

ASPIRE
SUCCEED
PROGRESS



Complete Physics

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Second Edition







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Objective

 Explain why some things float and some things sink in water



▲ A coconut floats.



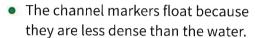
▲ Pumice is a rock that floats, but sandstone sinks...

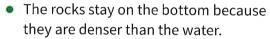
Floating and sinking

Icebergs can have a mass of more than 100 000 tonnes, which is the same as over 50 000 cars. How can they float?

Why do some things sink and some things float?

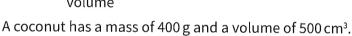
Floating metal buoys mark out the deep-water channel for boats coming into harbour, so that they don't hit underwater sand or rocks.





An object will float on a liquid if it has a **density** that is *less* than that of the liquid. We calculate density using this equation:

density =
$$\frac{\text{mass}}{\text{volume}}$$



density of coconut =
$$\frac{400 \text{ g}}{500 \text{ cm}^3}$$
$$= 0.8 \text{ g/cm}^3$$

The density of water is $1.0\,\mathrm{g/cm^3}$. The density of the coconut is less than that, so it floats.

Imagine what would happen if you had a ball with exactly the same volume as a coconut but with twice the mass. The density of the ball would be twice that of the coconut, and it would sink.

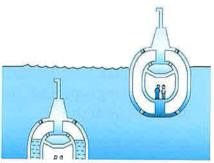
Some people think that rocks always sink and wood always floats. It is not always easy to predict whether something will float or sink.



... and ironwood sinks.



▲ A massive iceberg floats.



▲ Channel markers made of iron can float.

- Pumice is a volcanic rock that floats its density is about 0.3 g/cm³.
- Ironwood is a type of wood that sinks – its density is 1.3 g/cm³.

If you are swimming, it is much easier to float in salt water than in a swimming pool. This is because salt water is denser than the water in the swimming pool. Liquids have different densities.

Liquid	Density of liquid (g/cm³)
Pure water	1.0
Salt water	1.2
Petrol/gasoline	0.7
Bromine	3.12
Mercury	13.6

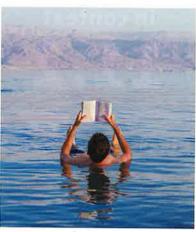


Another way of thinking about why something floats or sinks is to compare the **upthrust** with the weight. You learned about upthrust on page 109. The object floats if the upthrust is equal to the weight. We can explain upthrust with the particle model.

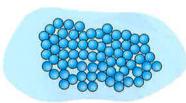
- Particles in liquids and gases collide with solid objects.
- Particles in the air collide with a floating object from above.
- Particles in the water collide with a floating object from below.
- The force exerted on the object depends on the *difference* between the forces due to the particles.
- The particles in a dense liquid will exert a bigger force than those in a less dense liquid, because they are more massive.

Ice and water

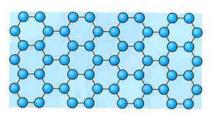
Ice is made of water, so how can it float? When water freezes, the water molecules form a solid structure that takes up more space than the water. The ice is less dense than the water. This is unusual – most solids are denser than their liquids.



▲ Humans float very well in salt water like the Dead Sea.



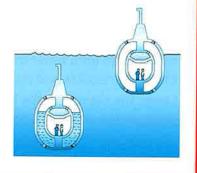
▲ Molecules in liquid water.



▲ Molecules in ice.

Questions

- 1. Explain why a person floats in a swimming pool in terms of density.
- 2. An object has a mass of 100 g and a volume of 90 cm³.
 - a. Calculate its density.
 - **b.** Write down whether it would float or sink in water. Explain your answer.
- **3.** The diagram shows what happens in a submarine when it dives below the surface of the water.
 - a. Explain why it is able to dive.
 - **b.** Suggest and explain what happens when the submarine needs to return to the surface.



(Rey points

- An object will float on water if it is less dense than water.
- Objects float because liquids exert a force on them, called upthrust.
- Collisions of liquid and gas particles produce upthrust.

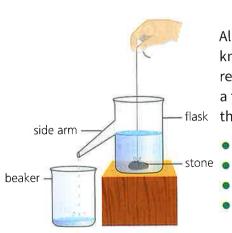
Science in context 11.2

Objectives

- Describe how ideas about density have been used
- Describe how scientists worked in the past and how they work now



Al-Biruni investigated many topics.



▲ Al Biruni's equipment.

Using ideas about density

For thousands of years people have prized jewellery. They made necklaces and rings from metals such as gold that they found in streams, and gemstones such as red rubies and green emeralds. But quartz and glass could be mistaken for gemstones. How could people tell whether they were real?

Identifying gemstones

Gemstones are **minerals** found in the Earth that have distinctive colours.

Over 1000 years ago Al-Biruni was born in a country that is now a region of Uzbekistan. He was a Muslim scientist and mathematician who wrote books on a wide range of topics from astronomy to geography.

He was very interested in geology and minerals, and he knew that people needed to be able to identify gemstones correctly.

- Quartz is the most common mineral on Earth.
- People could make a lot of money by pretending that a lump of quartz was diamond.
- It isn't easy to tell the difference between quartz and diamond just by looking at them.

Al-Biruni wondered if he could identify stones by their density. He knew how to measure their masses, but the stones did *not* have regular shapes. Finding their volume was more difficult. He designed a flask with a side arm to measure the volume accurately, as shown in flask the diagram. This was his method.

- Fill the flask until water overflows through the side arm into a beaker
- Empty the beaker and replace it under the side arm.
- Lower the stone into the flask.
- Measure the volume of the water that overflows into the beaker.



Are these gemstones or glass?



Quartz and rough diamond can be hard to tell apart.

Al-Biruni used the equation for calculating density to work out the density of the gemstones.

Density =
$$\frac{\text{mass}}{\text{volume}}$$

The table shows the densities that he worked out for some minerals.

Mineral	Al-Biruni's measured density (g/cm³)	Modern value for density (g/cm³)
quartz	2.58	2.58
ruby	4.01	4.4
pearl	2.7	2.7

As well as measuring density, Al-Biruni built on the work of earlier scientists by classifying gemstones according to:

- their colour
- whether white light splits into a spectrum when it goes through the gem
- their hardness
- their crystal shape.

One of the most important things about Al-Biruni's density measurements was their **precision** (see pages 94–95). It was not until over 700 years later that scientists in Europe made measurements of density with the same level of precision.

Modern science

Scientists and jewellers can still use Al-Biruni's technique to work out the density of an object to help to identify it.

Today there are also other techniques for identifying gemstones. Scientists can find the **refractive index** of a gemstone, or measure how well it conducts electricity. You learned about refractive index in Chapter 7: Light on page 137.

Al-Biruni had many research areas, building on the ideas of other scientists. He designed new techniques to make more accurate measurements. He worked alone. Today scientists usually specialise in one area of science, often with a team of people. They share their ideas in publications that are read all over the world and build on each other's ideas.

Questions

- **1.** Explain why Al-Biruni wanted to find a method to measure the density of gemstones.
- 2. Scientists work in lots of different ways.
 - **a.** Describe one way in which Al-Biruni's method of working was similar to the way scientists work today.
 - **b.** Describe one way in which it was different.
- **3.** Suggest why scientists did *not* improve on the precision of Al-Biruni's measurements for hundreds of years.



Today most research is published by teams of scientists.

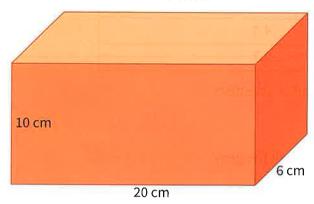
(Key points

- Density can be used to identify materials.
- In the past most scientists worked alone.
- Today most science is done by teams of people.
- Today, as in the past, scientists build on the work of other scientists.

Review

11.3

1. A student wants to find the density of a brick. He measures the sides of the brick.



- a. Calculate the volume of the brick.
- **b.** He measures the mass of the brick and finds that it is 2.4 kg. Calculate the density of the brick. [2]
- **c.** Water has a density of 1 g/cm³. Explain why the brick does *not* float on water. [1]
- 2. The table below lists the densities of some materials.

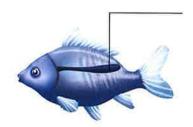
Material	Density in g/cm³
Air	0.001
Ice	0.9
Iron	7.9
Plastic	1.4
Wood	0.7
Water	1.0

- a. Write down which of these statements is true.
 - i. 10 cm³ of iron has a smaller mass than 10 cm³ of wood.
 [1]
 - ii. 2 cm³ of ice has a bigger mass than 1 cm³ of water.
 - iii. 1 cm³ of plastic has a bigger mass than 100 cm³ of air. [1]

[1]

iv. 5 cm³ of plastic has a smaller mass than 1 cm³ of iron.

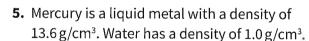
- **b.** Explain which solid materials would float in:
 - i. water [1]
 - ii. mercury, which has a density of 13.6 g/cm³. [1]
- **3.** A fish can move up and down in the water. It has a sac inside it called a swim bladder. If the fish fills the sac with oxygen from its gills it will float upwards. Explain why.



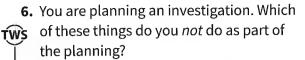
swim bladder allows fish to float or sink

[2]

- **4.** Which of the statements about the way that scientists work today is *not* correct? [1]
 - A Scientists share their ideas and scientific evidence in publications that others read.
 - **B** Scientists use creative ideas to interpret the evidence that they collect in experiments.
 - **C** It is unusual for scientists to read about the work of other scientists.
 - **D** It is possible to make measurements that are more precise and accurate using new technology.



- **a.** Gold has a density of 19.3 g/cm³.
 - i. Will it float or sink in mercury?
 - ii. In water? [1]
- **b.** Silver has a density of $10.5 \, \text{g/cm}^3$.
 - i. Will it float or sink in mercury?
 - ii. In water? [1]
- **c.** Wood has a density of 0.8 g/cm³
 - i. Will it float or sink in mercury?
 - ii. In water? [1]



[1]

- A Decide on a question to investigate.
- **B** Work out how to take precise and accurate measurements.
- **C** Write down what you found out.
- **D** Decide which measurements to make.



- **E** Describe how to work safely.
- 7. A thermometer designed in 1666 and now known as a Galileo thermometer uses changes in density with temperature. As the temperature drops, small glass bulbs containing different amounts of air and liquid move upwards in another liquid. Suggest why. [2]



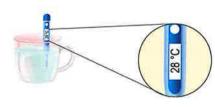
▲ A Galileo thermometer when it is warm (left), and when it is cold.

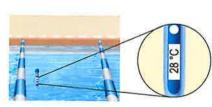
Objectives

- Descibe the difference between heat and temperature
- Define heat dissipation



A liquid and a digital thermometer.

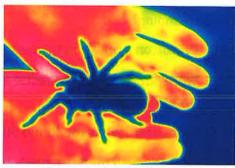




The water is at the same temperature.

Hot and cold

A scorpion is a cold-blooded animal, and the person holding it is warm-blooded. You cannot tell the temperature of the scorpion or the person by looking at them. This image of the scorpion is taken with a special camera. It produces a **thermal image** that shows the differences in temperature.



▲ A thermal image shows that the scorpion is colder than the person holding it.

What is the difference between energy and temperature?

The **temperature** tells us how hot or cold something is. We use a **thermometer** to measure temperature. A liquid inside a very narrow glass tube expands when it is heated.

- Thermometers used to be made with liquid mercury.
- Mercury is poisonous, so now the liquid in thermometers is alcohol.
- Digital thermometers do *not* use a liquid instead they use a sensor to measure the temperature directly.

We measure temperature in **degrees Celsius** (°C).

- Human body temperature is 37°C.
- The coldest temperature ever recorded on Earth was -89.2°C, in Antarctica in 1983.
- The hottest temperature ever recorded was 56.7 °C in Death Valley, USA in 1913.

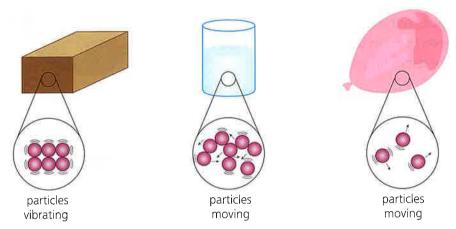
Heating a substance such as water causes its temperature to rise. We transfer energy produced from burning fuel to the water. Energy, and temperature are *not* the same.

- A cup of warm water and a swimming pool can have exactly the same temperature.
- There is much more energy in the thermal store of the swimming pool than there is in the thermal store of the cup of water.
- Energy depends on the amount of material, but temperature does not.

What happens when you heat materials?

The process of heating changes the motion of particles. If you heat a solid, the particles in the solid vibrate more. In liquids and gases the particles move faster. The temperature has increased. Temperature is related to the average speed of the particles.

You cannot say that the individual particles in a solid, liquid, or gas get hotter. Each particle can only move or vibrate faster. The temperature of a solid is a property of the solid, *not* of the individual atoms or particles that make it.



▲ Particle arrangements in solids, liquids, and gases.

The energy needed to raise the temperature of an object depends on:

- the mass of the object greater mass means more particles, so more energy is needed
- the type of material of the object if the particles are more massive, more energy is needed
- the temperature rise needed a bigger temperature rise means more energy is needed.

How do things cool down?

Energy is always transferred from a hot object to a cold object. If you put a cold object in contact with a hot object the temperature of the cold object will increase, and the temperature of the hot object will decrease. Energy has been transferred. This is called **dissipation**.

If you put a hot pan in cold water the water gets hotter. Energy is transferred from the pan to the water. Eventually the pan and the water have the same temperature. The water and the pan are in **thermal equilibrium**.

Questions

- 1. Describe the difference between temperature and energy.
- 2. Copy and complete these sentences.

 When you heat a liquid, the particles in it move ______. The same thing happens when you heat a ______. When you heat a ______ the particles just vibrate more. Dissipation is when energy moves from a ______ to a _____ region.
- **3.** Explain why it takes more energy to heat 1 kg of cold water than 0.5 kg of cold water to the same temperature.
- **4.** Explain why it takes longer to boil a kettle of water than to warm the same kettle of water to a lower temperature.



Energy is transferred from the water to the ice, so the ice melts and the water cools.

(III) Key points

- Temperature is a measure of how hot something is, measured in degrees Celsius.
- Thermometers are used to measure temperature.
- When you heat a solid, liquid, or gas, the particles move faster or vibrate more.
- Energy is dissipated when it moves from a hot to a cold region.

Objectives

- Write down the law of conservation of energy
- Apply ideas about energy conservation and dissipation to different situations

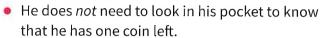


Energy is conserved if you consider the surroundings and the buildings together.

Conservation of energy

Energy is a bit like money

Jamal goes out with four coins in his pocket, and uses three of them to buy some food. How many coins are left in his pocket?

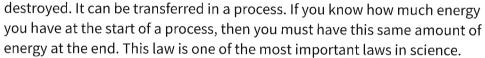


- If he gets home and no longer has a coin, he knows that he must have lost it.
- He will not find more than one coin in his pocket.

Coins cannot appear or disappear. Energy is like the coins.

This is called the **law of conservation of energy**.

This law says that energy cannot be created or



This law allowed scientists to work out how energy is stored and transferred. If they found a process in which there seemed to be less energy at the end than there was at the beginning, then they knew there must be another type of energy involved.

Useful and wasted energy

What happens when you turn on a light? The light bulb emits light, and it also gets warmer.

- The useful energy is transferred by the light.
- We can think of the energy heating the surroundings as wasted energy.
- Energy that is dissipated is usually wasted energy.

Suppose only 20 J of the 100 J of energy transferred to the light bulb is then transferred as light. Most of the energy is wasted.

100 J 20 J transferred transferred electrically by light 80 J heating the surroundings

▲ This diagram show what happens every second in one type of light bulb.

In all processes some energy is wasted.

- A car engine has moving parts.
- There is friction between moving parts.
- The friction makes those parts get warm.
- Energy is dissipated it is transferred to the surroundings, which heat up. All the energy heating the surroundings is wasted.

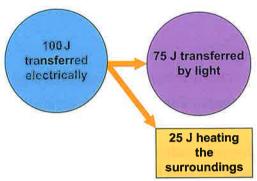


'Wasted' doesn't mean that the energy is 'lost', just that it is *not* the energy that we want.

Energy that is transferred by heating is not always wasted energy. When we cook food we want it to get hot, but the air around the pan heats up as well, which is *not* useful.

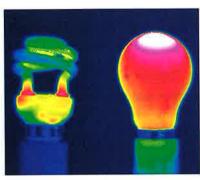
Energy conservation and efficiency

Some light bulbs transfer most of the energy into light. We say that they are **efficient**. This is the energy transfer diagram for an energy-efficient light bulb. Less of the energy transferred to the light bulb is wasted.



▲ The energy transfer diagram for an energy efficient light bulb.

The efficiency of a machine or device tells you how much of the energy that you put in is transferred as useful energy. If a lot of the energy that you put in is wasted, then the machine is *not* very efficient. Most energy that is wasted is dissipated.



▲ The energy-efficient light bulb on the left does not get as hot as the normal light bulb.



- 1. a. State the law of conservation of energy.
 - **b.** Compare energy conservation and energy dissipation.
- 2. Copy and complete these sentences using the words below.

wasted useful thermal

A machine is more efficient if it transfers more ______ energy
than _____ energy. A lot of the wasted energy in a machine with
moving parts is transferred as _____ energy due to friction.

- 3. Write down the useful energy and the wasted energy in these items:
 - a. hairdryer
 - **b.** television
 - c. kettle.
- **4.** Describe what you would notice if you stood next to an energy-efficient light bulb compared with a normal light bulb.
- **5.** Explain why more efficient electrical devices save you money.

(Key points

- The law of conservation of energy says that energy cannot be created or destroyed, only transferred or stored.
- In all processes you have the same amount of energy at the end as you had at the beginning.
- In all processes some energy is dissipated, usually heating the surroundings.

Objectives

- Know the names of some conductors and insulators
- Explain why some materials feel warmer than others



▲ Energy transfers very slowly through a special material called aerogel.

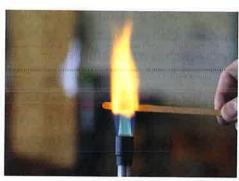


Plastic conducts heat less well than metal.



Energy transfer: Conduction

Neela wants to light a Bunsen burner. She takes a piece of wood, called a splint, and lights it from the teacher's Bunsen burner. She carefully carries the splint back to her Bunsen burner and lights it. The splint is on fire at one end, but she can hold it without burning her hand. This is because the energy from the flame is *not* transferred easily down the splint to her hand.



Only one end of the splint is hot.

What is the difference between conductors and insulators?

Energy is transferred through a solid by **conduction**. Some solids conduct energy better than others.

