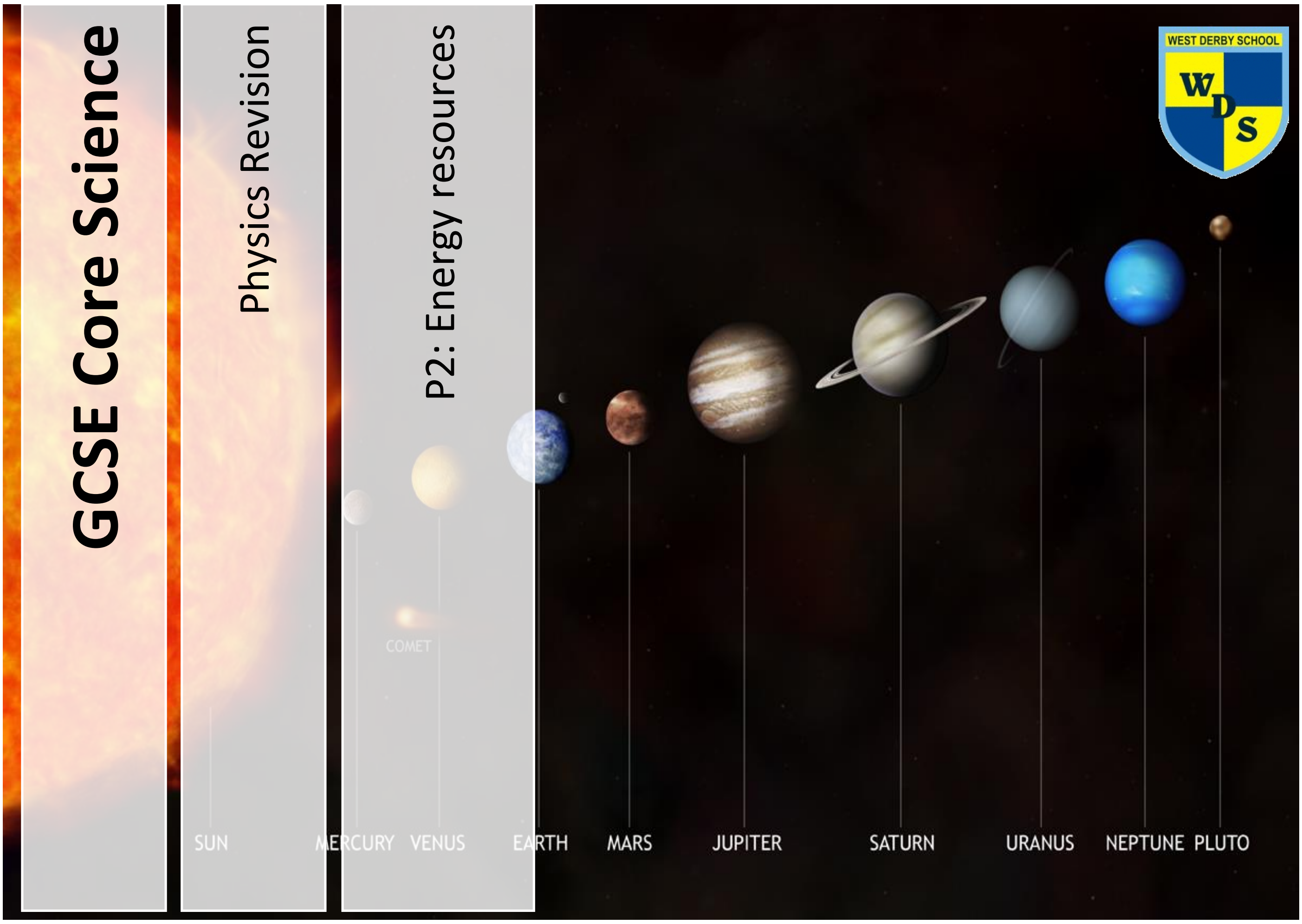


P2: Energy Resources

1. Collecting energy from the Sun

The Sun provides a stable source of heat and light energy. Photocells transfer light into electricity, and glass can provide passive heating for buildings. Wind turbines transfer kinetic energy in the wind into electricity.

Photocells

Solar-powered ticket machine

The Sun is a stable source of energy that is transferred to the Earth as light and heat energy. We can use this energy.

Photocells are devices that transfer light energy directly into electrical energy. They produce DC - **direct current** - electricity. This is electricity in which the current moves in the same direction all the time.

Photocells have no moving parts. They do not need to be connected to the National Grid, so no cables are needed and they can work in remote locations. For example, they are used to power the lights for some road signs.

The output of photocells depends on the surface area that is exposed to light. For a given light intensity, the larger the area, the greater the power output.

The Hubble Space Telescope uses photocells to generate the electricity it needs - image courtesy of NASA

You may have seen photocells in pocket calculators. Very large panels of photocells are used to power satellites in orbit around Earth.

