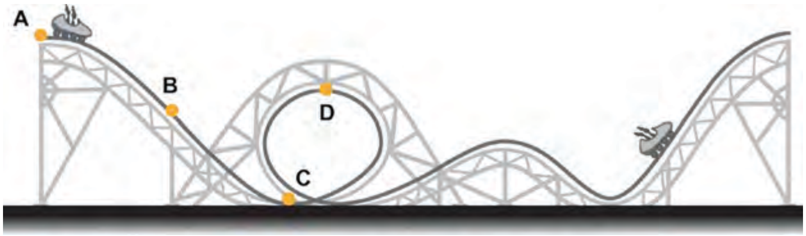
Remember and understand

1. State the Law of Conservation of Energy.
2. Classify the following as examples of potential energy or kinetic energy:
   - An athlete running
   - A spring being squashed
   - Sound coming from a speaker
   - A sky diver about to jump from an aeroplane
   - The light emitted from a globe
3. List five types of potential energy.

Apply and analyse

4. Are the following true or false? Justify your response.
   a. As a ball is thrown up into the air, it gains more gravitational potential energy the higher it moves.
   b. Elastic energy is a type of kinetic energy.
   c. Only springs and rubber bands can have elastic potential energy.
   d. Sound is a type of kinetic energy.
   e. Fusion is the process of splitting the nucleus.
5. Identify four types of energy that are present during a lightning strike.
6. How can you tell that a high diver has gravitational potential energy?

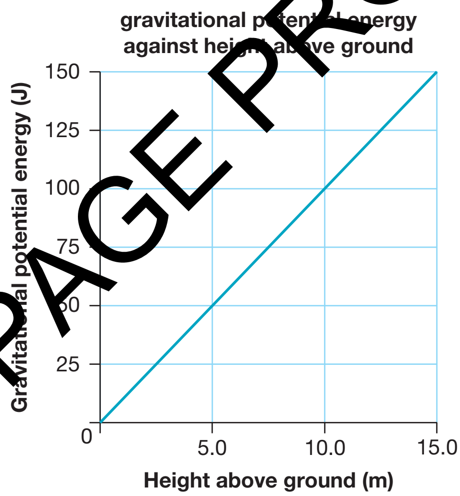
7. Consider points A, B, C and D on the roller-coaster in the diagram.



At which point does the roller-coaster have the greatest gravitational potential energy?

Evaluate and create

8. **SIS** Create a poster that illustrates the different forms of energy found in a moving car. Include a diagram of a car with arrows and labels indicating where different forms of energy exist.
9. **SIS** For one whole day, keep a tally of the number of times you come across each of the different forms of energy. Present your results in a bar chart.
10. **SIS** The following graph shows the relationship between gravitational potential energy (J) against height above the ground (m) of a 1 kg ball thrown into the air.
    a. How much gravitational potential energy does the ball have when it is 10 m above the ground?
    b. At what height above the ground is the ball when it has 75 J of gravitational potential energy?
    c. Describe the relationship between height and gravitational potential energy shown in this graph.
    d. If gravitational energy is directly proportional to the mass of an object, sketch a graph showing the gravitational potential energy versus height for a ball with mass 2 kg thrown into the air.



Fully worked solutions and sample responses are available in your digital formats.

10.3 Transforming energy

LEARNING INTENTION

At the end of this subtopic you will be able to describe energy transformations using flow diagrams, explain why sometimes energy appears to be lost, and calculate the efficiency of an energy converting device.

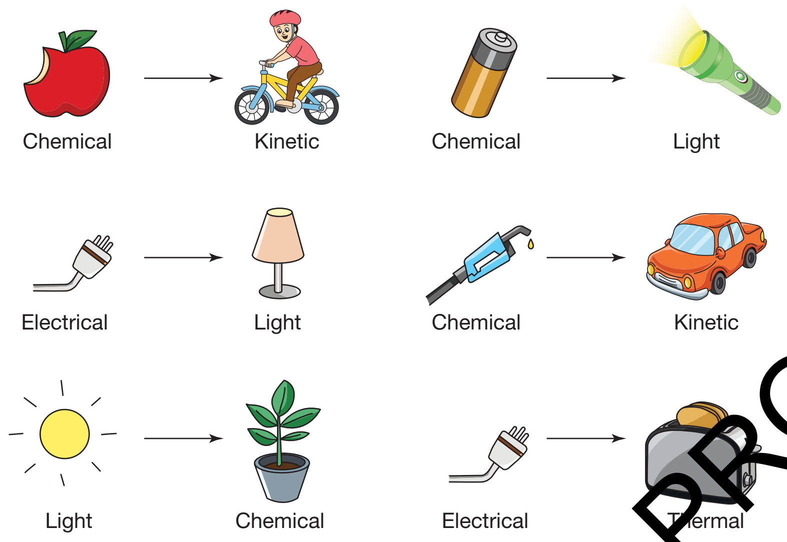
10.3.1 Energy can be transformed

Energy can change from one form to another; we call this an energy transformation or an energy conversion. Sometimes energy transformations result in something happening that we can see with our eyes; other times the result of an energy transformation may not be so obvious.

Examples illustrating some everyday energy transformations are shown in figure 10.15.

- The chemical energy stored in food is transformed into kinetic energy in the body when you move.
- Electrical energy is transformed into light when a lamp is plugged into a power point.
- Light from the Sun is transformed into chemical energy by plants via a process called photosynthesis.
- Chemical energy stored in batteries is transformed into light when a torch is switched on.
- Chemical energy stored in petrol is transformed into kinetic energy when a car is moving.
- Electrical energy is transformed into thermal energy when a toaster is switched on.

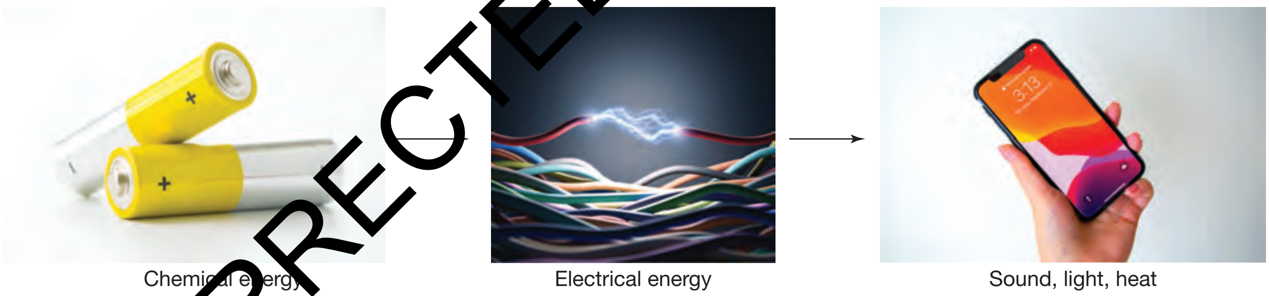
FIGURE 10.15 Examples of different energy transformations, or energy conversions



10.3.2 Energy flow diagrams

Energy flow diagrams are a visual way to show the energy transformations occurring in a system. In an energy flow diagram, an arrow is drawn from the energy input to the useful energy output (see figure 10.16).

FIGURE 10.16 An example of the energy transformations occurring in a mobile phone are shown in the flow diagram.



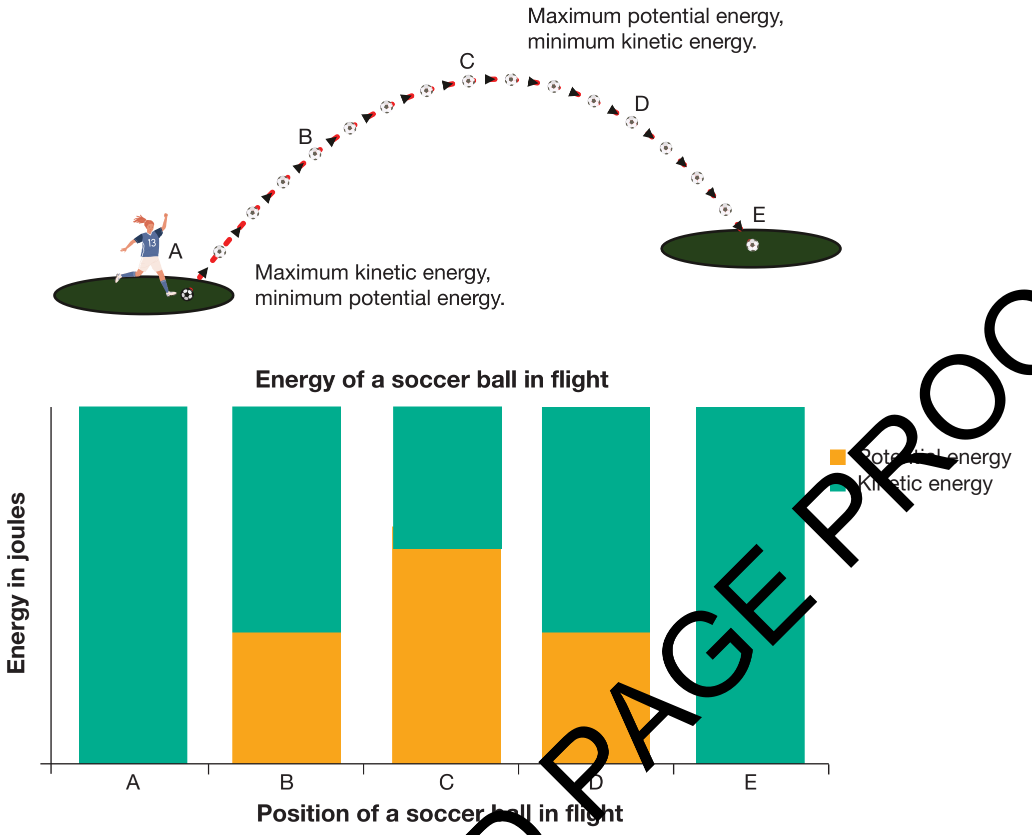
It is usual for there to be more than one energy output, but only the useful forms of energy are listed in energy flow diagrams. In the example given, heat would not usually be listed as it is not a useful form of energy for a mobile phone. Minor energy outputs that are not useful are known as by-products.

10.3.3 Falling objects

As an object falls from a height, its gravitational potential energy is converted to kinetic energy. When the object reaches the ground, all its gravitational potential energy has been transformed to kinetic energy.

In figure 10.17, notice that at position A, where the ball has just been kicked, the ball has no potential energy because it is on the ground — all its energy is kinetic.

FIGURE 10.17 The energy transformations of a soccer ball in flight



When the ball reaches position B, some of its kinetic energy has been converted to potential energy as it rises above the ground.

At position C, the ball reaches its highest point. The gravitational potential energy reaches its maximum; however, because the ball is still moving horizontally it still has some kinetic energy.

At position D, some of its potential energy is converted back to kinetic energy as the ball falls.

When the ball reaches position E, all of the ball's energy has been converted back in to kinetic energy, and the ball hits the ground at its maximum speed.

Notice that although the ball has different amounts of potential and kinetic energy at each position, the total amount of energy is the same at each position. The ball never gains or loses energy, it simply transforms kinetic energy to potential energy and then back again. Thus, we say that the energy is conserved.

Next, consider the energy transformations involved in bouncing on a trampoline (figure 10.18). As the person jumping falls towards the trampoline, some of their gravitational potential is converted to kinetic energy. When they reach the trampoline mat, their gravitational potential and kinetic energy are converted to elastic potential energy stored in the springs. Then, as the person jumps back up into the air, the elastic potential energy is converted back into kinetic and gravitational potential energy.

on Resources

Interactivity Coaster (int-0226)

FIGURE 10.18 Energy conversions that occur when bouncing on a trampoline

10.3.4 Solar cells

A solar cell, or photovoltaic cell, is a device that converts light energy from the Sun into electrical energy. When light from the Sun strikes the thin semiconductor layer in the solar cell, electrons are knocked free from their atoms. If the solar cell is connected to an electrical circuit, the free electrons flow through the circuit creating electricity that can be used to power devices. Energy can also be stored in the solar cell for later use, for example at night when there is little light. The most efficient solar cells designed for home use convert around 20 per cent of the energy arriving from the Sun into useful energy.

Several solar cells can be connected together to form a photovoltaic module, more commonly known as a solar panel. Multiple modules can then be wired to form an array. You may have seen an array of solar panels on the roof of a house (figures 10.19 and 10.20).

FIGURE 10.19 Solar arrays are made up of modules, which are made up of cells.

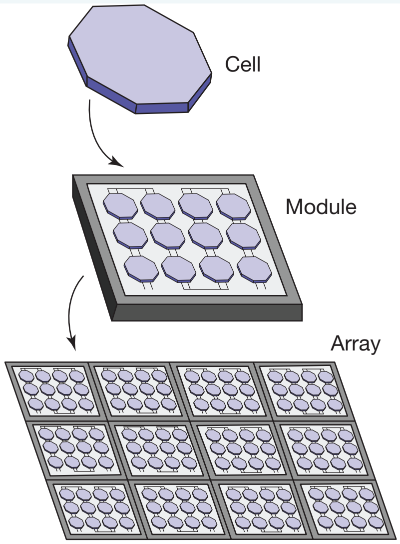


FIGURE 10.20 Solar arrays are often placed on roofs to provide cheap sustainable energy.

10.3.5 Energy '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. None of the wasted energy is actually lost, it is just transformed into less useful forms of energy. Table 10.2 shows some examples of energy conversion by electrical appliances.

TABLE 10.2 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

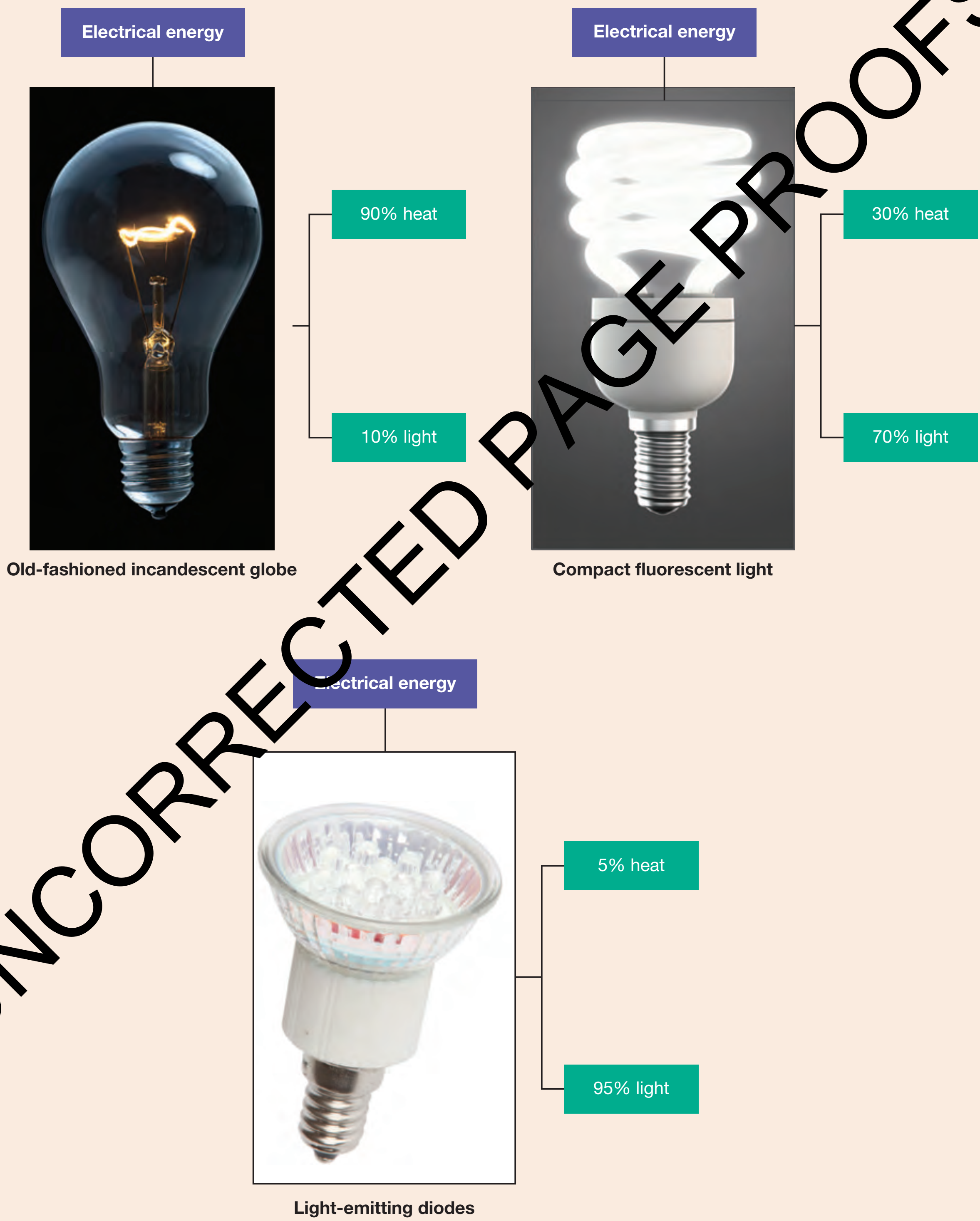
This loss of useful energy is also apparent when you step on the brake pedal in a car — not all the energy you transfer to the pedal is used to stop the car. Much of it is lost in the brakes; it is converted to thermal energy and is released to the surrounding air as heat. The same applies to using the brakes of a bicycle. Also, when you drop a tennis or 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 substantially less 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.

