PHYSICS

Energy Transfers and Sound

Ideas you have met before

Gravity

Gravity is a force that pulls objects towards the Earth. When they fall, they speed up – think of a bungee jumper, freewheeling on a bike down a hill or riding on a roller coaster.

Sound and vibrations

Sounds are only possible when a vibration occurs. Banging on a drum or plucking a guitar produces vibrations that cause a sound to be made.

Sound and volume

We can change the vibrations of a sound by giving them more energy. The stronger the vibrations, the louder the sound. When you pluck a guitar string lightly, a soft sound is made. Pluck it very hard and a much louder sound can be heard.

Sound and pitch

Some sounds we hear have a high pitch, like a whistle or a siren. Some have a low pitch, like the rumble of thunder. When we change the pitch, we change how rapidly an object vibrates.

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6.1

In this chapter you will find out

Energy

- Energy makes things happen.
- Energy can be stored in something that is high up, as gravitational potential energy. This is transferred as movement energy when the object moves downwards.
- Energy can be transferred in many different ways. Useful energy transfers make life easier.

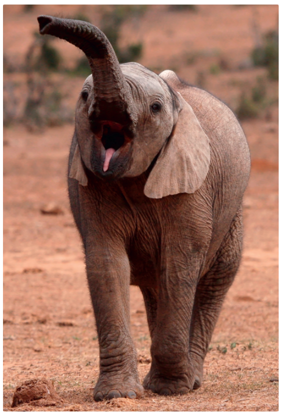
Useful and useless energy transfers

- Energy can be transferred by different processes. Some transfers result in useful changes, such as using an energy-efficient light bulb.
- In other situations useless energy transfers occur, for example the noise from a hairdryer.

Transferring more energy

- Fuels are special chemicals that release a lot of heat energy by burning.
- Different fuels store and transfer different amounts of energy.

Energy is carried by sound



- Sound energy is transmitted by waves (vibrations) being passed on by air particles.
- Echoes occur when sound waves are reflected by hard materials.
- The ear is designed to capture sound waves.
- Many animals communicate with sounds that we cannot hear. We have found useful applications for ‘ultrasound’ and ‘infrasound’.

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Exploring energy transfers

We are learning how to:

- Recognise what energy is and its unit.
- Describe a range of energy transfers using simple diagrams.
- Use a Sankey diagram as a model to represent simple energy changes.

The Sun is our main source of energy. Plants convert this energy by chemical processes to make food. Solar panels transfer the Sun's energy by electric current to provide electricity for our use. By transferring energy from the Sun, useful energy can be provided for our planet.

FIGURE 1.6.2a: Where has the energy to light this bulb come from?

What is energy?

When energy is transferred, useful things can happen. When a log is burned, energy is transferred by chemical reactions to the surroundings by light and heat. Switching on a light bulb transfers energy by electric current to the bulb. Energy is then transferred from the bulb to the surroundings by light and heat.

Energy is never lost or made, it is just transferred by different processes to different places. We measure it in a unit called a **joule** (J).

1. Look at the photos on this page. In which of them is energy being transferred?

2. a) What is happening as a result of the energy transfer you can see in Figure 1.6.2b?

b) What is happening in the other photo in Figure 1.6.2b? Why is it not possible for energy to be transferred here?

FIGURE 1.6.2b: Describe the differences, in terms of energy transfer.

Energy transfers

It is useful to track the processes by which the energy is transferred. This can be done using a simple **energy transfer diagram** (see Figure 1.6.2c). When you switch on a light bulb, you want to transfer energy by light. However, the light bulb also gets hot. Transferring energy by heat is not a useful change in this instance. Energy-efficient light bulbs have been designed to transfer more energy by light and less by heat.

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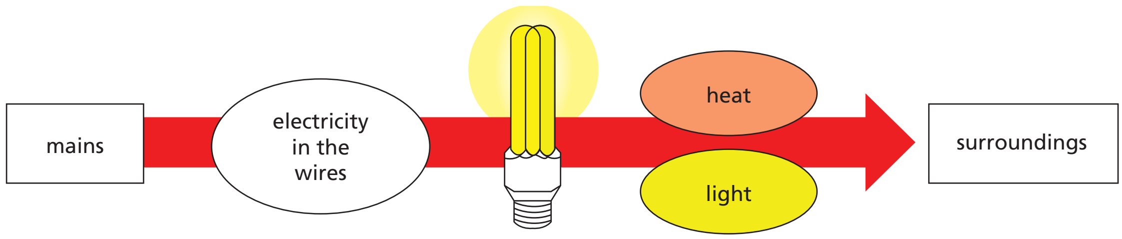

FIGURE 1.6.2c: Simple energy transfer diagram for a light bulb

3. Write a sentence to describe the energy transfers shown in Figure 1.6.2c.
4. Draw a diagram to show how energy is transferred by:
   a) a boiling kettle **b)** a toaster **c)** a log fire
5. In your answers to question 4, underline the useful energy transfers and circle the unwanted energy transfers.

Did you know...?

The amount of energy transferred to the Earth from the Sun in one minute is enough to meet the world's energy demands for one year.

Sankey diagrams

If you move a weight of 1 N through a distance of 1 m, you transfer 1 joule (1 J) of energy. One joule of energy is also needed to heat 1 cm^3 of water by 1 °C.

A **Sankey diagram** is an energy transfer diagram that shows the relative amounts of energy transferred by a device. The width of each arrow shows how much energy is transferred. The non-useful energy transferred is always shown pointing downwards.

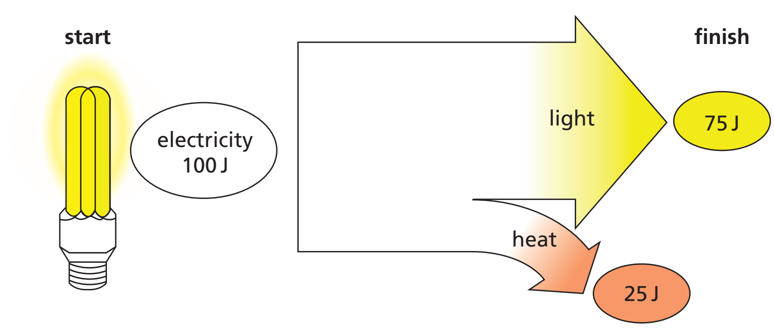

FIGURE 1.6.2d: Sankey diagram for an energy-efficient light bulb. How would the Sankey diagram for an old-style, less efficient light bulb compare with this one?

For example, in Figure 1.6.2d, 100 J of energy is transferred to the light bulb by electric current. It transfers 75 J by light (useful) and 25 J by heat (non-useful) to the surroundings. If you draw these on graph paper, you can accurately represent the proportions of energy involved.

6. On graph paper, draw a Sankey diagram for an electric drill that transfers 500 J of electricity by 100 J of sound, 100 J of heat and 300 J of movement energy. You will need to decide which of the outputs are useful and which are useless.
7. How could you make the drill in question 6 more efficient?

Key vocabulary

joule

energy transfer diagram

Sankey diagram

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Understanding potential energy and kinetic energy

We are learning how to:

- Recognise energy transfers due to falling objects.
- Describe factors affecting energy transfers related to falling objects.
- Explain how energy is conserved when objects fall.

Many theme parks make use of energy transfer in their rides. An object high up has the potential to transfer energy. There are plans for a new vertical-drop ride, the 'Drop of Doom', which, at 126 metres tall, will be the tallest ever. People will fall from a stationary position at the top and reach speeds of up to 200 km per hour.

FIGURE 1.6.3a: How is energy being transferred as people drop from the top to the bottom of this ride?

What is gravitational potential energy?

Objects at a height possess energy, because of **gravity** – think of parachute jumpers or sky divers. This energy is known as **gravitational potential energy**.

You use this energy when you cycle down a hill, ride a zip wire or go on a roller coaster.

1. What is the unit for gravitational potential energy?
2. What is the name of the force acting on objects that causes them to have gravitational potential energy?

Factors affecting gravitational potential energy

The higher an object is the more gravitational potential energy it has. More energy can be transferred to make it move. When the object falls, energy is transferred by **kinetic energy**. The object moves faster as more energy is transferred.

FIGURE 1.6.3b: How does gravitational potential energy affect these people?

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The greater the force acting on the object, the more energy can be transferred. The force of gravity is greater on Jupiter than on Earth, so an object falling the same distance on Jupiter will transfer more gravitational potential energy than it would on Earth.

3. A tennis ball falls from the following heights. Which will transfer the most gravitational potential energy?

a) 10 mm **b)** 10 cm **c)** 10 m

4. Look at Table 1.6.3. If a ball of mass 2 kg is dropped from a height of 1 m on each planet, on which planet will it reach the highest speed?

TABLE 1.6.3: Gravitational strengths on different planets

Planet	Gravitational strength (N/kg)
Earth	9.8
Mercury	3.6
Mars	3.7
Saturn	11.3

Did you know...?

The Three Gorges Dam in China is the biggest use of gravitational potential energy in the world. It is a hydroelectric dam that uses water stored at about 175 m above sea level. Its gravitational potential energy is transferred to produce about ten per cent of China's electricity output.

Conservation of energy in falling objects

Gravitational potential energy is transferred by movement and heat. As a falling object drops lower, its gravitational potential energy decreases and the amount of energy transferred to kinetic energy increases. Some energy will also be transferred to the surroundings by heat, due to friction with the air particles during the fall. The faster the object falls, the greater the energy transferred by heat. When the object hits the ground, all the kinetic energy is transferred by heat and sound to the surroundings.

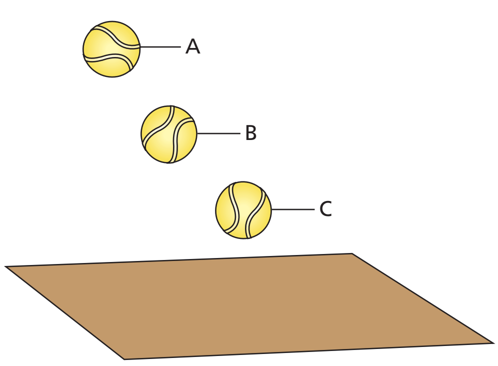

FIGURE 1.6.3c: A ball transferring gravitational potential energy

5. Look at Figure 1.6.3c of a ball falling from a height. In which position (A, B or C) does the ball have:

a) the highest gravitational potential energy?

b) the lowest gravitational potential energy?

c) the lowest kinetic energy?

d) the highest kinetic energy?

6. Sketch two graphs to show how the gravitational potential energy and the kinetic energy of the ball in Figure 1.6.3c change during the fall.

Key vocabulary

gravity

gravitational potential energy

kinetic energy

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Doing work

We are learning how to:

- Recognise situations where work is done.
- Describe the relationship work done = force × distance.
- Apply the equation for work done to different situations.