Advantages and disadvantages

Photocells produce no power in bad weather, or at night. But sunlight is a renewable energy resource and photocells do not produce polluting waste while they are in use. Here are some other advantages to photocells:

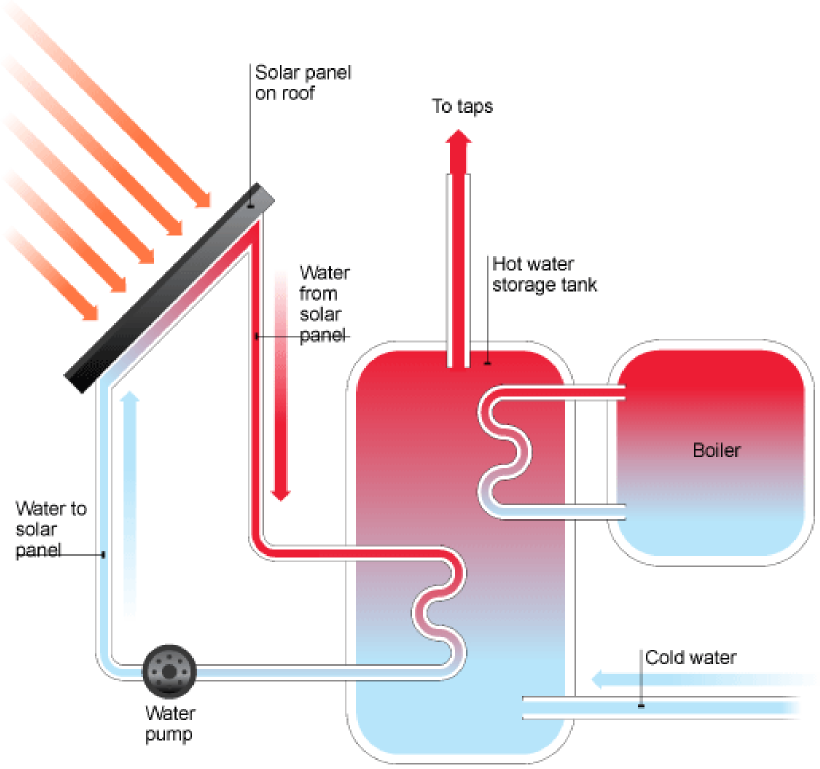
- no fuel is needed
- no power cables are needed
- they have a long life and are rugged - little maintenance is needed.

Solar heating

Glass windows provide **passive solar heating** for buildings. Sunlight passes through the glass and is absorbed by surfaces in the building. It is transferred into heat energy, which is emitted as infrared radiation. This is reflected back into the building by the glass.

Solar panels

Solar panels do not generate electricity - rather they heat up water. They are often located on the roofs of buildings, where they can receive energy from the Sun. The diagram outlines how they work:



Solar panel

A pump pushes cold water from the storage tank through pipes in the solar panel. The water is heated by energy from the Sun and returns to the tank. In some systems, a conventional boiler is used to increase the temperature of the water.

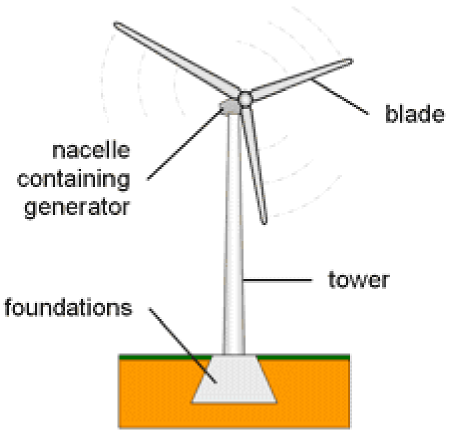
Solar collectors

Solar collectors use mirrors to focus the Sun's rays onto a small area. In some parts of the world this is used to make simple solar ovens to cook food without using fuel. More complex solar collectors use curved mirrors to reflect the Sun's rays onto a focus point.

Wind power

Wind is produced as a result of giant convection currents in the Earth's atmosphere, which are driven by heat energy from the Sun. This means the kinetic energy in wind is a renewable energy resource - so long as the Sun exists, wind will too.

Wind turbines



A wind turbine

Wind turbines have huge blades mounted on a tall tower. The blades are connected to a nacelle, or housing, that contains gears linked to a generator. As the wind blows, it transfers some of its kinetic energy to the blades, which turn and drive the generator.

Several wind turbines may be grouped together in windy locations to form **wind farms**.

Advantages and disadvantages

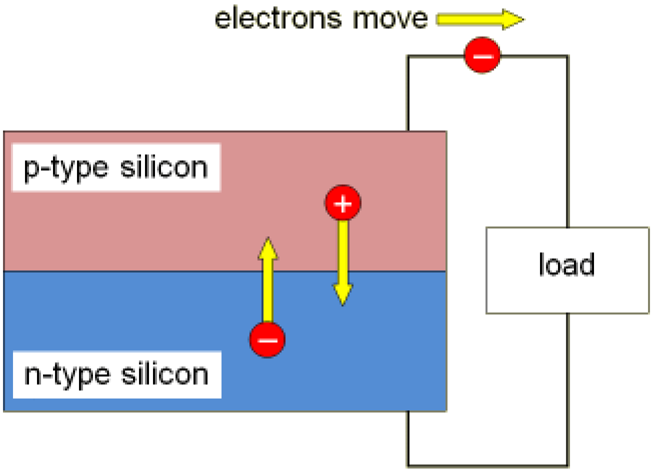
Wind is a renewable energy resource and there are no fuel costs. No harmful polluting gases are produced. On the other hand, wind farms are noisy and may spoil the view for people living near them. The amount of electricity generated depends on the strength of the wind - if there is no wind, there is no electricity.