- Metals, like copper, are very good thermal conductors.
- Cooking pans are often made of copper because it quickly conducts the energy to the food in the pan.

Many non-metals are poor conductors of energy. They are **insulators**. This does *not* mean that they do *not* conduct at all, but that energy is transferred very slowly through them.

- Materials such as paper, cloth, wood, and plastic are all insulators.
- You stir hot food with wooden spoons so you do not burn yourself.

Why do some objects feel hot and others feel cold?

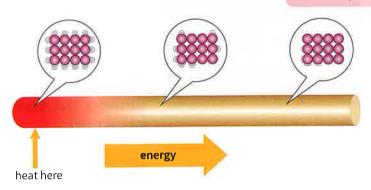
Bicycle handlebars are made of metal but the ends are often covered in plastic. Neela touches the metal of her handlebars, and then the plastic.

- Neela thinks the metal is colder than the plastic.
- Our skin detects the transfer of energy rather than the temperature.
- When Neela puts her hand on the metal, energy is quickly transferred away from her hand to the metal. She says it feels cold.
- When Neela puts her hand on the plastic, energy is not transferred quickly away from her hand because the plastic is an insulator. She says it feels warm.
- The plastic is at the same temperature as the metal.

If you touch something hotter than your skin, it feels warm because energy moves from the object to your hand.

How do metals conduct?

The diagram shows a piece of metal being heated at one end. The metal atoms on the left are vibrating a lot and the atoms on the right are *not* vibrating very much. The left end of the bar is hot and the right end of the bar is cold, so energy is transferred from the left to the right. Electrons also transfer energy in metals.

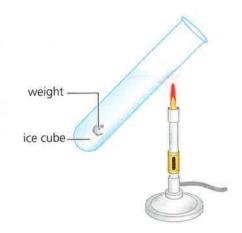


Do liquids and gases conduct energy?

Liquids like water are poor conductors of energy compared with metals. You can see this if you heat one end of a test tube of water. An ice cube held down by a weight will *not* melt, even if the water at the top is boiling.

A diver wears a wetsuit to dive in cold water.

- Inside the wetsuit a small amount of water forms a thin layer between the diver's skin and the thick elastic suit.
- The water is *not* free to flow away.
- Energy is *not* easily transferred from the diver to the sea water so the diver does *not* feel cold.



▲ The ice cube will not melt.

Science in context

Air is a good insulator if it is trapped and cannot move.

- Clothing, for example padded jackets, and bedding can be made from materials that trap air.
- Gases, like air, do *not* transfer energy easily because their particles are far apart.

A vacuum is an even better insulator. Scientists designed windows with two panes of glass and a near vacuum between the panes. This 'double glazing' helps insulate houses, and reduce fuel bills.

Questions

- **1. a.** Describe the difference between a conductor and an insulator.
 - **b.** Give an example of a conductor and an insulator.
- **2.** Describe what would happen if you heated water in a saucepan made of a material that is *not* a good conductor of energy.
- **3.** Some divers use drysuits rather than wetsuits. They wear clothing underneath that traps a layer of air between their skin and the suit.
 - **a.** Explain how a drysuit keeps a diver warm.
 - **b.** Which keeps a diver warmer, a wetsuit or drysuit? Explain your answer.
- **4.** A student says that her blanket keeps her warm because it traps heat. What would you say to her?

(III) Key points

- Energy is transferred through a solid by conduction.
- Metals are good conductors of energy, but plastic and wood are poor conductors; they are insulators.
- Liquids and gases that are not free to move around are poor conductors of energy.
- Objects feel cold when they conduct energy away from your skin.

Objectives

- Describe how energy is transferred by convection
- Describe how convection currents form in everyday situations



▲ Convection currents form in the water as it is heated.

Energy transfer: Convection

If there is a fire in a house, firefighters may crawl along the floor to look for survivors. This is because there is less smoke near the floor than higher up. Why is that?



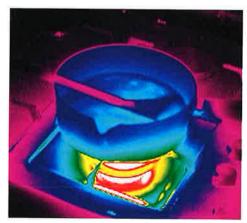
▲ In a fire the cleanest air is closer to the floor due to convection.

What is convection?

When you heat the bottom of a saucepan of water, all of the water gets warm, *not* just the bottom part. The liquid in the pan is free to move so energy is transferred by **convection**.

The bottom of the pan is heated by the flame. Energy is transferred through the pan to the water at the bottom of the pan by conduction. This is because the bottom of the pan is solid.

- The water in contact with the bottom of the pan gets warmer.
- The molecules in the warmer water are moving faster than the molecules in the cooler water above.
- The molecules in the warmer water move further apart.
- The warmer water becomes less dense.
- The warmer water rises (floats up).
- Cooler, denser water moves down to take its place.



Energy transferred through a pan of liquid.

Eventually all the water in the pan is circulating up and down. The circulation of water that is set up in this way is called a **convection current**. Convection currents can happen in all liquids and gases that are free to move.

In a fire the hot smoky air expands and rises. That is why firefighters crawl on the floor.

Where do convection currents form?

The atmosphere is heated by the Sun, and also by the warm land beneath it. The land heats up more quickly than the air or the oceans.

Sea breezes

If you live near the coast you might notice that a breeze comes off the sea during the day, but changes direction at night. We can explain this using convection.

During the day:

- The air just above the ground gets hot.
- This hotter air expands and rises just like the hot water in a pan.
- The rising air is replaced with cooler air from above the sea.
- The breeze comes off the sea onto the land.

During the night:

- The ground cools much more quickly than the sea.
- Now the air above the sea is warmer and rises.
- This pulls cooler air from above the ground to replace it, so the breeze comes off the land.

Atmospheric currents

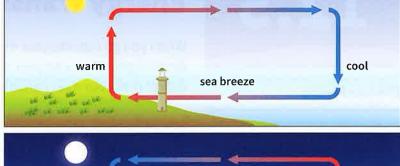
Convection also happens on a bigger scale. The Sun heats the Earth more at the equator than it does nearer the poles. The air near the equator rises and is replaced by cooler air. This causes the air in the atmosphere to move. Weather patterns across the world are affected.

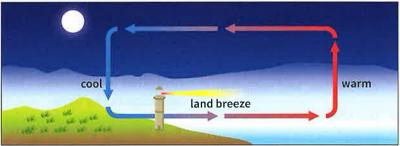
Thermals

You might see birds using the convection currents produced when the Sun heats the ground. Convection currents in the air are called **thermals**.

Questions

- **1.** Describe the difference between conduction and convection.
- **2.** Explain what 'hot air rises' means, in terms of the particles in a gas.
- **3.** This diagram of the Earth shows a convection current in the atmosphere (not to scale).
 - **a.** Draw a clockwise or anticlockwise arrow to show the direction of the convection current.
 - **b.** Explain your answer.





▲ The breeze by the sea or ocean changes direction at night.



Birds of prey use thermals caused by convection to climb high and look for prey.

(Rey points

- When a gas or liquid gets hot it expands and becomes less dense.
- The less dense gas or liquid rises and is replaced by cooler gas or liquid.
- This sets up a convection current.
- A convection current in the atmosphere is called a thermal.

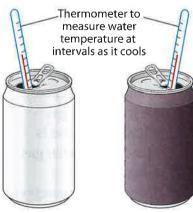


Objectives

- Describe how energy is transferred by radiation
- Describe the differences between conduction, convection, and radiation
- Use ideas about radiation to explain the greenhouse effect



Humans emit infrared radiation.



The dark surface emits more infrared radiation than the silver surface.

Energy transfer: Radiation

When you go outside your eyes detect light. What can your skin detect that your eyes cannot?

What is radiation?

There are several sorts of radiation, but the sort that your skin can feel is thermal radiation, or **infrared radiation** (or infrared). This radiation is like light:



Your skin can feel warmed by the Sun.

- It travels from the Sun to the Earth.
- It travels as a wave.
- It can be reflected, transmitted, and absorbed.

All objects emit radiation. The type of radiation that they emit depends on their temperature. The wire inside a torch bulb can get hot enough to give out infrared *and* light. You will only ever emit infrared radiation.

How is radiation different from conduction and convection?

Energy can be transferred by conduction and convection. Both methods need a material for the energy to travel through.

Infrared radiation does not need a material to transfer energy.

Light and infrared reach the Earth from the Sun by travelling through space. There is no material in space. We say it is a **vacuum**.

Light can be	Infrared can be
emitted by hot objects	emitted by hot objects
reflected well by shiny surfaces	reflected well by shiny surfaces
absorbed by objects and your retina	absorbed by objects and your skin
detected by a camera	detected by a thermal imaging
	camera
transmitted through a vacuum as	transmitted through a vacuum as
a wave	a wave

Dull, dark surfaces tend to absorb more infrared than light, shiny surfaces. Dark surfaces also *emit* more infrared than light surfaces.

Some examples of infrared radiation in everyday life are:

- Marathon runners use foil wraps to keep warm after they stop running.
- Pale-coloured houses stay cooler in the summer.
- Dark or black clothes will dry first on a washing line.

What is the greenhouse effect?

When radiation from the Sun reaches the Earth:

- About 50% of the radiation is reflected by the Earth's atmosphere.
- The rest of the radiation gets through and is absorbed by the land and oceans.
- The Earth itself emits infrared outwards, and some of that is reflected back in by the atmosphere.
- The rest is transmitted out into space.

The temperature of the Earth depends on the *balance* between the radiation that is absorbed and the radiation that is emitted. If more is absorbed than is emitted, then the temperature will increase.

The atmosphere contains greenhouse gases.

- Greenhouse gases include carbon dioxide, methane, and water vapour.
- These gases absorb infrared and then emit it again.
- Some is re-emitted back towards Earth instead of out into space.
- This is the greenhouse effect.

Without an atmosphere the Earth would be very, very hot in the daytime, and very, very cold at night. However, the concentration of greenhouse gases is increasing, and this is raising the average global temperature and causing **climate change**. Climate change is altering the weather, melting the icecaps, and affecting how easy it is to grow food.

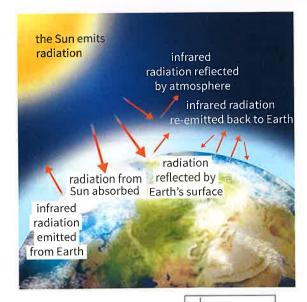
The electromagnetic spectrum

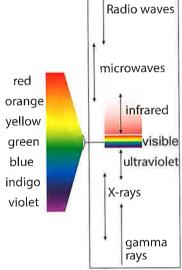
Light and infrared are just two of the types of radiation emitted by the Sun. They are two waves in the **electromagnetic spectrum**. Light and infrared are parts of the electromagnetic spectrum just like blue and green are two colours of the light spectrum.

All the waves of the electromagnetic spectrum can travel through a vacuum, and they all travel at the same speed in a vacuum. They have different uses. Some are more dangerous than others.

Questions

- 1. Name some gases that produce the greenhouse effect.
- 2. Look at the picture of the person taken with a thermal imaging camera.
 - **a.** Explain why this image is different from the image that we would see with our eyes.
 - **b.** Explain why the person does not emit visible light.
- **3.** Describe a situation in which the temperature of the Earth would go down.





▲ The visible spectrum on the left is part of the electromagnetic spectrum on the right.

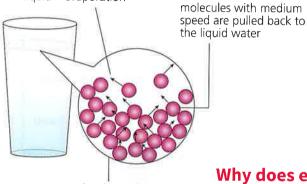
(Rey points

- All objects emit thermal radiation. They emit light if they are hot.
- Radiation, including light and infrared, is emitted by the Sun.
- Radiation does not need a medium – it can travel in a vacuum.
- The atmosphere reflects radiation like glass in a greenhouse.

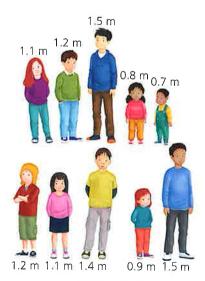
Objectives

- Explain why liquids cool when they evaporate
- Describe some uses of cooling by evaporation

molecules at the surface with high speed escape from the liquid – evaporation



molecules with lower energy remain in the liquid water



A group of 10 children and their heights in metres.

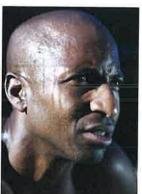
Cooling by evaporation

How do you keep cool? Your body produces sweat to help to keep your body from getting too hot. You can feel the same cooling effect if you wet your hands and leave them to dry.

How does **evaporation** remove energy from your body?

What is evaporation?

If you leave a dish of water out, it will evaporate – dry up. We can think about the particles inside a liquid moving around in every direction.



Sweating removes energy from your body.

There is *not* very much space between the particles and they move over each other. Each particle is attracted to the particles around it.

When particles are travelling fast enough they can break free and move into the air. The liquid **evaporates**.

Why does evaporation produce cooling?

You can explain evaporative cooling using ideas about particles.

- Their average speed depends on the temperature of the liquid.
- At a higher temperature the average speed will be higher.
- The particles do *not* all move at exactly the same speed: some travel faster, some slower.
- The particles are colliding with each other, and energy is transferred in those collisions.
- A few of the particles at the surface will be travelling fast enough to be able to escape.
- When fast-moving particles escape, the average speed of the particles left behind is slower.
- A smaller average speed means the liquid is cooler evaporation has cooled it.
- The cooler liquid absorbs energy from the air and more particles escape.
- Eventually all the particles escape. The liquid has evaporated. The air around the liquid has cooled.

A model for evaporative cooling

You can think of it like this. Imagine a group of 10 children.

To calculate the average height we add up all the heights and divide by 10.

Average height

$$= (1.1 + 1.2 + 1.5 + 0.8 + 0.7 + 1.2 + 1.1 + 1.4 + 0.9 + 1.5) / 10$$

$$= 1.14 \text{ m}$$

If the two tallest children leave the group, the average height will be smaller.

Average height

$$= (1.1 + 1.2 + 0.8 + 0.7 + 1.2 + 1.1 + 1.4 + 0.9) / 8$$

$$= 1.05 m$$

Removing tall children has reduced the average height.

Where is this cooling effect used?

Cooling animals

Your body uses cooling by evaporation. When you get very hot you sweat. Droplets of sweat, which is mainly water, form on the surface of your skin. The water evaporates as energy is transferred from your skin to the water. You feel cooler because energy is being transferred away from your body.

Dogs pant to help them cool down. Water evaporates from their tongues. Elephants use water on their skin to cool down.

Evaporative coolers and refrigerators

Some people use **evaporative coolers** instead of air conditioning to cool their house. In an evaporative cooler a fan draws warm air over water. Energy is transferred to the water. It evaporates, and the air cools down. The cooled air circulates around the house.

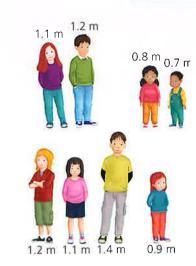
Science in context

For thousands of years people have used water to cool their homes. Before air conditioning they used fans and water. In ancient Egypt people hung wet mats over the open doorway and used fans to cool down the air in the room.

In a **refrigerator** a special liquid called a **refrigerant** is pumped around tubes at the back. Energy from inside the refrigerator evaporates the refrigerant. This cools down the inside of the refrigerator. Air conditioning works in the same way.

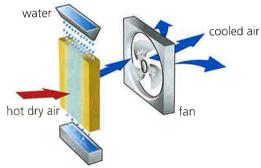
Questions

- **1.** Describe the difference between the particles that escape when a liquid evaporates, and the particles that are left behind.
- 2. Explain why your hands feel cool if they get wet.
- **3.** Explain why water evaporates faster if the air around it is warmer.
- **4.** Modern evaporative coolers need a supply of electricity to work. Why?





Evaporation keeps animals cool.



Evaporation cools air.

(Rey points

- Liquids evaporate when faster particles escape.
- The average speed (the temperature) of the particles is decreased.
- Evaporative coolers transfer energy from air to a liquid to cool the room.
- Animals use liquids on their skin to cool down.

Review

12.7

- 1. Copy and complete these sentences.
 - **a.** You measure ______ in degrees Celsius. [1]
 - **b.** You measure _____ in joules. [1]
 - **c.** A bath will have _____ energy than a cup of warm water at the same temperature.
- 2. The amount of energy that you need to raise the temperature of something does not just depend on the size of the temperature rise.
 - a. Name two other things the temperature rise depends on. [1]
 - **b.** Put these in order from the smallest to the largest amount of energy required. [1]
 - A The energy needed to raise the temperature of 1 kg of water by 20 °C
 - **B** The energy needed to raise the temperature of 2 kg of water by 20 °C
 - **C** The energy needed to raise the temperature of 1 kg of water by 10 °C
- 3. Explain why:
 - a. Saucepans are usually made of metal. [1]
 - **b.** Black clothes dry quicker than white clothes if they are drying in the Sun. [1]
 - c. A hot air balloon rises. [1]
 - **d.** A bird fluffs up its feathers if it is cold. [1]
- 4. Copy and complete the sentences below, choosing the correct bold words.

The law of conservation of energy says that energy cannot be created/dissipated or destroyed/transferred.

- When you burn coal, you transfer energy from a chemical/thermal store to a chemical/ thermal store [5]
- 5. A student puts two thermometers on the desk underneath a lamp. She covers the bulb of one thermometer with black paper and the other with aluminium foil.
 - a. Write down which thermometer will show the higher temperature after half an hour.
 - **b.** Explain why. [1]

[1]

6. There is a hot drink on the table.

[1]



- a. Explain how conduction changes the temperature of the tea. [1]
- b. Explain how convection changes the temperature of the tea. [1]
- c. Explain how radiation changes the temperature of the tea. [1]
- **d.** Explain why putting a lid on top of the cup would keep the tea hotter for longer. [1]
- 7. You are cooking a pizza. You place your pizza on a metal tray at room temperature and put it in the oven. When the pizza is cooked you remove the tray from the oven. Eventually it reaches room temperature again.

Describe and explain in detail what happens to the motion of the particles in the metal tray. [6]

[3]

[3]

[1]

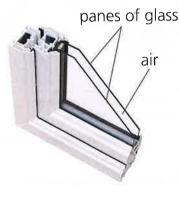
8. A student has left his drink outside in the Sun.



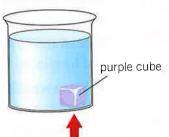
a. Explain why the can of soft drink is warmer than it would be if it was inside the house. [1]

The student decides to use the Sun to cool down a can of drink on a hot day. He covers the can of drink with a clay pot and pours water over the pot. He keeps pouring water over it for a few minutes. When he takes the can out it is cooler than before.

- **b.** Explain why the can is cooler.
- **c.** Explain why he has to keep pouring water over the pot.
- 9. Explain why:
 - a. Houses are painted white in hot countries. [1]
 - b. You can't find people in burning buildings with a thermal imaging camera.[2]
- **10.** Some double-glazing systems trap air between two panes of glass.