Ancient Egyptians used a 'shadouf' to lift heavy buckets of water from deep rivers. A shadouf is a type of lever – a simple machine that uses a force to transfer energy. Machines help us to do work.

FIGURE 1.6.4a: A shadouf, lifting water from a lake

Linking energy and force

A force can transfer energy. If you were pulling a heavy load along, you would need to use a large force. Energy is transferred in this situation. Chemical energy from your muscles is transferred by kinetic energy and heat. We say that work is done when a force is used to transfer energy.

The **work done** is equal to the energy transferred, and is measured in joules (J).

1. Which situation in the photos needs the biggest force?
2. Draw an energy transfer diagram for both situations in Figure 1.6.4b.

Defining work done

The further you pull or push a load, the more work you do. If two people were pushing identical boxes along a floor but one person pulls it twice the distance, that person will do twice as much work. Or if one box is much heavier and needs double the force to push, then double the amount of work will be done. The work done depends on the size of the force applied and the distance a load is moved.

work done (J) = force (N) × distance (m)

FIGURE 1.6.4b: Which forces are doing work in these situations?

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3. Calculate the work done in the following situations.
   a) A man uses a force of 50 N to push a box 1 m along a smooth floor.
   b) A striker at a fairground uses a force of 100 N to raise the puck a height of 6 m.
4. How much work is done by the engine of a car that applies a force of 20 000 N to move the vehicle 1 kilometre?

Did you know...?

Just as work is done in making a car move, it is also done in making it stop. In some racing cars so much energy is transferred by the brakes that the brake disks glow.

Force multipliers and energy

In Chapter 5, you learned that a lever is a machine that can multiply force. This means that a large load can be moved by a smaller effort. How is this possible? The answer is that the effort force on the lever acts over a larger distance.

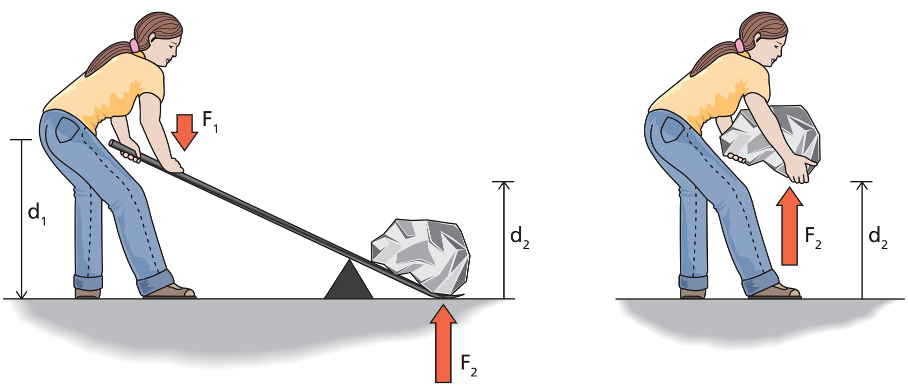

FIGURE 1.6.4c: Which job is easier?

Look at the girl lifting the stone with a lever in Figure 1.6.4c. She pushes down on the lever with a force F_1.

Work done by girl on lever = $F_1 \times d_1$

Work done on stone by lever = $F_2 \times d_2$

Energy is conserved, so:

work done by girl = work done on stone

$$F_1 \times d_1 = F_2 \times d_2$$

So the stone can be lifted using a force F_1. Without a lever, the girl would have to use a larger force F_2.

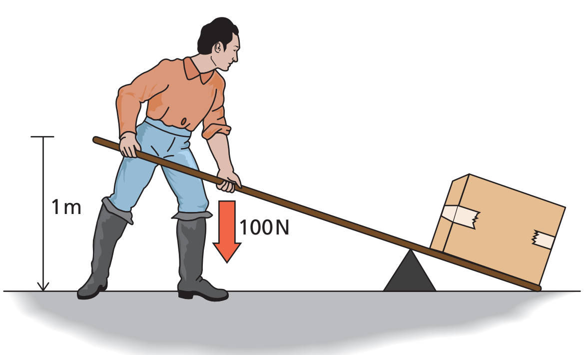

FIGURE 1.6.4d

5. a) In Figure 1.6.4d, what is the work done by the man using the lever?
   b) What must the work done be when the box is lifted for energy to be conserved?
   c) If the weight of the box means it needs a force of 200 N to lift it, how high will the box rise up?

Key vocabulary

work done

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Looking at dynamos

We are learning how to:

- Describe the energy changes in a dynamo.
- Explain how a dynamo works.

A dynamo is a device that can transfer energy of movement into electrical energy. The idea behind it was Michael Faraday's. He built a machine in 1831 that consisted of a copper disc rotating between two magnets. This generated a very small amount of electricity. It paved the way to the generation of electricity on a global scale.

FIGURE 1.6.5a: How does this bike lamp work without a battery?

Uses of dynamos

Have you ever wondered how the lights on some bicycles work without using batteries, or how some torches are able to operate simply by turning a handle? When an electricity supply or batteries are not available, **dynamos** can be very useful to produce small electric currents.

During World War 2, portable radios were operated using dynamos. A handle had to be turned, and the dynamo converted **kinetic energy** into energy of an electrical current, which enabled the radio to work.

Dynamos are not used much in our country today because we have mains electricity from the National Grid, and batteries are widely available. However, dynamos are still used extensively in some countries. Wind-up radios have been designed with built-in torches and mobile phone chargers.

FIGURE 1.6.5b: Dynamos transfer energy of rotary motion to electrical energy.

1. The photos show some uses of dynamos. Can you think of one other device that could be run using a dynamo?
2. Suggest some advantages of using dynamos.

How do dynamos work?

Dynamos rely on **magnetism** and movement to work. If a piece of wire is moved between two magnet poles, the kinetic energy of the wire's movement is transferred as **electrical energy**. If the wire is in a circuit, an electric current is produced.

A dynamo has a coil of wire that moves (or the magnets may move). This increases the amount of electrical energy transferred.

3. What useless energy transfers would there be in a dynamo?
4. Draw an energy transfer diagram for a dynamo.

Increasing the energy

To increase the amount of electrical energy converted by a dynamo, many turns of wire are used on the coil and the coil is turned as fast as possible in a strong magnetic field.

Dynamos used to be operated using water power or steam to spin the coil. These were able to supply plenty of energy by movement. Victorian lighting systems in large houses were run by this system, before the National Grid was established.

FIGURE 1.6.5c: How could energy from a water wheel supply electrical energy for lights?

5. How can you increase the electrical energy transferred in a dynamo to produce a bigger current?
6. What are the advantages of using water power to provide the kinetic energy for a dynamo?
7. What are the advantages of using steam to power the dynamo?

Did you know...?

The invention of the dynamo stimulated much interest and research into generating electrical energy. The power that dynamos could produce was limited. Nikola Tesla, one of the greatest inventors, changed the technology to produce a more powerful form of electricity, used today worldwide.

Key vocabulary

dynamo
kinetic energy
magnetism
electrical energy

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Understanding elastic potential energy

We are learning how to:

- Describe different situations that use the energy stored in stretching and compressing elastic materials.
- Describe how elastic potential energy in different materials can be compared.
- Explain how elastic potential energy is transferred.

Elastic materials have the ability to store energy ready for use. The muscle tissue in animals consists of fibres of protein that can expand and contract, providing a potential store of elastic energy. This ability allows us to jump and move – and allows fleas to jump more than a hundred times their own height!

FIGURE 1.6.6a: A flea's jump is an example of elastic potential energy being transferred.

What is elastic potential energy?

Energy is stored when an elastic material is stretched or compressed (squashed) by a force. You do work when you pull an elastic band or squash a spring.This transfers energy, which is stored as **elastic potential energy**.

The stored energy is transferred when the elastic material returns to its original shape.

The further a material is stretched or compressed, and still be able to return to its original position, the more elastic potential energy can be transferred.

1. In which of the situations in Figure 1.6.6b is more elastic potential energy transferred?
2. What causes the jack-in-the-box to bounce up when the lid is opened?

FIGURE 1.6.6b: What do these have in common?

Applications of elastic potential energy

Catapults and archery bows use elastic materials. Elastic potential energy is stored when the elastic is stretched or the bow is bent. More elastic potential energy is stored if the elastic is harder to stretch because more work is done in pulling it back.

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Some shock absorbers in cars have strong springs. When driving over a bump, energy is transferred by movement into elastic potential energy in the springs. This energy is released slowly when the car gets beyond the bump.

3. Some students are testing two different elastic materials for use in a catapult. They want to find out which would transfer more energy.

a) How should they make the investigation a fair test?

b) What should they measure to collect evidence?

4. Describe the energy transfers in a wind-up clock.

Explaining elastic potential energy

Elastic materials, such as rubber, are made up of molecules that are bound together. When the material is stretched, the bonds between the molecules store potential energy.

In its relaxed state, rubber consists of long strands of molecules which are all coiled up. When the rubber is stretched, the coils become elongated and straightened, enabling the rubber to extend in length. When the stretching force is removed, the molecules return to their coiled-up state and the material returns to its original length.

Did you know…?

Most elastic materials can stretch up to five times their original length. The first type of elastic material was natural rubber, made from the sap of rubber trees. Scientists have recently invented a gel material that can stretch up to 20 times its original length and still recover. It has a possible application as artificial cartilage, because it is also extremely strong.

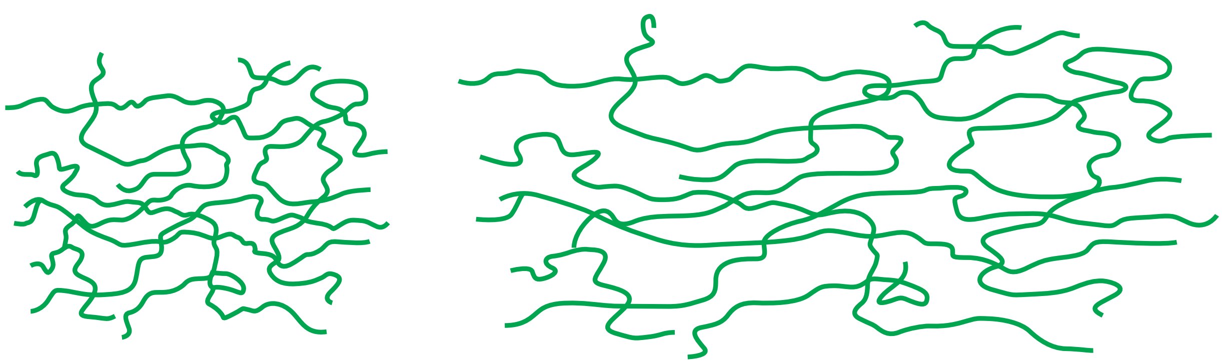

FIGURE 1.6.6c: Molecules of rubber in relaxed and stretched states

The elastic potential energy stored in a rubber band or a spring is equal to the **work done** in stretching it. This energy can be transferred as kinetic energy when the stretching force is removed.