Solar energy - Higher tier

Photocells

Photocells consist of two types of silicon crystal. When light energy is absorbed by the silicon:

- negatively charged electrons are knocked loose from the silicon atoms in the crystal
- the electrons flow freely, creating an electric current.



Positive 'holes' are also formed, which move in the opposite direction to the electrons

The power output of a photocell increases as the exposed surface area increases. It also increases as the light intensity increases if, for example:

- the light intensity increases
- the light source is brought closer to the photocell.

Solar heating

Passive solar heating works because:

- glass is transparent to the Sun's radiation and lets it pass through to a dark surface
- the dark surface absorbs the Sun's radiation and warms up
- the heated surface emits infrared radiation
- the infrared radiation has a longer wavelength and does not pass through the glass – it is reflected back by it instead.

The position of the Sun in the sky changes during the day because the Earth spins. This means that a solar collector has to track the Sun in the sky. Motors move the collector so that it can remain facing the Sun.

2. Generating electricity

Electricity is generated when a coil of wire moves in a magnetic field. This is the basis of electricity generators. Most electricity is made in power stations by burning fuels.

The dynamo effect

An electric current is produced when a magnet is moved into a coil of wire in a circuit. The direction of the current is reversed when the magnet is moved out of the coil. It can also be reversed if the other pole of the magnet is moved into the coil. Check your understanding of the **dynamo effect** with this simulation:

Notice that no current is induced when the magnet is still, even if it is inside the coil.

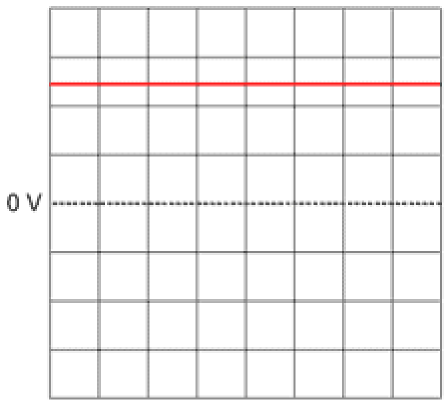
Increasing the induced current

To increase the induced current:

- move the magnet more quickly
- use a stronger magnet
- increase the number of turns on the coil.

DC and AC electricity

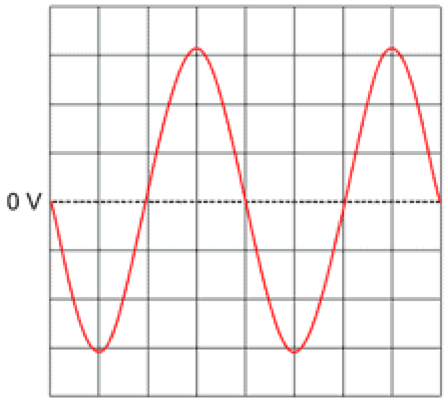
DC electricity



Direct current

If the current flows in only one direction it is called direct current, or DC. Batteries and solar cells supply DC electricity. A typical battery may supply 1.5 V. The diagram shows an oscilloscope screen displaying the signal from a DC supply.

AC electricity



Alternating current

If the current constantly changes direction it is called alternating current, or AC. Mains electricity is an AC supply. The UK mains supply is about 230V. It has a frequency of 50 Hz, which means that it changes direction and back again 50 times a second. The diagram shows an oscilloscope screen displaying the signal from an AC supply.

AC generators

When a wire is moved in a magnetic field, the movement, magnetic field and current are all at right angles to each other. If the wire is moved in the opposite direction, the induced current also moves in the opposite direction.

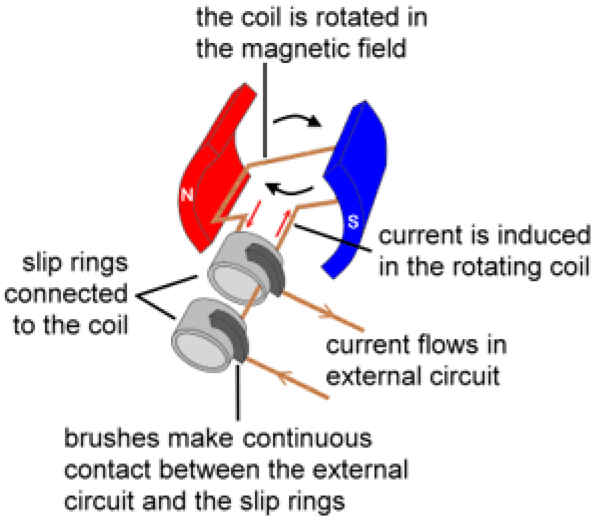
Dynamos

One simple example of a generator is the bicycle dynamo. The dynamo has a wheel that touches the back tyre. As the bicycle moves, the wheel turns a magnet inside a coil. This induces enough electricity to run the bicycle's lights.

The faster the bicycle moves, the greater the induced current and the brighter the lights.