CASE STUDY: Comparing the energy efficiency of light bulbs

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

FIGURE 10.21 LEDs are much more efficient than the alternatives. Note that the figures quoted are approximate.



10.3.6 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, and can be calculated using the following formula:

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

The efficiency of the incandescent light globe in figure 10.21 is 10 per cent because 10 per cent of the total electrical energy input is usefully transformed into light. The efficiency of the compact fluorescent light is 70 per cent, and the LED light is 95 per cent 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.

efficiency the fraction of energy supplied to a device as useful energy

DISCUSSION

- Should it be mandatory to use energy-efficient devices?
- Outline at least one reason efficiency is important for devices that use fossil fuels.
- Are solar-powered cars a realistic alternative to cars that run on fossil fuels or biofuels such as ethanol? What criteria would you use to evaluate this?

on Resources

Video eLesson	The Australian International Model Solar Challenge (eles-0068)
eWorkbook	Skateboard flick cards (ewbk-5148) Types of energy (ewbk-5150)
assesson	Additional automatically marked question sets

10.3 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 7	Questions 3, 5, 8, 10, 13	Questions 6, 9, 11, 12

Remember and understand

1. Complete the table listing the useful energy and the wasted energy converted by the following devices.

TABLE The useful energy and the wasted energy converted by the devices

Device	Source of energy	Energy usefully converted to ...	Forms of energy wasted
A torch			
A wind-up toy			
A pop-up toaster			
A gas cooktop			
A car engine			

2. Outline at least three reasons efficiency is important for devices that use fossil fuels.
3. If a stretched rubber band has 12 J of elastic potential energy, and 9 J of kinetic energy is produced when the band is released:
   a. what is its percentage efficiency
   b. where has the ‘lost’ 3 J of energy gone?
4. A friend tells you that a light globe transforms 60 J of electric potential energy into 100 J of light. Is she correct? Why or why not?

Apply and analyse

5. An object is dropped from a height of 20 m. At a point during its fall towards the ground, it has 15 J of gravitational potential energy and 5 J of kinetic energy.
   a. What is the total amount of energy of the ball at any time during its flight?
   b. How much gravitational energy did the ball have before it was dropped?
   c. How much kinetic energy will the ball have just before it hits the ground (assuming it is 100 per cent efficient)?
6. When a tennis ball is bounced on the ground, it never returns to its original height.
   a. Does this break the Law of Conservation of Energy? Explain your answer.
   b. Why has the ball not reached its original height after the bounce? Explain with the aid of an energy flow diagram.
   c. Will the ball have the same amount of gravitational potential energy when it reaches the maximum height of its path after the bounce, compared to when it was originally dropped? Explain.
7. **SIS** A student investigating the energy of a skateboarder in a half pipe records the following data. Fill in the missing values.

TABLE The change in energy of a skateboarder in a half pipe

Position of skateboarder	Gravitational potential energy (J)	Kinetic energy (J)	Total energy (J)
Top of half pipe	600	0	
Part way down		200	600
Bottom of half pipe		600	
Part way up	300		
Top of half pipe			

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

Evaluate and create

9. The energy we get from eating a piece of fruit starts from the Sun! Describe the energy transformations involved in this process using a flowchart.
10. A catapult like the one in figure 10.22 was used by the Romans more than 2000 years ago to attack castles, cities and invading armies.The long arm was held in its usual vertical position with rope twisted around its base in what is known as a torsion bundle (figure 10.23). The arm was pulled back towards the ground using a second rope so that the bucket could be loaded with a missile. This causes the torsion bundle to twist more tightly. When the arm was released, the torsion bundle quickly untwisted and it returned to its vertical position, releasing the missile from the bucket at high

speed towards the target. The missiles fired included rocks, burning tar and even human corpses. Use flowcharts to show:

a. the energy transfers that take place during the loading and firing of the missile
b. the energy transformations that take place from the time that the missile is loaded until the time that the missile finds its target.

FIGURE 10.22 A Roman catapult

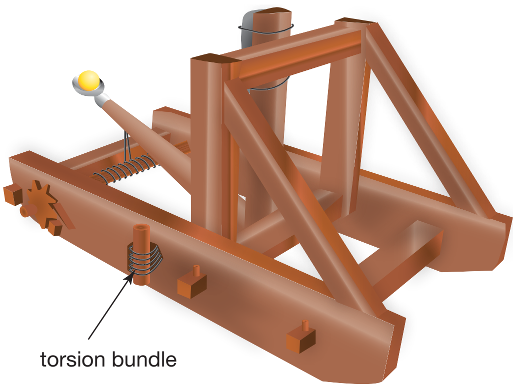
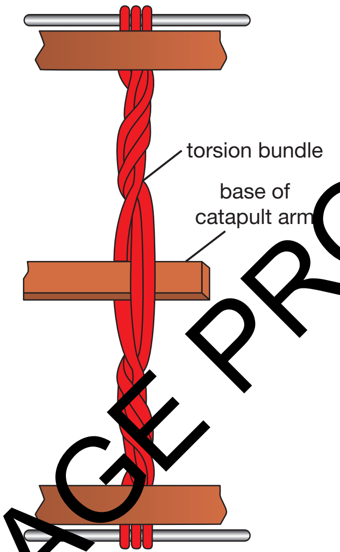


FIGURE 10.23 The torsion bundle



11. SIS 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.)
12. SIS Waterwheels have been used in the past (and are still being used) to convert the energy of moving water to other useful forms of energy. Research and report on one example of the use of a water wheel. In your report, use flowcharts to illustrate the transformations and transfers of energy that take place.
13. SIS Are solar-powered cars a realistic alternative to cars that run on fossil fuels or biofuels such as ethanol? Find out what scientists, engineers and members of the public have contributed to the design of solar-powered vehicles.

Fully worked solutions and sample responses are available in your digital formats.

10.4 Transferring energy

LEARNING INTENTION

At the end of this subtopic you will be able to describe how energy can be transferred from one object or place to another when a force causes movement or by heating and cooling.

10.4.1 From object to object

Energy transfer from one object to another object is usually easy to observe because one or both objects slow down, speed up or change direction. A transfer of energy to or from an object can also cause it to start or stop spinning. Some examples of energy transfer from object to object are explained here.

- When the golfer in figure 10.24 swings his club, energy is transferred from his body to the club. When the club strikes the ball, most of its energy is transferred to the ball to make it move. The ball gains both kinetic energy and gravitational potential energy as a result of the transfer. It might also spin. In this case the force on the ball is supplied by the club.
- When we lift an object into the air, we are transferring energy from our body to the object in the form of additional gravitational potential energy. When we throw a boomerang, we transfer energy from our body to the boomerang in the form of kinetic and gravitational potential energy. In both cases the force is supplied by your body.

FIGURE 10.24 Energy transfers from your muscles into the club and finally into the ball in a golf swing.

- In an electrical circuit, chemical energy in the cell or battery is transferred to electric charge, causing it to move around the circuit. The force causing the movement is the electrical force of attraction between opposite electric charges. The electrical energy of the moving electric charge is then transformed in a load such as a light globe or smart phone.

10.4.2 Heat

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.

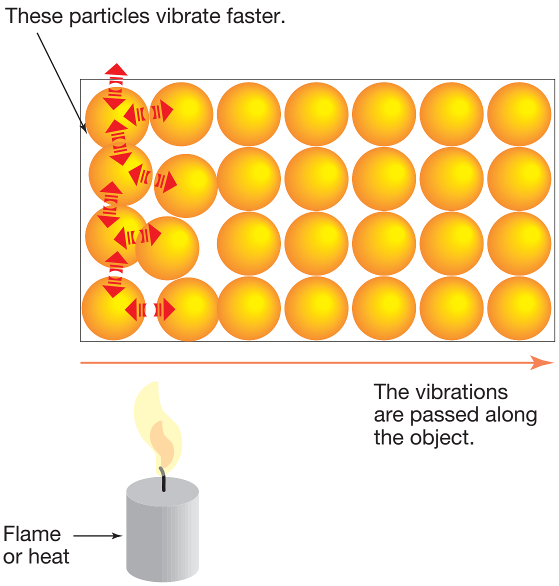
Heat is energy in transit from an object or substance to another object or substance with a lower temperature. Heat can move from one place to another in three different ways — by conduction, convection or radiation.

conduction transfer of heat through collisions between particles

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 (see figure 10.25). 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 section of a solid object, its temperature increases. The particles vibrate faster and bump into each other, transferring some of their energy to neighbouring particles when they collide. The vibrating and transferring of energy continues from particle to particle, transferring energy along the object until the whole object is hot.

FIGURE 10.25 Conduction of heat occurs as a result of vibrating particles.



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 plastic or wooden handles for this reason.

insulator a material that is a poor conductor of heat
convection transfer of heat through the flow of 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**.

FIGURE 10.26 Modelling heat transfer in air by convection

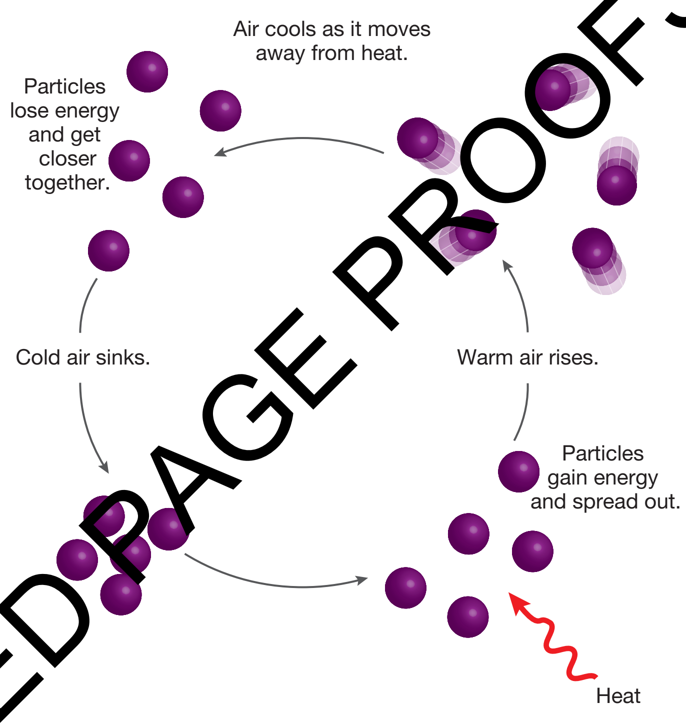
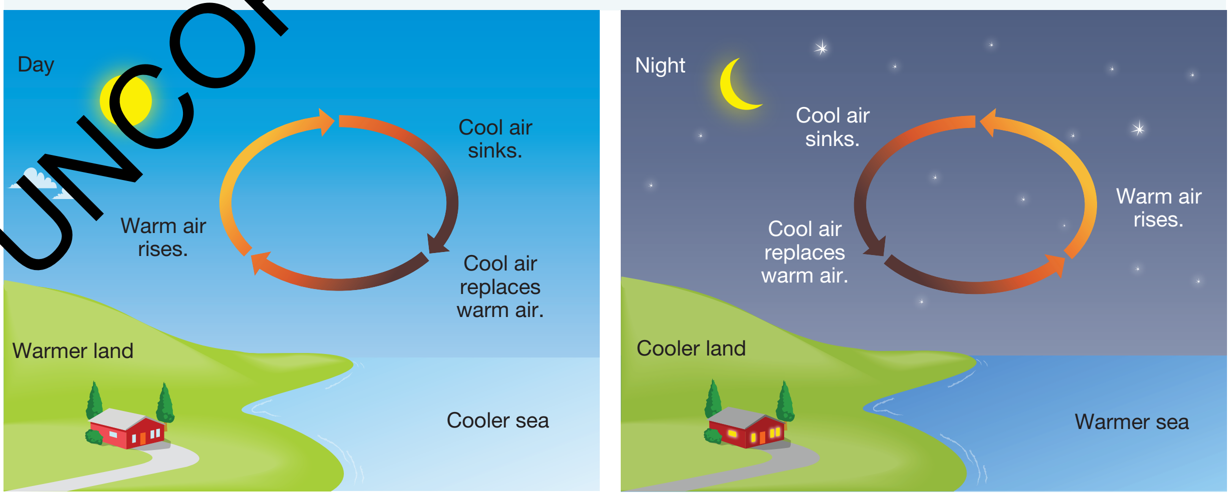


Figure 10.26 shows how convection takes place. Heat causes the particles of air to gain energy, move faster and spread out. This warmer air is less dense than the air around it, so it rises. As it rises it begins to cool. The particles lose some of the energy gained, slow down and move closer together. 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. The gentle breezes at seashore are formed by convection of air currents (see figure 10.27). The warm air above the land rises up and the cool air over the sea takes its place, producing the sea breeze in the daytime. At night, as the sea is warmer than the land, the roles of land and sea changes and convection of air produces the land breeze.

int-5346

FIGURE 10.27 Sea breezes caused by convection currents



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, and does not require any contact between the heat source and the heated object, as is the case with conduction and convection.

FIGURE 10.28 A camp cookout — heat is transferred by radiation, conduction and convection.

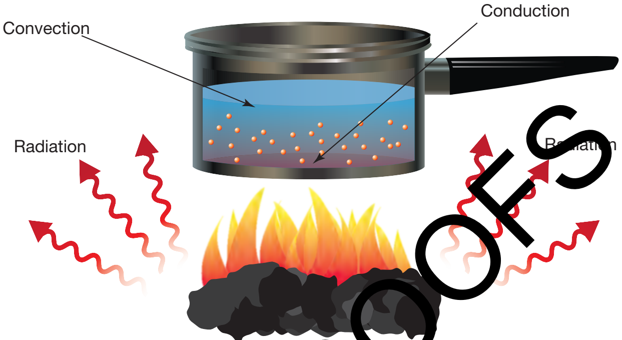
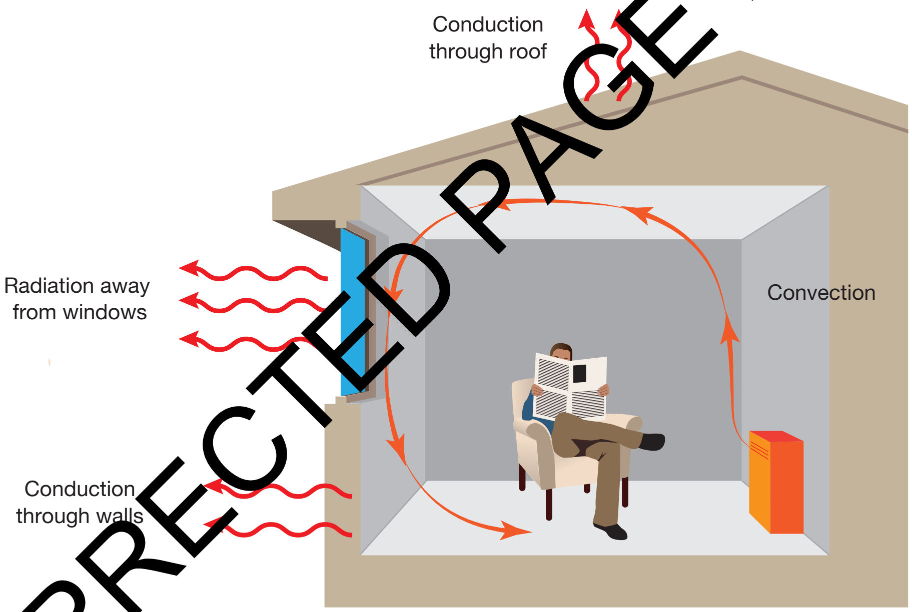


FIGURE 10.29 The transfer of heat in a house by conduction, convection and radiation



on Resources

Interactivity A hot-water system (int-3399)

Video eLesson Convection currents (eles-2056)

radiation emission of energy as electromagnetic waves

radiant heat heat transferred by electromagnetic radiation

elog-0641

INVESTIGATION 10.1

Moving particles

Aim

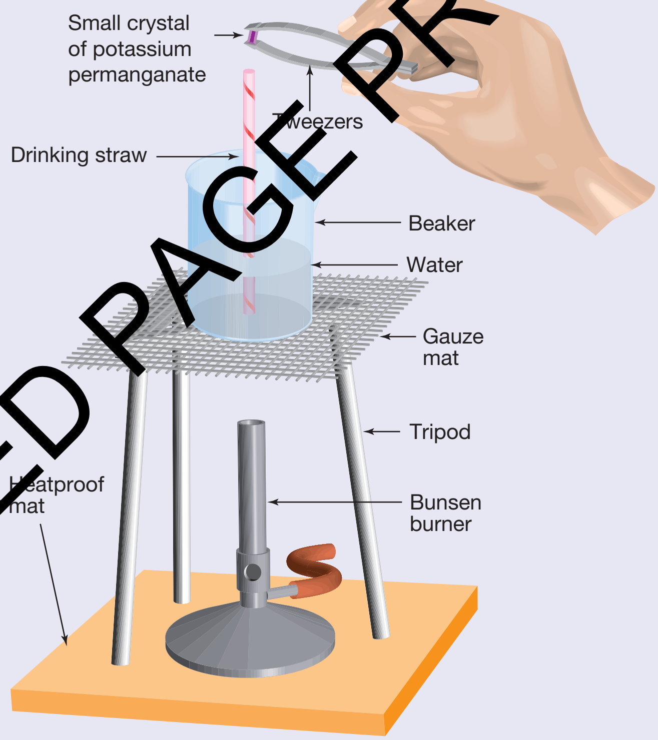
To model convection currents in a liquid

Materials

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

Method

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



Results

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

Discussion

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

Conclusion

What can you conclude about modelling convection currents in a liquid?