5. Can all materials store elastic potential energy? Explain your answer.

6. How would you test which had more elastic potential energy – a coiled metal spring or an elastic band?

Key vocabulary

elastic potential energy

work done

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Knowing the difference between heat and temperature

We are learning how to:

- Recognise what we mean by temperature.
- Describe how temperature differences lead to energy transfer.
- Explain the difference between heat and temperature.

The hottest temperature ever recorded on Earth was 56.8 °C in Death Valley, USA in 1913. The coldest was –89 °C in Vostock, Antartica in 1983. What do we actually mean by how hot or how cold something is?

Temperature

We use a scale of **temperature** to measure how hot or how cold something is. The common unit is **degrees Celsius** (°C). The instrument we use to measure temperature is called a thermometer. Standard thermometers measure temperatures from 0 °C (the temperature at which water freezes) to 100 °C (the temperature at which water boils).

1. Put the following objects in order of temperature, with the hottest first.

A the Sun's surface, B boiling water, C volcano lava, D glacier of ice

2. Using Figure 1.6.7a to help you, match up the objects and their corresponding temperatures in Table 1.6.7.

TABLE 1.6.7

Object	Temperature (°C)
1 body temperature	a) 20
2 bath water	b) 5
3 temperature of a hot sunny day	c) 57
4 highest air temperature recorded	d) 30
5 room temperature	e) 37
6 cold drink from the fridge	f) 50

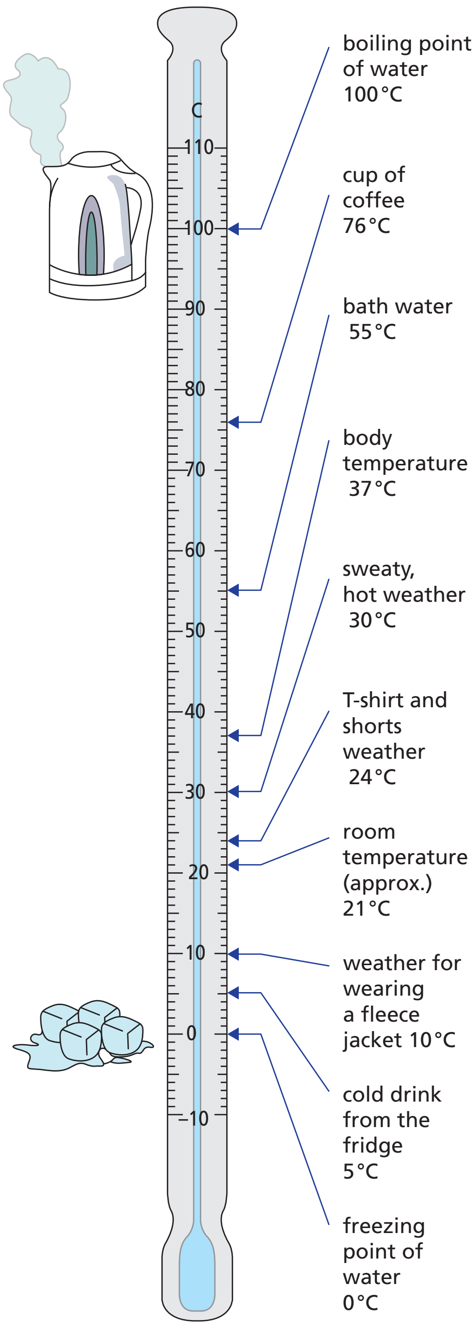

FIGURE 1.6.7a: A temperature scale

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Heat flow

If there is a difference in temperature between two objects in contact, or between an object and its surroundings, there is a transfer of energy as a flow of **heat**. Heat always flows from the hotter object to the colder object. Heat will continue to flow in this direction until the two objects reach the same temperature. The greater the difference in temperature, the faster the flow of heat.

We use this principle of heat transfer to heat and cool objects or our surroundings. If you put some food at room temperature (20 °C) in a fridge (at 5 °C), energy from the warmer food will transfer to the colder surroundings of the fridge. This will reduce the temperature of the food and cool it down.

Did you know...?

The coldest temperature possible is called 'absolute zero'. It is –273.15 °C. Some scientists have won the Nobel prize for finding ways to cool matter to within billionths of a degree of absolute zero.

3. Look at the diagrams in Figure 1.6.7b. State the direction of heat transfer in each situation.
4. Put the diagrams in order of the quickest to transfer heat to the slowest. Explain your answer.
5. If you wanted to cool a container of water as quickly as possible, would you put it in a fridge or in a freezer? Explain your answer.

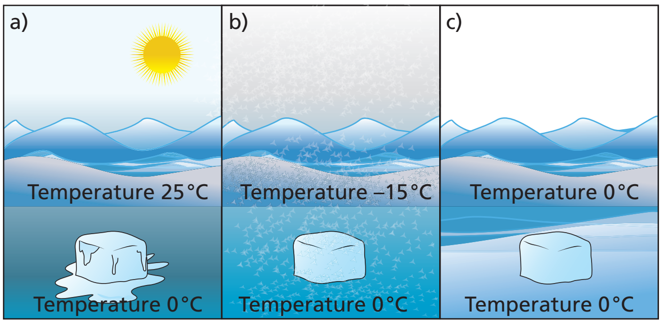

FIGURE 1.6.7b: Will the heat flow from the ice cube or to the ice cube?

Heat and temperature

Think about a cup of hot water at 80 °C and a big bucket of warm water at 30 °C. You know that the water in the cup has a higher temperature. But which holds more heat energy?

Say that a cubic centimetre of water particles in the bucket has 40 J of energy, and a cubic centimetre of water particles in the cup has 250 J. Which would hold the most energy overall – the cup or the bucket?

- Temperature is a measure of the energy of the individual particles – how fast they are moving about.
- Heat is the total energy of all the particles – a measure of not only how fast particles are moving but also the total number and type of particles.

6. Which would have most energy – a cup of boiling water or a gigantic iceberg? Explain your answer.
7. Explain in terms of the particle model why the direction of energy flow is always from a hotter to a cooler object.

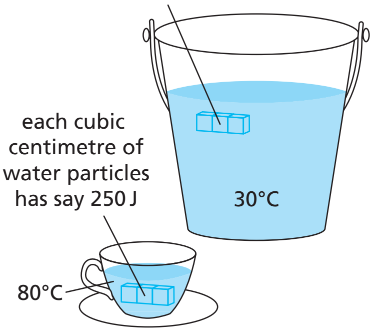

FIGURE 1.6.7c: The water in the cup has a higher temperature. But which has more energy?

Key vocabulary

temperature

degrees Celsius

heat

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Thinking about fuels

We are learning how to:

- Identify examples of fuels and their uses.
- Describe the combustion of fuels and recognise that different fuels transfer different amounts of energy.
- Describe the advantages and disadvantages of using different fuels.

Dried animal dung has served as a fuel for humans, all over the world, since prehistoric times. Today, over two billion people still use this as their main source of fuel. Dung from cows, buffalo and camels is commonly heated and burned. The energy is used for cooking food, heating and drying.

FIGURE 1.6.8a: What are the advantages of using animal dung as a fuel?

Common fuels

Fuels are chemicals that transfer energy to the surroundings by heat when they burn. They have **chemical potential energy**. Many different types of fuels exist, and they may be solids, liquids or gases.

The most commonly used fuels are coal, crude oil and methane (natural gas). Car engines use liquid fuels such as petrol and diesel, or a gas called propane. Aeroplanes use a heavier liquid fuel called kerosene, and racing cars use a lighter liquid fuel such as nitromethane. All of these are processed from crude oil. They have the advantage of burning quickly and easily, transferring energy rapidly.

Wood and wax are solid fuels that provide heat and light. These burn much more slowly than liquid fuels.

TABLE 1.6.8: Some common fuels

Fuel	Solid, liquid or gas	Uses
coal	solid	making electricity; coal fires
natural gas	gas	making electricity; cookers
petrol	liquid	fuel for vehicles
diesel	liquid	in engines of cars, boats and trains
kerosene	liquid	fuels for planes
methanol and nitromethane	liquid	fuels for racing cars
wood	solid	fires and boilers

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1. State one advantage of using a liquid fuel, rather than a solid fuel.
2. Suggest how life would change if we ran out of crude oil.

Did you know...?

Hydrogen is being developed as an alternative fuel to hydrocarbons. Water vapour is given off when hydrogen burns. This returns back to the Earth as rain.

Combustion

When fuels are burned, they combine chemically with **oxygen** from the air. This process releases heat energy – it is called **combustion**. A heat source, for example a match or a spark in an engine, starts the process off. Chemical energy is transferred to the surroundings by heat, and also by light and a small amount by sound.

3. Describe the energy transfer when a fuel is burned. State the useful and useless energy transfers.
4. How might fuels vary from each other?

Problems with fuels

Fuels derived from crude oil belong to a family of chemicals known as **hydrocarbons**. When they burn, the following chemical reaction takes place, transferring energy by heat and light to the surroundings:

hydrocarbon + oxygen → carbon dioxide + water

Carbon dioxide is a greenhouse gas and so contributes to global warming. Burning hydrocarbons also produces acid rain. This damages forests, plants and living things in lakes.

FIGURE 1.6.8b: Burning hydrocarbons causes global problems. How do these occur?

We have used so much crude oil that the Earth's supply of oil is running low. Crude oil is a **fossil fuel**, meaning it takes millions of years to form.

5. When hydrogen is used as a fuel, the only product is water. What advantage does this fuel have compared with hydrocarbon fuels?
6. Because hydrocarbons from fossil fuels cause so many problems, why are we still using them?

Key vocabulary

chemical potential energy

oxygen

combustion

hydrocarbon

fossil fuel

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Investigating fuels

We are learning how to:

- Describe how to measure the energy of fuels.
- Collect evidence to investigate the energy of different fuels.
- Present data using appropriate graphs and evaluate the quality of evidence collected.

Fuels vary widely in their properties. Hydrogen and natural gas are extremely explosive; petrol is highly flammable; lumps of coal and logs of wood are quite hard to set alight. Fuels also vary in how much energy they can transfer per gram. Hydrogen transfers the highest amount of energy, whereas wood transfers the least.

FIGURE 1.6.9a: How are fuels different?

Energy in fuels

The amount of energy transferred by the **combustion** (burning) of a fuel depends on:

- the amount of fuel burnt
- how much energy is stored in the fuel.