Generators

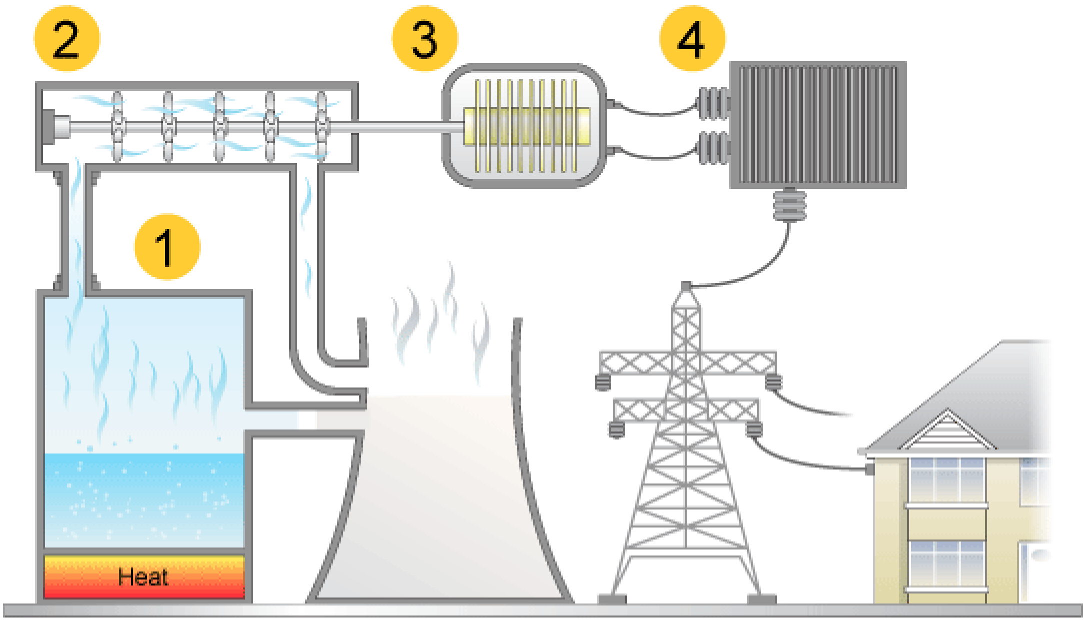
One side of a coil in an AC generator moves up during one half-turn, and then down during the next half-turn. This means that, as a coil is rotated in a magnetic field, the induced current reverses direction every half-turn.



Coil motion in a AC generator

Conventional power stations

About three-quarters of the electricity which is generated in the UK comes from power stations operated by fossil fuels.



Power station

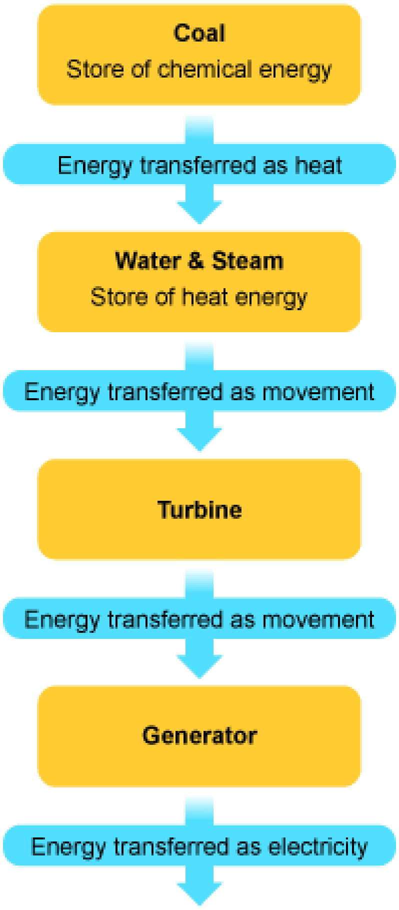
There are four main stages:

1. fuel is burned to boil water to make steam
2. steam makes a turbine spin
3. spinning turbine turns a generator which produces electricity
4. electricity goes to the transformers to produce the correct voltage.

The National grid uses power lines to connect power stations to the consumers. These include homes, factories, offices and farms.

Energy transfers

Power stations generate significant heat losses to the environment. Below is an energy transfer diagram for the generation of electricity from a fossil fuel such as coal:



Energy transfer for the generation of electricity from a fossil fuel

Efficiency

The efficiency of a device or process is the proportion of the energy supplied that is transferred in useful ways. You should be able to calculate efficiency as a decimal or as a percentage.

Calculating efficiency

The efficiency of a power station can be calculated as follows:

- efficiency = useful energy out ÷ total energy in (for a decimal efficiency)
- efficiency = (useful energy out ÷ total energy in) × 100 (for a percentage efficiency)

For example, the coal for a power station contains 10,000 MJ of chemical energy. If the power station can produce 3,800 MJ of electricity from this coal, what is its efficiency?

The efficiency of the power station is 3,800 ÷ 10,000 = 0.38 (or 38 per cent)

This means that 62 per cent of the chemical energy supplied is not usefully transferred. For example, it may be transferred to the surroundings as heat energy and sound energy.

Note that the efficiency will always be less than 100 per cent. You might be given the power in W instead of the energy in J. The equations are the same - just substitute power for energy.