- **a.** Explain how energy is transferred through a double-glazed window from a hot room to the cold air outside.
- b. State and explain how the rate of energy transfer would change if you removed the air from the gap.[3]
- **11.** Here is an experiment to demonstrate convection.



Bunsen burner heats here

[2]

[1]

- **a.** Describe what will happen to the purple colour during heating.
- b. Explain why the purple colour forms a convection current. [3]
- c. Describe where convection currents are formed in everyday life. [1]
- **12. a.** Explain why there are no convection currents in solids. **[1]**
 - **b.** If you stand near a fire on a cold night you feel warm even though the air is cold. Explain why.
 - c. Write down one similarity between light and infrared radiation.[1]

Objectives

- Define wavelength, amplitude, and frequency
- Describe what affects the loudness of a sound
- Draw and interpret waveforms showing differences in amplitude

Loudness and amplitude

Imagine a string attached to a wall. You can make a wave in it by moving your hand up and down. Your friend takes a picture of the wave so that the wave is frozen in time. How can you describe the wave that you have made?

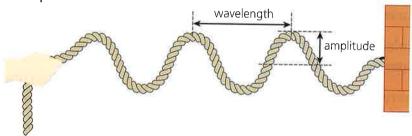
What are the properties of waves?

We can describe waves using three properties that all waves have: amplitude, wavelength, and frequency.

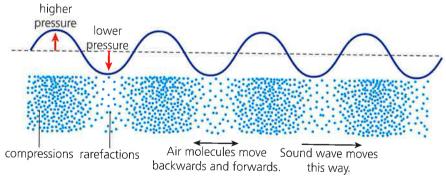


▲ Some sounds are very loud.

- Wavelength is the distance from one point on a wave to the same point on the next wave.
 For example, the distance from the top of one wave to the top of the next wave is one wavelength.
- Amplitude is the distance from the centre of the wave to the highest or lowest point.



The diagram does *not* show the frequency. If you count how many waves go past in 1 second, that is the **frequency**.

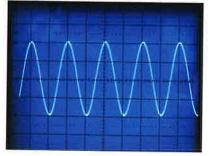


▲ A sound wave is a pressure wave.

Using an oscilloscope

To 'see' what sound waves are like we can attach a microphone to an **oscilloscope**.

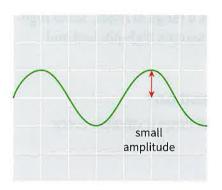
- The microphone produces an electrical signal that represents the sound.
- The signal is displayed on the screen.
- The image on the screen shows how the pressure varies with time.
- Where the line on the screen goes up the particles are close together, and where it goes down they are far apart.

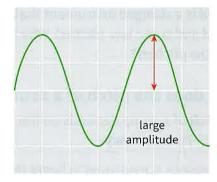


▲ The signal from a microphone.

What is loudness?

Anil sings a note into a microphone while he looks at the oscilloscope screen. Then he sings the same note, only louder. This is what he sees.





▲ A soft sound.

▲ A loud sound.

A soft sound has a small amplitude. A loud sound has a large amplitude.

What happens when you amplify a sound?

You might hear people say that sound 'dies away'. They think that the sound wave gets 'weaker' as it travels. The sound *spreads out* as it travels away from the source. Some energy is transferred to the medium that the sound is travelling through – energy is dissipated, so the sound becomes softer.

Singers cannot sing loud enough for everyone in a big concert hall to hear well. They use a microphone connected to an **amplifier** to make their voice louder. An amplifier increases the amplitude of the electrical signal produced by the sound wave, so that when it is broadcast through a loudspeaker it sounds louder.

Questions

1. Copy and complete this sentence.

A ______ sound has a larger amplitude than a _____ sound.

You can look at a sound wave on a screen using an ______.

- 2. Sunil says that the amplitude of a wave is the distance from the centre to the top of a wave. Write a different definition of amplitude.
- **3.** Which of these distances is one wavelength on a sound wave?
 - **A** the distance from a compression to a rarefaction
 - **B** the distance from a compression to the next compression
 - **C** the distance from a rarefaction to the next rarefaction
- **4.** Is the wave on the rope on the previous page a longitudinal wave or a transverse wave? Explain your answer.
- **5.** The picture of the sound wave on the oscilloscope screen is a transverse wave. Sound waves are longitudinal waves. Describe what is being shown on the screen.





This microphone is connected to an amplifier.

(Rey points

- Waves have wavelength, amplitude, and frequency.
- Wavelength is the distance from one peak to the next.
- Amplitude is the distance from the centre to the top of a wave.
- Frequency is the number of waves per second.
- An oscilloscope connected to a microphone can display a sound wave on a screen.
- The loudness of a sound depends on the amplitude.

Objectives

- Describe what affects the pitch of a sound
- Draw and interpret waveforms showing differences in frequency



Ouds have been played for thousands of years.



A younger person has a bigger audible range.

Pitch and frequency

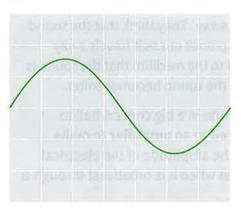
High and low

The oud is a stringed instrument that produces a range of notes, some highpitched and some low-pitched. Why are some sounds high-pitched and some low pitched?

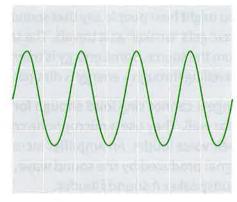
What does the pitch of a sound depend on?

The **pitch** of a string depends on the number of times it vibrates every second – its **frequency**.

- Frequency is measured in hertz (Hz).
- High-pitched sounds have a high frequency and low-pitched sounds have a low frequency.
- High frequencies are measured in kilohertz (kHz): 1 kHz = 1000 Hz.



▲ A low-pitched sound has a low frequency



A high-pitched sound has a high frequency.

- A high-frequency sound has a short wavelength.
- A low-frequency sound has a long wavelength.

Changing the frequency (and wavelength) of a sound wave does *not* have the same effect as changing the amplitude. The amplitude determines how loud the sound is. Loud sounds may be high-pitched, like a scream, or low-pitched, like an earthquake.

What can you hear?

When you listen to speech or music you are listening to a range of frequencies, from very high to very low. Young people can hear a much larger range of frequencies than older people can.

- Humans have an audible range (range of hearing) from about 20 Hz to 20 000 Hz.
- As people get older they find it harder to hear very high frequencies.
- By the time you are 30 you may be able to hear only up to about 14 000 Hz.

What is ultrasound?

Ultrasound is sound with a frequency higher than 20 000 Hz, which is outside the audible range of humans. We cannot hear sounds of this frequency, or make sounds so high-pitched, but other animals can.

What can other animals hear?



Species	Audible range (Hz)		
bat	2000-110 000		
cat	45-8000		
chicken	125-2000		
cow	23-35 000		
dog	67-45 000		
dolphin	100-100 000		
elephant	16-12 000		
guinea pig	54-50 000		
horse	55-33 500		
mouse	1000-91 000		
rat	200-76 000		
whale	1000-123 000		





Animals can have very different audible ranges to humans.

Some animals can make and detect ultrasound, but humans cannot. Some animals, like grasshoppers, make sounds that they cannot hear.

Questions

- 1. Copy and complete the sentences. The pitch of a sound depends on the _____ of the sound. A high-pitched sound will have waves that have a ___ wavelength.
- 2. Aditya plays a note on a guitar. The note has a frequency of 512 Hz. Write down the number of times a second that the string vibrates.
- 3. Sort these frequencies into those that are sound and those that are ultrasound.

4500 Hz

100 000 Hz

30 000 Hz

30 Hz

1500 Hz

- 4. Sketch the oscilloscope trace for a:
 - a. low-pitched, loud sound
 - **b.** high-pitched, soft sound.
- 5. a. Name the animal in the table above with the biggest range of hearing.
 - **b.** Name the animals that can hear ultrasound.

Key points

- Higher notes have a higher frequency.
- The range of frequencies that you can hear is the audible range.
- Different animals have different audible ranges.
- Your audible range (the range of frequencies you can hear) gets smaller as you get older.

Science in context

13.3

Objectives

- Name the unit of sound intensity, or loudness
- Describe some of the risks of loud sounds and how to reduce the risks

Hearing, decibels, and risk

What is noise?





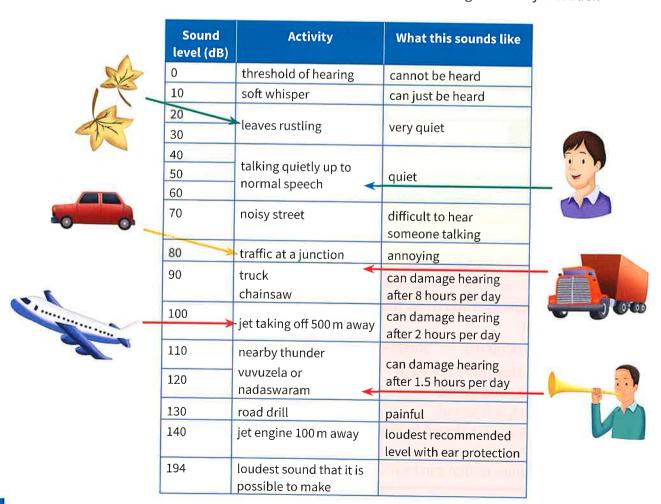
▲ We like listening to some sounds...

... but not to others.

Our ears are very sensitive to sounds. Most people can hear very quiet sounds and also very, very loud ones. We like to hear sounds like music and the voices of our family or friends. Sounds that we do not want to hear are called **noise**.

Sound levels

The **intensity** of a sound is measured with a **sound-level meter** on a scale called the **decibel** (**dB**) **scale**. A sound with a high intensity is louder.



The decibel scale is *not* like a ruler. Every increase of 10 dB increases the intensity 10 times. A 50 dB sound is 100 times as intense as a 30 dB sound.

- The nadaswaram is an Indian musical instrument that is so loud it is usually played outside.
- The vuvuzela is a horn used at football matches in South Africa. It can emit noise of 120 dB.
- The loudest possible continuous sound has a loudness of 194 dB.
 Explosions, earthquakes, or meteor impacts can produce much louder sounds, but they do not last for long.

What can damage your hearing?

Loud sounds can damage your hearing. Sudden loud sounds can burst your eardrum. However, the risk depends not only on the number of decibels but also on the length of time you are exposed to the sound.

When scientists talk about the **risk** of an activity, they consider:

- the probability that something bad will happen
- the consequence if it did. Some activities have serious consequences, like an aeroplane crashing, but a very low probability of happening.

We often take risks when the consequences do *not* seem serious. Listening to music or going to concerts may *not* seem risky, but there is a probability that your hearing will be damaged by loud music. That probability gets bigger the longer you listen to the music.

How do you reduce the risk?

There are three main ways of reducing the risk from noise if you cannot change the sound level:

- shielding putting something between the source of the sound and your ears, such as ear defenders
- increasing the distance moving away from the source of the sound
- reducing the time that you spend near the source of the sound.

People can use decibel meters to help to reduce their risk.

Questions

- 1. a. Write down what 'dB' stands for.
 - **b.** Write down how much louder a 40 dB sound is than a 30 dB sound.
- **2.** Jamal likes to listen to music with earphones. Write down two things he could do to reduce the risk of damage to his hearing.
- 3. a. Suggest two jobs for which people should wear ear defenders.
 - **b.** One reason why truck drivers should *not* drive for long periods is that they may get tired and fall asleep. Suggest another reason.



▲ One of the world's loudest musical instruments.



Ear defenders can reduce risk.

Rey points

- Sound levels are measured in decibels (dB).
- Loud sounds can damage your hearing over time.
- You can reduce the risk of damage by making the sound quieter, shielding your ears, reducing the time you are exposed, or moving away from the sound.

Objectives

- Describe what happens when waves interact
- Sketch waveforms of waves adding up and cancelling out

Adding up and cancelling out

Some people have 'perfect pitch'. They can tell you which note you are playing on a musical instrument just by listening.

Most people cannot. The people who make sure that musical instruments are in tune use the interaction of sound waves to work out whether the correct note is being played. How do they do that?

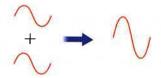


Tuning a musical instrument.

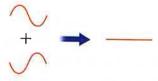
What happens when waves interact?

When waves interact, they can add together or cancel out. This is called **interference**.

- If the waves add up to produce a bigger wave, we say that it is constructive interference.
- If the waves cancel out to produce a smaller or no wave, we say that it is **destructive interference**.



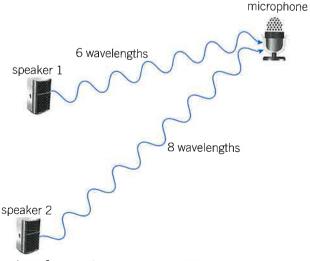
constructive interference



destructive interference

▲ Waves add up or cancel out.

Constructive interference	Destructive interference
The waves are in step	The waves are out of step
All the peaks are in the same	Peaks of one wave and troughs of the
place	other are in the same place
The total sound will be louder	The total sound will be quieter/silence



▲ Interference between sounds from two speakers.

For two waves to be in step and interfere constructively, the difference in position of the two waves will be zero or a whole number of wavelengths.

If the waves are out of step by half a wavelength, they will cancel out.

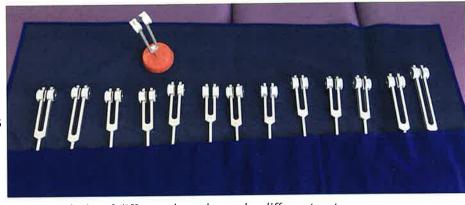
In destructive interference the waves need to have exactly the same amplitude to cancel out completely. You do *not* usually get silence. If the amplitude of one wave is bigger than the other, then the sound will be quieter.

How is the interference of sound useful?

People who tune pianos and guitars use the interference of sound to work out whether strings or keys are playing the correct note.

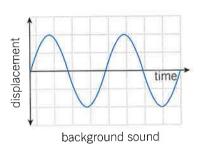
If you pluck the string of a guitar you hear a note. If you strike a tuning fork and hold it near the string you will hear a loud note if the string is in tune.

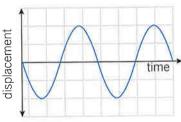
If it is *not* in tune, then the two waves will interfere. There will be times when the waves add up, and times when they cancel out. The tuner hears loud and soft sound. They adjust the string until they hear a loud note that does *not* change.



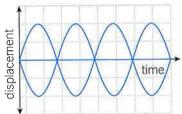
Tuning forks of different lengths make different notes.

If you travel or work in a noisy place it can be helpful to be able to block out the noise. You can do that with noise-cancelling headphones. The headphones produce a sound that cancels out the noise.





flipped background sound

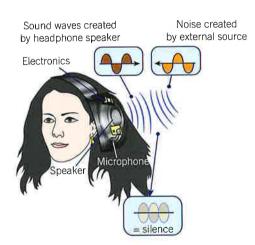


➤ Some headphones produce sounds that cancel out noise.

background sound and flipped sound superposed, producing cancellation

Questions

- **1.** Copy and complete the sentences by choosing the correct word or words in bold:
 - When waves are **in step/out of step** they will add up. This is called **constructive/destructive** interference. If you listen to the sound it will sound **louder/softer**. The waves need to have exactly the same **amplitude/magnitude** and **frequency/speed** to cancel out completely.
- **2.** Draw two waveforms that will cancel out completely when they interact.
- **3.** Explain why some noise-cancelling headphones need a microphone as well as a loudspeaker.



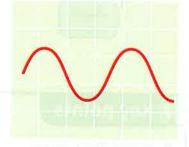
Rey points

- Waves that interact (interfere) can add together or cancel out.
- If they add, then the total sound is louder.
- If they cancel out, then the total sound is quieter or there is silence.
- We use interference in noise-cancelling headphones and to tune musical instruments

Review

13.5

- For each of the quantities listed below write the letter of the definition and the unit. You need to use one letter twice.
 - a. The wavelength of a wave
 - **b.** The frequency of a wave
 - c. The amplitude of a wave
 - **A** The number of waves per second.
 - **B** The distance from the middle to the top of a wave.
 - **C** The distance from the top of one wave to the next.
 - **D** hertz
 - E metres [3]
- **2.** A tuning fork produces this wave on an oscilloscope screen.



- **a.** Draw the wave you would see if the sound was louder.
- **b.** Draw the wave you would see if the sound had a higher pitch.
- **3. a.** A note has a frequency of 400 Hz. State how many sound waves pass a point per second. **[1]**
 - **b.** Another wave has a frequency that is half that of the wave in part **a**. Choose the number of waves per second for this wave.
 - 100

200

400

800

[1]

[1]

[1]

4. a. Write down the audible range of a human.

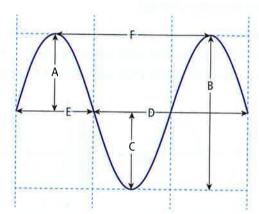
[1]

b. Complete this sentence by choosing the correct word in bold:

All animals have **different/the same** audible ranges.

[1]

5. Look at the arrows on the diagram below. Copy the table and tick the correct columns to show whether each arrow shows the wavelength, the amplitude, or neither.



Arrow	Wavelength	Amplitude	Neither
Α			
В			
С			
D			
E			
F			

[6]

- **6.** A boy is whistling a note that has a frequency of 1500 Hz.
 - a. Explain what 'a frequency of 1500 Hz' means.[1]
 - b. Describe what would change about the sound he would hear if he whistled at 2000 Hz.[1]

[1]

[1]

[1]

[1]

[1]

7. Rani used a sound-level meter to survey the noise at different places and times during the day. Here are her results.

Place	Noise level (dB)
by the road on the way to school	70
sitting in a classroom	50
playing with friends	60
traffic on the way home	80
reading a book	40

- a. Describe what 'dB' means.
- **b.** Write down which sound is loudest.
- c. Rani's brother likes to listen to very loud music on his headphones. Describe two things that he could he do to reduce the risk of damaging his hearing.
- 8. A teacher uses an oscilloscope to display some sound waves. The sounds shown are either loud or soft, and either high or low pitched. Match each number to a letter in the pictures below.

1 a low-pitched loud sound	A
2 a high-pitched soft sound	B
3 a low-pitched soft sound	c
4 a high- pitched loud sound	D

- 9. For each statement about ultrasound, write 'true' or 'false'.
 - a. Ultrasound can be used to see an unborn baby.

b. Ultrasound is sound with a frequency [1] greater than 2000 Hz.

- c. Ultrasound is very-high-frequency sound.
- d. Ultrasound cannot be heard by humans. [1]
- 10.a. Describe what is necessary for two waves to:

ii. cancel out.