The more fuel burned, the greater the amount of chemical energy transferred by heat. The type of fuel will also determine how much energy is transferred. With some fuels, such as petrol, only a small amount has to be burned to obtain a large amount of heat. In contrast, a lot of wood has to burn to obtain the same amount of heat.

1. Name two fuels that you use regularly.
2. If you wanted to transfer more heat from a fuel, what two things could you do?

Differences between fuels

Fuels with the most chemical energy to transfer will produce the highest amount of heat, using the least amount of fuel.

One way to compare the energy transferred from different fuels is to burn the same mass of each fuel, use the heat energy to warm the same amount of water and record the temperature rise of the water. Fuels that transfer the most energy will produce the highest rise in temperature.

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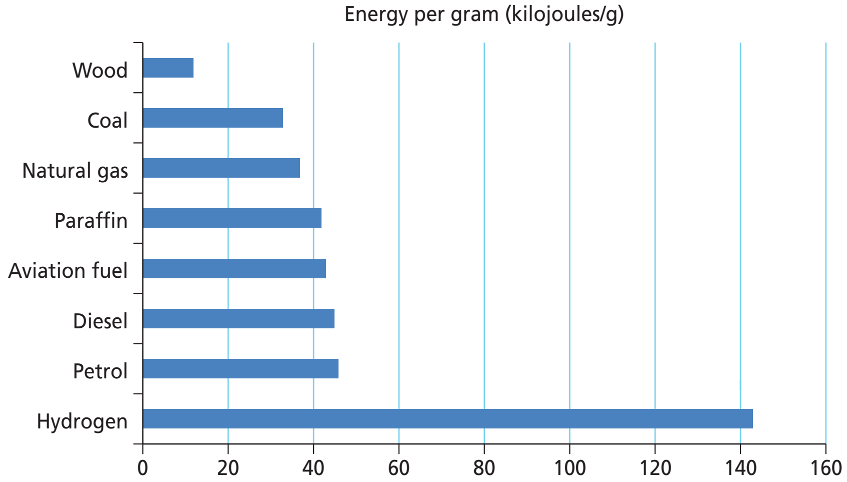
3. Which fuel in Table 1.6.9 has the lowest energy per gram?
4. Approximately how much of the fuel you have named in question 1 would be needed, to give the same energy as 1 g of coal?
5. Use the information in the table to suggest which fuel might be suitable for use in a rocket. Give a reason for your answer.

Interpreting graphical data

Graphs are a useful way to compare energy data for different fuels. Different types of graph show data in different ways. Look at those in Figure 1.6.9b, which present the data from Table 1.6.9.



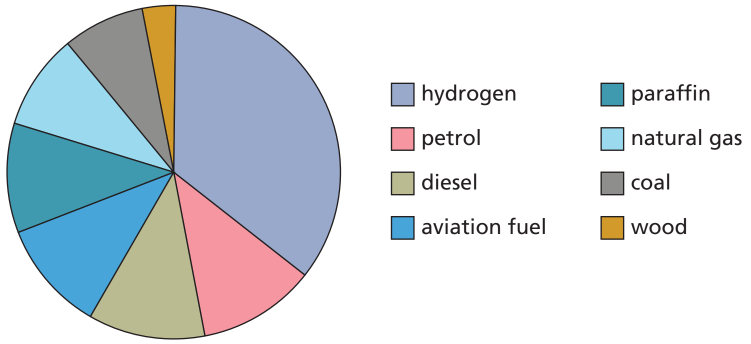


FIGURE 1.6.9b: Two different types of graph showing the energy of different fuels

6. Compare and contrast the two graphs in Figure 1.6.9b. What are their strengths and their weaknesses?
7. Why is it not possible to produce a line graph from this data?
8. Can you deduce any patterns from these graphs?

TABLE 1.6.9: Energy of different fuels

Fuel	Energy (kJ/g)
hydrogen	143
petrol	46
diesel	45
aviation fuel	43
paraffin	42
natural gas	37
coal	33
wood	12

Did you know...?

Uranium is the fuel with the highest amount of energy per gram on Earth. It does not burn but undergoes nuclear reactions to transfer energy by heat. One kilogram of uranium will release the same amount of energy as 3000 tonnes of coal!

Key vocabulary

combustion

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Applying key ideas

You have now met a number of important ideas in this chapter. This activity is an opportunity for you to apply them, just as scientists do. Read the text first, then have a go at the tasks. The first few are fairly easy, then they get a bit more challenging.

Energy changes – making electricity

The dynamo was the first device to transfer energy of movement to the energy of an electric current. In a dynamo there is a magnet and a coil of copper wire. When the coil spins in the magnetic field, energy is transferred to the wires as electricity. It also works if the magnet spins, with the coil stationary.

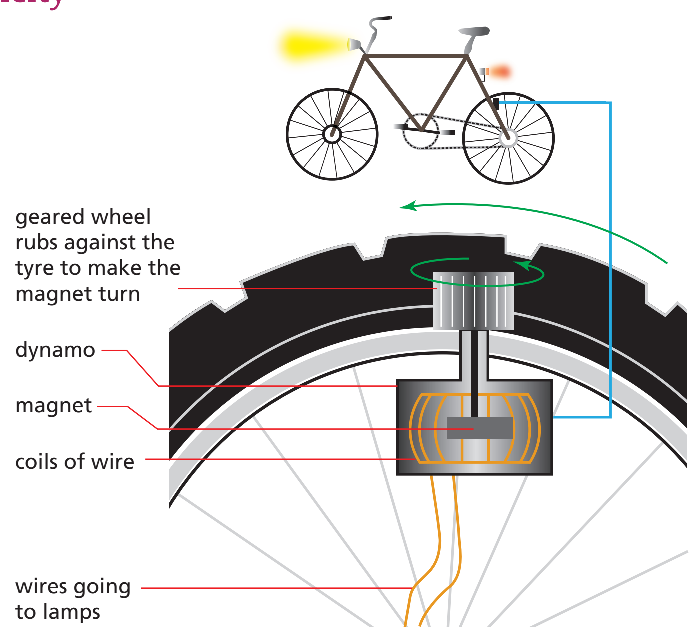

FIGURE 1.6.10a: Bicycle dynamo

The kinetic energy needed to operate a dynamo can come from different sources. Originally a hand-turned wheel was used. Later designs incorporated gears. Eventually bicycles were used. The dynamo head was placed against the wheel of the bicycle. The spinning wheel caused the head to turn, transferring energy from the movement of the bike into electrical energy. This method is still used to operate the lights on a bike at night, without the need for batteries. In larger applications, dynamos were driven by water wheels, using moving water from a river or waterfall. The energy of the moving water provided the energy needed to spin the dynamo and produce electricity.

The design of dynamos has changed over time. Figure 1.6.10a shows a modern design, fitted with gears. Gearing in a dynamo means that fewer turns are needed to produce the same amount of electricity.

Dynamos are only used nowadays for applications where mains electricity is unavailable – for example camping torches, radios, mobile phone chargers and emergency lights.

Electrical energy from chemical energy

Most of our electricity comes from burning a fuel such as gas, coal or oil. These are all fossil fuels. The stored chemical energy is transferred as heat to water, turning it into steam. The steam has kinetic energy and drives a turbine, which is rather like a water wheel. This is used to turn a generator, a similar device to a dynamo, and so produce electricity. Most of the electricity in the world comes from this process. The generator is more efficient than a dynamo and more electricity can be made from it.

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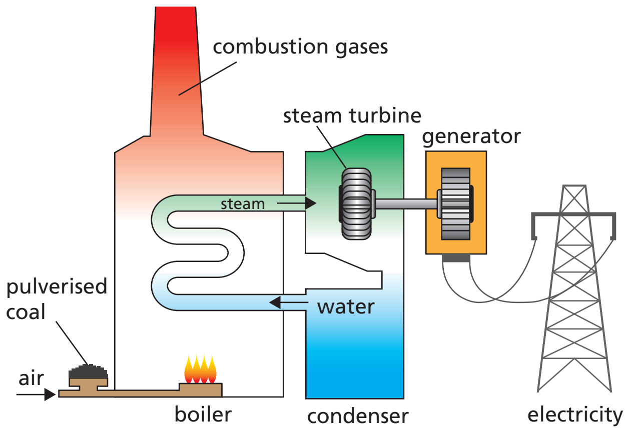

FIGURE 1.6.10b: Coal-fired electricity generating station

Task 1: Identifying energy changes

Explain how energy is transferred in a water-fed dynamo, like that in Figure 1.6.5c.

Task 2: Useful energy changes

Read the text and use the information to draw energy transfer diagrams to represent the following:

a) a bicycle dynamo making a light work

b) a hand-held dynamo operating a radio, like that in Figure 1.6.5b.

Task 3: Useless energy

Think about a bicycle dynamo. What are the ways in which energy is transferred that are not useful?

Task 4: Heat and temperature

Consider these two different systems that make electricity.

The first is a coal-fired power station. The burning coal turns water into steam to drive a turbine generator. The second is a hydroelectric power station, in which a waterfall drives a water wheel powering a dynamo. Compare and contrast the energy transfers of the two systems.

Task 5: Different processes to transfer energy

Using a hand-crank dynamo to light a bulb uses muscles, which contain chemical energy and elastic potential energy. Explain each process of the energy transfer, including useful and useless transfers. Make justified predictions about the efficiency of each process and draw a Sankey diagram for the overall energy transfer.

Exploring sound

We are learning how to:

- Identify how sounds are made.
- Describe how sound waves transfer energy.
- Explain how loud and quiet sounds are made.

Sound is hugely important throughout the animal kingdom as a means of communication, location and defence.

Making sounds

If you place a finger over your voice box when speaking or singing, you will feel your voice box **vibrate**. This is where the sound comes from.

When an instrument is plucked or blown through, the string or the air vibrates. Often the vibrations are too small to see.

All vibrations result in a sound. The vibrations from the object are passed on to air particles. These air particles bump into others and the wave progresses. Eventually the energy of the vibrations is transferred to your ears.

1. What causes the sound when a bell is rung?
2. How does the sound from a concert reach the audience?

FIGURE 1.6.11a: How does a guitar make a sound?

Making waves

Energy is transferred by sound in the form of waves. In Figure 1.6.11b a slinky spring provides a model that shows how these waves work. When you push the end of a slinky back and forth, some of the coils squash together and others pull apart. A wave of energy passes along the length of the spring. A wave like this which travels in the same line as the vibrations of the source is called a **longitudinal wave**.