3. Global warming

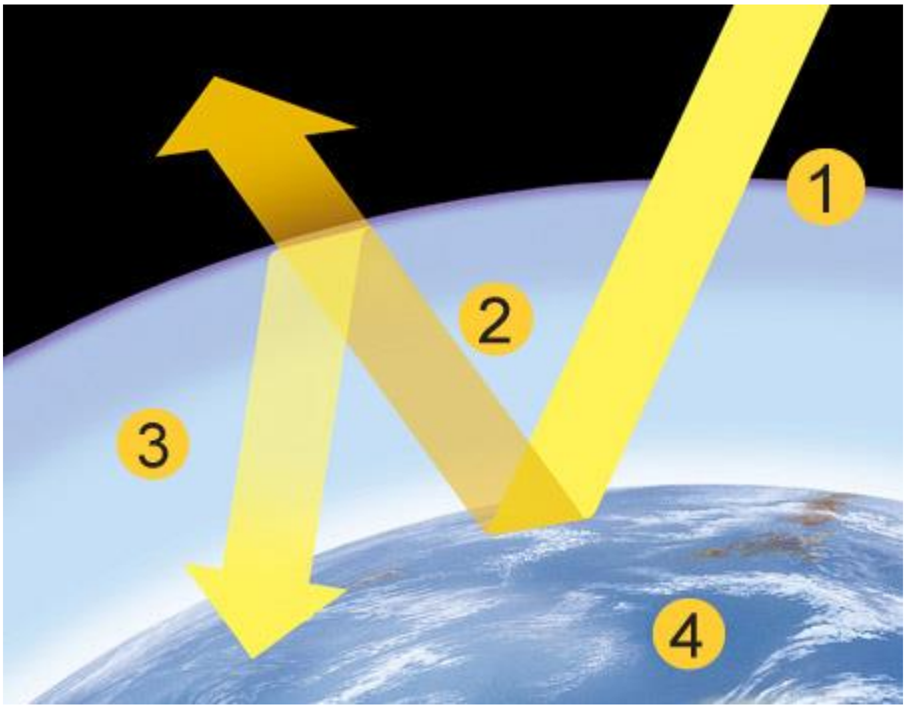
Greenhouse gases such as water vapour, methane and carbon dioxide stop heat escaping from the Earth into space. An increased greenhouse effect can lead to global warming and climate change.

The greenhouse effect

Some gases in the Earth's atmosphere stop heat radiating into space from the Earth. This is called the greenhouse effect and the gases involved are called greenhouse gases. They include:

- methane
- water vapour
- carbon dioxide.

The diagram shows how the greenhouse effect works.



Greenhouse effect

1. Electromagnetic radiation at most wavelengths from the Sun passes through the Earth's atmosphere.
2. The Earth absorbs electromagnetic radiation with short wavelengths and so warms up. Heat is radiated from the Earth as longer wavelength infrared radiation.
3. Some of this infrared radiation is absorbed by greenhouse gases in the atmosphere.
4. The atmosphere warms up.

Global warming

Some sources of greenhouse gases are natural and some are man-made. The table shows some of these sources.

Some sources of greenhouse gas

Greenhouse gas	Natural source	Man-made source
Methane	Decomposing plant material	Rice paddy fields, cattle, coal mines
Water vapour	Evaporation from oceans, lakes and rivers	Burning hydrocarbon fuels
Carbon dioxide	Respiration by plants and animals, forest fires, volcanoes	Making cement, burning fossil fuels

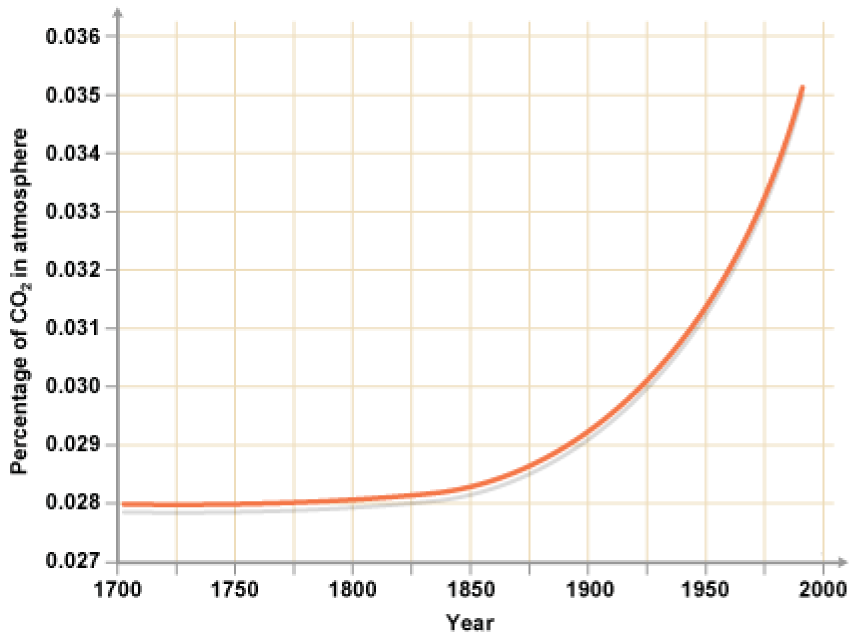
The amount of man-made water vapour is insignificant compared to the amount of water vapour from natural sources. However, emissions of methane and carbon dioxide are contributing to increased global warming.