- [1] i. add up [1]
- b. A microwave oven has a turntable to rotate the food through places where microwaves superpose. Suggest what will happen if the turntable breaks. [2]
- 11. A singer produces sounds that vary in pitch and loudness. Suggest and explain in detail what her vocal chords do to produce different types of [3] sound wave.
- 12. A student wants to investigate this question: 'How does the loudness of a sound change with the distance from a speaker?'
 - a. Write down the independent variable.
 - **b.** Write down the dependent variable.
 - c. Write down one control variable.
 - d. Suggest why it might be difficult for the student to carry out this investigation. [1]

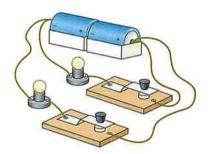
[1]

[1]

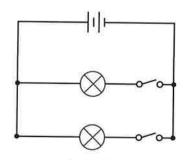
[2]

Objectives

- Describe the difference between a series and a parallel circuit
- Describe what happens to current in a parallel circuit
- Describe how to measure current in series and parallel circuits
- Describe the effect on the current of adding cells and lamps in series and parallel circuits



▲ This is a parallel circuit...



▲ ... and so is this.

Current in series and parallel circuits

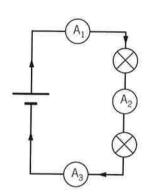
When you turn off a light in one room of a house the others will stay on. How does that **circuit** work?

What is a series circuit?

A circuit with a single loop is called a **series circuit**. The **current** will only flow if it is a complete circuit. You can turn the lamp on and off with a switch, because an open switch is a break in the circuit.

In a series circuit with several lamps:

- You cannot turn the lamps on and off separately.
- The lamps are either all on or all off.
- A switch in the circuit will turn them all on, or turn them all off.
- If one lamp breaks, or 'blows', then all the lamps go out.



You can use an ammeter to measure the current at different points in a series circuit. The current in A_1 , A_2 , and A_3 is the same, so the reading on each of the ammeters is the same. Current is *not* used up in an electric circuit.

What is a parallel circuit?

Neela makes a series circuit with a battery, one lamp, and a switch. Then she adds another loop containing a lamp and a switch that uses the same battery as in the first circuit. Here are pictures of some circuits that she made.

In a series circuit there is only one loop. In a **parallel circuit** there is more than one loop. The cell or battery pushes the current around each loop. Neela made a parallel circuit when she made the circuit with two loops.

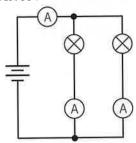
- The different loops of the circuit are sometimes called branches.
- Parallel circuits are sometimes called branching circuits.
- In a series circuit, if one lamp breaks then all the lamps go off.
- In a parallel circuit, if one lamp breaks then the others still work.
- The switch in each branch of the circuit controls the lamps in that branch.

Each lamp can be turned on and off independently. This is how lights in your house are connected.

How do you measure current in parallel circuits?

Neela decided to measure the current in the branches of a parallel circuit.

She connected up a circuit with a battery, lamps, ammeters, and switches. She connected an ammeter in each branch of the circuit, and another ammeter near the battery.







Think of parallel circuits like this

I connected up my circuit and measured the current in each of the branches and next to the battery. The current in each branch was 0.4 A. The current next to the battery was 0.8 A.

Neela wondered what would happen if she added another lamp in parallel.

This time the current near the battery was 1.2 A, but the current in each branch was still 0.4 A.

Number of lamps in the circuit	Reading A ₂	Reading A ₃	Reading A ₄	Reading A ₁
1	0.4	- -	=======================================	0.4
2	0.4	0.4		0.8
3	0.4	0.4	0.4	1.2

As you add more branches, the current in each branch stays the same. The total current increases. You could increase the current in each branch, and the total current, by increasing the number of cells.

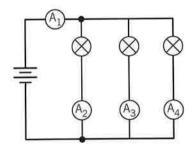
You can think of the current splitting when it gets to a junction of two or more branches.

Questions

- 1. Copy and complete these sentences.
 - **a.** An ammeter measures the _____ flowing per_____
 - **b.** A ______ is flowing per second.
 - **c.** If a bulb breaks in a series circuit the current will be _____
- 2. Explain why you only need one switch in a series circuit.
- **3.** A student connects up an ammeter in a circuit with a lamp and a cell. The reading is 0.5 A. She moves the ammeter to the other side of the lamp.
 - a. What will the ammeter read now? Explain your answer.
 - **b.** She then connects another lamp in parallel with the first. Describe what happens to the total current in the circuit.



Car headlights are connected in parallel.

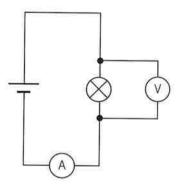


(Rey points

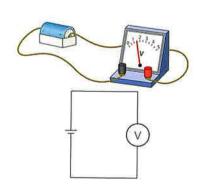
- The current in a series circuit is the same everywhere.
- A parallel circuit contains more than one branch.
- Each loop (or branch) is independent.
- Components in a parallel circuit can be turned on and off independently.
- The current near the battery is equal to the sum of the currents in all the branches.
- The current splits when it gets to a junction.

Objectives

- Describe what is meant by voltage
- Describe how to measure voltage in series and parallel circuits
- Describe the effect on the voltage of adding cells and lamps in series and parallel circuits



▲ A voltmeter is connected across a component.



▲ The voltage of this cell is 1.5 V.

Voltage in series and parallel circuits

New batteries in a torch make the lamp brighter.

What makes the lamps brighter?

In a circuit, the force needed to make charges move – the 'push' – is provided by the battery.

The size of the force depends on the **voltage**. The voltage also tells us about the energy that is transferred to the charge by the battery. Voltage is sometimes called **potential difference**.

- If the voltage is bigger, the push is bigger.
- More charge will pass a point in each second, so the current will be bigger.
- More energy will be transferred to the components in the circuit.
- Lamps will be brighter and buzzers will be louder.

Measuring voltage

Voltage is measured in **volts (V)** using a **voltmeter**. The circuit symbol for a voltmeter is: -(v)

You use a voltmeter to measure the voltage *across* a component. Voltmeters are connected to each side of a component, *not* in series like ammeters.

- A voltmeter connected across the battery tells you the energy supplied to the charge by the battery.
- A voltmeter connected across a component tells you the energy supplied by the charge to the component.

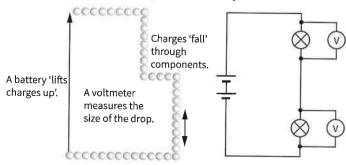
The energy stored in the battery is transferred to the components by the current.

What happens to voltage in a series circuit?

You can think of a battery in terms of 'lifting up' charges. When the charges go through the components they 'fall back down'.

A circuit contains two lamps and a battery. The voltage of a battery is 6 V.

- Each lamp emits light when the current flows.
- Half of the energy from the cell is transferred in each lamp, so the reading on each voltmeter is 3 V.



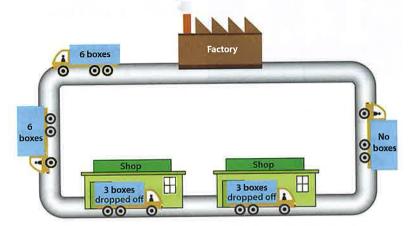
Measuring voltages in a series circuit.

You can use the factory model (page 65) to help you to work out what is happening.

- A factory supplies two shops.
- Each lorry loads 6 boxes at the factory. This
 is like the 6V of the battery.
- The lorry delivers 3 boxes to each shop. The lorry has 3 fewer boxes after delivering to each shop. Each lamp has a voltage of 3 V.

The voltages across the components add up to the voltage of the battery.

If the components in the circuit are *not* the same, then the voltages across them will be different.



The factory model for a series circuit.

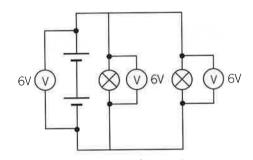
What happens to voltage in a parallel circuit?

In a parallel circuit the voltage across each lamp is the same.

- Each branch is connected directly to the battery.
- The voltage across each component is the same as the voltage across the battery.
- Each component is independent of the other components.

We could add more lamps in parallel and the reading on the voltmeters would still be the same.

If the voltages are all the same, what is the effect of adding more lamps? When you add more and more lamps in parallel, the battery is drained faster.



Measuring voltages in a parallel circuit.

Questions

- 1. a. Describe the difference between current and voltage.
 - **b.** Compare how voltmeters are connected in a circuit with how ammeters are connected.
- 2. Calculate the number of 1.5 V cells that provide a voltage of 9 V.
- **3.** Explain why the voltages across components in a series circuit add up to the voltage across the battery.
- **4.** Dilip connects up a series circuit with a lamp and a buzzer. The voltage of the battery is 6 V.
 - **a.** If the voltage across the lamp is 2 V, calculate the voltage across the buzzer.
 - **b.** Compare the current through the lamp with the current through the buzzer.
 - **c.** Dilip now connects the lamp and buzzer in parallel. Explain why you do not have to calculate the voltage.
- **5.** A student says that the circuit drains the battery because the charge is used up. What would you say to him?

(Rey points

- Voltage tells you the energy transferred to or by a charge.
- Voltage is measured in volts (V) using a voltmeter.
- The voltages across components in a series circuit add up to the voltage of the battery.
- The voltage across each branch of a parallel circuit is the same, and is equal to the voltage of the battery.

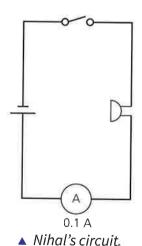
14.3

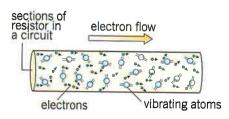
Objectives

- Describe how resistance affects current
- Calculate resistance
- Know the circuit symbols for fixed and variable resistors



▲ A rope model can help you to understand resistance.





Flowing charge has to get past obstacles that offer resistance: vibrating atoms slow electrons down.

Resistance

It is *not* possible to predict whether a battery will produce a large or a small current in a circuit just from the battery. It depends on the components in the circuit.

What is resistance?

Each component such as a lamp provides a **resistance** to the flow of charge.



The current in a circuit depends on the components.

Think about the rope model of a circuit (page 64). If two people hold the rope instead of one, there is more resistance to the rope's movement.

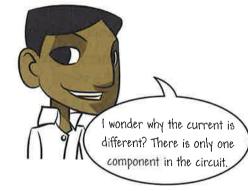
Two lamps provide more resistance than one lamp, so less charge flows per second.

Nihal connects a circuit with one lamp. He measures a current of 0.5 A. He replaces the lamp with a buzzer.

The current is *less* than it was when the lamp was in the circuit.

The buzzer provides *more* resistance to the flow of charge. The current is less.

This is like someone squeezing the rope a bit harder.



How do you calculate resistance?

In the rope model, the speed of the rope depends on:

- how hard the 'battery' person is pulling the rope (the voltage)
- how hard the 'component' person is squeezing the rope (the resistance).

The current in a circuit is like the speed of the rope. It depends on the voltage and the resistance. Resistance is measured in **ohms**, which has the symbol Ω .

current (A) =
$$\frac{\text{voltage (V)}}{\text{resistance }(\Omega)}$$

This means that you can calculate the resistance of a component using the current and the voltage.

resistance (
$$\Omega$$
) = $\frac{\text{voltage (V)}}{\text{current (A)}}$

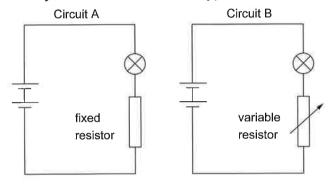
Nihal decides to calculate the resistance of each component. He sees that the voltage of the battery is 6 V.

resistance of the lamp =
$$\frac{\text{voltage (V)}}{\text{current (A)}}$$
 resistance of buzzer = $\frac{\text{voltage (V)}}{\text{current (A)}}$
= $\frac{\text{6 V}}{\text{0.5 A}}$ = $\frac{\text{6 V}}{\text{0.1 A}}$ = $\frac{\text{6 O }\Omega}$



What are the circuit symbols for resistors?

The symbols for two different types of resistor are shown below.



In circuit A the resistance of the resistor does not change.

In circuit B the resistance of the resistor changes. As the resistance increases the lamp will get dimmer. This is how a dimmer switch works.



- 1. A student measures the current in a circuit with a variable resistor. Describe what she must do to the variable resistor to increase the current in the circuit.
- 2. Calculate the resistance of a resistor that carries a current of 0.25 A when there is a voltage of 12 V across it.
- **3.** A parallel circuit has a motor and a buzzer connected across the same battery. The current through the battery is 1.5 A, and through the buzzer is 0.4 A.
 - a. Deduce the current through the motor.
 - **b.** Suggest which of the two components has the bigger resistance.
 - **c.** The battery has a voltage of 6 V.

 Justify your answer to part **b** with two calculations.
- **4.** Explain why adding an additional branch to a parallel circuit *reduces* the overall resistance of the circuit.



▲ You can adjust the light level with the variable resistor on the right.



Our understanding of voltage, current, and resistance along with other technologies has enabled us to develop sophisticated electronic systems such as phones, computers, and the Internet.

(Rey points

- If the resistance increases the current decreases (if the voltage is kept the same)
- resistance (Ω)

 Both fixed and variable resistors can be used in circuits.

Thinking and working scientifically

14.4

Objectives

- Make decisions about when to use primary data
- Describe how to plan an investigation



I wonder how
the resistance of the
wire depends on the
thickness of the wire.

Dipali I wonder how the resistance of the wire depends on the length of the wire.

Planning investigations: resistance of a wire

Chetana, Dipali, and Lakshima have been learning about current and voltage. Their teacher explained that the current flowing in a component depends on the voltage of the battery and the resistance of the component. If the voltage stays the same, then increasing the resistance will make the current smaller.

What affects the resistance of a wire?

Asking questions

Chetana has noticed that the filaments of the lamps that they use in their experiments are made of very thin wire.

Dipali looks at a filament. She notices that it is curled up and thinks that it must be very long.

Lakshima wonders what the filament is made of.

The students list the **variables** in their investigation:

- · the length of the wire
- the thickness of the wire
- the material that the wire is made of
- the voltage of the battery.

When you are choosing ideas to test, you need to make sure they can be tested by collecting data. All these questions involve variables that the students can change. They can control the other variables so that the data show the link between their chosen variable and the resistance of the wire.

Lakshima

I wonder how the resistance of the wire depends on the material that the wire is made of.

A student might wonder if some bulbs look brighter than others to different people. This is an interesting question, but *not* one that you can easily collect data to test.

The students decide to investigate the length of the wire. They will:

- measure the current that flows through different lengths of wire
- use the current and voltage to calculate resistance
- keep the thickness of the wire, the material that the wire is made of, and the voltage of the battery the same.

Planning investigative work: preliminary work

The students need to work out which type of wire to use, which thickness of wire, and which voltage to use. They do some preliminary work to help them decide how to do the experiment safely, and how to get a good range of results.

They use secondary sources to find the most suitable	
wire. They try out different voltages for different	
lengths of wire. They notice that the wire gets very hot for	or high voltages, so
they choose a lower voltage of 1.5 V.	

voltage (v)	Current for 10 cm of wire (A)	current for 1 m of wire (A)
1.5		
3.0		
6.0		

Students recorded their preliminary work in this table.

Planning investigative work: choosing equipment

The students use a digital ammeter to measure the current in the wire. The ammeter will measure the current to the nearest 0.1 A.

They decide to change the length using clips to connect to different positions on the wire. They will use a ruler to measure the length of wire between the clips. They can measure the length to the nearest 1.0 mm.

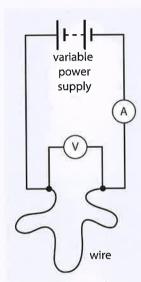
Planning investigative work: assessing hazards and controlling risk

The students know that the wire can get very hot. They put the wire on a heatproof mat and do not leave the battery connected for very long.

Obtaining and considering evidence

The students collect evidence by measuring the current for different lengths of wire. They repeat each experiment three times to make their results more reliable. Before calculating any averages they discard any anomalous results.

They plot a graph to try to find a pattern in their results. This will help them make a conclusion about the link between the current and the length of the wire.



This circuit can be used to measure the current through the wire.

Questions

- 1. List two measuring instruments the students will need.
- **2.** Look at Chetana's question about the thickness of the wire. She decides to carry out an investigation to answer this question.
 - a. Identify the variables she should change, measure, and control.
 - **b.** Describe a difficulty she might have in this investigation.
- 3. Describe the safety issues in the investigation into length of wire.
- **4.** Lakshima completes an investigation into her question about the material of the wire.
 - **a.** What would be the difference between Lakshima's graph and Chetana's graph? Explain your answer.
 - **b.** Draw a table that Lakshima could use to collect her data.

(Rey points

Planning an investigation may involve:

- identifying variables
- doing preliminary work
- choosing equipment
- assessing hazards and controlling risk.

Extension

14.5

Objectives

- Describe the difference between energy and power
- Calculate power





Top: CFL lamp; middle: LED lamp; bottom: filament lamp.

Energy and power

The Kovalam lighthouse in Kerala, India, has a very bright light at the top of a tall cylindrical tower. The light flashes 4 times every minute and can be seen nearly 40 km away. Ships use the light to navigate to the harbour at Kovalam.



The light from a lighthouse has to be seen from a long distance.

What is power?

Some lamps are brighter than others. The lamp in the lighthouse is much, much brighter than the lamps used in torches or in houses or offices.

An electric current transfers energy from the mains supply to the lamp.

A bright lamp transfers more energy per second. It emits more light per second than a dim lamp.

- The rate at which energy is transferred is called the power.
- Power is measured in watts (W) or kilowatts (kW).
- 1 kW = 1000 W.

How do you calculate power?

You can calculate power using an equation:

Power (W) =
$$\frac{\text{energy transferred (J)}}{\text{time taken (s)}}$$

The lighthouse lamp transfers 24 000 J of energy each minute.

The lamp in a torch transfers energy more slowly than the lighthouse lamp so the power is much less. The torch lamp transfers energy at a rate of 120 J each minute.

To calculate the power you have to convert the time to seconds.

For the lighthouse:

For the torch:

Power =
$$\frac{24\,000\,\text{J}}{60\,\text{s}}$$
 = 400 W

Power =
$$\frac{120 \text{ J}}{60 \text{ s}} = 2 \text{ W}$$

A lighthouse lamp is 200 times more powerful than a torch lamp.

How do light bulbs differ?

For over 100 years light bulbs have been widely used.

- **Filament** (or incandescent) lamps contain a piece of wire that is very thin and glows when it gets hot.
- Compact fluorescent lamps (CFLs) are energy-saving lamps first sold in 1981.
- Light-emitting diode (LED) lamps are very efficient.

The table below shows how much power, or energy per second, each type of lamp needs to produce different light levels.

	Light intensity (lumens)	Power of incandescent light bulb (W)	Power of CFL (energy-saving lamp) (W)	Power of LED lamp (W)
	800	60	15	10
Ì	1800 100		25	18
	2800	150	45	26

- LEDs produce a lot of light for their size.
- LEDs can be made small enough to sew into your clothes.
- Doctors use the intense light in cancer treatments.
- LEDs were used in the London and Rio de Janeiro Olympics to make spectacular patterns inside the Olympic stadium.