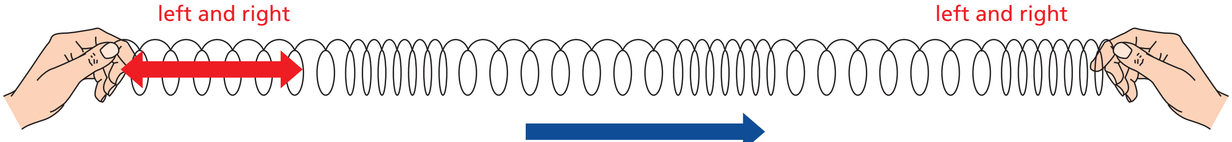

FIGURE 1.6.11b: Why is this called a longitudinal wave?

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A sound wave works in the same way. Vibrations push air particles together and also pull them apart, creating a longitudinal wave of energy. The energy passes from the source of the vibration to our ears.

3. Describe the movement of air particles in a longitudinal sound wave.

4. What happens to the energy in a longitudinal wave?

Louder and quieter sounds

Sounds can be made louder by increasing the energy in the vibration. Plucking a string harder, blowing harder through a wind instrument or beating a drum harder will all transfer more energy. The loudness of sound is measured in a unit called a **decibel (dB)**. The loudest sound that humans can listen to without damage to their hearing is about 120 dB.

The size of a vibration is represented by its **amplitude**. Figure 1.6.11d shows that the amplitude is the maximum distance that a particle travels in the to-and-fro vibration. The greater the amplitude, the greater the energy of the vibration and the louder the sound. In other words, a bigger wave will transfer more energy and be heard as a louder sound.

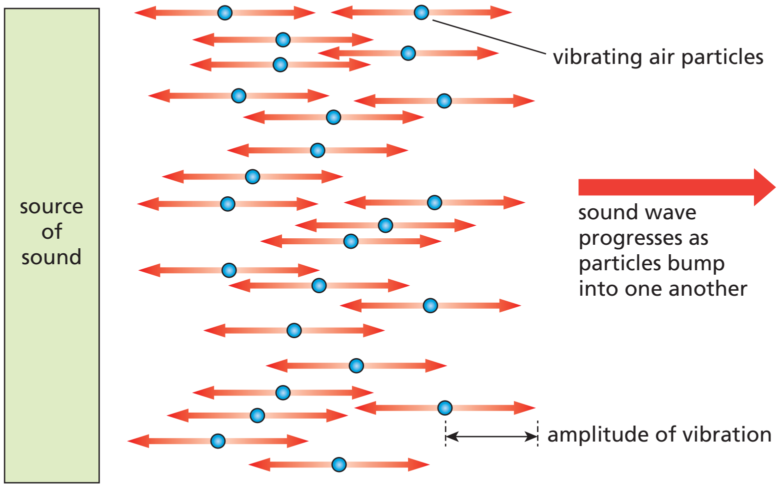

FIGURE 1.6.11d: What effect will a smaller amplitude have?

5. Look at Table 1.6.11. Match the sounds to the correct loudness.

6. The loudness of a sound also depends on the distance from the source. Explain what happens to the energy as you get further away.

7. Is there a limit to how loud a sound can be made? Explain your answer.

Did you know...?

The ocean-dwelling tiger pistol shrimp is known to produce the loudest sound on Earth, reaching over 200 dB. It uses the sound as a defence mechanism. The vibrations can kill prey and fish up to 2 metres away!

FIGURE 1.6.11c: A pistol shrimp

TABLE 1.6.11

Sound	Loudness (dB)
1 whisper	a) 80
2 phone dial tone	b) 140
3 jet engine	c) 100
4 motorbike	d) 30

Key vocabulary

vibrate

longitudinal wave

decibel (dB)

amplitude

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Describing sound

We are learning how to:

- Describe how the pitch of a sound wave can be changed.
- Apply the terms frequency, wavelength and amplitude to different waveforms.

There are many different types of sound. Think of the sounds made by a whale compared with the high-pitched screeching of a monkey, or the sound of a bass guitar compared with a violin. Differences in sound waves arise from different characteristics of the sound waves.

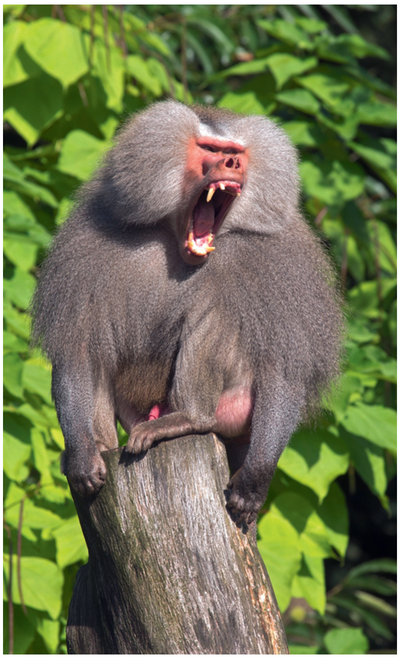

FIGURE 1.6.12a: How would you describe the scream of a monkey?

What is pitch?

A ship's horn produces a sound that is very deep and low – this is known as a low pitch. Whistles, alarms and sirens produce high-pitched sound.

The pitch of a note is also called its **frequency**. A high frequency means a high pitch and a low frequency means a low pitch. Muscial notes change in pitch by changing the frequency of the vibration.

Feel your voice box as you make sounds of different pitches. What do you notice?

1. Describe one other sound with a low pitch and one other sound with a high pitch.
2. What is meant by the 'frequency' of a note?

Frequency, wavelength and amplitude

Sound waves can be represented in a diagram like that shown in Figure 1.6.12b. The curve, or **waveform**, is a graph of the displacement of the air particles at different distances along the wave. The **wavelength** is the distance along a wave from one point to the next point where the wave motion begins to repeat itself.

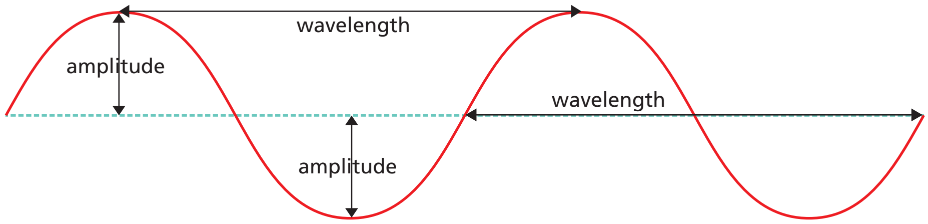

FIGURE 1.6.12b: Parts of a wave

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The higher the frequency of a wave, the shorter the wavelength. A high frequency means more vibrations are produced per second.

The maximum dispacement is called the **amplitude**. The energy transferred by the wave depends on this. The larger the amplitude of a sound wave, the louder the sound.

3. Why is it more useful to use the wave representation in Figure 1.6.12b, compared with a drawing of a longitudinal vibration, as in Figure 1.6.11d of Topic 6.11?

4. How could you tell from a waveform whether a sound is getting:

a) louder? **b)** higher pitched?

Interpreting sound waves

All sound waves can be detected using a **microphone** and shown as a waveform on a screen. The microphone receives the sound waves and converts them into electrical signals. Some typical examples are shown in Figure 1.6.12c.

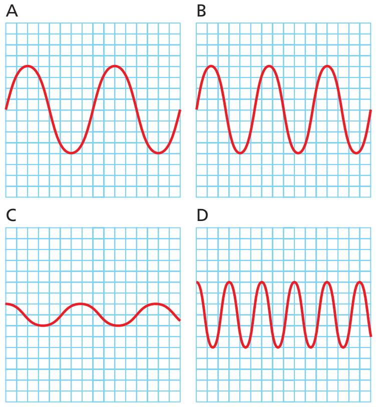

FIGURE 1.6.12c: How are these waves different?

Detectives use traces like these to match voices patterns from recordings to known criminals or to identify patterns from the shots of particular guns.

5. a) Which wave in Figure 1.6.12c results from the loudest sound?

b) Which wave results from highest-pitch sound?

c) Which wave is transferring the most energy? Explain your answer.

6. Draw waves to represent a loud high-pitched sound and a quiet low-pitched sound.

7. Look at the graph in Figure 1.6.12d, which shows the sound wave detected from a gun as time progresses. Describe what is happening to the frequency, wavelength and amplitude of the wave.

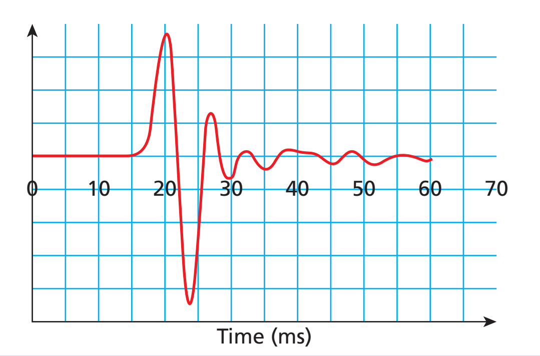

FIGURE 1.6.12d: Sound wave from a gun

Did you know...?

Microphones have a thin diaphragm made of plastic or metal. This vibrates when even small sound vibrations hit it. The energy from the vibrations is transferred by electric current and can be fed to a loudspeaker. This transfers the electrical energy back into sound energy.

Key vocabulary

frequency

waveform

wavelength

amplitude

microphone

Measuring the speed of sound

We are learning how to:

- Describe what an echo is.
- Describe how the speed of sound can be measured using echoes.
- Calculate distances using ideas about echoes.

Echoes are used by bats and dolphins to navigate, find prey and find mates. Dolphins can tell the difference between a golf ball and a ping-pong ball using echoes, and bats can detect tiny insects in pitch-black darkness. Humans have learned from these creatures to use echoes in similar ways.

FIGURE 1.6.13a: Some bats are completely blind. How do they find food?

What is an echo?

Sound waves can bounce back from a surface. We call this **reflection** of sound an **echo**. A hard surface will reflect more sound than a soft surface, making a stronger echo. Shouting across a rocky outcrop or in a long tunnel can produce good echoes.

An echo transfers less energy back to the listener, and so is quieter than the original sound. This is because some energy has been transferred as heat in the material it is reflected from.

1. What do we mean by a 'reflection' of sound?
2. Which types of place would not allow echoes to be created?

FIGURE 1.6.13b: Why is this a particularly good place for echoes?