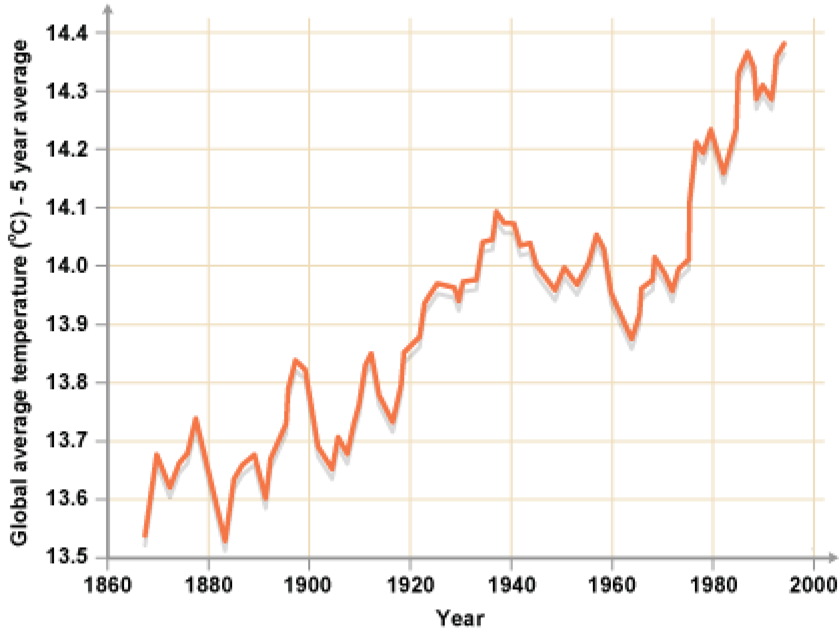
Global warming

Human activities are causing the release of large amounts of carbon dioxide. These activities include:

- deforestation - cutting down trees for fuel, farms, buildings and roads
- increased use of energy (and so an increased use of fossil fuels).

As the percentage of carbon dioxide in the atmosphere has increased, so in general has the Earth's mean temperature.





Climate change

Increased global warming will lead to climate change – changes in the average weather experienced over 30 years or more. Climate change may make it impossible to grow certain food crops in some regions. Melting polar ice, and the thermal expansion of sea water, could cause rising sea levels and the flooding of low-lying land.

Difficulties

There is a good agreement between scientists about how the greenhouse effect works. However, there is less agreement about the extent to which human activities are causing an increased greenhouse effect, and so global warming with its associated climate change. The balance of scientific opinion is that human activities are to blame.

It is not just the release of carbon dioxide and methane that can contribute to global warming. Dust produced from factories goes into the atmosphere that reflects radiation back to the Earth and causing warming too.

However, it is not just human activities that can affect weather patterns and climate. Ash and gases released by volcanic eruptions also go into the atmosphere. They reflect radiation from the Sun back into space, causing cooling. This, and other effects, can make it difficult for scientists who study the atmosphere and global warming.

4. Fuels for power

The heat energy for power stations comes from a variety of sources. Some of these are non-renewable, such as oil, coal, natural gas and nuclear fuels. Others are renewable, such as wood, straw and manure.

The cost of electricity depends on the power rating of the appliance used, how long it is used for, and the price of a unit of electricity.

Fuels for power stations

The common fuels used in power stations include:

- fossil fuels (coal, oil and natural gas)
- nuclear fuels (uranium and, sometimes, plutonium)
- renewable biomass (wood, straw and manure).

Each type of fuels has advantages and disadvantages.

Fossil fuels

Fossil fuels are non-renewable energy resources. Their supply is limited and they will eventually run out. Fossil fuels cannot be replaced once they have been used up.

Fossil fuels release carbon dioxide when they burn, which adds to the greenhouse effect and increases global warming. Of the three fossil fuels, for a given amount of energy released, coal produces the most carbon dioxide and natural gas produces the least.

Coal and oil release sulfur dioxide gas when they burn, which causes breathing problems for living creatures and contributes to acid rain.

Nuclear fuels

Like fossil fuels, nuclear fuels are non-renewable energy resources. If there is an accident, large amounts of radioactive material could be released into the environment. In addition, nuclear waste remains radioactive and is hazardous to health for thousands of years. It must be stored safely.

Unlike fossil fuels, nuclear fuels do not produce carbon dioxide or sulfur dioxide when they are used.

Renewable biomass

Wood, straw and manure are cheap and a readily available source of energy. If trees and crops crops are replaced, biomass can be a long-term, sustainable energy source. However, a lot of land would be needed to produce enough biomass to replace the fossil fuels and nuclear fuels used around the world.

Voltage, current and power

Power is a measure of how quickly energy is transferred. You can work out power using this equation:

power (watt, W) = voltage (volt, V) × current (ampere, A)

The cost of using electricity

You should be able to calculate the cost of using an electrical appliance when given enough information about it.

The unit

The amount of *electrical energy* transferred to an appliance depends on its power and the length of time it is switched on. The amount of mains electrical energy transferred is measured in kilowatt-hours, kWh. One unit is 1kWh.

The equation below shows the relationship between energy transferred, power and time:

energy transferred (kWh) = power (kW) × time (h)

Note that power is measured in kilowatts here instead of the more usual watts. To convert from W to kW you must divide by 1000.