How do you pay for electricity?

When people pay their electricity bill they pay for fuel to be burned to produce a current to transfer energy. The amount of energy transferred depends on the power of the appliances and how long they are used for.

We can rearrange the equation for power like this:

Energy $(J) = power(W) \times time(s)$

People transfer lots and lots of joules of energy each month. So, instead, the energy is measured in a different unit, the kilowatt-hour (kWh).

Energy (kWh) = power (kW) \times time (h)

For example, if you use a 10 W (0.01 kW) LED for 10 hours in one month, energy transferred = 0.01 kW \times 10 h = 0.1 kWh

To produce the same amount of light using a filament light bulb you would need to use a 60 W light bulb. You would pay for 0.6 kWh instead. Using new light bulbs can save a lot of money. LEDs are a lot more expensive to purchase than filament or CFL light bulbs, but they do last a long time.



Cancer treatment with LEDs.



▲ LEDs are used to make impressive light displays.

Questions

- 1. Calculate the number of watts in 2 kW.
- 2. A CFL transfers 1200 J of energy each minute. Calculate its power.
- **3.** Look at the table and the calculations above for the energy cost of using an LED and a filament bulb for 10 hours each month.
 - **a.** Calculate how much energy in kWh you would need for a CFL lamp to produce the same amount of light.
 - **b.** The electricity company charges 10 rupees per kWh. Calculate how much it would cost to use each lamp for 10 hours each month.
 - **c.** Calculate the money you would save each month if you used an LED instead of a filament bulb.

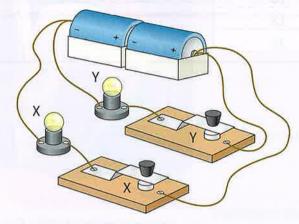
(III) Key points

- Power is the energy transferred per second.
- Power is measured in watts (W) or kilowatts (kW).
- Energy (J)= power (W) × time (s)
- LEDs have a wide range of uses.

Review

14.6

1. a. Draw a circuit diagram for the circuit below. [2]



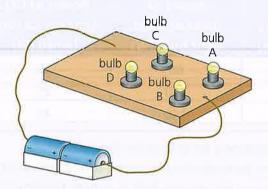
- **b.** State whether this is a series or a parallel circuit.
- c. Copy and complete the table to show what would happen when you press the switches. [3]

[1]

Switches closed	Bulbs lit
X	
Υ	
X and Y	

- **d.** Describe how you could measure the current flowing in each bulb. [1]
- 2. Look at the sentences below. Name the circuit component or type of circuit that each sentence describes.
 - **a.** This is the energy source for an electric circuit. **[1]**
 - b. In this circuit all the components are in a single loop.[1]
 - **c.** This enables you to turn a component on or off. [1]
 - **d.** In this circuit all the components can be turned on or off independently. [1]

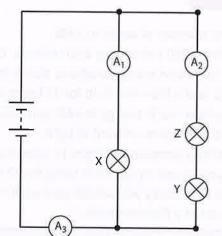
3. A student uses four bulbs and a battery pack to make a circuit. He puts a box over the circuit so the connections cannot be seen.



Another student unscrews each bulb in turn and watches the effect on the other three bulbs.

If you take this bulb out	this is what happens Bulbs B, C, and D go out.	
Α		
В	Bulb C goes out, bulbs A and D stay on.	
С	Bulb B goes out, bulbs A and D stay on.	
D	Bulbs A, B, and C stay on.	

- **a.** Draw a diagram to show how the bulbs must be connected. [3]
- b. Name the bulb or bulbs that will be the brightest. Explain your answer. [2]
- c. Name the bulb or bulbs that will be the dimmest. Explain your answer. [2]
- **4.** Here is a circuit diagram. All the lamps are the same.



- a. Are the lamps connected in series, parallel, or both? Explain your answer. [2]
- b. Which ammeter will show the lowest reading?Explain your answer. [2]
- c. Describe the link between the readings on the three ammeters.[1]
- d. Which lamp will be brightest? Explain your answer. [2]
- **e.** Describe what would happen to the other lamps if:
 - i. lamp X broke [1]
 - ii. lamp Y broke [1]
 - iii. lamp Z broke. [1]
- **5.** A circuit contains a 6V cell and two lamps connected in series.
 - **a.** Draw a circuit diagram showing how you would connect a voltmeter to measure the voltage across each bulb.
 - **b.** Both bulbs are identical. Write down the reading on each voltmeter. [1]

[1]

- **c.** Explain your answer to part **b**. [1]
- **6.** A student is planning how to collect some data to answer this question:

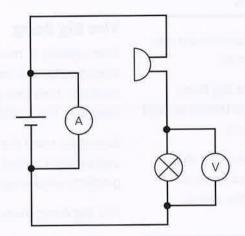
'Which circuit component has the biggest resistance?'

He writes down his ideas, but they are *not* in the right order. Put the statements in the right order using the letters. [1]

- A Think about how I can make sure that the experiment is safe.
- **B** Connect up the circuit and measure the current through each component.
- C Select equipment so that I can measure the current.
- **D** Do some preliminary work to find the best voltage to use.
- **E** Write the results in a table.

7. A student wires up a circuit to measure the current through a buzzer and a lamp. He connects a voltmeter to measure the voltage across the buzzer.

He draws the circuit in his notebook.



- a. List the things that are wrong with this circuit diagram.[2]
- **b.** Draw the correct circuit diagram. [2]
- **8.** A student connects one bulb, an ammeter, and a cell in series. He connects a voltmeter across the bulb. The current through the bulb is 0.4 A. The voltage across the bulb is 3 V.
 - a. Explain what is meant by current. [1]
 - **b.** Explain what is meant by voltage.
 - **c.** Calculate the resistance of the lamp.
 - **d.** The lamp transfers 72J in one minute. Calculate the power.
- **9.** A circuit contains two lamps and a cell. They are connected in series.
 - **a.** Describe and explain what happens to the brightness of the lamps if another lamp is added in series.
 - b. Describe how the brightness would change if the lamps were connected in parallel, not in series. Explain your answer. [2]
 - c. Describe how the brightness would change if another cell is added to both the series and the parallel circuits.[1]

[1]

[2]

[2]

Extension 15.1

Objectives

- Give the approximate age of the Universe
- Describe the Big Bang theory of the Universe, and evidence for it
- Compare the time that humans have lived on Earth with the age of the Earth



An astronomer using a telescope in an observatory.

The origin of the Universe

An **astronomer** looks at galaxies in the night sky. She works out that they are all moving away from the Farth. You might think that the Earth is special, or that it is the centre of the Universe, but that is *not* the case.

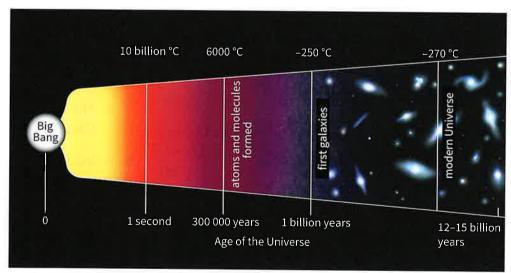
The Big Bang

Every galaxy is moving away from every other galaxy. Astronomers found evidence for this movement in the 1920s, when they used telescopes to measure how fast galaxies are moving. They also measured how far away they are. The further away they were, the faster they were moving.

Scientists used the evidence from their observations to develop an explanation called the **Big Bang**. It is an idea that explains observations and predicts what might happen in the future.

The Big Bang theory says:

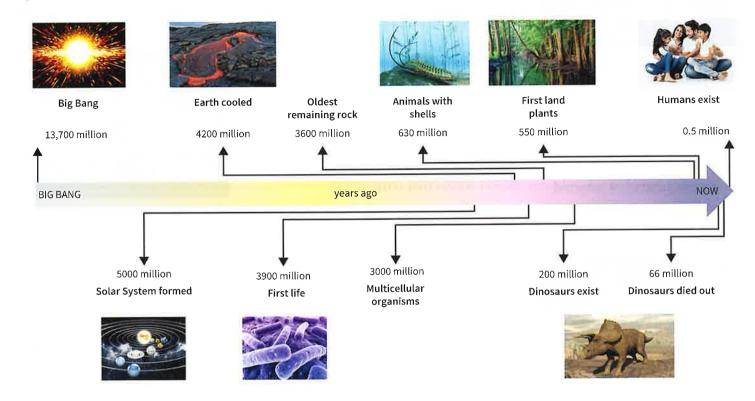
- The Universe began about 14 billion years ago.
- The whole Universe expanded from something smaller than an atom and hotter than anything we can imagine.
- In a fraction of a second the Universe grew to the size of a galaxy, and it has continued to expand ever since.
- As it expanded, it cooled, and energy changed into particles, making atoms and molecules of hydrogen and helium.
- Eventually there were stars, planets, moons, and galaxies, and the Universe we see today.



▲ The Big Bang theory explains how the modern universe was formed over billions of years.

The galaxies are moving away from us because the space in between all galaxies is expanding. There is nothing special about our galaxy, the Milky Way. If we lived in the **Andromeda** galaxy it would still appear that all the other galaxies, including the Milky Way, were moving away from us.

A timeline for the Universe



Sometimes it is easier to picture the timescale with an analogy.

- If the Universe started 24 hours ago, then the Earth would have formed 9 hours ago.
- The first animals would have appeared about an hour ago.
- Human beings would have existed for less than the time that it takes to blink your eyes.

The end of the Universe

No one knows what will happen to the Universe.

- It may expand forever.
- It may expand, and the expansion could get faster.
- Gravity may pull it back in again.
- It may expand to a certain size and stay that way.

To know what is going to happen we would need to be able to measure the mass of all the objects in the Universe.

This is *not* possible with the technology that we have at the moment.

② Questions

- 1. a. Write down the age of the Universe.
 - b. Write down the age of the Solar System.
- 2. Why is it difficult to predict what will happen to the Universe?
- 3. Could humans have seen a dinosaur? Explain your answer.

(Rey points

Scientists think that the Universe began

- with a Big Bang about 14 billion years ago.
- Some evidence for the Big Bang is that all the galaxies are moving away from each other.
- Earth has existed for a fraction of the time that the Universe has existed.
- Humans have existed for a tiny fraction of the time that the Earth has existed.

15.2

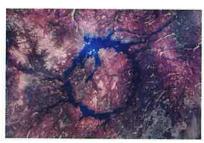
Objectives

- Describe evidence for asteroid collisions
- Describe some consequences of asteroid collisions



▲ There are millions of craters on the Moon.

The Lonar crater in India is now a lake.



▲ Some craters, like this one in Canada, are only visible from space.

Collisions, asteroids, and mass extinctions

About 66 million years ago a huge asteroid hit the Earth. Scientists think that this impact contributed to the extinction of the dinosaurs. Has this happened before?

How do we know there have been asteroid impacts?

Asteroids can be pulled out of their orbit in the asteroid belt by Jupiter's gravity. Their new direction may take them on a collision course with the Earth. You learned about asteroids and **meteorites** on page 183.



▲ An asteroid impact happened at the time the dinosaurs died out.

There is evidence that very many asteroids have collided with objects in the Solar System in the past. If you look at the Moon you see it covered in **craters**. The Moon has been hit by lots of pieces of rock in the past. The conditions on the Moon mean that the craters are still visible.

What is the evidence for asteroid impacts on Earth?

Meteor Crater in Arizona, USA, was formed when a piece of iron 40 m in diameter hit the Earth.



There are some visible craters on the Earth. The crater produced by the asteroid that may have caused the extinction of the dinosaurs is deep off the coast of Mexico, and was not discovered until 1978.

What happens when an asteroid hits the Earth?

An asteroid with a diameter of 50 m can make a crater over a kilometre wide.

On impact, the ground and the asteroid can be **vaporised**. This sends material into the air in the form of dust, ash, and gas. If the asteroid hits the ocean it can cause a tsunami.

The effect of the impact depends what the asteroid is made of, and what it hits.

A large, metallic asteroid hitting soft rock will make a large crater.

What effect does an asteroid impact have?

If the asteroid is very large there will be enough dust to block out light from the Sun. The material that ends up in the Earth's atmosphere can change climate, and cause mass extinctions.

The climate depends on the balance between the energy that reaches the Earth from the Sun, and the energy that the Earth radiates into space.

If radiation from the Sun is blocked, then the temperature of the Earth would fall very quickly. This is called an **impact winter**. If the Sun was blocked out for a long time, then plants that rely on photosynthesis and animals that eat the plants would die. An impact winter that continued for over a year would make it difficult for humans to survive.

An event that causes a large percentage (75%–90%) of all species to disappear in a relatively short time is called a **mass extinction event**. Scientists think that these events happen on average approximately every 25 million years.

The most famous was the event that probably killed off most of the dinosaurs when an asteroid about 9 km in diameter hit the Earth.

However, most mass extinction events are thought to result from climate change due to volcanic emissions or changes to the Earth's oceans.

How often do significant asteroid impacts happen?

More than 100 tons of dust hits the Earth every day, but it gets burned up in the atmosphere.

An object the size of	hits the Earth every	and produces
a car (5 m)	year	a fireball
a football field (100 m)	5000 years	a large crater, significant damage, tsunami
half (400 m) the tallest building in the world	100 000 years	climate change, impact winter, possible mass extinction

Questions

- 1. Describe the two main effects of large asteroid impacts.
- **2.** Explain why craters are easily seen on the Moon but *not* on Earth.
- **3.** Suggest whether there are any objects in the Solar System that do *not* have craters.
- **4.** Suggest why it is difficult to know the exact cause of a mass extinction event.

NOW-	Approx. time
	years ago
Mass extinction 5:	
50-70% species lost	65 million
Dinosaurs died out	65 million
	ľ
Mass extinction 4:	
50% marine invertebrates lost	
80% land quadrupeds lost	205 million
Mass extinction 3:	
80–95% marine species lost	251 million
Mass extinction 2:	
70% species lost	360-75
	million
Mass extinction 1:	
60% species lost	
3070 Species 1050	440 million
ORIGINS OF LIFE	3500 million
Olliding of Eli E	years ago
£	

▲ There have been five mass extinction events in Earth's history.

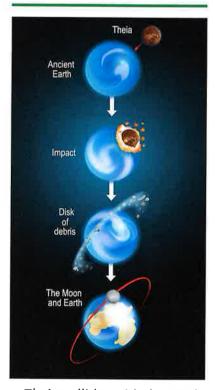
(Rey points

- Craters and meteorites show that asteroids have hit Earth in the past.
- Small asteroid impacts can cause small craters and fireballs.
- Large asteroid impacts can make craters, throw material into the atmosphere, and cause climate change and mass extinction.



Objectives

- Describe the giantimpact hypothesis for the formation of the Moon
- Describe some of the evidence for and against the hypothesis
- Describe the evidence for other theories



▲ Theia collides with the Earth.

Collisions and the Moon

When you look up in the night sky you can usually see the Moon. It was *not* there when the Earth formed. How did it get there?



▲ The Earth and Moon to scale.

What is the 'giant-impact' hypothesis?

Most astronomers think that the Moon was formed when a giant object smashed into the Earth.

The Earth had formed by about 4.54 billion years ago from the gas and dust left from the formation of the Sun. In addition, various objects had hit the Earth later and been absorbed into it. Other objects, including planets, were made from the leftover gas and dust too.

- Gravity pulled together dust and gas.
- The dust contained iron that had been made in other stars.
- The iron formed the central core of the objects that formed.
- Debris rained down on the surface of the young Earth and probably kept the surface molten for a long time.

The **giant-impact hypothesis** says that the Moon formed at some time before 4 billion years ago.

- An object the size of Mars called Theia collided with the Earth.
- The energy of the collision heated the Earth and Theia.
- The molten iron cores of the two objects merged to form the core that the Earth has today.
- The lighter rock was thrown out into orbit and formed the Moon.
- After the Moon formed, the surfaces of both the Earth and the Moon cooled to produce a crust.

Astronomers can make predictions based on this hypothesis. Here are some of the predictions and some of the evidence for and against them.

Prediction	Evidence
The Earth should have an iron core.	Evidence suggests it does.
Some of the material of the Moon should be the same as the Earth, and some should be different because it came from Theia.	The material brought back from the Moon by the Apollo astronauts suggests that there is very little difference between the composition of the Earth and the Moon.
The Moon should orbit the Earth at a distance we can predict from models.	It does orbit at that distance.
The Moon's orbit should align with the Earth.	The orbits of the Earth and Moon do align.

Scientists have no direct evidence that the core of the Earth is made of iron. They think that it is made of iron because:

- it would account for the density of the Earth (if the core is made of rock then the density would be too low)
- the Earth has a magnetic field around, so it is likely that some metal element is moving in the core.

Other theories for the formation of the Moon

Co-formation theory

In one version of the **co-formation theory**, the Moon was formed alongside the Earth by gravity pulling together dust and gas. In another version, two objects the size of Mars collided, and the Earth and Moon formed from them.

Evidence for this theory	Evidence against this theory
 The Moon has a similar composition to the Earth. The Moon would be in orbit at its present location. 	 The Moon is less dense than the Earth. The Moon does <i>not</i> seem to have a heavy core.

Capture theory

In the **capture theory** the Moon formed elsewhere in the Solar System. Earth's gravity captured the Moon as it was passing by.

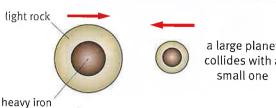
Evidence for this theory	Evidence against this theory
The Moon is less dense than the Earth.	 Objects that are captured are not usually spherical. The orbits of objects captured this way do not align.

Science in context

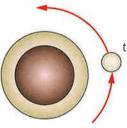
There have been other theories about how the Moon formed. We are still not completely sure that the giant impact hypothesis is correct. Theories change over time. The co-formation and capture theories have been around for a long time.

Questions

- **1.** Describe one piece of evidence that supports the giant-impact hypothesis, and one that does *not* support it.
- **2.** Suggest why most scientists don't believe the other theories that have been proposed.
- **3.** Suggest why astronomers might think that Mars's two moons are captured asteroids.



all the iron ends up in the large planet - Earth



the light rock throw up by the impact forms the Moon

▲ Did the molten iron cores merge?



▲ Some astronomers think that the two Martian moons (Phobos and Deimos) are captured asteroids.

(Rey points

- The giant-impact hypothesis says that an object called Theia collided with a young Earth.
- The iron cores of the objects merged and the lighter rock formed the Moon.
- A lot of evidence supports the hypothesis, but not all.
- There are other theories, with less evidence.

15.4

Objectives

- Describe what a nebula is
- Describe how stars form and die

The life cycle of stars

When we look into the night sky we are looking back in time. The light from some of the objects has taken millions or billions of years to reach us. Some of the stars we are seeing are very young, and others have reached the end of their life cycle.

What is a nebula?