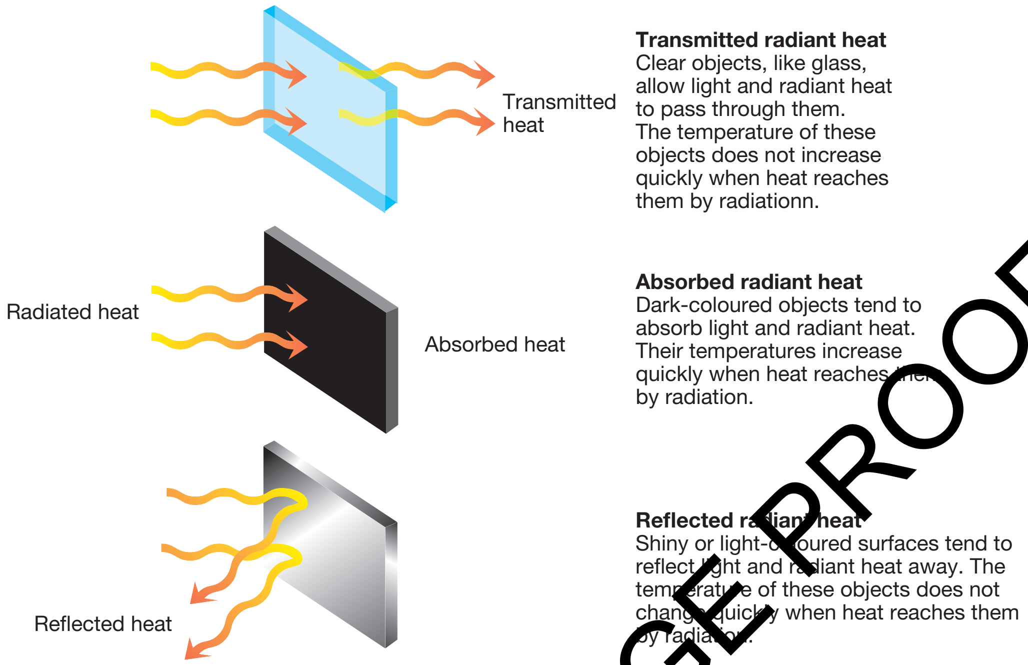
Transmission, absorption and reflection

When radiant heat strikes a surface, it can be **reflected**, **transmitted** or **absorbed** (figure 10.30). Most surfaces do all three; some surfaces are better reflectors, others are better absorbers and some transmit more heat.

reflected bounced off
transmitted passed through something, such as light or sound passing through air
absorbed taken in

int-3400

FIGURE 10.30 How different surfaces are affected by radiant heat.



on Resources

assesson Additional automatically marked questions

10.4 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 6	Questions 3, 4, 8, 10	Questions 7, 9, 11

Remember and understand

1. What are the two methods by which energy can be transferred?
2. When a girl kicks a soccer ball, energy from her body is transferred to the soccer ball. Which two useful forms of energy does the soccer ball gain as a result?
3. Complete the table.

TABLE Heat transfer by conduction, convection and radiation

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

4. What is an insulator? Name three different materials that can act as insulators.
5. Heat can travel through empty space (e.g. between the Sun and Earth). How does the heat move?
6. What three things can happen to radiated heat when it arrives at any surface?

Apply and analyse

7. 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.
8. When you hold a mug of coffee or hot soup, your hands feel warm. How is the heat transferred to your hands?

Evaluate and create

9. Draw a diagram to show how air-conditioners push cool air out near the ceiling to create convection currents that cool rooms in hot weather.
10. **SIS** Investigate how evaporative and refrigerated air-conditioners work and compare the advantages and disadvantages. Write a report summarising your findings.
11. **SIS** 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.
    a. Write down the aim of your investigation and state your hypothesis.
    b. List the set of steps that you will follow for your method.
    c. Decide what equipment is needed and make a list of it.
    d. Decide how your results will be recorded and draw up any necessary tables.
    e. Check your method and equipment list with your teacher before beginning.
    f. Use your results to write a conclusion. State whether your hypothesis was supported.

Fully worked solutions and sample responses are available in your digital formats.

10.5 A costly escape

LEARNING INTENTION

At the end of this subtopic you will be able to use your knowledge of energy transfer to suggest ways to keep your house warm in winter and cool in summer.

SCIENCE AS A HUMAN ENDEAVOUR: Saving energy and staying warm

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.

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).

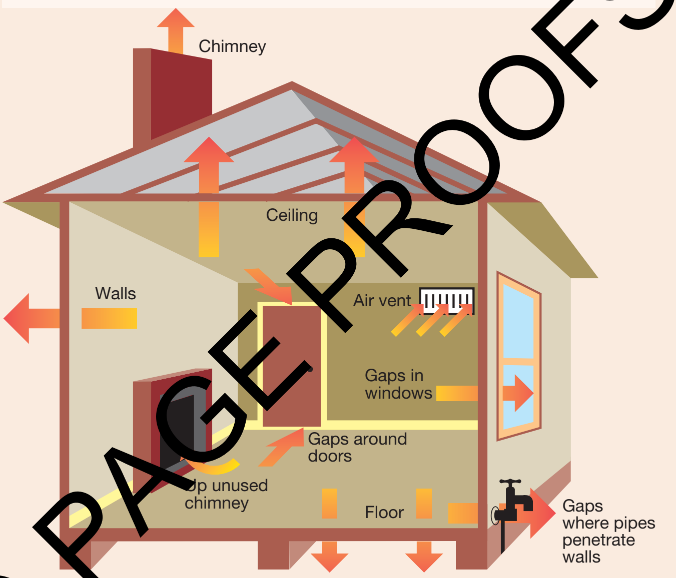
Using the Sun

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 (see figure 10.31). 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.

FIGURE 10.31 Heat can escape from many different places.



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.

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.

Resources

Interactivity A thermos flask (int-3401)

eWorkbook A costly escape (ewbk-5152)

deciduous trees and shrubs that lose their leaves and become dormant during winter

elog-0642

INVESTIGATION 10.2

Investigating insulators

Aim

To investigate the insulating ability of a range of materials

Materials

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

Method

1. Suggest a hypothesis for this investigation.
2. Surround each can except one with a different material.

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

3. Copy the table from the results section into your workbook to record your measurements.
4. Measure out and pour 100 mL of hot water into each of the cans.
5. Measure the temperature of the water in each can. Repeat the measurement of temperature every 5 minutes for 20 minutes.

Results

1. Complete the table provided.

TABLE Temperature of water in cans (°C)

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

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

Discussion

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

Conclusion

Summarise your findings and state whether your hypothesis was supported or not.

on Resources

assesson Additional automatically marked questions

10.5 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 5	Questions 2, 6, 7	Questions 4, 8, 9

Remember and understand

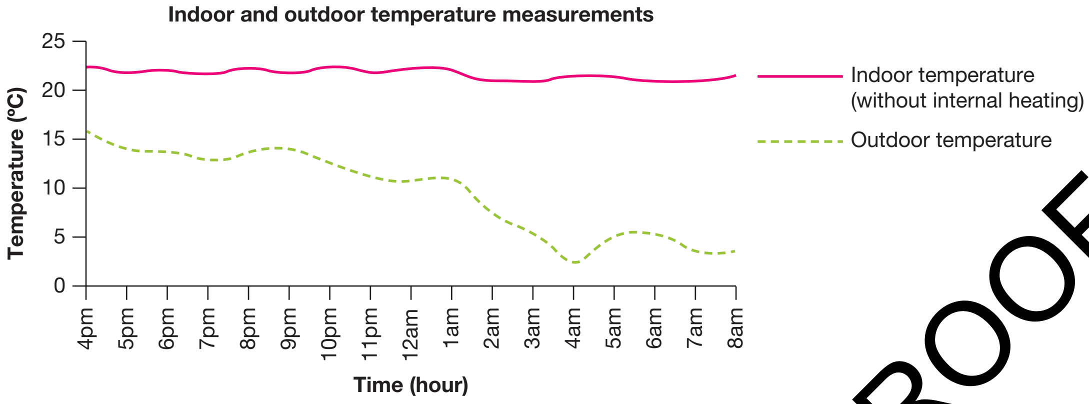
1. What property makes a material a good insulator?
2. Installing insulation in the ceiling reduces which methods of heat transfer?
3. What is the cheapest way of reducing heat losses from your home in cold weather?

Apply and analyse

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.
8. SIS Investigate how a thermos flask keeps its contents warm. What features of a thermos flask reduce heat loss by:
   a. conduction
   b. convection
   c. radiation?

Evaluate and create

9. **SIS** The temperature inside and outside a house was taken over a 16-hour period. The results are shown in the graph.



a. At what time was it coldest outside?
b. Describe the outside temperature during the 16 hours.
c. Do you think the house was insulated? Give reasons for your answer.
d. Construct a graph similar to the one provided by recording the temperature inside and outside your house over a period of time (without using any internal heating such as a heater).

Fully worked solutions and sample responses are available in your digital formats.

10.6 Light

LEARNING INTENTION

At the end of this subtopic you will be able to distinguish between incandescent and non-incandescent light sources and describe the different ways in which light can behave when it meets a substance. You will also be able to identify visible light as part of a larger electromagnetic spectrum.

10.6.1 The Sun

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.

10.6.2 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 in figure 10.32.

Most of the light sources shown are **incandescent**, which means 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**.

luminous releasing its own light
incandescent describes objects that emit light when they are hot
bioluminescent describes living things that release light energy

FIGURE 10.32 Each of the light sources shown here is luminous.

FIGURE 10.33 The angler fish, living in darkness about 4000 metres below the ocean surface, uses a luminous lure to attract its prey.

Most things that you see are not luminous; they do not emit their own light. We see **non-luminous** objects because light from luminous objects is reflected from them. 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 simply reflects light from the Sun.

EXTENSION: Glow in the dark

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.

Resources

Video eLesson Bioluminescent click beetle (Pyrophorus sp.) (eles-2678)

10.6.3 Seeing light

Light can be seen when looking at a luminous object, or when looking at an object that reflects light into your eyes. Light is not normally visible between its source and any surface that it strikes (figure 10.34). 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.

non-luminous describes objects that do not emit their own light, but can be seen by reflected light

scattered describes light sent in many directions by small particles within a substance

FIGURE 10.34 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.

Resources

Video eLesson Crookes radiometer for measuring radiant flux (eles-2679)

elog-0643

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

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

Results

1. What did you observe when the radiometer was in direct sunlight?
2. What did you observe when the radiometer was in the shade?

Discussion

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

Conclusion

What happens to a radiometer when it is placed in direct sunlight? Explain this effect.

elog-0644

INVESTIGATION 10.4

Seeing the light

Aim

To observe and explain the scattering of light

Materials

- moderately dark room
- torch or projector
- matches

Method

1. Shine the torch or projector on a nearby wall.
2. Light and blow out a match, so that the smoke falls between the light source and the wall.

Results

Record your observations.

Discussion

1. Can you see the light beam between the light source and the wall without the smoke?
2. What changes when the smoke is present?
3. Explain what happens to the light from the source to make it visible.

Conclusion

Why can a light beam only be seen when there are particles between its source and a surface?

WHAT DOES IT MEAN?

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

10.6.4 When light meets a substance

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.

FIGURE 10.35 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.

10.6.5 The visible spectrum

Light reaching us from the Sun is known as white light. Household lighting and torches are almost always designed to produce white light. By observing a rainbow, you can see that white light consists of many different colours. This set of colours is called the **visible spectrum**.

The colours of the visible spectrum are usually described as red, orange, yellow, green, blue, indigo and violet. However, there is no sharp boundary between the colours. They merge into each other.

White light can also be separated into the colours of the visible spectrum by passing a narrow beam through a triangular glass prism. In a rainbow, the separation of colours is caused by droplets of water. The separation of white light into the spectrum of colours is called **dispersion**.

FIGURE 10.36 A prism is used to disperse white light.

on Resources

Video eLesson Refraction in a prism (eles-2680)

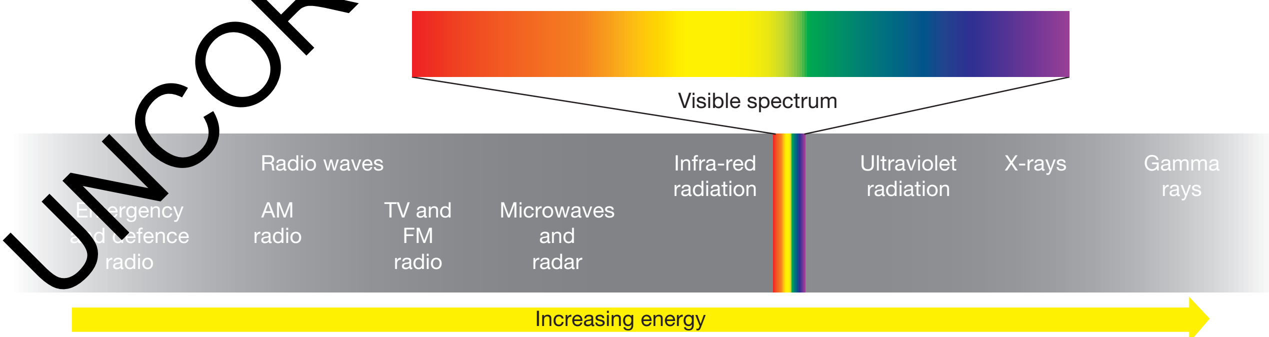
10.6.6 The electromagnetic spectrum

Visible light is just one part of a 'family' of forms of energy known as **electromagnetic radiation** emitted by the Sun and other stars. Together, this family makes up the **electromagnetic spectrum** and you are probably already familiar with most, if not all the members, including microwaves, ultraviolet radiation and x-rays (see figure 10.37). All types of electromagnetic radiation can be produced artificially here on Earth.

dispersion separation of the colours that make up white light

electromagnetic radiation the radiant energy such as radio waves, infrared, visible light, x-rays and gamma rays released by magnetic or electric fields

FIGURE 10.37 Visible light represents only a very small part of the electromagnetic spectrum.



All electromagnetic radiation travels through air at 300 million metres per second. Unlike sound waves, electromagnetic radiation can travel through a vacuum as particles are not required for this transfer of energy.

Radio waves

Radio waves include the low-energy waves that are used to communicate over long distances through radio, television. mobile phones and wi-fi. Radar uses radio waves to detect objects from a very long distance. The microwaves used in microwave ovens for cooking are also radio waves.

Infra-red radiation

Infra-red radiation, invisible to the human eye, is emitted by all objects and is sensed as heat. It has less energy than visible light but more energy than radio waves. The amount of infra-red radiation emitted by an object increases as its temperature increases. When you push a button on a remote control to operate a television, PlayStation® or other electronic device, a beam of infra-red radiation is sent towards the device. A detector in the device converts the infra-red energy into electrical energy, which operates the controls.

FIGURE 10.38 A gentle push of a button sends infra-red radiation to an electronic device at 300 million metres per second.

Ultraviolet radiation

Like infra-red radiation, **ultraviolet radiation** is invisible to the human eye. It is needed by humans to help the body produce vitamin D; however, too much exposure to ultraviolet radiation causes sunburn. Ultraviolet radiation has more energy than visible light.

FIGURE 10.39 X-rays showing a fracture in the left ulna (forearm)

X-rays

X-rays have enough energy to pass through human flesh. They can be used to kill cancer cells, find weaknesses in metals and analyse the structures of complex chemicals. X-rays are produced when fast-moving electrons give up their energy quickly. In x-ray machines, this happens when the electrons strike a target made of tungsten.

Some parts of the human body absorb more of the energy of x-rays than others. For example, bones absorb more x-ray energy than the soft tissue around them. This makes x-rays useful for obtaining images of bones and teeth. To obtain an image, x-rays are passed through the part of the body being examined. The x-rays that pass through are detected by photographic film on the other side of the body. Because bones, teeth and hard tissue such as tumours absorb more energy than soft tissue, they leave shadows on the photographic film, providing a clear image.