For example, 2000W = 2000 ÷ 1000 = 2kW.

Also note that time is measured in hours here, instead of the more usual seconds. To convert from seconds to hours you must divide by 3600.

For example, 1800s = 1800 ÷ 3600 = 0.5 hours.

The cost

Electricity meters measure the number of units of electricity (the number of kWh) used in a home or other building. The more units used, the greater the cost. The cost of the electricity used is calculated using this equation:

total cost = number of units × cost per unit

For example, if 5 units of electricity are used at a cost of 8p per unit, the total cost will be 5 × 8 = 40p.

The National Grid and transformers

Transformers

A transformer is an electrical device that changes the voltage of an AC supply. A transformer changes a high-voltage supply into a low-voltage one, and vice versa.

- A transformer that increases the voltage is called a step-up transformer.
- A transformer that decreases the voltage is called a step-down transformer. Step-down transformers are used in mains adapters and rechargers for mobile phones and CD players.

The National Grid

When a current flows through a wire, some energy is lost as heat. The higher the current, the more heat is lost. To reduce these losses, the National Grid transmits electricity at a low current. This requires a high voltage.

Power stations produce electricity at 25,000 V. Electricity is sent through the National Grid cables at 400,000 V, 275,000 V and 132,000 V.

Step-up transformers at power stations produce the very high voltages needed to transmit electricity through the National Grid power lines. These high voltages are too dangerous to use in the home, so step-down transformers are used locally to reduce the voltage to safe levels.

5. Nuclear radiations

Radioactive substances give out radiation all the time. There are three types of nuclear radiation - alpha, beta and gamma. Alpha is the least penetrating, while gamma is the most penetrating.

Radiation can be harmful, but it can also be useful. The uses of radiation include smoke detectors, paper-thickness gauges, treating cancer and sterilising medical equipment.

Types of radiation

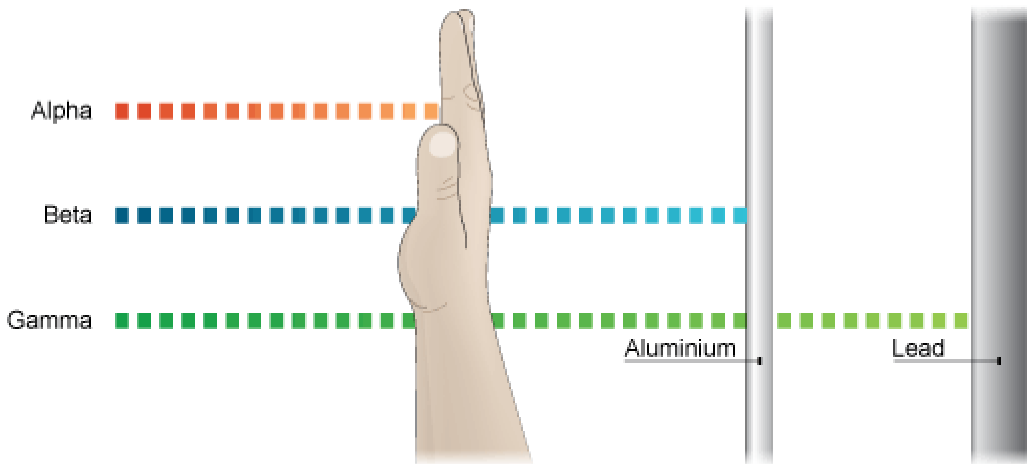
Nuclear radiation comes from the nucleus of an atom. Substances that give out radiation are said to be **radioactive**. There are three types of nuclear radiation:

- alpha
- beta
- gamma.

Radiation can be absorbed by substances in its path. For example, alpha radiation travels only a few centimetres in air, beta radiation travels tens of centimetres in air, while gamma radiation travels many metres. All types of radiation become less intense the further the distance from the radioactive material, as the particles or rays become more spread out.

The thicker the substance, the more the radiation is absorbed. The three types of radiation penetrate materials in different ways.

- Alpha radiation can be stopped by a sheet of paper.
- Beta radiation can penetrate air and paper, but is stopped by a few millimetres of aluminium.
- Gamma radiation can only be stopped by a few centimetres of lead, or many metres of concrete.



Penetrative properties of different types of radiation

Uses of radiation

Nuclear radiation **ionises** materials, and this changes atoms or molecules into charged particles.

- Positive ions are formed when electrons are lost.
- Negative ions are formed when electrons are gained.

Uses of alpha radiation

Ionisation is useful for smoke detectors. Radioactive americium releases **alpha radiation**, which ionises the air inside the detector. Smoke from a fire absorbs alpha radiation, altering the ionisation and triggering the alarm.

Uses of beta radiation

Beta radiation is used to monitor the thickness of materials such as paper, plastic and aluminium. The thicker the material, the more radiation is absorbed and the less radiation reaches the detector. It then sends signals to the equipment that adjusts the thickness of the material.

Handling radioactive materials

You cannot do much to reduce your exposure to natural background radiation, but great care is needed when handling radioactive materials. Precautions include:

- wearing protective clothing
- keeping as far away as is practicable - for example, by using tongs
- keeping your exposure time as short as possible
- keeping radioactive materials in lead-lined containers, labelled with the appropriate hazard symbol.