Measuring the speed of sound

An echo is the reflection of a sound wave from a surface, including back towards the sender. The echo travels twice the distance from the sender to the surface. When the echo from a sound wave comes back, it can be used to calculate the **speed of sound**.

$$\text{speed of sound} = \frac{\text{total distance travelled by the echo (m)}}{\text{time taken (s)}}$$

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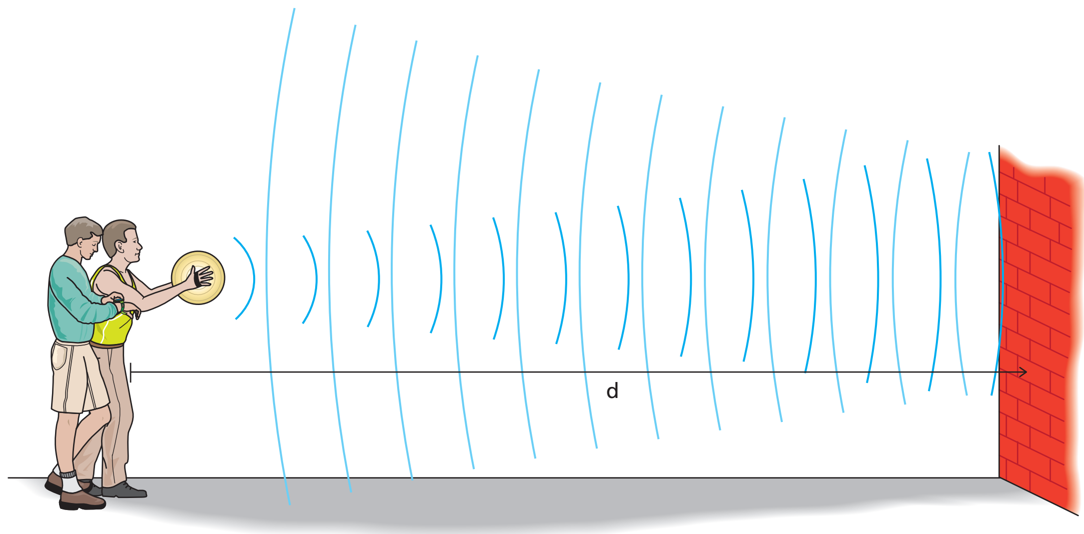

FIGURE 1.6.13c: How to measure the speed of sound

3. Describe how echoes can be used in this way to measure the speed of sound.
4. A man fires an air pistol towards a wall, a distance of 1 500 m from him. It takes 10 seconds before he hears the echo. Calculate the speed of sound from this information.
5. How far away is a quarry if the sound of blasting is heard 3.5 seconds after the explosion?

   (distance = speed × time; the speed of sound in air is 330 m/s)

Sonar

Naval ships use **sonar** to locate hidden submarines. They send sound waves through the water from the ship. The sound waves reflect off the sea floor and return to the ship as an echo. If a submarine is located under the passing ship, the echo returns more quickly, because the sound has a shorter distance to travel.

Fishermen also use this method to locate shoals of fish. The speed of sound through water is 1 500 m/s. When calculating the distance of an object from the boat, remember that the sound waves travel to the sea bed and back again:

distance of object to boat = ½ × speed of sound × time taken

6. A boat uses its sonar system to send a sound signal directly downwards to the sea bed. An echo is recorded on the boat 2 seconds later. How deep is the water?
7. A battleship records a sonar echo from a submarine below from the ship. There is 5 s between sending the sonar signal and receiving the echo. How far away is the submarine?

Did you know...?

Some blind people learn to use echoes as a way of locating objects around them. By clicking their tongue and listening to the echoes, they can avoid walking into obstacles.

Key vocabulary

reflection

echo

speed of sound

sonar

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Understanding how sound travels through materials

We are learning how to:

- Recognise how the speed of sound changes in different substances.
- Use the particle model to explain why there are differences when sound travels through solids, liquids and gases.

Whales are known to transmit sounds in the ocean over distances of 700 km. If whales were to transmit these same sounds in the air, would they travel faster or slower?

FIGURE 1.6.14a: How do sounds from whales travel under water?

Sound in a vacuum

Most of the sounds that you hear are transmitted by vibrating air **particles** (particles of gas). Sounds can also travel through solids and liquids. Sound waves need particles of matter to transmit energy. As the particles vibrate, the energy is passed on to adjacent particles and carried in the form of a wave.

Sounds cannot travel through a **vacuum**, nor through space, which has hardly any particles in it.

1. Why can sound travel not through a vacuum?

2. How is it possible for sounds to travel through solids?

Speed of sound through different materials

Table 1.6.14 shows the speed that sound travels through different materials.

TABLE 1.6.14: Speed of sound in different materials

Material	Speed of sound (m/s)
air	343
oxygen	316
carbon dioxide	259
water	1482
lead	1960
copper	5010
steel	5960
diamond	12 000

3. a) In which material does sound travel the fastest?

b) In which material does sound travel the slowest?

c) Does sound travel fastest in solids, liquids or gases?

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Sound and particles

Particles of matter in solids, liquids and gases differ in their arrangement and behaviour. This affects how well sound waves can travel through them. The speed at which the wave moves depends on the arrangement of the particles, the elastic nature of the forces between them, and how fast the particles are moving.

- In a gas the particles are very far apart. Sound travels slowly because the particles do not collide very often.
- In a liquid the particles are much closer to one another. Sound travels more quickly because the particles are able to collide with each other much more frequently. Sound travels about five times faster through liquids than it does through gases.

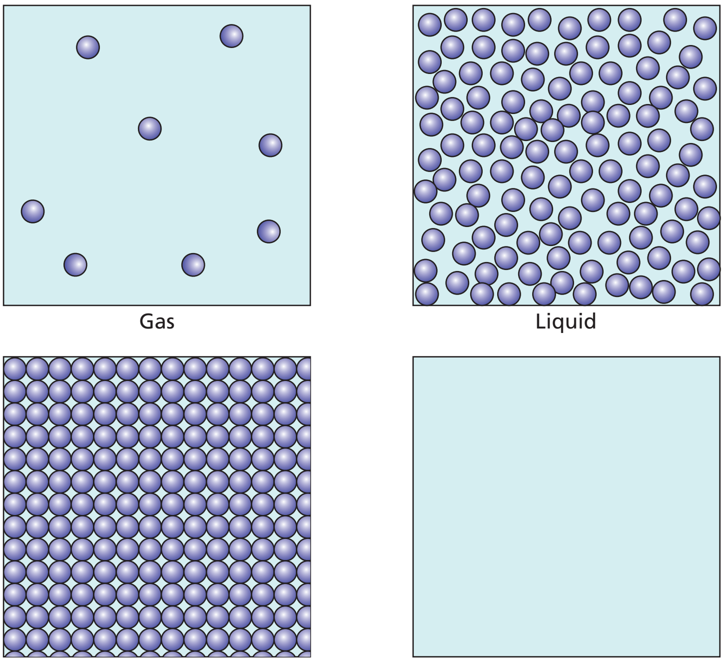

FIGURE 1.6.14b: The particle theory of matter explains how sound travels in a solid, liquid and gas. Why does sound not pass through a vacuum?

- In a solid the particles are packed very closely together. Also, the forces between the particles are more elastic. The vibrating particles collide with neighbouring particles and bounce back very quickly, so the sound wave progresses very quickly.

4. Do you think sound will travel faster through water or ice? Explain your answer.

5. Why do you think sound travels much faster through some solids compared to others?

6. Temperature can also affect the speed of sound. Develop a **hypothesis** to explain why.

Did you know...?

Native Americans used to put an ear to railway tracks to know when trains were coming. This is a dangerous thing to do because you can never tell how soon the train will arrive.

Key vocabulary

particle

vacuum

hypothesis

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Learning about the reflection and absorption of sound

We are learning how to:

- Recognise which materials affect the quality of sound.
- Analyse the effect of different materials on sound waves.
- Use ideas about energy transfer to explain how soundproofing works.

Concert halls are designed for good acoustics – so that the music sounds good to the whole audience. This means controlling the amount of echo and making sure sound reaches all corners. Different materials and shapes are used to achieve this.

FIGURE 1.6.15a: Can you identify materials that help to reflect sound and those that help to absorb it?

Effect of materials on sound waves

Echoes are sound waves that are reflected back to our ears. Hard, flat surfaces **reflect** sound well and produce strong echoes.

Soft surface materials that contain lots of air pockets, like fabric, foam and sponge, are not good at reflecting sound. They **absorb** it. The sound waves transfer energy to the air in the pockets so less is reflected.

1. What do we mean by 'absorbing' sound?

2. a) What would you hear if the sound waves from a bell were directed at a metal panel?

b) What would you hear if the sound waves from a bell were directed at a panel made of sponge?

3. When might it be useful to absorb sound waves?

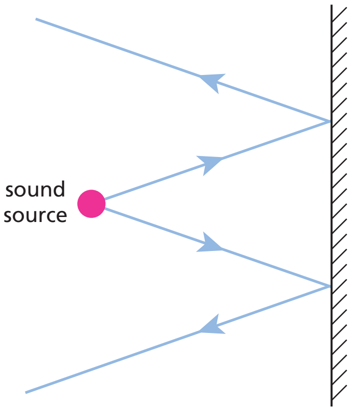

FIGURE 1.6.15b: What kind of echoes will this produce? How can the echoes be reduced?

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Effect of shapes on sound waves

Some materials can be shaped to reflect sounds in different ways. Look at the jagged surface in Figure 1.6.15c. When sound waves hit this surface, the reflected waves do not bounce back to the source. They are, instead reflected randomly, mostly away from the source.

The curved surface, on the other hand, reflects the sound until all the energy focuses towards a particular point. The sound at this point will be the loudest, whereas in places away from it, hardly any sound will be heard at all.

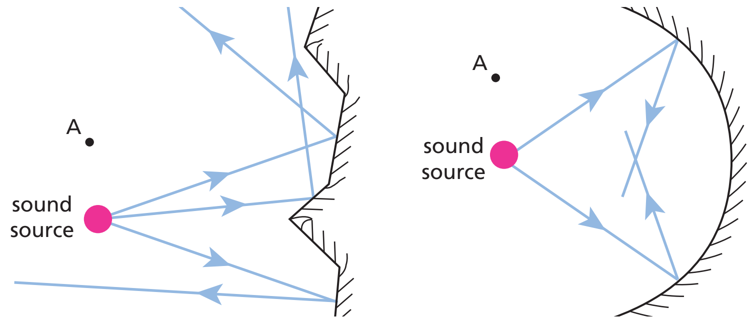

FIGURE 1.6.15c: How sound is reflected off a jagged and a curved surface

4. Imagine you are standing in position A in each of the diagrams in Figure 1.6.15c. Describe what you will hear if the surface is:

a) jagged **b)** curved

compared with the flat surface in Figure 1.6.15b.