Computed tomography scanners (CT or CAT scanners) are x-ray machines that are rotated around the patient being examined.

radio waves low-energy electromagnetic radiation

infra-red radiation low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light

ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy

x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about the structure

Gamma rays

Gamma rays are emitted by radioactive substances and larger stars. Gamma rays have even more energy than x-rays and can cause serious damage to living cells. They can also be used to kill cancer cells and find weaknesses in metals. Gamma rays are produced when energy is lost from the nucleus of an atom. This can happen during the radioactive decay of nuclei or as a result of nuclear reactions.

Gamma cameras are used in positron emission tomography scans (PET scans) to obtain images of some organs. To obtain a PET scan, a radioactive substance that produces gamma rays is injected into the body (or, in some cases, inhaled). As it passes through the organ being examined, it produces gamma rays, which are detected by the camera.

FIGURE 10.40 Cameras that detect gamma rays are used in PET scans. This patient is undergoing a PET scan of her brain.

gamma rays high-energy electromagnetic radiation produced during nuclear reaction

on Resources

eWorkbook Light energy (ewbk-5154)

assess**on** Additional automatically marked question sets

10.6 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6, 9, 10	Questions 3, 5, 7, 11, 12, 14	Questions 4, 8, 13, 15

Remember and understand

1. What is light and how fast does it travel through space?
2. MC Which of the following objects are luminous?
   A. The Sun
   B. The Moon
   C. The stars
   D. A burning candle
3. 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.
4. Why do you see the beam of light from a torch if it is foggy?
5. Describe what can happen to light energy travelling through the air when it meets a new substance.
6. List the commonly known colours of the visible spectrum.
7. List the forms of electromagnetic radiation that have more energy than visible light.
8. State two properties that all forms of electromagnetic radiation have in common.
9. Apart from visible light, what other forms of energy come to the Earth from the Sun?

Apply and analyse

10. How do you know that white light consists of different colours?
11. Explain how it is that you can see a page of a book even though it does not emit light of its own.
12. 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?
13. 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?

Evaluate and create

14. SIS Find out how the energy that reaches the Earth is produced by the Sun. Present your findings in a poster.
15. SIS Investigate and explain in detail how a rainbow is formed.

Fully worked solutions and sample responses are available in your digital formats.

10.7 Light forms images

LEARNING INTENTION

At the end of this subtopic you will be able to describe how images are formed by reflection, refraction and lateral inversion using mirrors and lenses.

10.7.1 Rays

Light is especially important to us because of its ability to form images. The reflection of light allows you to see images in mirrors. When you take a photo, the image is created when light is bent by a lens. In fact, everything that you see is an image, created at the back of your eye when light energy entering your eye bends. To understand how images are formed, we need to have a closer look at how light energy behaves.

Light travels in straight lines as it travels through empty space or through a uniform substance like air or water. The lines that are used to show the path of light are called rays. A beam is a stream of light rays.

FIGURE 10.41 Flat mirrors show undistorted images of people and objects.

10.7.2 Reflections

When you look in a mirror you see an image of yourself. If the mirror is a plane or flat mirror, the image will be very much like the real you. If the mirror is curved, the image might be quite strange, like the one in figure 10.42.

The images in mirrors are formed when light is reflected from a very smooth, shiny metal surface behind a sheet of glass. Images can also be formed when light is reflected from other smooth surfaces, such as a lake.

FIGURE 10.42 Mirrors that are not flat create strange, distorted images.

on Resources

Video eLesson Children's reflections are distorted by this playground mirror (eles-2681)

elog-0645

INVESTIGATION 10.5

Reflection and refraction

Aim

To investigate the reflection of light and its transmission through a prism and lens

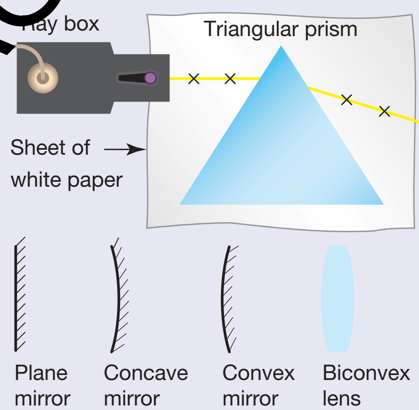
Materials

- ray box kit
- power supply
- several sheets of white paper
- ruler
- fine pencil

Method

1. Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Move the lens backwards and forwards until a beam of light with parallel edges is projected.
2. Use one of the black plastic slides to produce a single thin beam of light that is clearly visible on the white paper.
3. Trace the path of this single beam of light as it meets the lens, prism or one of the mirrors shown in the diagram. The path can be traced by using pairs of very small crosses along the centre of the beam before and after meeting each 'obstacle'. Trace and label the shape of each 'obstacle' before you trace the light paths.
4. Change the slide in the ray box so that you can project several parallel beams towards each of the 'obstacles'.
5. Use a ruler to draw a small diagram showing the path followed by the parallel beams when they meet each of the 'obstacles'.
6. Change the black plastic slide to produce a single thin beam of light from the ray box.
7. Place the triangular prism in front of the beam and move it around until you can see a band of colours on the white paper.

Tracing the path of a beam of light



Results

Your ray tracing diagrams should appear in the results section.

1. Which colour is bent most by the triangular prism?
2. Which colour is bent least by the triangular prism?
3. Describe your observations of the path followed by the three parallel beams when they meet each of the mirrors and the lens.

Discussion

1. What happens to a beam of light when it meets a perspex surface:
   a. 'head on'
   b. at an angle?
2. What happens to a beam of light when it meets a plane mirror surface:
   a. 'head on'
   b. at an angle?
3. Explain why droplets of water can cause white light from the Sun to separate into the colours of the visible spectrum.

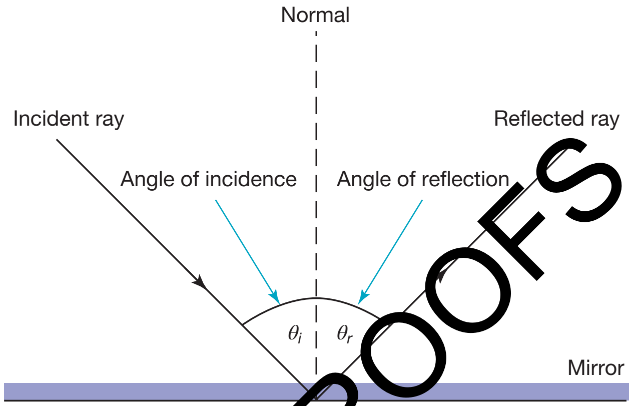
Conclusion

Write a conclusion for this investigation.

Reflections from flat mirrors

Whenever light is reflected from a smooth, flat surface, it bounces away from the surface at the same angle from which it came. This observation is known as the Law of Reflection (figure 10.43). This law can be used to find out where your image is when you look into a mirror. The best way to describe the way the light is reflected from a mirror is to draw a dotted line at right angles to the mirror. This line is called the normal **normal**.

FIGURE 10.43 The Law of Reflection



The Law of Reflection

When a ray of light is reflected from a smooth surface, it is reflected at the same angle from which it came; the angle of incidence, *i*, is equal to the angle of reflection, *r*.

Figure 10.45 shows how the Law of Reflection can be used to find the image of the tip of your nose.

Almost all of the light coming from the tip of your nose and striking the mirror is reflected. (A very small amount of light is absorbed by the mirror.) All of the reflected light appears to be coming from the same point behind the mirror; and that is exactly where the image is. The image of the tip of your nose is the same distance behind the mirror as the real tip of your nose is in front of the mirror.

FIGURE 10.44 Light rays from the tip of the nose reflect off the mirror and enter the eye.

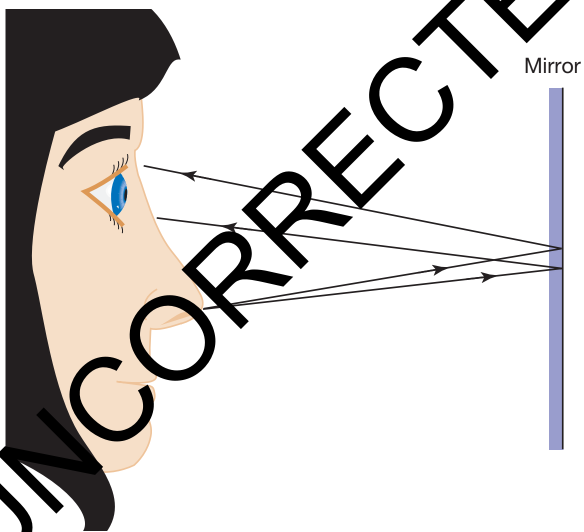
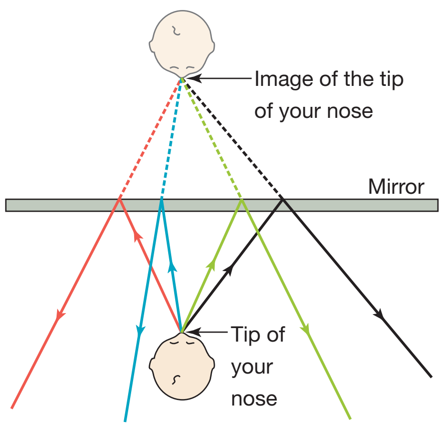


FIGURE 10.45 The reflected light appears to be coming from just one place. That's where the image is.

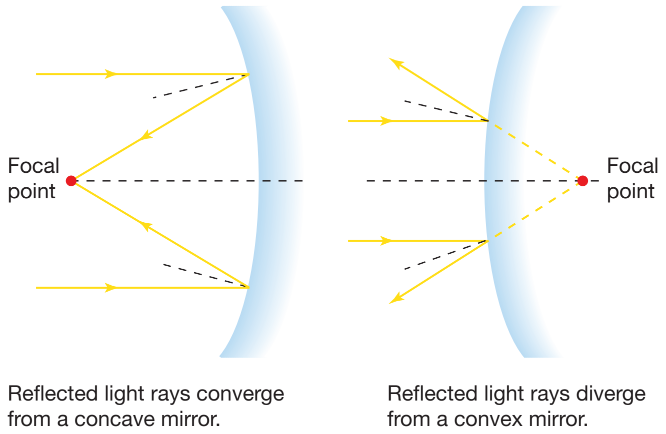


Reflection from curved mirrors

Flat mirrors are commonly found in the home. Curved mirrors have many applications too, including make-up mirrors, security mirrors in shops and safety mirrors at dangerous street intersections. Curved mirrors may be **concave** (curved inwards) or **convex** (curved outwards). Light reflecting from concave and convex mirrors also follows the Law of Reflection, such that the parallel rays of light are reflected to a **focal point** as shown in figure 10.46. Concave mirrors can sometimes make an image appear upside down!

normal (the) line drawn
concave curved inwards
convex curved outwards
focal point a point at which parallel rays of light meet after reflection by a curved mirror of refraction through a lens

FIGURE 10.46 Concave and convex mirrors also follow the Law of Reflection.



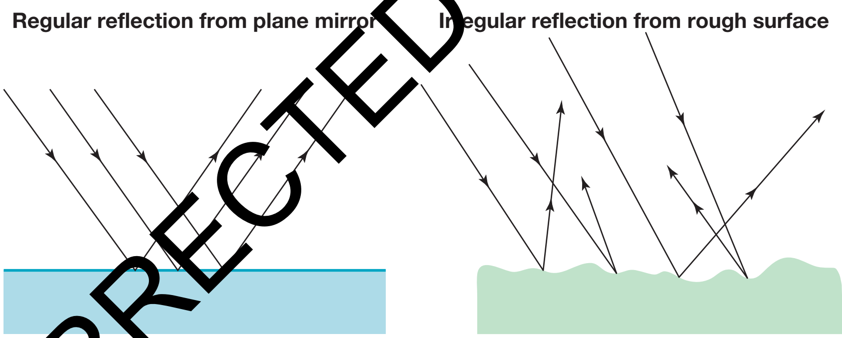
Why can't you see your image in a wall?

When you look very closely at surfaces like walls, you can see that they are not as smooth as the surface of a mirror (figure 10.47). The laws of reflection are still obeyed, but light is reflected from those surfaces in all directions. It doesn't all appear to be coming from a single point. There is no image.

lateral inversion sideways reversal of images in a mirror

refraction change in the speed of light as it passes from one substance into another

FIGURE 10.47 Rough surfaces reflect light in many directions because the light hits the surface at lots of different angles.



10.7.3 Lateral inversion

The sideways reversal of images that you see when you look at yourself in a mirror is called **lateral inversion**. The sign on the ambulance in the photograph at right is printed so that drivers in front of it can easily read the word 'AMBULANCE' in their rear-view mirrors.

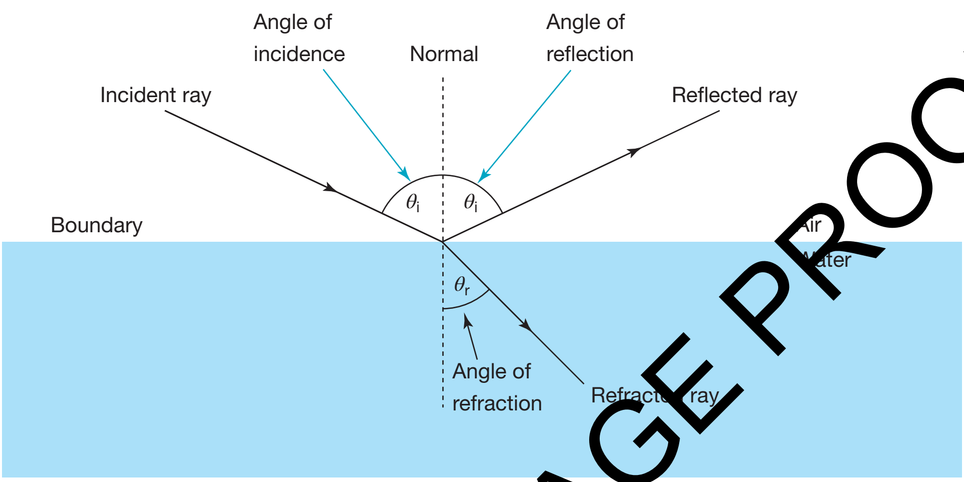
FIGURE 10.48 Why is the word 'AMBULANCE' printed in reverse?

10.7.4 Refraction

When light is transmitted from one substance into another substance, it can slow down or speed up. This change in speed as light travels from one substance into another is called **refraction** (figure 10.49). Refraction causes light to bend, unless it crosses at right angles to the boundary between the substances.

The best way to describe which way the light bends is to draw a normal line to the boundary between the two substances. When light speeds up, as it does when it passes from water into air, it bends away from the normal. When light slows down, as it does when it passes from air into water, it bends towards the normal. The angle between the normal and the incident ray is the **angle of incidence** and the angle between the normal and the refracted ray is the **angle of refraction**.

FIGURE 10.49 Angle of refraction

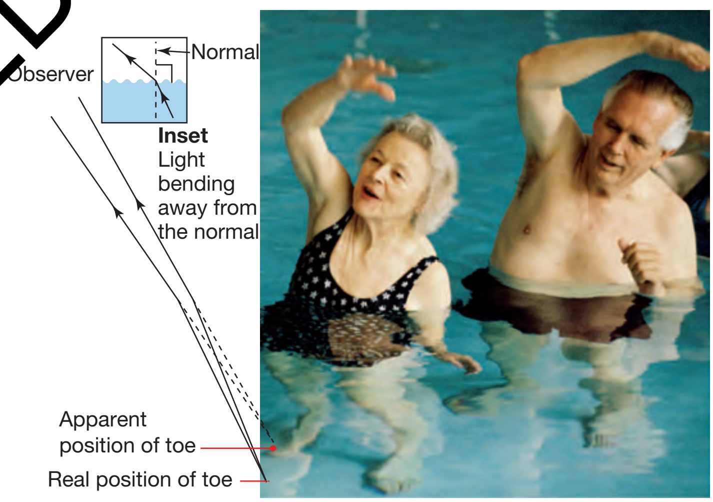


What happened to my legs?

Looks can be deceiving! The people in figure 10.50 do not have unusually short legs. Everything you see is an **image**. An image of the scene you are looking at forms at the back of your eye. When light travels in straight lines, the image you see provides an accurate picture of what you are looking at. However, when light bends on its way to your eye, the image you see can be quite different.

The light coming from the swimmers' legs in the photograph bends away from the normal as it emerges from the water into the air. The light arrives at the eyes of an observer as if it were coming from a different direction. The diagram shows what happens to two rays of light coming from the swimmer's right toe. The rays travelling to the observer's eye can be traced back to locate where the observer sees the toe; to the observer, the rays appear to be coming from a point higher than the real position of the toe. It can be seen by looking at the diagram that the amount of bending depends on the angle at which the light crosses the boundary.

FIGURE 10.50 The refraction of light as it travels from water to air makes legs look shorter when standing in water.



angle of incidence angle between an incident ray of light and the normal

angle of refraction angle between a refracted ray of light and the normal

image visual representation of an object; what we see

A spectrum of colour!