A **nebula** is a cloud of dust and gas. In some nebulae gravity pulls the gas together to make a star. These are called **stellar nurseries.**



▲ The Eagle Nebula is a stellar nursery.

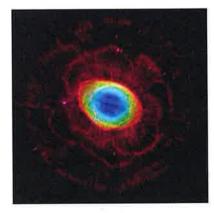
When does a star shine?

Our Sun has a life cycle, as an animal does. Like all stars, it is born and it will die.

- The Sun was born from a cloud of gas and dust.
- Gravity pulled the gas together to form a main-sequence star, like our star is now.



▲ The life cycle of our Sun.



▲ The Ring Nebula is a planetary nebula, not a stellar nursery.

Nuclear fusion reactions produce the energy that makes the Sun shine. In nuclear fusion, hydrogen atoms fuse to make helium, and energy is released. Helium then fuses to make other elements. Elements up to iron in the Periodic Table are made in stars like our Sun. The temperatures and pressures needed for nuclear fusion are found in the centre of stars.

The Sun has enough fuel to shine like this for another 5 billion years. Eventually all of the hydrogen will be used up and it will go through the final stages of its life.

- It will grow to become a red giant and will swallow up Mercury, Venus, and possibly Earth as well.
- The outer layers will be thrown out into space to form clouds of gas called a **planetary nebula**. (A planetary nebula has nothing to do with planets. Astronomers thought they looked like planets.)
- The centre will shrink and become a hot **white dwarf**, and then cool down to become an invisible **black dwarf** star.

How is a stellar nursery formed?

Stars that are much bigger than our Sun are called massive stars. A massive star will turn into a red supergiant, explode to form a supernova, and then form a neutron star or a black hole.

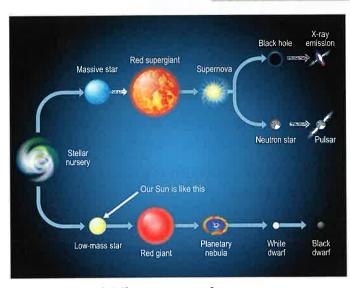
Massive stars eventually become supernovae. These are some of the most energetic explosions in the Universe. Elements that are heavier than iron in the Periodic Table are made in supernova explosions.

The remnants of the star are flung out into the universe to form nebulae. These nebulae can produce new stars and planets, like our Sun and our planet Earth.

You are made of stardust.



▲ The Orion Nebula can be seen with the naked eye.



Life cycles of different types of stars.



▲ The Orion Nebula looks beautiful through a large telescope.

Key points

- Stars have two different possible life cycles depending on their mass.
- Low-mass stars like our Sun have a life cycle that ends up as a white dwarf, then a black dwarf.
- Massive stars end up as black holes or neutron stars.
- Both types of stars produce nebulae, which can go on to form new stars.
- Heavy elements are only made in supernova explosions.

Questions

1. Match the words to their definitions:

A	Nebula	1	The type of star our Sun is now
В	Nuclear fusion	2	Cloud of dust and gas
С	Main sequence	3	The process that produces energy in stars
D	Red giant	4	What our Sun will become in about 5
			billion years

- **2.** Describe one similarity and one difference between the life cycle of a low-mass and a massive star.
- 3. Suggest why gold is more precious than diamond.

Review

15.5

- **1. a.** Describe one piece of evidence that there have been asteroid impacts on Earth. [1]
 - **b.** Explain why scientists might disagree about the evidence. [1]
- **2.** Give the letter of the correct statement. [1]
 - A The size of an impact crater does not depend on the type of ground an asteroid hits.
 - **B** The size of an impact crater does not depend on the type of material of the asteroid.
 - **C** A bigger crater will be formed if the asteroid hits softer rock.
 - **D** The Earth has only been hit by a few asteroids.
- **3.** Which of the following is a piece of evidence for the giant-impact hypothesis? [1]
 - **A** The Moon is orbiting the Earth at the expected distance.
 - **B** People have landed on the Moon.
 - **C** There is no atmosphere on the Moon.
 - **D** The Moon has less gravity than the Earth.
- 4. Put these statements in order to describe the giant-impact hypothesis. [5]
 - A The lighter rock was thrown out into orbit.
 - **B** After the Moon formed the surfaces of Moon and Earth cooled to produce crusts.
 - C The molten iron cores of the two objects merged to form the core that the Earth has today.
 - **D** The energy of the collision heated the Earth and Theia.
 - **E** The lighter rock came together to form the Moon.
 - **F** An object the size of Mars called Theia collided with the Earth.

- **5.** You can use primary and secondary data to **Tws** develop explanations in science.
 - a. Describe the difference betweenprimary and secondary data. [1]
 - **b.** An astronomer uses some data from a science book to develop an explanation about the location of the Moon's orbit. Are the data primary or secondary data? [1]
 - A student uses a table of numbers that they found in a magazine to find out about the number of moons around all the planets.
 Are the data primary or secondary data? [1]
 - d. A teacher uses a telescope to make some observations of the craters on the Moon.Are the data primary or secondary data? [1]
 - e. Which type of data are likely to be more reliable? Explain your answer. [2]
- **6.** Put these in order of age from youngest to oldest. [3]
 - A the Sun C the Earth

 B the Universe D the Moon
- **7.** An asteroid hit the remote Tunguska region of Russia in 1908, producing a fireball that flattened 80 million trees. No one was hurt.



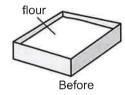
- **a.** Explain why the complete asteroid was *not* found on the ground. [1]
- **b.** Define 'mass-extinction event'. [1]
- **c.** Describe how an asteroid produces a mass extinction event. [3]
- **d.** Explain why mass extinctions are rare. [1]

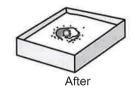
[2]

8. A student wants to investigate impact craters. They get a deep tray and fill it with flour.

When they drop a marble onto the tray it makes a crater.







a. Complete this sentence for a hypothesis about forming craters that they could test.

Craters are formed because the _ of the falling marble is transferred to the flour, which makes the flour move. [1]



rws b. Complete this sentence for a question that they could investigate.

> I wonder how changing the _____ that I drop the marble from affects the ___ of the crater. [2]

- c. Name the independent variable. [1]
- [1] **d.** Name the dependent variable.
- e. Name one control variable. [1]



- f. Describe and explain the type of graph that they could plot. [2]
- 7. Here are some statements that would provide evidence for different theories for how the Moon was formed.
 - A The Earth should have an iron core.
 - **B** Some of the material of the Moon should be the same as the Earth, and some should be different because it came from Theia.
 - C The Moon should orbit the Earth at a distance we can predict from models.
 - **D** The Moon's orbit should align with the Earth.

- a. Give the letter or letters of the statements that are true. [1]
- **b.** Give the letter of a statement that supports the giant-impact theory over other theories. [1]
- c. Describe an alternative theory for the formation of the Moon. [2]
- **d.** Explain why the theory you have described has not overtaken the giant-impact theory. [1]
- **10.** A student is trying to explain the timeline for the formation of the Universe. They use the idea of condensing the length of time that the Universe has been in existence to one year.
 - a. Copy the table and add the following events at the correct time.

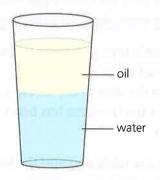
dinosaurs became extinct Milky Way formed Earth formed

Date	Event
January 1	Big Bang
May	
Early September	Sun formed
Middle September	
December 7th	Dinosaurs lived
December 30th	
December 31st 9.25pm	Humans walk
	upright

- **b.** Described what happened to the temperature of the Universe over time. [1]
- c. The Universe has been expanding for about 14 billion years. Suggest the maximum distance, in light years, that the most powerful telescope possible could see into the Universe. Explain your answer. [2]

Review Stage 9

 A girl is playing with some oil and some water. She pours the oil and water into a glass and the oil floats on the water.



a. Write down which liquid is more dense, the oil or the water. Explain your answer. [2]

She cuts up a cube-shaped piece of banana and puts it into the glass.

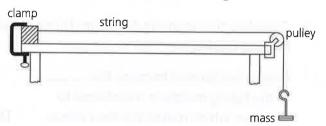
It floats between the layer of oil and water.

b. Write down what can you say about the density of the banana compared to the density of the oil and the density of the water. [2]

She decides to measure the density of the banana.

- **c.** Write down what equipment she will need to use. [2]
- TWS
- d. Explain how she could use that equipment to measure the density.[3]
- 2. During the day in the desert it can get very hot. Some people even run marathons in the desert. There is an 'ultra-marathon' that takes place in the Sahara desert.
 - The temperature in the Sahara can reach 45 °C.
 Describe the difference between temperature and energy.
 - **b.** Describe how energy from the Sun reaches a runner in the desert. [1]

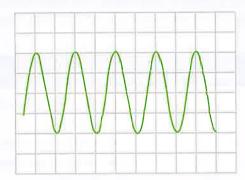
- c. A runner will perspire (sweat) when he gets hot.Explain how that helps to keep him cool. [2]
- d. At the end of the race he goes inside a cool room. It feels cold. In which direction is energy being transferred: from the room to him, or from him to the room?
 [1]
- e. Is the energy being transferred by conduction, convection, or radiation, or more than one of these methods? Explain your answer. [2]
- 3. A student is planning an investigation into the effect of changing the tension in a string on the pitch of the sound produced. Here is a diagram of the experiment that he is planning to do.



He plans to change the masses hanging on the string, pluck it to make a sound, and use a microphone to look at the wave on the screen of the oscilloscope. He knows that the screen shows the number of waves in 10 milliseconds. His teacher explains that he can count how many waves there are on the screen and divide by 0.01 to get the frequency in Hz.

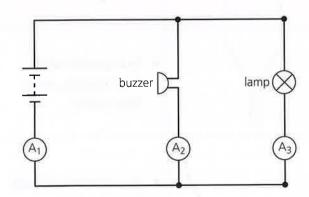
- a. Give the name of the independent variable. [1]
- **b.** Give the name of the dependent variable. [1]
- c. Give the name of the variable or variables he will need to control. [1]
- **d.** Draw the table he needs to use to record his results. [2]
- **e.** Give the name of the type of graph he should plot from his results. Explain your answer. [2]
- f. He does the experiment and finds that as he adds more masses the frequency gets bigger.
 Name a musical instrument where this would be important.

4. A referee needs to blow a whistle in a football game to stop play. This is a picture of the whistle sound wave on the screen of an oscilloscope:



He blows his whistle again, but this time with a lower pitch and quieter.

- **a.** Draw a wave to show what this sound would look like. [2]
- **b.** Explain why you have drawn the wave in the way that you have. [1]
- c. On a sketch of the wave draw the wave that would superpose destructively with the wave on the screen.
- **d.** Suggest where it is useful to have waves cancelling out. [1]
- **5.** A student has connected a parallel circuit.



- a. The reading on ammeter 1 is 0.5 A, and the reading on ammeter 2 is 0.2 A. Give the reading on ammeter 3.
- b. Describe what would happen to the ammeter readings if you swapped the buzzer and the lamp.[2]

 c. Describe what would happen if you used a battery with a bigger voltage. Explain your answer. [2]

The student replaces the buzzer with a different lamp. The reading on ammeter 2 is now 0.1 A.

- d. Deduce the reading on the other two ammeters.[2]
- **e.** Describe where to put a voltmeter to measure the voltage across the lamp. [1]
- **f.** Describe where to put a voltmeter to measure the voltage across the battery. [1]
- g. Would the two voltmeter readings be the same or different? Explain your answer. [2]
- h. What would happen to the reading on ammeter 3 if you added another bulb in that branch? Explain your answer. [2]
- 6. The Earth has a magnetic field.
 - **a.** Describe one theory for why the Earth has a magnetic field. [1]
 - **b.** Explain why a student might think that the 'bar magnet' producing the Earth's magnetic field is the wrong way round. [2]
- **7.** An astronomer observes a planet around a distant star. It is not possible to see whether there are craters on the planet.
 - **a.** Suggest why the astronomer might think there would be craters. [1]
 - **b.** Suggest what might have caused the craters, and where they come from. [2
 - A crater on Earth was formed at about the time of the last mass-extinction event. Name one of the types of animals that died out in that event.
 - **d.** An object is thought to have collided with the Earth to produce the Moon. Name this theory. [1]

Reference

Choosing apparatus

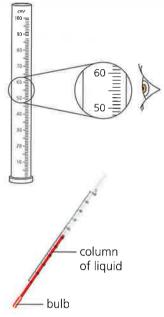
There are many different types of scientific apparatus. The table below shows what they look like, how to draw them, and what you can use them for.

Apparatus name	What it looks like	Diagram	What you can use it for
test tube			 heating solids and liquids mixing substances small-scale chemical reactions
boiling tube			 a boiling tube is a big test tube; you can use it for doing the same things as a test tube
beaker	400 ref = 30 cm 30 c		heating liquids and solutionsmixing substances
conical flask			heating liquids and solutionsmixing substances
filter funnel			 to separate solids from liquids, using filter paper
evaporating dish			• to evaporate a liquid from a solution
condenser			to cool a substance in the gas state, so that it condenses to the liquid state

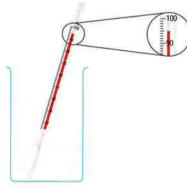
stand, clamp, and boss		• to hold apparatus safely in place
Bunsen burner		to heat the contents of beakers or test tubesto heat solids
tripod		to support apparatus above a Bunsen burner
gauze		 to spread out thermal energy from a Bunsen burner to support apparatus, such as beakers, over a Bunsen burner
pipette		 to transfer liquids or solutions from one container to another
syringe		 to transfer liquids and solutions to measure volumes of liquids or solutions
spatula	Elis Andrews	 to transfer solids from one container to another
tongs and test tube holders	a de	 to hold hot apparatus, or to hold a test tube in a hot flame

Reference

2



▲ The different parts of a thermometer.



▲ The temperature of the liquid is 95 °C.



▲ The balance measures mass.

Working accurately and safely

You need to make accurate measurements in science practicals. You will need to choose the correct measuring instrument, and use it properly.

Measuring cylinder

Measuring cylinders measure volumes of liquids or solutions. A measuring cylinder is better for this job than a beaker because it measures smaller differences in volume.

To measure volume:

- 1. Place the measuring cylinder on a flat surface.
- 2. Bend down so that your eyes are level with the surface of liquid.
- **3.** Use the scale to read the volume. You need to look at the bottom of the curved surface of the liquid. The curved surface is called the **meniscus**.

Measuring cylinders measure volume in cubic centimetres, cm³, or millilitres, ml. One cm³ is the same as one ml.

Thermometer

The diagram to the left shows an alcohol thermometer. The liquid expands when the bulb is in a hot liquid and moves up the column. The liquid contracts when the bulb is in a cold liquid.

To measure temperature:

- **1.** Look at the scale on the thermometer. Work out the temperature difference represented by each small division.
- 2. Place the bulb of the thermometer in the liquid.
- **3.** Bend down so that your eyes are level with the liquid in the thermometer.
- **4.** Use the scale to read the temperature.

Most thermometers measure temperature in degrees Celsius, °C.

Balance

A **balance** is used to measure mass. Sometimes you need to find the mass of something that you can only measure in a container, like liquid in a beaker. To use a balance to find the mass of liquid in a beaker:

- 1. Place the empty beaker on the pan. Read its mass.
- 2. Pour the liquid into the beaker. Read the new mass.
- 3. Calculate the mass of the liquid like this:

(mass of liquid) = (mass of beaker + liquid) – (mass of beaker)

Balances normally measure mass in grams, g, or kilograms, kg.

Working safely

Hazard symbols

Hazards are the possible dangers linked to using substances or doing experiments. Hazardous substances display **hazard symbols**. The table shows some hazard symbols. It also shows how to reduce risks from each hazard.

Hazard symbol	What it means	Reduce risks from this hazard by
	Corrosive – the substance attacks and destroys living tissue, such as skin and eyes.	wearing eye protectionavoiding contact with the skin
×	Irritant – the substance is not corrosive, but will make the skin go red or form blisters.	wearing eye protectionavoiding contact with the skin
	Toxic – can cause death, for example, if it is swallowed or breathed in.	wearing eye protectionwearing gloveswearing a mask, or using the substance in a fume cupboard
	Flammable – catches fire easily.	wearing eye protectionkeeping away from flames and sparks
	Explosive – the substance may explode if it comes into contact with a flame or heat.	wearing eye protectionkeeping away from flames and sparks
*	Dangerous to the environment – the substance may pollute the environment.	taking care with disposal

Other hazards

The table does not list all the hazards of doing practical work in science. You need to follow the guidance below to work safely. Always follow your teacher's safety advice, too.

- Take care not to touch hot apparatus, even if it does not look hot.
- Take care not to break glass apparatus leave it in a safe place on the table, where it cannot roll off.
- Support apparatus safely. For example, you might need to weigh down a clamp stand if you are hanging heavy loads from the clamp.
- If you are using an electrical circuit, switch it off before making any change to the circuit.
- Remember that wires may get hot, even with a low voltage.
- Never connect wires across the terminals of a battery.
- Do not look directly at the Sun, or at a laser beam.
- Wear eye protection whatever you are doing in the laboratory!

Reference

3

Using ammeters and voltmeters

Measuring current and voltage

In your experiments with electrical circuits you will measure current and voltage using meters. There are two types of meter: analogue and digital.

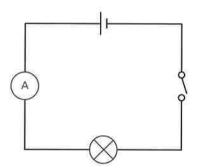
- Analogue meters have a needle that moves and shows the current on a scale.
- Digital meters have a display of numbers. A digital meter is usually a multimeter, which means that you can use it to measure current or voltage.

Using an analogue ammeter

An ammeter measures the current. You might want to find the current flowing through a component such as a lamp. To do this you place the ammeter *in series* with the lamp.



▲ An analogue ammeter.



An ammeter connected to a circuit with a cell or battery, a lamp, and a switch.

For most components in a circuit it does not matter which way round you connect them. This is not true for an ammeter. It needs to be connected so that, if you follow the wires back to the battery or cell, the wire in the *black* terminal on the ammeter is connected to the *negative* terminal of the battery. The wire in the *red* terminal should be connected to the *positive* terminal of the battery.

This is how you connect the ammeter into a circuit with a cell or battery, a lamp, and a switch.

- 1. Disconnect the cell or open the switch.
- **2.** Follow the wire from the negative terminal of the cell until you get to the lamp. Disconnect the lead from the lamp.
- 3. Plug that lead into the black terminal on your ammeter.
- **4.** Use another lead to connect the lamp to the red terminal of the ammeter.

An analogue meter may have two different scales. Start by connecting it up using the red terminal labelled with the higher value of current. If the ammeter does not show a current in your circuit using that scale, then move the lead to the terminal with the lower value of current.

Using an analogue voltmeter

A voltmeter measures the voltage. You might want to find the voltage across a component such as a lamp. To do this you place the voltmeter *in parallel* with the lamp.