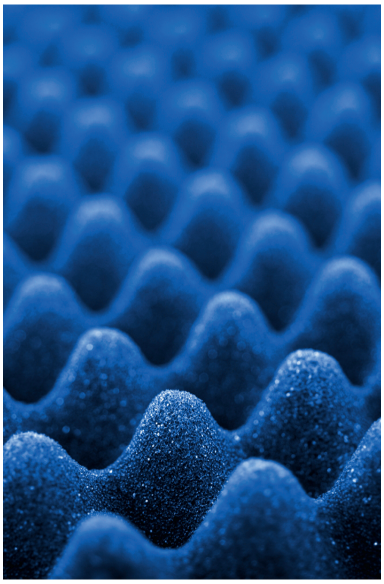

FIGURE 1.6.15d: This material is used in soundproofing. What makes it a good choice?

Soundproofing

When sound waves hit soft surfaces, they are absorbed by the air pockets. The sound waves become trapped, bouncing around in the air pockets, until all the energy is transferred as heat. Any sound reflected from the surface is therefore much quieter, as the sound waves have much less energy.

These soft materials are useful as **soundproofing**. A vacuum is also useful in soundproofing. Sheets of glass with a near-vacuum between them (very few gas particles) are very effective in stopping sound.

In the outdoor environment, trees, embankments and dense bushes are often for soundproofing around mining areas.

5. What happens to the energy of the sound wave during absorption?

6. Design a soundproofing plan for a hospital in a busy town centre.

Did you know...?

A 'whispering gallery' is the name given to a large circular room, where a whisper made in one place is reflected to the opposite side of the room and heard there but nowhere else. St Paul's Cathedral contains one.

Key vocabulary

reflect

absorb

soundproofing

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Hearing sounds

We are learning how to:

- Describe the structure and function of different parts of the ear.
- Explain how the ear is able to hear and detect sounds.

The ability to hear is important in all animals for communication, hearing predators, knowing when there is danger and seeking prey. The human ear relies on a combination of processes and ingenious engineering to help us to identify the wide range of sound waves we receive.

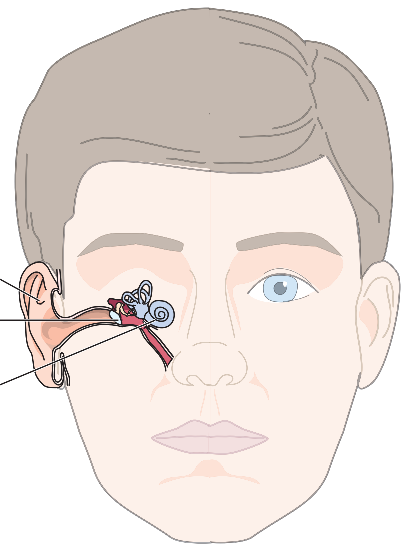

FIGURE 1.6.16a: The human ear is not just the part you can see.

Ears for hearing

A human ear is divided into three parts – the outer ear, the middle ear and the inner ear.

The outer ear is the part that can be seen, on the outside of your head. Its job is to capture sound waves. The waves pass along the **ear canal** to the **ear drum**. This separates the outer ear and middle ear. The ear drum transfers the energy from the vibrations to bones called **ossicles** in the middle ear, which make the tiny vibrations much bigger. This energy is passed on to the inner ear, which contains specialised cells that detect the vibrations and convert them into electrical signals. These are sent to the brain, which interprets them.

1. What are the jobs of the outer, middle and inner ear?
2. Suggest why are our ears are located in our head.

Structure of the human ear

The function (job) of the ear is to transfer energy by sound into electrical impulses that are interpreted by the brain.

Figure 1.6.16b shows the detailed structure of the ear, and Figure 1.6.16c describes what happens to the sound waves as they enter the ear.

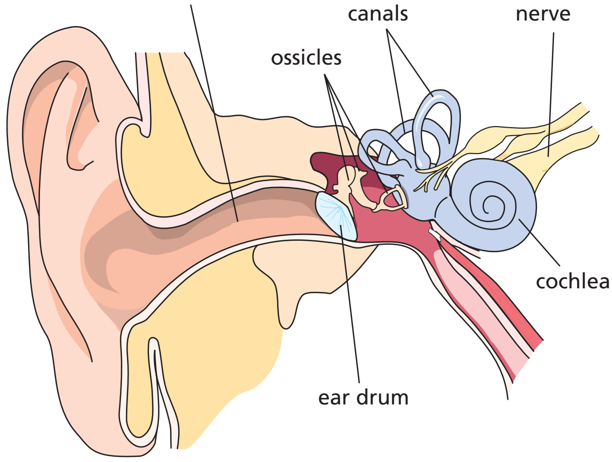

FIGURE 1.6.16b: Parts of the ear

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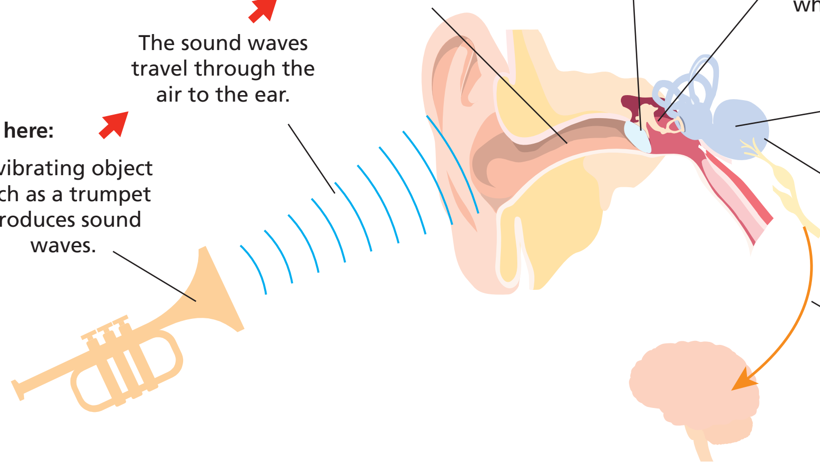

FIGURE 1.6.16c: How we hear

3. Suggest why incoming sound vibrations need to be amplified (amplitude made bigger) in the ear.
4. Where in the ear are:
   - a) electrical signals transmitted to the brain?
   - b) sound vibrations amplified?
   - c) vibrations first detected?

Adaptations of the ear

The ear drum is like a tiny drum skin. Muscles keep it very rigid, so even the slightest vibration causes it to move back and forth.

The three small, connected ossicles are called the malleus, incus and stapes. The malleus is connected to the ear drum, and the stapes is connected to the **cochlea**.

The ear drum has a surface area of about 55 mm^2, but that of the stapes is only about 3 mm^2. The energy of the vibrations is transmitted through a much reduced area. This multiplies the pressure by about 20 times, so amplifying the vibrations as they are passed on to the cochlea.

The cochlea is filled with fluid, enabling the the sound vibrations to travel much faster. It has thousands of tiny hair cells that convert the sound wave to electrical signals, which are passed on to the **auditory nerve** and to the brain.

5. What is the result of the difference in surface area in the middle ear?

Did you know...?

The cochlea is also responsible for detecting and controlling balance.

Key vocabulary

ear canal

ear drum

ossicles

cochlea

auditory nerve

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Physics

Understanding factors affecting hearing

We are learning how to:

- Describe factors which affect hearing.
- Explain how to prevent damage to ears.
- Understand the term hearing range.

The ability to hear different sounds varies widely across the animal kingdom. Many animals can hear sounds that humans are totally unaware of. Some animals do not have ears, but other organs have adapted to detect sounds. Our own hearing can be affected by factors such as disease and ear damage caused by loud sounds. It is important to learn how to protect our hearing.

FIGURE 1.6.17a: This bushbaby is active only in darkness. It has extremely good hearing.

Protecting our hearing

The human ear is only able to withstand sounds of a certain **loudness** – too loud and our ears can be permanently damaged. We can do several things to protect ourselves from loud noise:

- turn down the volume of sound-making devices
- increase the distance from the source of the noise
- reduce the time of exposure to loud sounds
- wear **ear defenders**
- obey laws that limit noise in the workplace
- use soundproofing materials.

1. Why is it important to protect your ears?
2. You are the manager of a new quarry that will blast stone from a rock face. Explain what measures you will take to protect the hearing of your workers.

Factors affecting hearing

Several factors can affect the health of our ears. Read about these in Table 1.6.17.

3. Why can some ear problems not be cured?
4. Who is most likely to be most at risk of having problems with poor hearing?

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TABLE 1.6.17 Causes of ear damage and what can be done

Causes of poor hearing or ear damage	Possible solutions
Ear canal can become blocked with wax.	Have the ear canal cleaned out.
Very loud sounds can rupture the ear drum.	Ear drum may heal itself over a long period of time.
Ear drum can be damaged by infection.	Use antibiotics to get rid of the infection.
Ossicles can become fused together.	An operation is needed.
Infection may occur in the middle ear.	Use antibiotics to get rid of the infection.
Hair cells and nerves in the cochlea may be damaged by loud noises.	There is no cure.
In older people, nerves cells may deteriorate.	There is no cure.

Did you know...?

Elephants can hear frequencies 20 times lower than the lowest frequency we can hear. They use their trunks as well as their ears to detect low frequency vibrations. This enables them to hear other elephants up to 6 km away.

Sound frequencies heard by different animals

The **frequency** of a wave is the number of waves per second. It is measured in hertz (Hz). If a sound wave has a high frequency it means that more vibrations arrive every second – it sounds higher pitched.

We can only hear certain frequencies of sounds. The sounds that we can hear, from the lowest frequency to the highest frequency, is known as our **hearing range**. This range differs widely for different animals – many animals can hear sounds so high pitched or so low pitched that we are unable to hear them. Figure 1.6.17b shows the hearing range for some different animals.

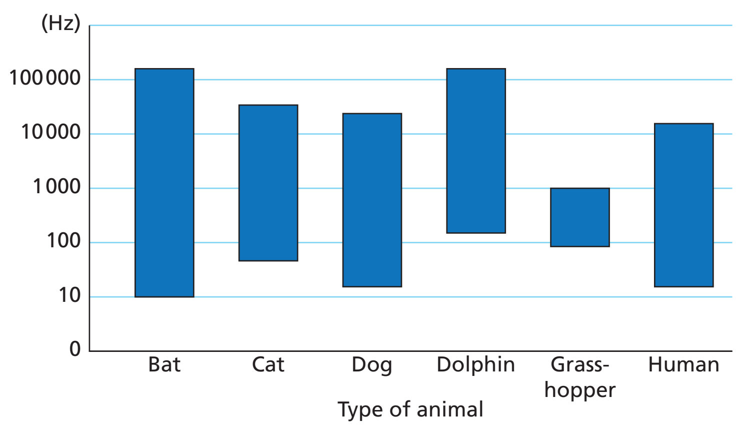

FIGURE 1.6.17b: Hearing ranges of different animals.