Refraction of light is responsible for the dispersion of white light as it passes through a prism. Each colour of light is refracted at a slightly different angle due to its **wavelength** and **frequency**, creating a visible rainbow.

wavelength distance between two neighbouring crests or troughs of a wave.

frequency number of vibrations in one second, or the number of wavelengths passing in one second

on Resources

Interactivity Bend it (int-0673)

elog-0646

INVESTIGATION 10.6

Looking at images

Aim

To observe and compare the reflection of light from plane mirrors and curved mirrors.

Materials

- plane mirror
- shiny tablespoon or soup spoon

Method

1. Look at your image in the back of a spoon. This surface is convex. Convex means curved outward. Move the spoon as close to your eyes as you can and then further away.
2. Record your observations in a table like the one in the results section. Is the image small or large? Right-side up or upside down? Is there anything strange about the image?
3. Look at your image in the front of the spoon. This surface is concave. Concave means curved inward. Move the spoon closer to you and then further away.
4. Record your observations in the table.
5. Look at the image of your face in a plane mirror. Wink your right eye and take notice of which eye appears to wink in the image.
6. Write the word IMAGE on a piece of paper and place it in front of the mirror so that it faces the mirror. Write down the word as you see it in the image.
7. Write down how you think an image of the word REFLECTION would look in the mirror, then use a mirror to check your answer.

Results

TABLE Observations of images using convex and concave sides of a spoon

	Observations of image		
	First observation	When you move closer	When you move further away
Convex side			
Concave side			

Include your diagrams of the word IMAGE and REFLECTION in the results section.

Discussion

1. When you wink your right eye in front of a mirror, which eye in the plane mirror image appears to wink?
2. Which letters in the image of the word IMAGE look different? Which look the same?
3. Was your hypothesis about the image of the word REFLECTION correct?
4. List some places where you have seen curved mirrors. State whether the mirrors were convex or concave and explain why they are used.

Conclusion

Write a conclusion describing how an image of an object appears when viewed in a plane, convex and concave mirror.

elog-0647

INVESTIGATION 10.7

Floating coins

Aim

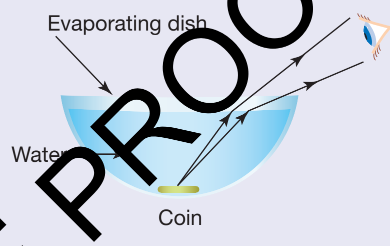
To observe the refraction of light

Materials

- 2 beakers
- evaporating dish
- coin

Method

Place a coin in the centre of an evaporating dish and move back just far enough so you can no longer see the coin. Remain in this position while your partner slowly adds water to the dish.



Results

Make a copy of the diagram. Use dotted lines to trace back the rays shown entering the observer's eye to see where they seem to be coming from. This enables you to locate the centre of the image of the coin.

Discussion

1. Is the image of the coin above or below the actual coin?
2. What appears to happen to the coin while water is added to the evaporating dish?

Conclusion

What can you conclude about the refraction of light from air through water?

on Resources

assesson Additional automatically marked question sets

10.7 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 5, 12	Questions 3, 7, 8, 10	Questions 6, 9, 11, 13

Remember and understand

1. You cannot usually see light as it travels through the air. What makes it possible to see a beam of light?
2. What does a mirror do to light in order to form an image?
3. How is your image in a plane mirror different from the real you?
4. What is refraction?
5. Which way does light bend when it slows down while passing from water into air: towards or away from the normal?

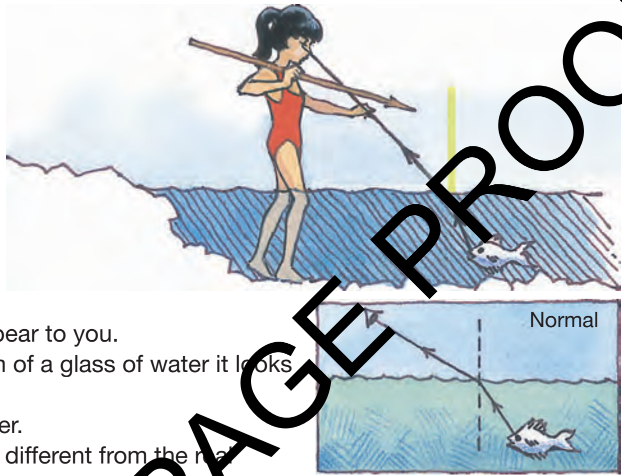
6. How would the word 'TOYOTA' on the front of a van look in the rear-view mirror of the driver in front of it?

Apply and analyse

7. In which type of mirror can your image be upside down?
8. Which type of mirror is used to help you see around corners? Why?
9. Why do dentists use concave mirrors to examine your teeth?
10. Explain how white light is separated into different colours by a triangular prism.

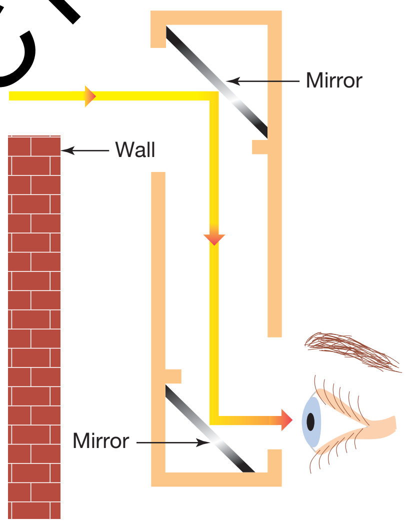
Evaluate and create

11. The illustration shows a ray of light emerging from still water after it has been reflected from a fish. Trace the rays of light entering the girl's eyes back to locate the image of the fish she sees.
    a. Should the spear be aimed in front of or behind the image of the fish? Use the diagram to explain why.
    b. Imagine that you are the fish:
        i. Will the image of the girl's head be higher or lower than her real head?
        ii. Draw a sketch of how the girl might appear to you.



12. When you look down on a coin at the bottom of a glass of water it looks closer to you than it really is.
    a. Draw a diagram to show why it looks closer.
    b. In what other way is the image of the coin different from the real coin?
13. **SIS** Design and build a simple periscope like the one shown in the diagram. You will need stiff card, scissors, two small mirrors, sticky tape or glue, a pencil and a ruler. Explain, with the aid of a diagram, how it works.

A periscope uses mirrors to enable you to see around corners or over objects.



Fully worked solutions and sample responses are available in your digital formats.

10.8 Seeing light

LEARNING INTENTION

At the end of this subtopic you will be able to describe how eyes produce images and apply this knowledge to explain corrective technologies.

10.8.1 The human eye

Everything that you see is an image, created when the energy of light waves entering your eyes is transmitted to a 'screen' at the back of each eye. This screen, called the **retina**, is lined with millions of cells that are sensitive to light. These cells respond to light by sending electrical signals to your brain through the **optic nerve**.

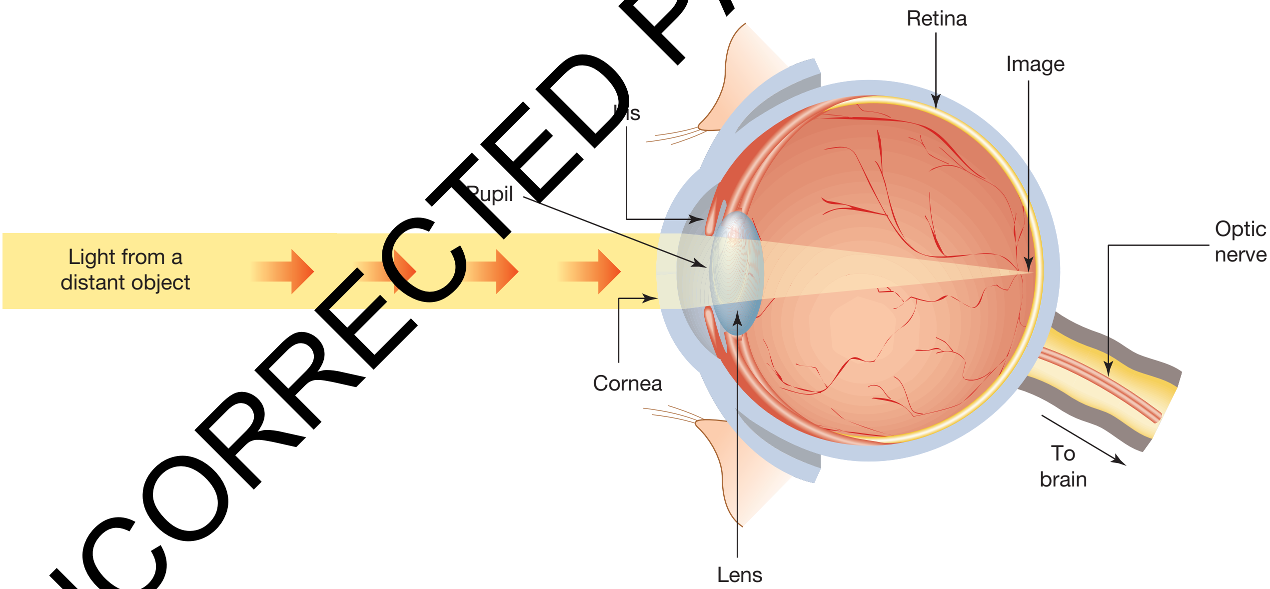
Some of the light reflected from your surroundings, along with light emitted from luminous objects such as the Sun, enters your eye. It is refracted as it passes through the outer surface of your eye. This transparent outer surface, called the **cornea**, is curved so that the light converges towards the **lens**. Most of the bending of light done by the eye occurs at the cornea.

FIGURE 10.51 The human eye

ewbk-6848

Int-8226

FIGURE 10.52 Side view of a human eye



retina curved surface at the back of the eye, that is lined with sight receptors

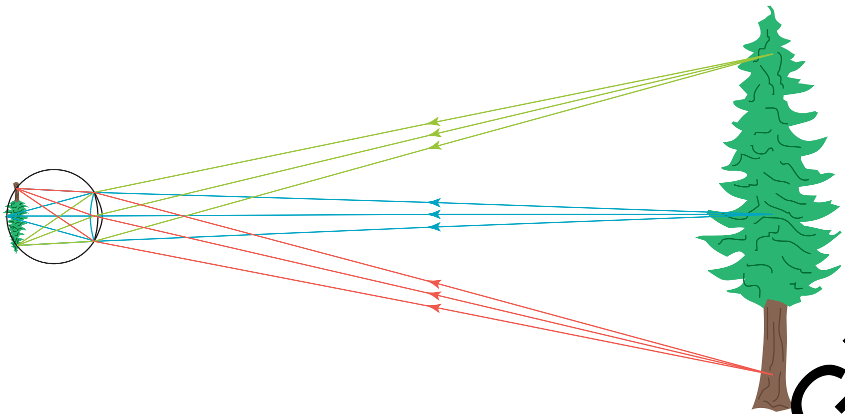
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina

cornea clear, curved outer surface of the eye

lens part of the eye that focuses light onto the retina, ensuring the image is sharp

On its way to the lens, the light travels through a hole in the coloured **iris** called the **pupil**. The iris is a ring of muscle that controls the amount of light entering the lens. In a dark room the iris contracts to allow as much of the available light as possible through the pupil. In bright sunlight the iris relaxes, making the pupil small to prevent too much light from entering. The clear, jelly-like lens bends the light further, ensuring that the image formed on the retina is sharp. The image formed on the retina is inverted (figure 10.53). However, the brain is able to process the signals coming from the retina so that you see things the right way up.

FIGURE 10.53 The image formed on the retina is upside down.



iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

pupil hole through which light enters the eye

converging lens lens that bends rays so that they move towards each other. Converging lenses are thicker in the middle than at the edges

biconvex convex on both sides

focal length distance between a lens or curved mirror and its focal point

diverging lens lens that bends rays so that they spread out Diverging lenses are thinner in the middle than at the edges

biconcave concave on both sides

virtual focal point a single point from which light rays seem to be coming after passing through a concave lens

10.8.2 Getting things in focus

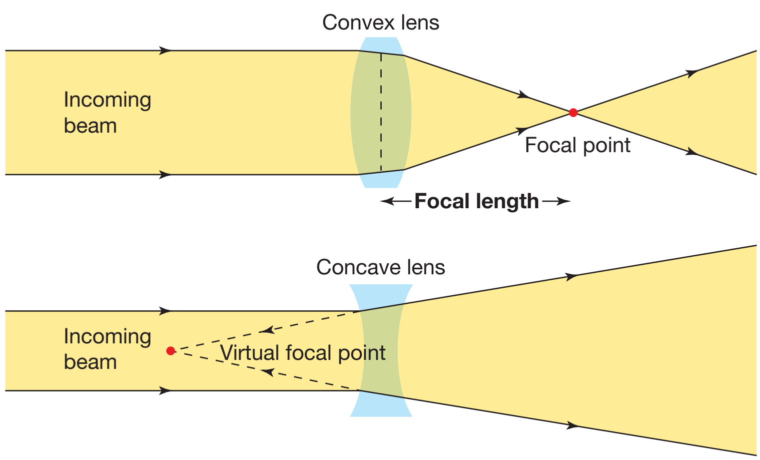
Although most of the bending of light energy done by the eye occurs at the cornea, it is the lens that ensures the image is sharp.

Two types of lenses

The lens in each of your eyes is a **converging lens**. Its shape is **biconvex** — that means it is curved outwards on both sides. A beam of parallel rays of light travelling through a biconvex lens 'closes in' (converges) towards a point called the focal point, or focus. The distance between the centre of the lens and the focal point is called the **focal length**.

Another type of lens is a **diverging lens**, which spreads light outwards because of its biconcave shape. A **biconcave** lens does not have a real focal point. When the parallel light rays emerge from a biconcave lens, they do not converge to a focal point. However, if you trace the rays back to where they are coming from, you find that they do appear to be coming from a single point. That point is called the **virtual focal point**, or virtual focus.

FIGURE 10.54 Convex lenses focus light rays whereas concave lenses make light rays spread out.



elog-0648

INVESTIGATION 10.8

Focusing on light

Aim

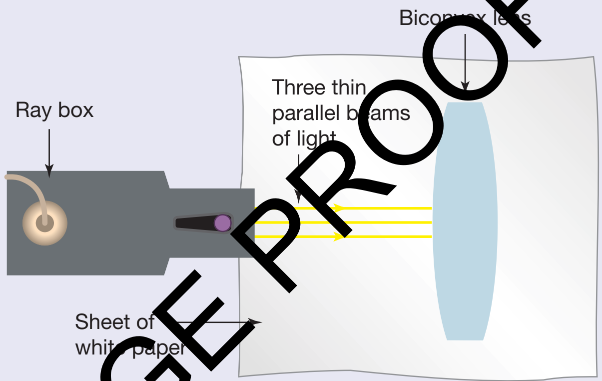
To investigate the transmission of light through different lenses

Materials

- ray box kit
- sheet of white paper
- 12 V DC power supply
- ruler and fine pencil

Method

1. Connect the ray box to the power supply and place it on a page of your notebook.



Part A: Biconvex lenses

2. Place the thinner of the two biconvex lenses in the kit on the page and trace out its shape. Project three thin parallel beams of white light towards the lens.
3. Trace the paths of the light rays as they enter and emerge from the lens. Remove the lens from the paper so that you can draw the paths of the light rays through the lens.
4. Replace the thin biconvex lens with a thicker one and repeat the previous steps.

Part B: Biconcave lenses

5. Place the thinner of the two biconcave lenses on your notebook page and trace its shape.
6. Trace the path of each of the three thin light beams as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light beams through the lens.

Results

1. Your ray diagrams should appear in this section.
2. Measure and record the focal length (distance from the focal point to the centre of the lens) for each lens.

Discussion

1. Which of the biconvex lenses bends light more: the thin one or the thicker one?
2. Explain why the middle light ray does not bend.
3. How many times does each of the other rays bend before arriving at the focal point?
4. Do the diverging rays come to a focus?
5. Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.
6. Predict where the diverging rays will appear to come from if you use a thicker biconcave lens. Check your prediction with the thicker biconcave lens in the ray box kit.

Conclusion

Summarise your findings by writing a conclusion for this investigation.

Accommodation

The exact shape of the clear jelly-like lens in your eye is controlled by muscles called the **ciliary muscles**. When you look at a distant object, the ciliary muscles are relaxed and the lens is thin, producing a sharp image on the retina. When you look at a nearby object, the light needs to be bent more to produce a sharp image. The ciliary muscles contract and the jelly-like lens is squashed up to become thicker. This process is called **accommodation**.

ciliary muscles muscles that control the shape of the lens in the eye

accommodation changing the lens shape to focus a sharp image on the retina

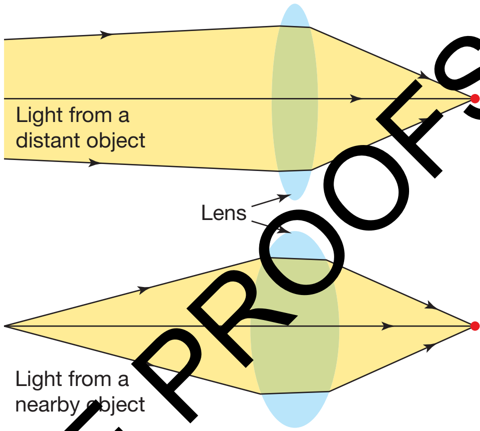
EXTENSION: Dragonfly eyes

Each human eye contains just one convex lens. Insects have compound eyes. Each eye contains many lenses. Some types of dragonfly have more than 10 000 lenses in each eye. Each eye can focus light coming from only one direction.