Like an ammeter, a voltmeter needs to be connected the right way round. This is how you connect the voltmeter into a circuit with a cell or battery, a lamp, and a switch.

- 1. Disconnect the cell or open the switch.
- 2. Follow the wire from the negative terminal of the cell until you get to the lamp. Do not disconnect the lamp but plug another lead into the terminal on that side of the lamp.
- 3. Connect the other end of this lead to the black terminal on your voltmeter.
- **4.** Use another lead to connect the other side of the lamp to the red terminal of the voltmeter.

Connecting meters

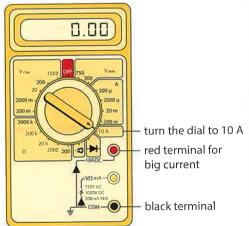
You connect an ammeter in series, and a voltmeter in parallel. It is important not to connect an ammeter in parallel with a component, or directly across a battery or cell. The resistance of the ammeter is very small so a very large current would flow that could damage the ammeter and drain the cell.

The resistance of a voltmeter is very, very high. If you connect it in series rather than in parallel no current will flow in the circuit.

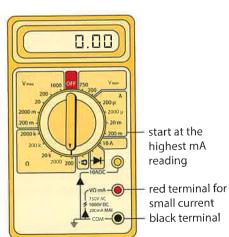
Using a multimeter

You can use a multimeter to measure current or voltage.

The multimeter has a dial that you turn to select current (A or mA) or voltage (V). You select whether you want to measure a large current (10 A) or a small current. Some examples of how to connect a multimeter are shown below.



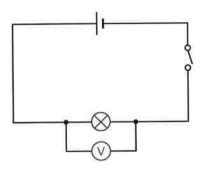
Using a multimeter to measure a big current.



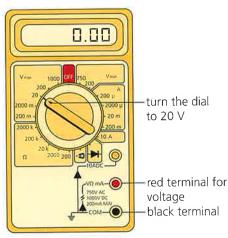
Using a multimeter to measure a small current.



An analogue voltmeter.



A voltmeter connected to a circuit with a cell or battery, a lamp, and a switch.



Using a multimeter to measure voltage.

Glossary

Absorbed What happens energy of electromagnetic radiation (e.g. light) or sound is transferred to a thermal store on passing through or into a medium.

Accelerating Speeding up, getting faster.

Acceleration The rate of change of increasing speed (the amount by which speed increases in one second).

Accuracy (of a measurement) How correct a measurement is – how close it is to its true value.

Air resistance The force on an object that is moving through the air, causing it to slow down (also known as drag).

Alloy A material made of a mixture of metals, or of carbon with a metal.

Ammeter A device for measuring electric current in a circuit.

Ampère (amp) The unit of measurement of electric current, symbol A.

Amplifier A device for making a sound louder.

Amplitude The distance from the middle to the top or bottom of a wave.

Analogy A way of explaining something by saying that it is like something else.

Andromeda The nearest galaxy to the Milky Way.

Angle of incidence The angle between the incident ray and the normal line.

Angle of reflection The angle between the reflected ray and the normal line.

Angle of refraction The angle between the refracted ray and the normal line.

Anomalous result A point on a graph that does not fit the general pattern (also called an outlier).

Anticlockwise The direction of rotation that is opposite to the movement of the hands of a clock.

Apparent depth How deep something underwater appears to be when viewed from above.

Area The size of a surface.

Archimedes' principle A law that states that the upthrust on an object

in a fluid is equal to the weight of fluid displaced.

Armature The coil of wire in an electromagnetic device such as a generator.

Artificial satellites Spacecraft made by people to orbit the Earth for various purposes.

Asteroid An irregularly shaped lump of rock in orbit around the Sun.

Asteroid belt A large number of asteroids between Mars and Jupiter.

Astronomer A scientist who studies space.

Atmosphere The layer of air above Earth's surface.

Atmospheric pressure The force on an area of the Earth's surface due to the weight of air above it, or the pressure in the atmosphere.

Atom The smallest particle of an element that can exist.

Attract Pull together, for example opposite poles of a magnet or positive and negative charges attract each other.

Audible Able to be heard.

Audible range The range of frequencies that can be heard.

Auditory canal The passage from the outer ear to the eardrum.

Auditory nerve Signals are sent from your ear to the brain along this nerve.

Aurora A display of lights in the sky due to the interaction of the solar wind with the magnetic field of a planet.

Average Found by adding a set of values together and dividing by the number of values (also called the mean).

Average speed The total distance travelled divided by the total time taken for a complete journey.

Average speed (molecules) The typical value of the speed of molecules in a gas or liquid.

Axis, of Earth The imaginary line through the Earth around which it spins.

Balanced Describes forces that are the same size but act in opposite directions on an object.

Bar chart A way of presenting data in which one of the variables is categoric (words).

Battery Two or more electrical cells joined together.

Big Bang The expansion of space which we believe started the Universe.

Biodegradable Able to be broken down by bacteria or other living organisms.

Biodiesel A biofuel made from plant oils.

Bioethanol A biofuel made from carbohydrates such as sugar.

Biofuel A fuel produced from renewable resources.

Biogas Gas produced from waste products, usually methane, used to generate electricity.

Biomass Material from plants used for fuel, e.g. wood.

Bioplastics Plastics made from starch.

Black dwarf A remnant of a star like our Sun that no longer gives out light.

Black hole A remnant of a star much bigger than our Sun from which nothing can escape, not even light.

Capture theory A theory that says that the Moon is an object that was formed outside the Solar System and captured by the Earth's gravity.

Categoric Describes a variable whose values are words not numbers.

Cell (electrical) A device that uses a chemical reaction to produce a voltage/potential difference.

Centre of mass (or centre of gravity) The point in an object where the mass appears to be concentrated or weight acts.

Centripetal force The force directed towards the centre that causes a body to move in a uniform circular path.

Charge This can be positive or negative. It is a property of protons and electrons.

Chemical store The store associated with the energy in fuels, food, and electrical batteries.

Circuit (electric) A complete pathway for an electric current to flow.

Circuit diagram A way of showing a circuit clearly, using symbols.

Circuit symbol A drawing that represents a component in a circuit.

Climate change Changes to long-term weather patterns as a result of global warming.

Clockwise The direction of rotation that is the same as the movement of the hands of a clock.

Coal A fossil fuel formed from dead plants that have been buried underground over millions of years.

Coal-fired power station A place where the fossil fuel coal is burned to generate electricity.

Cobalt A metallic element that is magnetic.

Cochlea A snail-shaped tube in the inner ear where the sensory cells that detect sound are.

Co-formation theory A theory that says that the Moon formed in the same way and at the same time as the Earth.

Colour blindness Someone with colour blindness cannot tell certain colours apart, because some cone cells in the retina of the eye do not work properly.

Comets Bodies in space made of dust particles frozen in ice, which orbit the Sun.

Communicate To share and exchange information.

Compact disc A metal disc that can store high-quality digital recordings.

Compass A device containing a small magnet that is used for finding directions.

Component An item used in an electric circuit, such as a lamp.

Compressed Squashed into a smaller space, or deformed by making smaller.

Compression (in a sound wave) The part of a sound wave where the air particles are close together.

Conclusion A statement about what the results of an investigation tell you.

Conduction (of energy) The way in which energy is transferred through solids (and, to a much lesser extent, liquids and gases).

Conductor A material such as a metal or graphite that conducts charge or energy well.

Cone A specialised cell in the retina that is sensitive to bright light and colour.

Consequence (risk) What can happen as a result of something you do.

Conservation (of energy) A law that says that energy is never created or destroyed but is is always transferred from one store to another.

Constant Not changing.

Constructive interference The effect of adding waves that are in step to produce a larger amplitude wave.

Contact force A force that acts when an object is in contact with a surface, air, or water.

Continuous Describes a variable that can have any value across a range, such as time, temperature, length.

Convection The transfer of energy by the movement of a gas or liquid.

Convection current The way in which energy is transferred through liquids and gases by the movement of their particles.

Core A rod of a magnetic material placed inside a solenoid to make the magnetic field of an electromagnet stronger.

Cornea The transparent layer at the front of the eye.

Correlation A link between two things; it does not necessarily mean that one thing causes the other.

Craters Holes in the ground caused when meteors or asteroids hit the Earth.

Creative thinking Thinking in a new way.

Crescent moon The shape that we see when a thin section of the Moon is lit, a few days after a new moon.

Critical angle The smallest angle of incidence at which total internal reflection occurs.

Current The flow of electric charge (electrons) around a complete circuit.

Data Measurements taken from an investigation or experiment.

Day The period of time when one section of the Earth (or other planet) is facing the Sun.

Decelerating Slowing down, getting slower.

Deceleration The amount by which speed decreases in one second.

Decibel (dB) A commonly used unit of sound intensity or loudness.

Deform To change shape.

Degrees Celsius (°C) A temperature scale with 0 °C fixed at the melting point of ice and 100 °C fixed at the boiling point of water.

Demagnetise To destroy a magnet by heating it up, hitting it, or putting it in an alternating current.

Density The mass of a substance in a certain volume.

Dependent variable The variable that changes when you change the independent variable.

Destructive interference The effect of adding waves that are out of step to produce a smaller amplitude wave.

Detector Something that absorbs electromagnetic radiation or sound to produce a signal.

Diffuse Describes reflection from a rough surface.

Diffusion The movement of particles in gases and liquids from where there are a lot of the particles to where there are fewer.

Directly proportional A relationship in which one quantity increases in the same way as another.

Discrete Describes a variable that can only have whole-number values.

Dispersion The splitting up of a ray of light of mixed wavelengths by refraction into its components.

Dissipated When transferred energy is not useful/is wasted.

Distance multiplier A type of lever that uses a larger force to produce a smaller force at a larger distance.

Distance-time graph A graph showing how the distance travelled varies with time.

Domain A small region inside a magnetic material that behaves like a tiny magnet.

Drag A force on an object moving through air or water, causing it to slow down.

Dwarf planet A lump of rock in orbit around the Sun that is nearly spherical but has other objects around it.

Dynamo A device that produces a potential difference when it spins (a small generator).

Ear The organ of the human body that detects sound.

Ear defenders A device used to protect the ears from noise.

Eardrum A membrane that transmits sound vibrations from the outer ear to the middle ear.

Earth A rocky inner planet, the third planet from the Sun.

Earth (charge) To connect a metal wire from an object to the ground to take any charge away.

Earthing The process of connecting objects to the ground.

Echo A reflection of a sound wave by an object.

Echolocation The process of finding out the position of something using echoes.

Eclipse The Sun or Moon is blocked from view on Earth (see also lunar eclipse or solar eclipse).

Efficient Describes something that does not waste much energy.

Effort The amount of force that you use to push down when using a lever.

Elastic Describes a type of material that can be stretched and will return to its original length when the pulling force is removed.

Elastic limit The point beyond which a spring will never return to its original length when the pulling force is removed.

Elastic potential energy (EPE) Energy stored in an elastic object that is stretched or squashed.

Elastic store The energy store associated with objects that are deformed

Electric car A car powered by electric batteries.

Electric circuit A complete pathway for an electric current to flow.

Electric current A flow of electric charge (electrons) around a complete circuit.

Electric field A region around a charged object where other charged objects feel a force.

Electrical signal (ear) Information is transferred from the ear to the brain as an electrical signal (nerve signal).

Electromagnet A temporary magnet produced using an electric current.

Electromagnetic spectrum A range of radiation with electrical and magnetic properties that can travel through a vacuum (for example, the Sun's radiation). It also refers to the range of wavelengths of electromagnetic radiation produced by the Sun and other sources.

Electron A tiny sub-atomic particle with a negative charge that flows through a wire to create an electric current.

Electrostatic attraction The force between two particles of objects that have opposite charge

Electrostatic force The force between two charged objects.

Electrostatic phenomena Things that happen because objects have become charged.

Electrostatic repulsion The force between two particles of objects that have the same charge

Element A substance that is made of one type of atom that cannot be split into other substances.

Emit To send something out (such as heat, light, vapour).

Endoscope A medical instrument for seeing inside the human body.

Energy A quantity that can be stored or transferred; a way of calculating which processes are possible.

Energy conservation Energy is never made or lost but can be transferred...

Energy store An object of collection of objects about which a quantity of energy can be calculated

Energy transfer Energy can be transferred by forces, electricity, heating, or waves.

Energy transfer diagram A diagram that shows how energy is transferred or changed in a process or device.

Equator An imaginary line round the middle of the Earth at an equal distance from both the North and South Poles.

Equilibrium Balanced (as in a lever or see-saw).

Evaporate To turn from a liquid to a vapour (gas).

Evaporation The change of state from liquid to gas that can happen at any temperature.

Evaporative coolers Equipment used in hot countries that uses the cooling effect of evaporation to cool houses.

Evidence Observations and measurements that support or disprove a scientific theory.

Exoplanet A planet in orbit around a star other than our Sun.

Expand To increase in size, get bigger.

Explanation A statement that gives a reason for something using scientific knowledge.

Extension The distance by which an object gets longer when you stretch it.

Eye The organ of sight, which focuses and detects light.

Fair test A controlled investigation in which only one variable at a time is changed, while all other conditions are kept the same.

Field study An experiment or observations made in the natural habitat of an organism.

Filament The very thin, coiled piece of wire that glows inside a light bulb.

Filter A piece of material that allows some radiation (colours) through but absorbs the rest.

First quarter/third quarter The shape that we see when about half the Moon is lit, about a week before or after a new moon.

Floating An object floats when the upthrust from the water is equal to the downwards force of the object's weight.

Force A push or a pull that acts on an object to affect its movement or shape.

Force multiplier A lever or hydraulic machine that can lift or move heavy weights using a force smaller than the weight.

Forcemeter A device used to measure forces; also called a newtonmeter or spring balance

Fossil fuel Fuel made from the decayed remains of animals and plants that died millions of years ago. Fossil fuels include coal, oil, and natural gas.

Frequency The number of complete

waves or vibrations produced in one second (measured in hertz).

Friction A force that resists movement because of contact between surfaces.

Fuel A material that contains a store of energy and can be burned, e.g. gas, oil, coal, petrol (gas or gasoline).

Fulcrum The point about which a lever or see-saw turns, also called the pivot.

Full moon The shape that we see when the whole disc is lit, when the Moon is opposite the Sun.

Fundamental (sound) The lowest frequency of sound produced by an instrument or object.

Galaxy A number of stars and the solar systems around them grouped together.

Gas (natural) A fossil fuel that collects above oil deposits underground.

Gas pressure (air pressure) The force exerted by air particles when they collide with 1 square metre (1 m²) of a surface.

Gemstone A stone made from minerals that can be cut and used in jewellery.

Generator A device that produces a voltage.

Geocentric model A model of the Universe with the Earth at the centre.

Geothermal An energy source that uses water heated to steam underground to produce electricity.

Giant impact hypothesis A hypothesis that suggests that the Moon formed from an object produced by a collision between a very young Earth and a Marssized planet.

Gibbous moon The shape that we see when most of the Moon is lit, a few days after a full moon.

Global positioning system (GPS) A system that pinpoints the position of something using signals from a satellite.

Gradient The slope or steepness of a graph.

Gravitational field A region in which there is a force on a mass due to its attraction to another mass.

Gravitational field strength The force on a mass of 1 kg, measured in N/kg.

Gravitational potential energy (GPE) Energy stored in an object because of its height above the ground. **Gravity** (**gravitational force**) The force of attraction between two objects because of their mass.

Gravity store The energy store associated with moving objects away from the Earth.

Greenhouse effect The effect of heating the Earth because the energy from the Sun is reflected back to the Earth from a layer of greenhouse gases in the atmosphere.

Greenhouse gases Gases that reflect energy back to the surface of the Earth, warming it and maintaining a temperature suitable for life, such as carbon dioxide, water vapour, and methane.

Hazard symbol A warning symbol on a substance that shows what harm it might cause if not handled properly.

Heating The energy transfer process that involves changing the temperature or state of a material.

Heat pump A device that transfers heat from the ground to a building on the surface.

Heliocentric (model) A model of the Universe with the Sun at the centre.

Hertz (Hz) The unit of frequency.

Hooke's law A law that says that the extension is proportion to the force applied up to the elastic limit.

Hydroelectricity Electricity generated using water falling downhill to turn generators.

Hypothesis A scientific theory or proposed explanation made on the basis of evidence which can be further tested.

Image The point from which rays of light entering the eye appear to have originated.

Impact winter The period of cold weather that scientist think would follow an impact by a very large asteroid or meteor.

Incident ray The ray coming from a source of light.

Incompressible Describes something that cannot be compressed (squashed).

Independent variable The variable that you change, that causes changes in the dependent variable.

Induced (voltage) A voltage produced when a conductor is in a changing magnetic field.

Inertia The tendency of an object to resist a change in speed caused by a force.

Infinite Without end.

Infrared (radiation) A type of electromagnetic radiation that transfers energy from a hotter to a colder place, which can be known as heat.

Inner ear The part of the ear made up of the cochlea and semi-circular canals.

Inner planets Mercury, Venus, Earth, and Mars.

instantaneous speed Speed at a particular moment.

Insulator A material that does not conduct energy or electricity very well.

Intensity (sound) How loud a sound is, measured in decibels.

Interference (of waves) The effect of combining two or more waves.

International Space Station (ISS) A research station in orbit around the Earth.

Interstellar space The space between stars or solar systems.

Inversely proportionalA relationship in which one quantity decreases as the other increases.

Inverted Upside down.

Investigation An activity such as an experiment or set of experiments designed to produce data to answer a scientific question or test a theory.

Ions Atoms that have gained or lost electrons.

Iris The coloured part of your eye that controls the size of the pupil.

Iron A metallic element that is the main substance in steel. Iron is a magnetic material.

Joule The unit of energy, symbol J.

Jupiter A large outer planet made of gas, the fifth from the Sun.

Kilogram The unit of mass, symbol kg. **Kilojoule (kJ)** 1000 joules.

Kilometres per hour The unit of speed, km/h.

Kilowatt 1000 watts.

Kinetic energy Energy associated with moving objects.

Kinetic store The energy store associated with moving objects.

Kuiper belt The region outside the Solar System where astronomers think that some comets come from.

Last quarter The shape that we see when about half the Moon is lit, about a week after a full moon.

Laterally inverted The type of reversal that occurs with an image formed by a plane mirror.

Law of conservation of energy The law that says that energy cannot be created or destroyed but can be transferred.

Law of reflection The law that says that the angle of incidence is equal to the angle of reflection.

Lens A device made of shaped glass which focuses light rays from objects to form an image.

Lever A simple machine consisting of a rigid bar supported at a point along its length.

Life cycle (of a star) The process that describes how a star is formed and what will happen to it.

Light A form of electromagnetic radiation that comes from sources like the Sun, and transfers energy.

Light source An object that emits visible light, also called a luminous object.

Light year The distance light travels in one year.