5. What is the human hearing range?

6. Draw two diagrams to show what is meant by 'wave frequency'.

7. What range of frequencies can be heard by all the animals in Figure 1.6.17b?

Key vocabulary

loudness

ear defenders

frequency

hearing range

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Finding out about sounds we cannot hear

We are learning how to:

- Recognise what is meant by ultrasound and infrasound.
- Describe some applications for ultrasound and infrasound.
- Explain how some applications work.

There are many sounds that humans cannot hear. Infrasounds are sounds at frequencies below our hearing range, and ultrasounds are those above our hearing range. The animal world uses both infrasound and ultrasound for communication and detection. We have also found useful applications for these sound waves that we cannot hear.

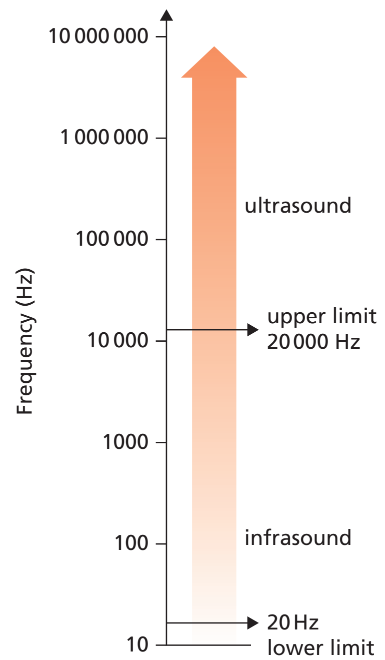

FIGURE 1.6.18a: Range of sound frequencies

What are ultrasound and infrasound?

Humans can hear sounds within the frequency range of 20 Hz to 20 000 Hz.

- Sound below 20 Hz is called **infrasound**.
- Sound above 20 000 Hz is called **ultrasound**.

Humans cannot detect these sounds because our ears are not sensitive enough.

1. Refer back to the 'Did you know…?' box in Topic 6.17.

a) What is the lowest frequency that elephants can hear?

b) What do we call that type of sound?

c) Why can humans not hear such sounds?

FIGURE 1.6.18b: Image produced by a 3D ultrasound scan of an unborn baby.

Using ultrasound and infrasound

Bats, whales and dolphins emit ultrasound waves in the echo-location of prey, predators and obstacles.

We can use devices that generate ultrasound waves, and also to detect reflected ultrasound. This has led to many useful applications.

- Ultrasound can be used to safely **scan** body organs and unborn babies, allowing checks for anything unusual.
- Metals in aircraft parts and underground pipes can be scanned for cracks using ultrasound.

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- Sonar involves sending ultrasound through water and detecting its reflection from objects.

The high frequency of ultrasound waves means that they transfer energy rapidly.

- Kidney stones can be broken up using ultrasound, without the need for surgery.
- Surgical equipment, electronic components, machinery, jewellery and teeth can all be safely cleaned using ultrasound.

Infrasound waves transfer little energy, but they can be detected by microphones.

- Some large animals use infrasound waves to communicate. Scientists can detect these waves to track herds, in conservation and protection projects.
- Scientists can detect infrasound from volcanoes that are about to erupt, and so warn people of impending risk.
- Infrasound can be used to track the passage of meteors in space, so preparing us for any probable collision.

2. Describe two applications of ultrasound or infrasound that can potentially save lives.

3. Why can items such as electronic components not be cleaned using sound waves that we can hear?

FIGURE 1.6.18c: Ultrasound was used to clean these gear teeth.

How ultrasound scanners work

An ultrasound scanner contains a special quartz crystal. When a changing electric current is passed through the crystal, it vibrates at very high frequency and emits ultrasound waves.

The ultrasound is directed at the object to be scanned. Different parts of the object reflect the ultrasound by different amounts.

When the reflected ultrasound waves hit the same crystal, it produces a varying electric current that can be detected. This can be built up into a picture using a computer.

4. What are the energy transfers in an ultrasound scanner?

5. You cannot hear ultrasound waves, so how can you be sure they are there?

Did you know...?

Some animals – such as giraffes, whales, hippopotamuses and rhinoceroses – produce infrasound waves to communicate with each other. Elephants produce infrasound waves with their feet. The ground can carry these waves several kilometres to neighbouring herds.

Key vocabulary

infrasound

ultrasound

scan

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Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

☐ Recognise that energy is transferred by a range of different processes.	☐ Interpret and draw energy transfer diagrams for a range of different energy transfers, including gravitational potential energy, elastic potential energy, chemical energy and electrical energy.	☐ Use Sankey diagrams to explain a range of energy changes and demonstrate that all energy is always accounted for.
☐ Identify simple energy transfers that involve gravitational potential energy, elastic potential energy and chemical energy.	☐ Explain how energy is transferred using elastic, gravitational and chemical potential energy.	☐ Analyse changes in gravitational potential energy in different situations, and compare the energy per gram of different fuels.
☐ Recognise that work can be done by a force, and that the work done is equal to the energy transferred.	☐ Calculate the work done in different situations, given the size of the force and the distance moved.	☐ Explain how simple machines transfer energy in a way that offers an advantage.
☐ Recognise what is meant by temperature and how it is measured.	☐ Explain and make predictions about the direction of heat flow in different situations.	☐ Explain the difference between temperature and heat.
☐ Recognise that sound energy is transferred by waves and describe how sound waves are made in different situations.	☐ Explain how longitudinal waves carry sound. Relate the terms frequency and amplitude to sounds.	☐ Interpret and devise wave diagrams to represent different sounds of different wavelength and amplitude.

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☐ Recognise an echo as a reflection of sound.	☐ Describe how to measure the speed of sound, and how the speed of sound can be used in different applications to measure distances.	☐ Use calculations to measure the speed of sound and the distance of objects in different applications, applying ideas about echoes.
☐ Recognise that some materials are good at reflecting sound and others can absorb it.	☐ Use the particle model to explain why sound cannot travel through a vacuum. Explain what is meant by reflection and absorption of sound.	☐ Use the particle model to explain why the speed of sound is different in solids, liquids and gases, and how energy is transferred in the reflection and absorption of sound.
☐ Recognise that different organisms hear differently. Name different parts of the human ear.	☐ Explain how parts of the ear are adapted to enable us to hear. Describe what is meant by the term hearing range.	☐ Compare and contrast the detection of sound by an ear and a microphone.
☐ Describe what is meant by infrasound and ultrasound.	☐ Describe a wide range of applications for ultrasound and infrasound.	☐ Explain why these waves are suitable for their applications.

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Questions

Questions 1–7

See how well you have understood the ideas in the chapter.

1. Which of the following is the unit of energy? [1]

a) kilogram **b)** kilojoule **c)** kilometre **d)** kilohertz

2. Which of the following is not a fuel? [1]

a) petrol **b)** hydrogen **c)** coal **d)** air

3. What is the frequency range of ultrasound? [1]

a) below 20 Hz **b)** between 20 and 20 000 Hz **c)** above 20 000 Hz **d)** there is no range

4. Describe the energy transfer when a ball falls from a height. [2]

5. Describe *two* uses of ultrasound. [2]

6. State *two* ways that energy can be stored. [2]

7. Describe how to measure the speed of sound. [4]

Questions 8–13

See how well you can apply the ideas in this chapter to new situations.

8. Julia's science teacher tells her that ‘energy-efficient’ light bulbs are better to use because they waste less energy as heat. But Julia knows that her mother, who is a farmer, uses old-fashioned filament light bulbs to keep newly hatched chicks warm in winter. Which of these statements is correct?

a) Julia's teacher is right – bulbs that transfer most of the energy as heat are always wasteful.

b) The chicks don't need heat – they just need to see where they are going.

c) Heat is only wasteful if you don't make use of it.

d) Julia's mother should switch to energy-efficient light bulbs.

9. Look at the different waves shown in 1.6.20a. Wave (a) represents a note played in the middle of a piano. Which wave best represents a siren? [1]

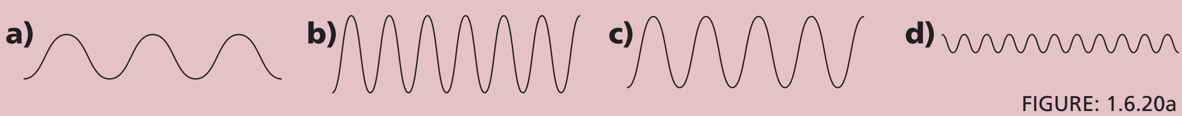

FIGURE: 1.6.20a

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10. Emily's family are moving house. Their lounge is empty, with no curtains, carpets or furniture, and it sounds 'echoey'. Which of these statements is correct?

a) Hard surfaces are good at absorbing sound.
b) Sound travels faster than light.
c) Sound travels faster in an empty room.
d) Soft surfaces such as curtains are good at absorbing sound.

11. A bat sends out an ultrasound signal. It receives an echo just 0.5 seconds later. How far away is its prey? (distance = speed × time; the speed of sound in air is 330 m/s) [2]

12. Describe the energy transfers that occur as a waterfall drives an electricity generator. [2]

13. Figure 1.6.20b shows two different types of lever being used to lift the same load through the same distance.

a) Calculate the work done in each case.
b) Which lever makes the work easier? Explain. [4]

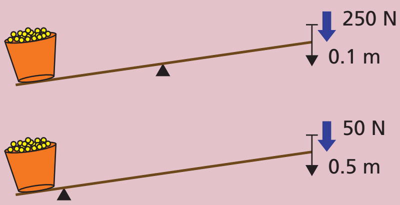

FIGURE 1.6.20b

Questions 14–15

See how well you can understand and explain new ideas and evidence.

14. You are looking for the best possible fuel source for the future. Use the data in the table to make your choice. Give reasons for your answer. [2]

Fuel	Energy per gram (J/g)	State	Harmful products of combustion	Availability
coal	24	solid	carbon dioxide, soot, acid rain	running out
hydrogen	123	gas	none	plenty
petrol	46	liquid	carbon dioxide	running out
biofuel	33	liquid	carbon dioxide	renewable

15. The graph shows how people of different ages have reduced ability to hear certain frequencies. Use your knowledge of the ear and the data in Figure 1.6.20c to prove or disprove the statement 'Hearing loss gets worse as we get older'. [4]

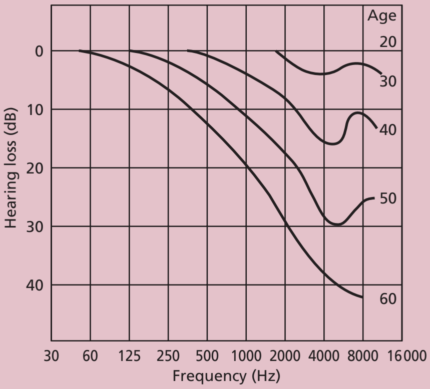

FIGURE 1.6.20c: Hearing loss with age

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