WHAT DOES IT MEAN?

The word accommodation comes from the Latin term *accommodatio*, meaning 'adjustment'.

FIGURE 10.55 The light coming from a nearby object needs to be bent more than the light coming from a distant object. The lens in your eye becomes thicker when you look at nearby objects.



10.8.3 Presbyopia

As you get older, the tissues that make up the lens become less flexible. The lens does not change its shape as easily. Images of very close objects (like the words you are reading now) become blurred. The lens does not bulge as much as it should and the light from nearby objects converges to a point behind the retina instead of on the retina. You may have to hold what you are reading further away in order to obtain a clear image.

This change in accommodation with age is known as **presbyopia** and is a natural process. Some people are not inconvenienced at all while others need to wear reading glasses so that they can read more easily and comfortably. Table 10.3 shows how the smallest distance at which a clear image can be obtained changes with age. The distances shown are averages and there is a lot of variation from person to person.

TABLE 10.3 The shortest distance at which a clear image can be obtained changes with age.

Age (years)	Distance (cm)
10	7.5
20	9
30	12
40	18
50	50
60	125

presbyopia blurring of images of very close objects caused by loss of flexibility of the lens in the eyes

elog-0649

INVESTIGATION 10.9

Getting a clear image

Aim

To investigate accommodation

Materials

- ruler

Method

1. Look closely at the **X** printed here from the smallest distance at which you can see it clearly and sharply with comfort. Quickly look away and focus on a distant object for a second or two and then focus on the 'X' again from the smaller distance.
2. Try to feel the action of the muscles that allow you to see a sharp image of the 'X'.
3. Use the following procedure to estimate the smallest distance at which you can obtain a clear image of a nearby object. (If you are wearing glasses, remove them during this part of the experiment.)
4. Hold this book vertically at arm's length from your eyes and focus on it. Move the book to a position about 3 or 4 centimetres from your eyes and then gradually move the book further away until you can see the print clearly and sharply.

5. Have a partner use the ruler to estimate the distance between the page and your eyes. The ruler should be placed carefully beside your head for this measurement.

Results

1. Record the distance measured.
2. Collate the results for the whole class and determine the average smallest distance at which a clear image could be obtained.

Discussion

1. How does your result compare with the average distance for your class?
2. Write down the highest single result and lowest single result for your class. Comment on the range of results.

Conclusion

Write a conclusion for this investigation.

10.8.4 Improving the image

The eye is truly an amazing optical system. It is able to focus on distant objects many kilometres away as well as very close objects only centimetres away. However, the ability to obtain sharp images varies from person to person — as well as with age.

The most common conditions that reduce the ability to obtain sharp images are **short-sightedness** and **long-sightedness**.

short-sightedness A person who is short-sighted is unable to obtain sharp images of distant objects

long-sightedness A person who is long-sighted is unable to obtain sharp images of nearby objects.

Short-sightedness (myopia)

A person who is short-sighted is unable to obtain sharp images of distant objects. That happens when the cornea and lens bend the light too much. As a result, the light from a distant object focuses in front of the retina causing the image formed on the retina to be blurry.

Short-sightedness can be corrected by wearing glasses with convexo-concave lenses (see figure 10.56). These lenses diverge the light just a little before it enters the eye. As a result, the light from the object focuses on the retina instead of in front of it.

FIGURE 10.56 A convexo–concave lens has one slightly convex side and one slightly concave side. The concave side is more curved than the convex side, so it acts like a concave (diverging) lens.

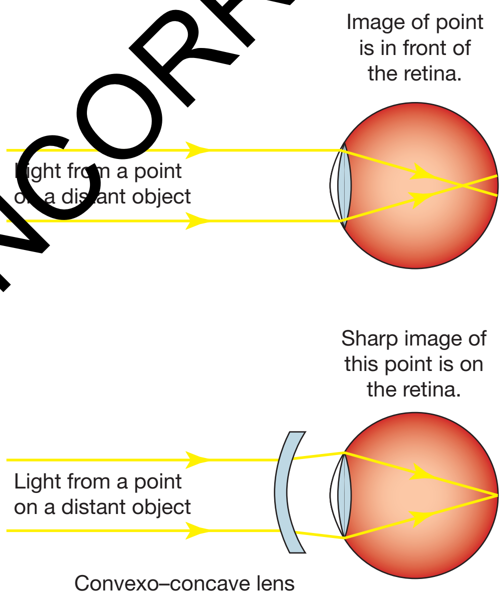
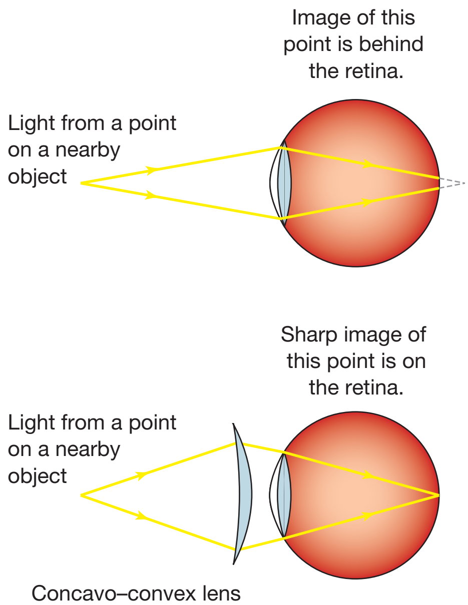


FIGURE 10.57 A concavo–convex lens has one slightly concave side and one slightly convex side. The convex side is more curved than the concave side, so it acts like a convex (converging) lens.



Long-sightedness (hyperopia)

A person who is long-sighted is unable to obtain sharp images of nearby objects. That happens when the cornea and lens don't bend the light enough. As a result, the light from a nearby object reaches the retina before it comes to a focus causing the image formed on the retina to be blurry.

Long-sightedness can be corrected by wearing glasses with concavo-convex lenses (see figure 10.57). These lenses converge the light just a little before it enters the eye. As a result, the light from the object focuses on the retina instead of behind it.

Multifocal lenses

As people get older, they are more likely to have difficulties in forming clear images of distant as well as nearby objects. In days gone by the solution to this problem was to have two pairs of glasses — one with a converging lens for reading and the other with a diverging lens for distance vision.

Multifocal lenses remove the need for two separate pairs of glasses. They can be bifocal with two parts or trifocal with three parts that merge into each other. Bifocal lenses are shaped so that the top part of the lens converges light to assist reading. The bottom part is shaped to diverge light to assist distance vision. A clear boundary between the two parts of the lens is visible. Trifocal lenses gradually change in shape from bottom to top to assist with close-up vision, arm's length vision and distance vision. There are no visible boundaries between the different parts of the lenses.

multifocal lenses lenses that are composed of different sectors of lens with differing focal length, which allow people with both short-sightedness and long-sightedness to see clearly

FIGURE 10.58 Bifocal lenses have two types of lenses that merge so that distant and nearby images are clear.

DISCUSSION

Should the eyesight of older drivers be tested when they renew their driving licence? What factors are involved in making this decision?

Resources

Video eLesson Galileo and the telescope (eles-1765)

Interactivity Lenses (int-1017)

assesson Additional automatically marked questions

10.8 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 6, 7, 8	Questions 3, 5, 11, 13, 15	Questions 9, 10, 12, 14, 16

Remember and understand

1. Which part of the human eye does most of the bending of light occur?
2. Describe the function that the iris and pupil work together to perform.
3. Name and sketch the shape of a lens that:
   a. converges a beam of light to a single point
   b. makes the rays in a beam of light diverge.
4. What is the focal length of a converging lens a measure of?
5. What is accommodation?
6. What is the name given to the shape of the lens in the human eye?
7. Why is it common to see older people holding a newspaper at arm's length while they are reading it?
8. What are bifocal lenses and why are they used?

Apply and analyse

9. Explain why the focal point of a diverging lens is called a virtual focal point.
10. Does light slow down or speed up when it passes from the air into the cornea? How do you know this?
11. Which condition of the eye is most likely to be responsible for each of these problems?
    a. A student who can read the whiteboard from the back of the room but has to strain to read the print in a textbook and gets headaches while reading from a computer screen at home
    b. A science teacher who has never had eye problems before begins to find it easier to read books and newspapers when they are held further away
    c. A person who has no problem reading a newspaper but can't read the numbers on the scoreboard at an AFL football match
12. Sketch the shape of the lens in the eye when you are viewing:
    a. a nearby object
    b. a distant object.
    c. How does the lens change its shape?

Evaluate and create

13. SIS Use the data in the table 10.3 to draw a line graph to show how the ability to focus on nearby objects changes with age.
    a. Use your graph to predict the smallest distance at which a clear image can be obtained by an average person of your age.
    b. At what age does the decrease in focusing ability appear to be most rapid?
14. SIS Use two or more lenses and lens holders to make a model microscope or telescope on a laboratory workbench. Investigate the effect of changing the distance between the lenses on the magnification and write a report on your findings.
15. SIS Research and report on astigmatism of the eye and how it is corrected.
16. SIS Use the internet to research and report on the development of the bionic eye by Australian scientists. Include in your report information about:
    - macular degeneration
    - which patients it is designed to benefit
    - how it works
    - a comparison with the bionic ear.

Fully worked solutions and sample responses are available in your digital formats.

10.9 Sound energy

LEARNING INTENTION

At the end of this subtopic you will be able to use a wave model to describe properties of sound, measure the speed of sound, and explain how musical instruments produce sound.

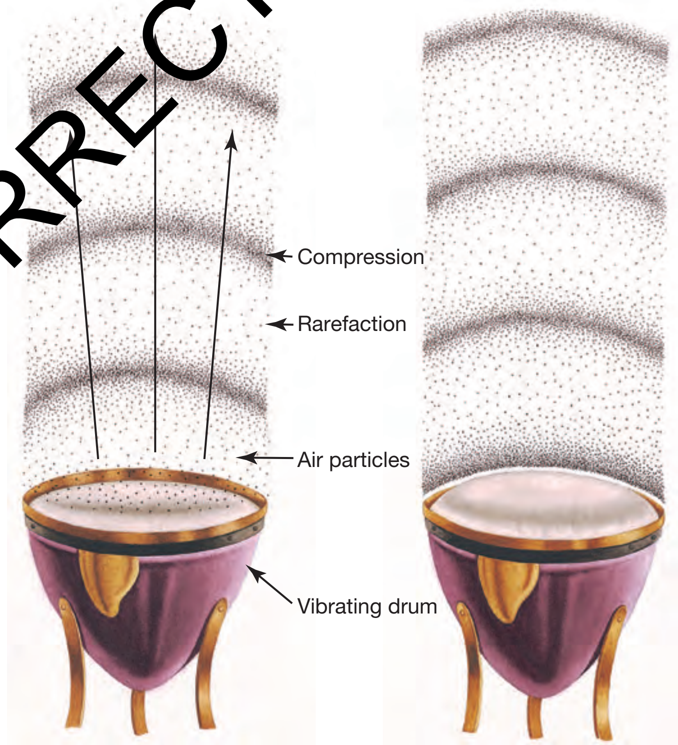
10.9.1 Sounds are caused by vibrations

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?

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 (see figure 10.60). 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.

FIGURE 10.59 When you sing, your vocal chords vibrate, sending sound waves through the air.

FIGURE 10.60 Sound waves consist of a series of vibrating air particles.



vibrations repeated fast, back-and-forth movements

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) 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. It is important to note that although the air particles move to and fro when they vibrate about their usual position, they do not actually travel anywhere. Because the air particles move to and fro in the same direction as the sound is travelling, sound waves are a type of **longitudinal wave**. Light is not a longitudinal wave because its components vibrate perpendicular to the direction in which the wave is propagating, which classifies it as a **transverse wave**. The waves that you see on the ocean are also transverse waves because until they break on the shore the water particles are actually moving up and down. A 'Mexican wave' that you might see at some sporting events is also an example of a transverse wave.

compression a region where air particles are closer together than usual

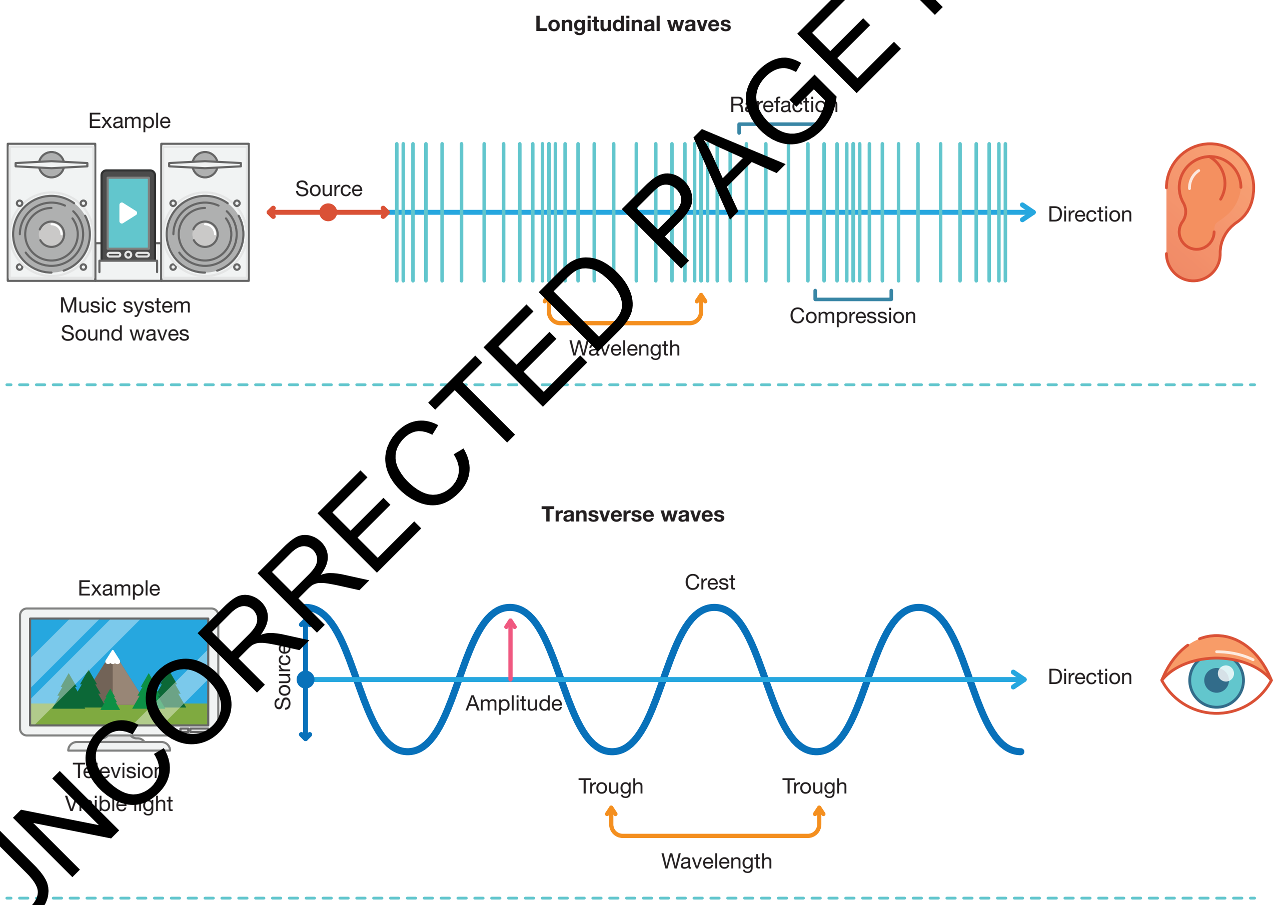
rarefactions in sound waves, the layers of air particles that are spread apart (between compressions)

sound waves vibrations of particles in the air

longitudinal wave a wave that vibrates in the direction of propagation

transverse wave a wave that vibrates perpendicular to the direction of propagation

FIGURE 10.61 Longitudinal waves and transverse waves



WHAT DOES IT MEAN?

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

elog-0650

INVESTIGATION 10.10

Modelling sound waves

Aim

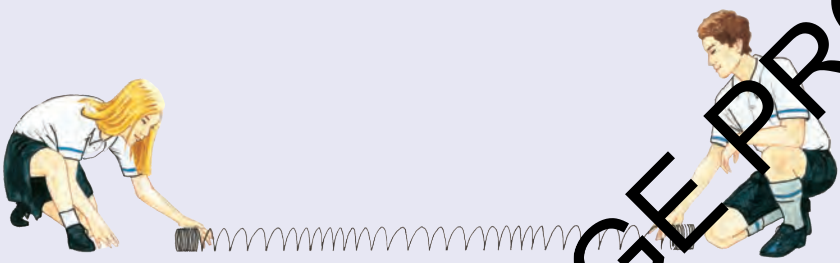
To model sound waves on a slinky

Materials

- slinky spring

Method

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



Results

Describe your observations when the wave moved along the slinky.