Light-emitting diode (LED) A low-energy lamp.

Lightning conductor A piece of metal connected to tall buildings to conduct lightning to the ground.

Line graph A way of presenting results when there are two numerical variables.

Line of best fit A smooth line on a graph that travels through or very close to as many of the points plotted as possible.

Liquid pressure The pressure produced by collisions of particles in a liquid.

Load An external force that acts over a region of length, surface, or area.

Lodestone A naturally occurring magnetic rock.

Longitudinal Describes a wave in which the vibrations are in the same direction as the direction in which the wave moves.

Loudspeaker A device that changes an electrical signal into a sound wave.

Lubrication Reducing friction between surfaces when they rub together.

Luminous Describes something that gives out light.

Lunar eclipse Occurs when the light from the Sun is blocked by the Earth because it is in a direct line between the Earth and the Sun, and the Moon is in shadow.

Magnet An object that attracts magnetic materials and repels other magnets.

Magnetic field An area around a magnet where there is a force on a magnetic material or another magnet.

Magnetic field lines Imaginary lines that show the direction of the force on a magnetic material in the magnetic field.

Magnetic force The force between the poles of two magnets, or between a magnet and a magnetic material such as iron.

Magnetic material A material that is attracted to a magnet, such as iron, steel, nickel, or cobalt.

Magnetic resonance imaging (MRI) scanner A machine that uses strong magnetic fields to produce images of the inside of the human body.

Magnetised Made into a magnet.

Magnetism The property of attracting or repelling magnets or magnetic materials.

Main sequence star The longest stage of a star's life cycle; the current stage of our Sun.

Mains supply Electricity generated in power stations and available through power sockets in buildings.

Mars A rocky planet, the fourth from the Sun.

Mass The amount of matter in an object. The mass affects the acceleration for a particular force.

Mass extinction event An event that causes the extinction of a large number of species over a relatively short (geological) timescale.

Massive (star) Having lots of mass (massive does not mean large).

Matter The scientific word for materials or objects which can be solid, liquid or gas

Measuring cylinder A cylinder used to measure the volume of a liquid.

Medium (sound/light) The material that affects light or sound by slowing it down or transferring the wave.

Meniscus The curved upper surface of a liquid.

Mercury The rocky inner planet nearest the Sun.

Meteor A piece of rock or dust that makes a streak of light in the night sky.

Meteorite A stony or metallic object that has fallen to Earth from outer space without burning up.

Metres per second The unit of speed, m/s.

Microphone A device for converting sound into an electrical signal.

Middle ear The eardrum and ossicles (small bones) that transfer vibrations from the outer ear to the inner ear.

Milky Way The galaxy containing our Sun and Solar System.

Milliamp One thousandth of an amp.

Minerals Chemicals in rocks.

Model A way of representing something that you cannot see or experience directly. A model may be a physical model built on a different scale to the original system, or it may take the form of equations.

Moment A measure of the ability of a force to rotate an object about a pivot.

Moon A rocky body orbiting Earth; it is Earth's only natural satellite.

Moons The natural satellites of planets.

Natural satellite A moon in orbit around a planet.

Neap tide The lower tide that occurs when the Moon is not aligned at all with the Sun.

Nebula A region of dust and gas where stars are born.

Negative charge Describes the charge on an electron, or the charge on an object that has had electrons transferred to it.

Negatively charged Describes an object that has had electrons transferred to it.

Neptune A large outer planet made of gas, eighth from the Sun.

Neutral Describes an object that has no charge; its positive and negative charges cancel out.

Neutral point (magnetic field) A point where there is no force on a magnet or magnetic material because two or more magnetic fields cancel out.

Neutralise To cancel out, when you add an equal amount of positive charge to negative charge.

Neutron A tiny sub-atomic particle with no charge that is found in the nucleus of an atom. The relative mass of a neutron is 1.

Neutron star A very small, massive star.

New moon The shape that we see when the Moon is in between the Earth and the Sun.

Newton the unit of force including weight, symbol N.

Newton's first law of motion A law that says that a resultant force is needed to change the motion of an object.

Newtonmeter A meter that is used to measure the magnitude of a force; also called a forcemeter or spring balance

Newtonmetre the unit of moment, symbol Nm.

Nickel A metal that is magnetic.

Night The period on one section of the Earth or other planet when it is facing away from the Sun.

Noise Any undesired or unwanted sound.

Non-contact force A magnetic, electrostatic, or gravitational force that acts without being in contact with something.

Non-luminous Describes objects that produce no light; objects that are seen by reflected light.

Non-renewable Describes energy sources that will run out eventually (such as fossil fuels).

Normal An imaginary line at right angles to a surface where a light ray strikes it.

Normal (force) The force from a solid object that pushes at 90° to the surface.

North pole The pole of a magnet that points north. A north pole repels another north pole.

Northern hemisphere The half of the Earth between the Equator and the North Pole.

Nuclear fission The process of splitting atoms that releases energy in a nuclear power station

Nuclear fusion The process of joining hydrogen together in the Sun and other stars that releases energy.

Nuclear store The energy store associated with the process of nuclear fusion.

Nucleus The central part of an atom, made up of protons and neutrons.

Object Something that can be seen or touched.

Observations The results of looking carefully at something and noticing properties or changes.

Oil (or crude oil) A thick black liquid formed underground from the remains of prehistoric plants and animals that died millions of years ago. It is used to make fuels such as petrol/gasoline and diesel, and many plastics.

Oort cloud A cloud of comets and dust outside the Solar System.

Opaque Describes objects that absorb, scatter, or reflect light and do not allow any light to pass through.

Optic nerve A sensory nerve that runs from the eye to the brain.

Optical fibre A very fine tube of plastic or glass that uses total internal reflection to transmit light.

Orbit The path taken by one body in space around another (such as the Earth around the Sun).

Oscilloscope A device that enables you to see electrical signals that change, such as those made in a microphone.

Ossicles The small bones of the middle ear (hammer, anvil, and stirrup) that transfer vibrations from the eardrum to the oval window.

Outer ear The pinna and auditory canal.

Outer planets Jupiter, Saturn, Uranus, and Neptune.

Oval window The membrane that connects the ossicles to the cochlea in the ear.

Oxide A compound made when an element combines with oxygen.

Parallel circuit An electric circuit in which there are two or more paths for an electric current.

Partial eclipse Occurs when part of the light from the Sun is blocked by the Moon or the Earth.

Particles The tiny pieces of matter that everything is made from.

Pascal The unit of pressure, symbol Pa, equal to 1 N/m².

Pendulum Any rigid body that swings about a fixed point

Penumbra The area of blurred or fuzzy shadow around the edges of the umbra.

Period The time taken to complete one cycle of motion.

Periscope A tube with mirrors or prisms that enables you to see over objects.

Permanent magnet A piece of metal that stays magnetic.

Permanently extended The irreversible extension of a spring when loaded beyond its elastic limit.

Petrol (gas or gasoline) A hydrocarbon fuel (containing hydrogen and carbon) that comes from crude oil.

Phases of the Moon Parts of the Moon that we see as it orbits the Earth.

Photosynthesis The process by which plants make their own food from carbon dioxide and water, using light.

Pie chart A way of presenting data in which only one variable is a number.

Pinna The outside part of the ear that we can see.

Pitch A property of sound determined by its frequency.

Pivot A support on which a lever turns or oscillates.

Plane mirror A mirror with a flat reflective surface.

Planet Any large body that orbits a star in a solar system.

Planetary nebula A cloud of dust and gas from which planets are formed.

Plastic A type of material that can be stretched and does not return to its original length.

Pluto Used to be regarded as the ninth and last planet from the Sun; now called a dwarf planet together with others of the same size that are beyond Pluto's orbit.

Pole, of Earth The north and south points of the Earth connected by its axis of tilt.

Poles, of magnet The opposite and most strongly attractive parts of a magnet.

Positive charge Describes the charge on a proton, or the charge on an object that has had electrons transferred away from it.

Potential difference Also known as voltage, a measure of the energy that each charge transfers.

Potential energy Stored energy as a result of a object's change of position or change of shape.

Power The rate of transfer of energy, measured in watts.

Power station A place where fuel is burned to produce electricity.

Precision The number of decimal places given for a measurement.

Prediction A statement saying what you think will happen.

Preliminary work The work that you do before or during the planning stage of an investigation, to work out how to do it.

Pressure The force applied by an object or fluid divided by the area of surface over which it acts.

Pressure gauge An instrument for measuring pressure in a liquid or gas.

Primary colours For light these are red, blue, and green.

Primary data Data collected directly by scientists during a particular investigation.

Primary source Sources of data that you have collected yourself.

Primary sources (of energy) Energy sources from the environment or underground, such as coal, uranium, or the wind.

Principle of moments The law that says that the sum of the clockwise moments is equal to the sum of the

anticlockwise moments about a fixed point.

Prism A triangular-shaped piece of glass used to produce a spectrum of light.

Probability (risk) The chance that something will happen.

Proportional A relationship in which two variables increase at the same rate, for example when one is doubled the other doubles too.

Proton A tiny sub-atomic particle with a positive charge that is found in the nucleus of an atom. The relative mass of a proton is 1.

Proxima Centauri The nearest star to our Sun.

Pupil The hole in the front of your eye where the light goes in.

Question In science, a problem that is stated in a form that you can investigate.

Rainbow An optical phenomenon that appears as the colours of the spectrum when falling water droplets are illuminated by sunlight.

Rarefaction The part of a sound wave where the air particles are most spread out.

Ray diagram A model of what happens to light, shown by drawing selecting rays.

Reaction The force from a solid object that pushes at 90° to the surface.

Reaction time In humans, the time the brain takes to process information and act in response to it.

Real Describes an image that you can put on a screen, or the image formed in your eyes.

Real depth The depth underwater that an object actually is.

Receiver (sonar) A device that absorbs sound waves.

Red giant Part of the life cycle of a star like our Sun when it becomes much bigger and cooler.

Red supergiant The next stage in the life cycle of our Sun.

Reed switch A switch that uses a magnet to work.

Refinery A place where crude oil is refined and separated into fuels.

Reflects When a surface causes light or sound to it bounce off it, it reflects it.

Reflected ray The ray that is reflected from a surface.

Reflection The change in direction of a light ray or sound wave after it hits a surface and bounces off.

Refraction The change in direction of a light ray as a result of its change in speed.

Refractive index A measure of how much light slows down when it goes from one medium to another.

Refrigerant A liquid used in a refrigerator.

Refrigerator a machine for keeping things cold using evaporation.

Relay An electrical device that allows current flowing through it in one circuit to switch on and off a larger current in a second circuit.

Reliable Describes an investigation in which very similar data would be collected if it was repeated under the same conditions.

Renewable Describes energy resources that are constantly being replaced and are not used up, such as falling water or wind power.

Repel To push away.

Reservoir A large amount of water behind a dam; it is used in hydroelectric power.

Resistance How difficult it is for current to flow through a component in a circuit.

Resultant force The single force equivalent to two or more forces acting on an object.

Retina The layer of light-sensitive cells at the back of the eye.

Retrograde motion The apparent 'backwards' motion of planets due to the motion of the Earth and the planet around the Sun.

Reverberation The persistence of a sound for a longer period than normal.

Risk The chance of injury from a hazard. A combination of the probability that something will happen and the consequence if it did.

Risk assessment A statement of what could cause injury or damage, and the action to be taken to reduce the probability that it will happen.

Rod A specialised cell in the retina that is sensitive to bright light.

Satellite Any body that orbits another (such as the Moon or a weather satellite around Earth).

Saturn A large outer planet made of gas, the sixth from the Sun.

Scatter graph A graph that shows all the values in a set of measurements.

Seasons Changes in the climate during the year as the Earth moves around its orbit.

Secondary colours Colours that can be obtained by mixing two primary colours.

Secondary data Data collected by other scientists and published.

Secondary source Sources of data collected by others that you use.

Secondary sources (of energy)
Sources of energy that are produced from primary sources, such as electricity produced from coal, or petrol/gasoline produced from crude oil.

Semicircular canals The part of the ear that helps you to balance.

Series circuit An electrical circuit in which the components are joined in a single loop.

Shadow An area of darkness on a surface produced when an opaque object blocks out light.

Shielding Putting something in between a source and a receiver, for example, sound is shielded by ear defenders.

Signal (electrical) A current or voltage that changes over time.

Significant figures The number of digits in a decimal number.

Solar cells Devices that use light to produce a voltage

Solar eclipse Occurs when the Moon blocks out the light from the Sun because it is in a direct line between the Earth and the Sun, and part of the Earth is in shadow.

Solar energy Energy from the Sun which can be used directly to heat water or to make electricity.

Solar panels Devices that use light and infrared radiation to heat water.

Solar System The Sun (our star) and the planets and other bodies in orbit around it. There are other solar systems in the Universe as well as our own.

Solar wind The continuous flow of charged particles from the Sun.

Solenoid A core of wire used to make an electromagnet.

Sonar A system that uses ultrasound to detect underwater objects or to determine the depth of the water.

Sound Vibrations of molecules produced by vibrating objects and detected by your ear that transfers energy.

Sound-level meter A device for measuring the intensity (loudness) of a sound.

Sound wave A series of compressions and rarefactions that moves through a medium.

Source (of light/sound) Something that emits (gives out) light or sound.

South pole The pole of a magnet that points south. A south pole attracts a north pole.

Southern hemisphere The half of the Earth between the Equator and the South Pole.

Spark A flash of light that you see when the air conducts electricity.

Spectrum A band of colours produced when light is spread out by a prism.

Speed The distance travelled in a given time, usually measured in metres per second, m/s.

Speed of light The distance light travels in one second (300 million m/s).

Speed-time graph A graph that shows how the speed of an object varies with time.

Spring A metal wire wound into spirals that can store elastic potential energy.

Spring balance A device for measuring forces; sometimes called a forcemeter or a newtonmeter.

Spring tide The higher tide that occurs when the Earth, Moon and Sun are aligned.

Stable Describes an object in equilibrium that cannot easily be toppled.

Star A body in space that gives out its own light. The Sun is a star.

Static (charge) Charge on an insulator that does not move.

Steady speed A speed that doesn't change.

Steel An alloy of iron with carbon and other elements. Steel is a magnetic material.

Stellar nurseries Regions of interstellar space containing dust and gas where stars form.

Streamlining Designing the shape of an object so as to reduce resistance to motion from the air or a liquid.

Stretch The extension when an elastic material such as a spring is pulled outwards or downwards.

Sun The star at the centre of our Solar System.

Sunlight Light from the Sun.

Sunspots Dark spots on the surface of the Sun.

Supernova An exploding star.

Supersonic Describes a speed that is faster than the speed of sound.

Symbol A sign that represents something (see also circuit symbols, and hazard symbols).

Tangent A straight line that touches a curve or circle.

Telescope A device made with lenses that allows distant objects to be seen clearly.

Temperature A measure of how hot something is, which is related to the average speed of the particles.

Tension A stretching force.

Terminal (of a cell) The positive or negative end of a cell or battery.

Terminal velocity The highest velocity an object reaches when moving through a gas or a liquid; it happens when the drag force equals the forward or gravitational force.

Thermal A rising current of heated air.

Thermal store The energy associated with objects or systems when there is a change in temperature.

Thermal equilibrium The state of two objects at the same temperature.

Thermal image An image made using thermal or infrared radiation.

Thermal imaging camera A device that forms an image using thermal or infrared radiation so that different temperatures appear as different colours.

Thermometer A device used to measure temperature.

Thought experiment The process of thinking through what might happen in an experiment without actually doing it.

Thrust The force from an engine or rocket.

Tidal energy/power Energy from the movement of water in tides which can be used to generate electricity.

Total eclipse Occurs when all of the light from the Sun is blocked out by the Earth or the Moon.

Total internal reflection The complete reflection of light at a boundary between two media.

Transducer A device that changes an electrical signal into light or sound, or changes light or sound into an electrical signal.

Transfer (of energy) Shifting energy from one place to another.

Translucent Describes objects that transmit light but diffuse (scatter) the light as it passes through.

Transmitted Light or other radiation passed through an object.

Transmitter A device that gives out a signal, such as sound in a sonar transmitter.

Transparent describes objects that transmit light; you can see through transparent objects.

Transverse Describes a wave in which the vibrations are at right angles to the direction in which the wave moves.

Turbine A component that spins due to steam, water or wind, and which is used to turn a generator.

Turning effect A force causing an object to turn.

Turning force The moment of a force.

Ultrasound Sound at a frequency greater than 20 000 Hz, beyond the range of human hearing.

Umbra The area of total shadow behind an opaque object where no light has reached.

Unbalanced Describes forces on an object that are unequal.

Universe Everything that exists.

Upright Describes an image that is the right way up.

Upthrust The force on an object in a liquid or gas that pushes it up.

Uranium A metal used in nuclear power stations.

Uranus A large outer planet made of gas, the seventh from the Sun.

Useful energy The energy that you want from a process.

Vacuum A space that has no particles, and so no matter.

Vaporized (meteor) What can happen to a meteor or asteroid on collision, when solid material is turned into dust.

Variable A quantity that can change, such as time, temperature, length, or mass. In an investigation you should change only one variable at a time to see what effect it has.

Venus A rocky inner planet, the second from the Sun.

Vibrate To move continuously and rapidly to and fro.

Vibration Motion to and fro of the parts of a liquid or solid.

Virtual Describes an image that cannot be focused onto a screen.

Volt The unit of measurement of voltage, symbol V.

Voltage A measure of the strength of a cell or battery used to send a current around a circuit; it is measured in volts.

Voltmeter A device for measuring voltage.

Volume (of space) The amount of space that something takes up, which is related to its mass by its density.

Waning Describes the Moon that we see when the amount of the lit side is decreasing.

Wasted energy Energy transferred to non-useful forms; often energy transferred to the surroundings.

Water (energy from) Using water to generate electricity from tides, water behind dams and waves.

Water resistance The force on an object moving through water that causes it to slow down (also known as drag).

Watts The unit of power, symbol W.

Wave A variation that transfers energy or information.

Wave energy/power Using energy from waves to generate electricity.

Wavelength The distance between two identical points on the wave, such as two adjacent peaks or two adjacent troughs.

Waxing Describes the Moon that we see when the amount of the lit side is increasing.

Weight The force of the Earth on an object due to its mass.

White dwarf A small, very dense star; part of the life cycle of our Sun.

Wind energy/power Energy from wind that can be used to generate electricity.

Wind farm A collection of wind turbines.

Wind turbine A turbine and generator that uses the energy of the wind to generate electricity.

Year The length of time it takes for a planet to orbit the Sun.

Acknowledgements

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Author's acknowledgments

I would like to thank my editors for their support and feedback, and my wonderful friends Michele, Rob, Lesa, and Bill for all their support, long walks and tea. I would also like to thank Oleksiy, my dance instructor, for providing continuing encouragement for my writing and for my foxtrot.

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