Discussion

1. Describe how your model is similar to real sound waves.
2. Describe how your model is different from real sound waves.
3. How could you use the slinky to model a transverse wave?

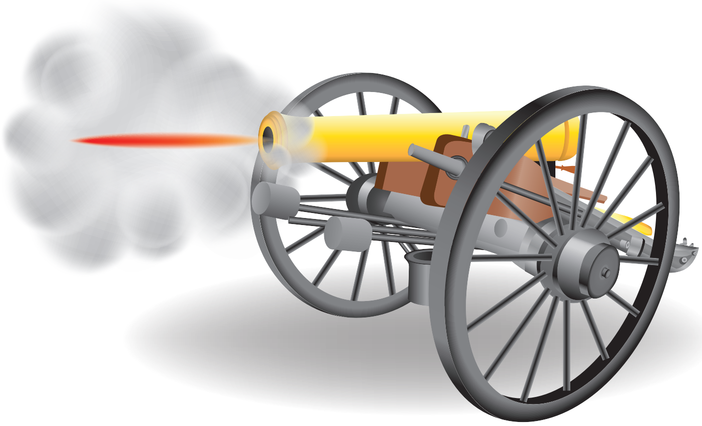
Conclusion

What can you conclude about modelling sound waves?

10.9.2 Measuring the speed of sound

The first known attempt to measure the speed of sound was made by French philosopher and scientist Pierre Gassendi in 1635. He measured the time taken between seeing the flash made by a cannon and hearing the sound it made from a long distance. He assumed (correctly) that the time taken for light from the flash to reach his eyes was very close to zero. In fact, we now know that light takes only 0.000 002 seconds to cover a distance of 500 metres. Gassendi measured the speed of sound to be 478 m/s, which is quite a bit more than the correct value of about 340 m/s at a temperature of 20 °C. But remember there were no accurate timing devices in 1635.

FIGURE 10.62 The flash of light from a cannon will reach you before the sound of the shot will.



CASE STUDY: The speed of sound

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 metres per second. Light energy travels through air at a speed of 300 000 kilometres per second. The delay between seeing lightning and hearing thunder is about 3 seconds for each kilometre that you are away from the lightning.

The number of compressions (or rarefactions) that reach your ear per second is known as the frequency of the sound. The musical note middle C, for example, creates 256 compressions every second. Frequency is measured in **hertz** (Hz), a unit named after Heinrich Hertz, the German physicist who, in 1887, was the first person to detect radio waves. One hertz is equal to one vibration every second. So the frequency of the note middle C is 256 Hz.

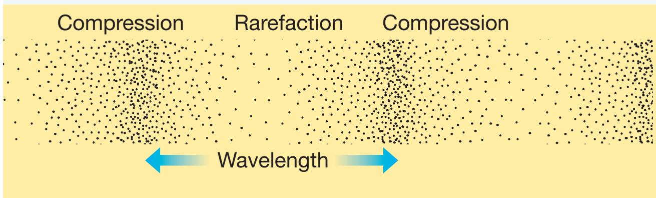
The frequency of a sound determines its **pitch**. The pitch that you hear depends on the frequency of the vibrating air. The faster a sound-producing object vibrates, the higher its frequency and the higher the pitch of the sound you hear. A short string vibrates faster than a long one and so has a higher frequency and pitch.

hertz unit of frequency; its abbreviation is Hz
pitch the highness or lowness of a sound

When you blow across the top of a straw, the air inside it vibrates. If the straw is shortened, the air inside vibrates faster, producing a higher frequency and a high pitch. A longer straw would produce slower vibrations, a lower frequency and a lower pitch.

The distance between two neighbouring compressions (or rarefactions) is known as the wavelength (see figure 10.63). The wavelength of the musical note middle C is about 1.3 metres. The wavelength of the sound produced during normal speech varies between about 5 centimetres and about 2.5 metres. When the frequency of a sound increases, the compressions become closer together, decreasing the wavelength of the sound. If you know the frequency and wavelength of a sound wave, you can calculate its speed using the following formula.

FIGURE 10.63 The wavelength of a sound is the distance between the centres of two neighbouring compressions or rarefactions.

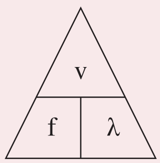


Wave equation

Wave speed = wavelength × frequency

$$v = f \times \lambda$$

where,
v is the speed of wave (m/s)
f is the frequency of wave (Hz)
λ is the wavelength of the wave (m)



The particles of air that vibrate when a sound is made don't move from the source of the sound to your ear. They just move backwards and forwards. Each vibrating particle makes the next one vibrate — that's how the sound energy travels through the air. The distance that each vibrating particle moves from its usual resting place is known as the sound's **amplitude**. Higher amplitudes make louder sounds.

amplitude maximum distance that a particle moves away from its undisturbed position

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INVESTIGATION 10.11

Measuring the speed of sound

This investigation should be conducted on a school sporting oval or a safe open space on a calm day.

Aim

To measure the speed of sound in air

Materials

- stopwatches (mobile phone stop watches are ideal)
- trundle wheel or long measuring tape
- starting pistol that emits smoke, two large blocks of wood or a pair of hand cymbals

CAUTION

Only a teacher wearing earplugs should fire a starting pistol.

Method

1. Position as many students with stopwatches as possible at a distance of at least 150 metres from the location of the starting pistol or wooden blocks. A longer distance up to 300 metres could be used if possible.
2. The sound is made by firing the starting pistol, banging the wooden blocks together or crashing the cymbals. Practise measuring the time taken between seeing the smoke, the wooden blocks being banged together or the hand cymbals crashed together. Repeat the practice several times to allow those with stopwatches to react as quickly as possible.
3. Prepare for a final recording of the time taken between seeing the sound being made and hearing the sound.
4. Conduct the timing and record the times measured by those with stopwatches.

Results

1. Calculate the average time for the sound to travel the distance.
2. Use the formula $\text{speed} = \dfrac{\text{distance}}{\text{average time}}$ to calculate the average speed of sound measured by the class.

Discussion

1. How does your measurement compare with the known speed of sound of about 340 m/s?
2. What is the biggest cause of error in your measurement of the time taken for the sound to reach the observers?
3. Suggest how you could make your results more accurate.
4. What assumption about the speed of light has been made in your calculation of the speed of sound?

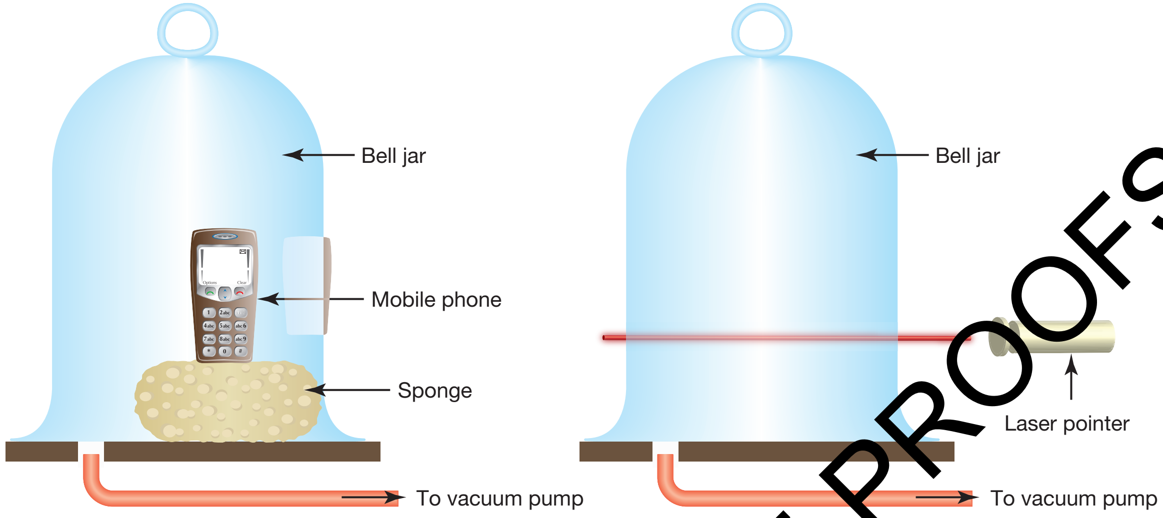
Conclusion

Write a conclusion for this investigation.

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.

FIGURE 10.64 Sound energy cannot travel through empty space. Sound waves require a medium to travel through; light does not.



10.9.3 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.

elog-0652

INVESTIGATION 10.12

Vibrations and pitch

Aim

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

Materials

- ruler
- 2 straws
- scissors
- spatula
- small beaker
- large beaker

Method

1. Hold a ruler over the edge of a table so that one end is firmly held down. Flick the overhanging end of the ruler.
2. Move the ruler so that more of it is over the edge of the table and flick it again.
3. 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.
4. Blow across the two shorter (cut) pieces of straw in the same way and listen to the sounds.
5. Tap the side of a small beaker gently with a spatula and listen to the sound. Do the same with a larger beaker.

Results

1. How does the sound change as the vibrating part of the ruler is made longer?
2. How does the sound change as the straws get shorter?
3. How does the sound of the large beaker compare with the sound of the smaller one?

Discussion

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

Conclusion

What can you conclude about the relationship between the size of a vibrating object and the pitch of the sound it produces?

elog-0653

INVESTIGATION 10.13

Making it louder

Aim

To explore methods of increasing the loudness of sound

Materials

- guitar
- guitar string
- tuning fork

Method

1. Pluck a stretched guitar string. Listen to the sound it makes.
2. Pluck a similar string attached to a guitar.
3. 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.

Results

1. How does the sound of a plucked string change when it is attached to a guitar?
2. How does the sound change when the tuning fork is placed on the table?

Discussion

Explain why the sound changes in each case.

Conclusion

What can you conclude about the ways to increase loudness?

10.9.4 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.

FIGURE 10.65 On a stringed instrument, vibrations are made by plucking 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.

on Resources

Video eLesson A street musician playing a didgeridoo, which is a wind instrument (eles-2682)
A saxophone player (eles-2683)

ACTIVITY: Making music

Have someone demonstrate how different types of musical instruments work.

For each instrument, write down:

a. what the player does to make the instrument work

b. what vibrates to make musical sounds.
What do all of the musical instruments have in common when it comes to the way they make sound?
What differences are there in how they make sound?

10.9.5 When sound meets a substance

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, such as curtains and carpet, absorb much more sound than walls of plaster or tiles.

reverberation longer-lasting sound caused by repeated reflection from hard surfaces

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.

FIGURE 10.66 The Elisabeth Murdoch Hall at the Melbourne Recital Centre

on Resources

assesson Additional automatically marked questions

10.9 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 6, 8, 9	Questions 2, 5, 10, 11, 13, 14	Questions 7, 12, 15, 16

Remember and understand

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. a. Name the unit of frequency and describe what it measures.
   b. Which quality of sound that you hear does the frequency determine?
4. a. What distance is the wavelength of a sound wave the measure of?
   b. What happens to the wavelength of a sound wave when its frequency increases?
5. What characteristic of vibrating air does amplitude describe?
6. Explain why sound can't travel through empty space.

Apply and analyse

7. If you blow across the top of a straw, a sound is made. How could you increase the pitch of the sound?
8. Which vibrates more quickly: a long string or a short string made of the same material?
9. How do we know, without taking any measurements, that light travels through air faster than sound?
10. Describe what can happen to sound energy travelling through the air when it meets a new substance.
11. Is sound energy a form of kinetic energy? Explain your answer.
12. How would you expect a carpeted classroom to sound compared with one with a hard vinyl floor? Give reasons for the differences.
13. Complete the gaps in the following table.

TABLE Making sound with the musical instruments

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

Evaluate and create

14. SIS The speed of sound in air at different temperatures is shown in the table.

TABLE The speed of sound at different temperatures

Temperature (°C)	Speed of sound (m/s^{-1})
–10	325.4
–5	328.5
0	331.5
5	334.5
10	337.5
15	340.5
20	343.4
25	346.3
30	349.2

a. Plot a graph of the speed of sound versus the air temperature.
b. Describe the relationship between the speed of sound and the air temperature.
c. Use your graph to determine the speed of sound in air when the temperature is 17 °C.

15. SIS 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?

16. SIS Research and then provide a brief description of the following careers that involve using and understanding sound energy.
a. Audiologist
b. Acoustic engineer
c. Audio engineer

Fully worked solutions and sample responses are available in your digital formats.

10.10 Thinking tools — Matrixes and Venn diagrams

10.10.1 Tell me

What is a matrix?

A matrix is a very useful thinking tool for comparing topics and identifying ways in which these topics are similar and different. A matrix shows similarities and differences between topics. They are sometimes called a table, grid or decision chart.

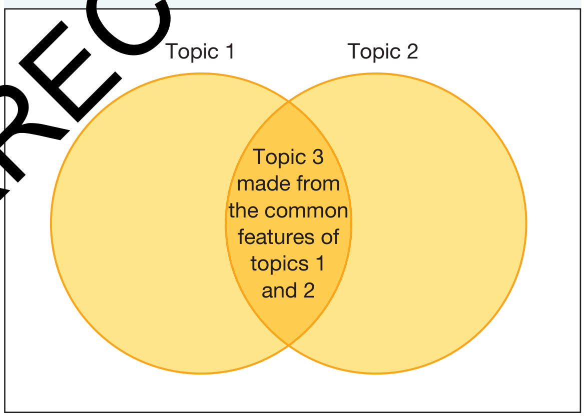
FIGURE 10.67 A matrix

Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓
4			✓	✓	✓

Why use a matrix over a Venn diagram?

Similar to a matrix, a Venn diagram identifies common points between two separate topics. However, they use different graphic formats to show the common features. A matrix uses a grid or table, whereas a Venn diagram uses overlapping circles.

FIGURE 10.68 A Venn diagram



10.10.2 Show me

To create a matrix

1. Write the topics in the left-hand column of the matrix.
2. Write the characteristics to be compared along the top row of the matrix.
3. If a characteristic applies to a topic, put a tick in the appropriate cell of the matrix.
4. The matrix now shows how the various topics are related.

The example below shows a matrix indicating the forms of energy that electrical energy is transformed into by each of the electrical devices.

TABLE Conversion of electrical energy by different electrical devices

Device	Electrical energy is converted into …				
	Light energy	Sound energy	Thermal energy	Kinetic energy	Potential energy
Hair dryer		✓	✓	✓	✓
Television	✓	✓	✓	✓	✓
Desk lamp	✓		✓	✓	✓
Vacuum cleaner		✓	✓	✓	✓
Home computer	✓	✓	✓	✓	✓
Incandescent light bulb	✓		✓	✓	✓
Air-conditioner		✓	✓	✓	✓
Elevator going up		✓	✓	✓	✓

Note: All substances and objects possess potential energy, but you can’t tell unless something happens to transform the potential energy into a different energy type.

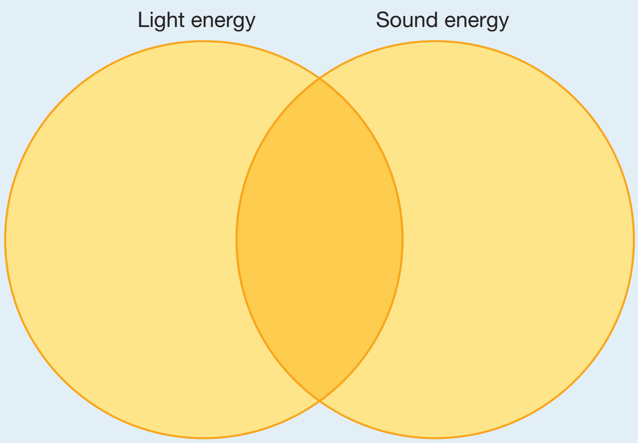
10.10.3 Let me do it

10.10 ACTIVITIES

1. a. Complete this matrix. Use ticks to show which statements refer to light and which refer to sound. Some of the statements refer to both light and sound.

Statement	Light energy	Sound energy
Travels through air at 300 000 kilometres per second		
Travels faster than a speeding bicycle		
Can be reflected		
Can be absorbed		
Is always caused by vibrating objects or substances		
Is observed in an electrical storm		
Can travel through empty space		
Can be produced from another form of energy		
Is used by physiotherapists to treat some muscle problems		

   b. The information in the matrix provided can be represented in a Venn diagram. Convert the information in the matrix into a large Venn diagram based on the example provided.



10.11 Project — Going green

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 10 000 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 the 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, hair dryers 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.)

FIGURE 10.69 Sustainable eco-tourist cottages

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

on Resources

ProjectsPLUS Going green (proj-0093)

10.12 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5170	ewbk-5172	ewbk-5174

on Resources

10.12.1 Summary

Different forms of energy

- Energy cannot be created or destroyed. This statement is known as the Law of Conservation of Energy.
- There are many different types of energy, all of which fall under one of two categories: potential or kinetic.
- Potential energy is energy that is stored in objects. Types of potential energy include gravitational, elastic, chemical, nuclear, electrical and magnetic.
- Kinetic energy is energy that involves movement. Types of kinetic energy include translational, thermal, radiant, sound and electrical.

Transforming energy

- Energy can be transformed from one type to another type.
- Potential energy can be transformed into kinetic energy in many ways. An example is gravitational potential energy transforming into kinetic energy when an object is dropped.
- Most energy transformations convert energy from one form into multiple other forms. Some of the forms that it is converted into are not very 'useful' and are sometimes classified as wasted energy.
- The efficiency of an energy transformation is the percentage of the initial energy that is converted into the desired form. Efficiency $= \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$

Transferring energy

- Energy can be transferred from an object to another object, or from one form into another form by forces or by heating.
- For example, when an object falls the gravitational force converts gravitational potential energy into kinetic energy. When the object hits the ground the upwards force on it converts the kinetic energy into sound and heat energy, along with elastic potential energy, causing it to bounce.
- The transfer of thermal energy is known as heat.
- There are three ways in which heat can be transferred.
  - Conduction is the transfer of heat due to the direct collisions of particles in a solid.
  - Convection is the transfer of heat in liquids and gases that occurs due to circulation of hotter particles throughout the liquid or gas.
  - Radiation is the transfer of heat by electromagnetic radiation. It is the only form of heat transfer that does not require the collision of warmer particles with other, cooler particles.

A costly escape

- Heat can escape buildings in many ways. Loss from conduction occurs in walls, floors and ceilings, and convection can move warmed or cooled air out through gaps under doors and around windows.
- To counter these unwanted heat transfers, many forms of insulation have been invented including insulation batts, foam inside walls, cavity bricks and double glazing.

Light

- Objects that radiate visible light are said to be luminous.
- Incandescent light sources radiate light because of their temperature. Sources that radiate light but are not hot are not incandescent.

- Objects that are not luminous can still be seen because they reflect light from other sources.
- When light meets a substance three things can happen.
  - It can be transmitted (travel through the substance).
  - It can be absorbed (transferred into the substance).
  - It can be reflected off the substance.
- Visible light is only a small segment of the larger electromagnetic spectrum.
- Other forms of electromagnetic radiation are radio waves, infra-red, ultraviolet, x-rays and gamma rays.

Light forms images

- Light travels in straight lines known as rays.
- When light reflects off a smooth surface the angle of incidence is equal to the angle of reflection.
- Reflections off curved mirrors distort images.
- Focal points are points at which parallel rays converge after reflection off a curved surface.
- Most surfaces are not smooth when you look at them on a very close scale. Rays of light bounce off these surfaces in all directions due to the roughness, reflecting light in all directions.
- When light passes from one substance to another it changes speed, causing it to refract (bend).

Seeing light

- The human eye is designed to obtain images by focusing light on the retina, which then converts the light into an image that is sent to the brain via the optic nerve.
- Light is focused as it passes through the cornea and the lens.
- As you get older the muscles in the eye that control the thickness of the lens become less effective making light focus either in front of or behind the retina. Glasses with slightly convex or concave lenses can counter this, ensuring the light focuses on the retina.

Sound energy

- Sound is the vibration of particles through substances.
- Sound waves are longitudinal waves caused by pressure variations in the air (or substance) through which it travels.
- The frequency of a sound wave is the number of wavelengths it travels per second and is known as the pitch of the sound.
- Instruments create and amplify vibrations at particular frequencies, causing sound waves to travel through the air.
- Sound can be transmitted, absorbed or reflected.

10.12.2 Key terms

absorbed taken in
accommodation changing the lens shape to focus a sharp image on the retina
amplitude maximum distance that a particle moves away from its undisturbed position
angle of incidence angle between an incident ray of light and the normal
angle of refraction angle between a refracted ray of light and the normal
biconcave concave on both sides
biconvex convex on both sides
bioluminescent describes living things that release light energy
ciliary muscles muscles that control the shape of the lens in the eye
compression a region where air particles are closer together than usual
concave curved inwards
conduction transfer of heat through collisions between particles
convection transfer of heat through the flow of particles
converging lens lens that bends rays so that they move towards each other. Converging lenses are thicker in the middle than at the edges
convex curved outwards

cornea clear, curved outer surface of the eye
deciduous trees and shrubs that lose their leaves and become dormant during winter
dispersion separation of the colours that make up white light
diverging lens lens that bends rays so that they spread out Diverging lenses are thinner in the middle than at the edges
efficiency the fraction of energy supplied to a device as useful energy
electromagnetic radiation the radiant energy such as radio waves, infrared, visible light, x-rays and gamma rays released by magnetic or electric fields
electromagnetic spectrum complete range of wavelengths of energy radiated as electric and magnetic fields
electromagnetic waves waves of electromagnetic radiation, light being just one example
element pure substance made up of only one type of atom
fission the process whereby a large nucleus splits into smaller fragments releasing large amounts of energy
focal length distance between a lens or curved mirror and its focal point
focal point a point at which parallel rays of light meet after reflection by a curved mirror of refraction through a lens
frequency number of vibrations in one second, or the number of wavelengths passing in one second
fusion the process whereby two small nuclei combine to form a larger nuclei releasing large amounts of energy
gamma rays high-energy electromagnetic radiation produced during nuclear reactions
hertz unit of frequency; its abbreviation is Hz
image visual representation of an object; what we see
incandescent describes objects that emit light when they are hot
infra-red radiation low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light
insulator a material that is a poor conductor of heat
iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
isotope atoms of the same element that differ in the number of neutrons in the nucleus
kinetic energy energy due to the motion of an object
lateral inversion sideways reversal of images in a mirror
Law of Conservation of Energy a law that states that energy cannot be created or destroyed
lens part of the eye that focuses light onto the retina, ensuring the image is sharp
longitudinal wave a wave that vibrates in the direction of propagation
long-sightedness A person who is long-sighted is unable to obtain sharp images of nearby objects.
luminous releasing its own light
multifocal lenses lenses that are composed of different sectors of lens with differing focal length, which allow people with both short-sightedness and long-sightedness to see clearly
non-luminous describes objects that do not emit their own light, but can be seen by reflected light
normal (the) line drawn perpendicular to a surface at the point where a light ray meets it
nuclear decay the spontaneous decay of unstable nuclei to a new nucleus
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina
pitch the highness or lowness of a sound
potential energy energy that has the potential to do work and so the energy is ‘stored’, such as gravitational energy, elastic energy and chemical energy
presbyopia blurring of images of very close objects caused by loss of flexibility of the lens in the eyes
pupil hole through which light enters the eye
radiation emission of energy as electromagnetic waves
radiant heat heat transferred by electromagnetic radiation
radio waves low-energy electromagnetic radiation
rarefactions in sound waves, the layers of air particles that are spread apart (between compressions)
reflected bounced off
refraction change in the speed of light as it passes from one substance into another
retina curved surface at the back of the eye, that is lined with sight receptors
reverberation longer-lasting sound caused by repeated reflection from hard surfaces
scattered describes light sent in many directions by small particles within a substance
short-sightedness A person who is short-sighted is unable to obtain sharp images of distant objects
sound waves vibrations of particles in the air
transmitted passed through something, such as light or sound passing through air

transmutation the process whereby a nucleus is bombarded with high energy neutrons in an attempt to convert it to another element
transverse wave a wave that vibrates perpendicular to the direction of propagation
ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy
vibrations repeated fast, back-and-forth movements
virtual focal point a single point from which light rays seem to be coming after passing through a concave lens
visible spectrum different colours that combine to make up white light; they are separated in rainbows
wavelength distance between two neighbouring crests or troughs of a wave.
x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about the structure

on Resources

Digital document	Key terms glossary (doc-34974)
eWorkbooks	Study checklist (ewbk-5163) Literacy builder (ewbk-5164) Crossword (ewbk-5166) Word search (ewbk-5168)
Practical investigation eLogbook	Topic 10 (elog-0639)

10.12 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

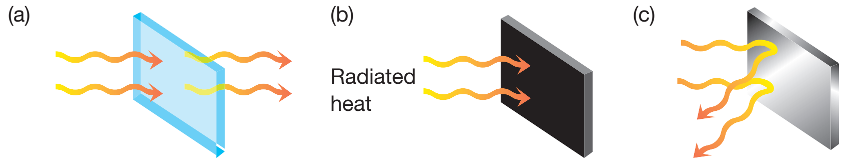
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 5, 8, 10, 13, 14, 24	Questions 4, 7, 9, 12, 15, 17, 19, 21, 22, 25	Questions 6, 11, 16, 18, 20, 23

Remember and understand

1. Replace each of the following descriptions with a single word.
   a. Energy associated with all moving objects
   b. Energy associated with the position of an object
   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. Heat moves from regions of high temperature to regions of low temperature by conduction, convection or radiation. Identify the method of heat transfer in each of the following situations.
   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

5. Each of the surfaces in the figure below shows radiated heat falling on a solid object. Which figure shows heat being:

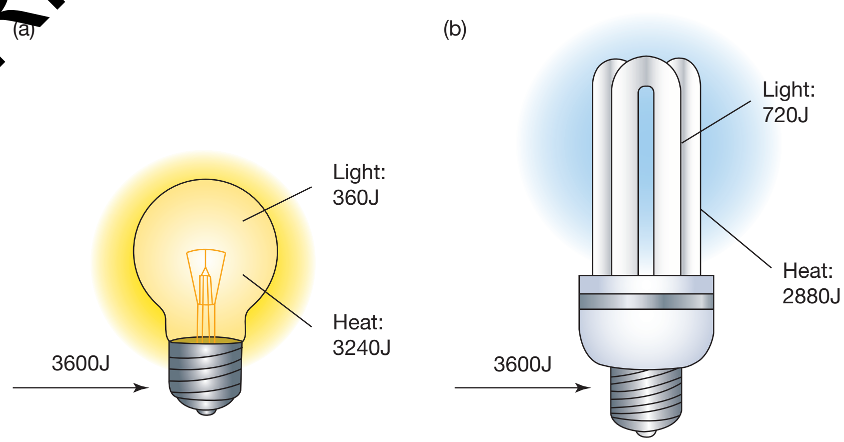


a. absorbed
b. reflected
c. transmitted?

6. 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?
7. Describe one example of evidence that white light is made up of many different colours.
8. To which form of electromagnetic radiation do microwaves belong?
9. Which form of electromagnetic radiation has:
   a. the least energy
   b. the most energy?
10. Which part of the electromagnetic spectrum is used:
   a. in remote control devices
   b. to help the human body produce vitamin D?
11. How does amplitude of a sound wave affect the sound that you hear?
12. Explain the difference in meaning of each of the following pairs of words.
   a. Ray and beam
   b. Scattering and reflection
   c. Refraction and dispersion
13. Describe the role of each of the following parts of the eye.
   a. Cornea
   b. Iris
   c. Lens
   d. Retina
   e. Ciliary muscles

Apply and analyse

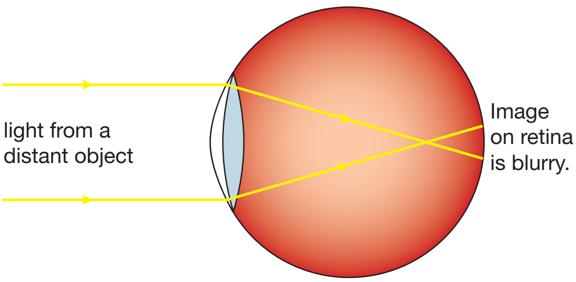
14. Calculate the efficiency of the light bulbs shown in figures a and b.



15. 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?
16. Explain why it is not possible for an energy converter like a battery or car to have an efficiency of 100 per cent.
17. Explain how fibreglass batts are able to reduce the loss of heat through the ceiling by both conduction and convection.

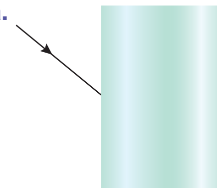
18. Explain how your body keeps its core temperature at 37 °C even when the air temperature is greater than this.
19. Explain how you are able to see an object such as a tree even though it doesn't produce its own light energy.
20. When a sound is made, what happens to the particles in the regions of the air nearby that are called:
    a. compressions
    b. rarefactions?
21. When an object vibrates faster what happens to the sound's:
    a. frequency
    b. pitch
    c. amplitude?
22. 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.
23. The figure shows how light rays from a distant object arrive at the retina of a person with blurry distance vision.
    a. What is the name of the condition illustrated in the figure?
    b. What does the correcting lens need to do to the incoming light to correct the problem?

The eye of a person with blurry distance vision

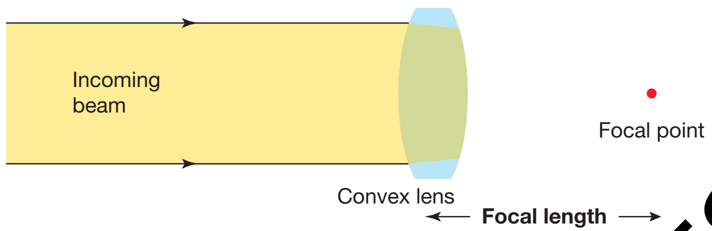


24. Complete the diagrams to show the path of light after it meets the objects shown.

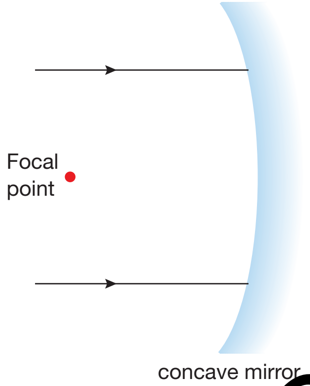
a.



b.



c.



Evaluate and create

25. 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.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-30[illegible]8)

teachon

Test maker

Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to being creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

10.1 Overview

eWorkbooks
- Topic 10 (ewbk-5158)
- Student learning matrix (ewbk-5160)
- Starter activity (ewbk-5161)

Practical investigation eLogbook
- Topic 10 (elog-0639)

Video eLesson
- Energy transformations (eles-2677)

10.2 Different forms of energy

Video eLesson
- Energy in disguise (eles-0063)

10.3 Transforming energy

eWorkbooks
- Skateboard flick cards (ewbk-5148)
- Types of energy (ewbk-5150)

Video eLesson
- The Australian–International Model Solar Challenge (eles-0068)

Interactivity
- Coaster (int-0226)

10.4 Transferring energy

Practical investigation eLogbook
- Investigation 10.1 Moving particles (elog-0641)

Video eLesson
- Convection currents (eles-2056)

Interactivities
- Convection currents (int-5346)
- A hot-water system (int-3399)
- Transmission, absorption and reflection (int-3400)

10.5 A costly escape

eWorkbook
- A costly escape (ewbk-5152)

Practical investigation eLogbook
- Investigation 10.2 Investigating insulators (elog-0642)

Interactivity
- A thermos flask (int-3401)

10.6 Light

eWorkbook
- Light energy (ewbk-5154)

Practical investigation eLogbooks
- Investigation 10.3 Observing a radiometer (elog-0643)
- Investigation 10.4 Seeing the light (elog-0644)

Video eLessons
- Bioluminescent click beetle (Pyrophorus sp.) (eles-2678)
- Crookes radiometer for measuring radiant flux (eles-2679)
- Refraction in a prism (eles-2680)

10.7 Light forms images

Practical investigation eLogbooks
- Investigation 10.5 Reflection and refraction (elog-0645)
- Investigation 10.6 Looking at images (elog-0646)
- Investigation 10.7 Floating coins (elog-0647)

Video eLesson
- Children's reflections are distorted by this playground mirror (eles-2681)

Interactivity
- Bend it (int-0673)

10.8 Seeing light

eWorkbook
- Labelling the human eye (ewbk-0647)

Practical investigation eLogbooks
- Investigation 10.8 Focusing on light (elog-0648)
- Investigation 10.9 Getting a clear image (elog-0649)

Video eLesson
- Galileo and the telescope (eles-1765)

Interactivities
- Lenses (int-1017)
- Labelling the human eye (int-####)

10.9 Sound energy

Practical investigation eLogbooks

- Investigation 10.10 Modelling sound waves (elog-0650)
- Investigation 10.11 Measuring the speed of sound(elog-0651)
- Investigation 10.12 Vibrations and pitch (elog-0652)
- Investigation 10.13 Making it louder (elog-0653)

Video eLessons

- A street musician playing a didgeridoo, which is a wind instrument (eles-2682)
- A saxophone player (eles-2683)

10.11 Project — Going green

ProjectsPLUS

- Going green (proj-0093)

10.12 Review

eWorkbooks

- Topic review Level 1 (ewbk-5170)
- Topic review Level 2 (ewbk-5172)
- Topic review Level 3 (ewbk-5174)
- Study checklist (ewbk-5163)
- Literacy builder (ewbk-5164)
- Crossword (ewbk-5166)
- Word search (ewbk-5168)
- Reflection (ewbk-3038)

Practical investigation eLogbook

- Topic 10 (elog-0639)

Digital document

- Key terms glossary (doc-34974)

To access these online resources, log on to www.jacplus.com.au