Radiation warning symbol

Radioactive waste

Uranium is used as a nuclear fuel in nuclear reactors. It is a non-renewable resource. Plutonium is a waste product from nuclear reactors. It is used to make atomic bombs and sometimes as a nuclear fuel in nuclear reactors.

Calder Hall nuclear power station

Waste from nuclear reactors does not cause global warming. On the other hand, it is radioactive and harmful. It needs to be disposed of very carefully.

Disposal

Low-level radioactive waste, such as contaminated gloves, can be disposed of in landfill sites. Higher level waste, which may be dangerously radioactive, is more difficult to dispose of. It can be reprocessed to extract nuclear fuel or encased in glass and left deep underground.

Radiation - Higher tier

Identifying types of radiation

Remember that:

- alpha radiation is stopped by paper
- beta radiation is stopped by a few mm of aluminium but not by paper
- gamma radiation is stopped by a few cm of lead but not by aluminium or paper.

Check your understanding by having a go at this animation. Click on each image of the rock to discover the reading on the radiation meter. Use the readings to confirm that the rock gives out beta radiation.

Ionisation

Radiation can ionise atoms and molecules. It can cause electrons to be lost or gained, leaving charged particles behind. Ionisation can cause chemical reactions to start. For example, traditional photographic film is blackened by radiation. Human cells can be damaged by ionisation.

Advantages and disadvantages of nuclear power

Unlike fossil fuels, nuclear fuels do not produce carbon dioxide or sulfur dioxide.

Like fossil fuels, nuclear fuels are non-renewable energy resources. If there is an accident or a terrorist attack, large amounts of radioactive material could be released into the environment. In addition, nuclear waste remains radioactive and is hazardous to health for thousands of years. It must be stored safely.

6. Exploring our solar system

The Solar System consists of the Sun with planets in orbit around it. Most planets have at least one satellite in orbit around them. Gravity provides the centripetal force needed to keep objects in orbit.

We can explore space using manned or unmanned spacecraft.

What’s in our Universe?

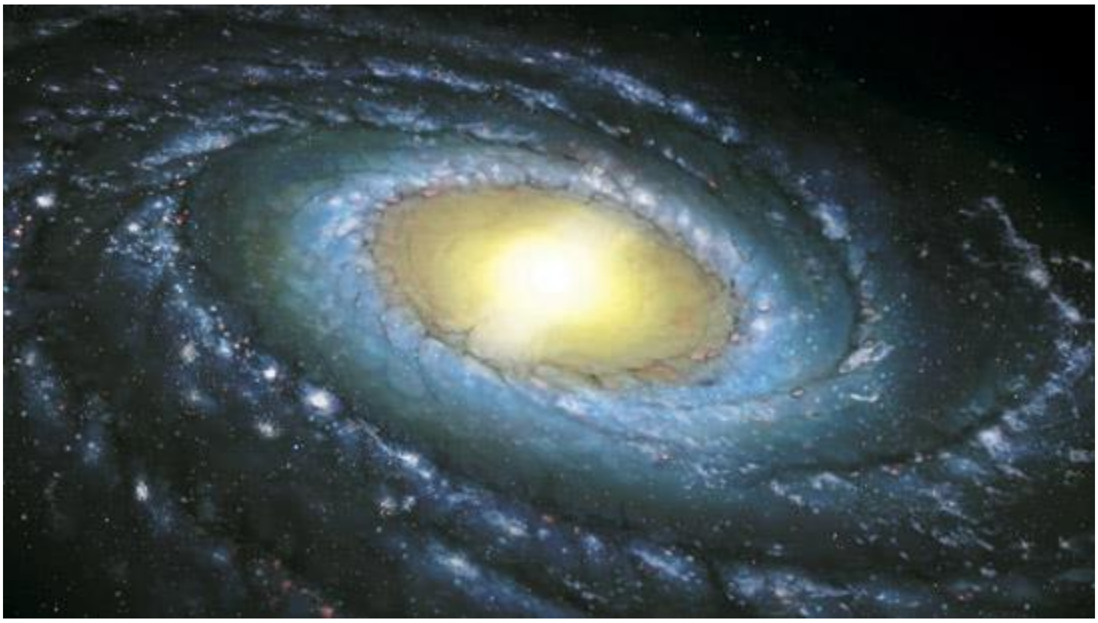
The Universe contains:

- galaxies
- stars
- black holes
- planets
- comets
- meteors.

Galaxies and stars

A star is a huge ball of gas, mostly hydrogen and helium. Nuclear fusion reactions inside the star release enormous amounts of energy. Stars are very hot and give off their own light. This is why we can see the Sun during the day, and distant stars in the night sky.

A galaxy is a large group of many millions of stars. Our Sun is just one of at least 200 billion stars in our galaxy, the Milky Way. The observable universe contains around 80 billion galaxies.



The Milky Way galaxy is home to planet Earth

Black holes

A black hole cannot be seen because light is unable to escape from it. A black hole forms when a large star collapses in on itself because of gravity.

Planets

A planet is a large rocky or gaseous object that orbits a star. Planets are large enough to sweep away any smaller objects in their orbit. Their orbits are almost circular.

Comets

Comets are balls of ice and dust. They are much smaller than planets and their orbit around a star is very elongated, rather than circular.

Meteors

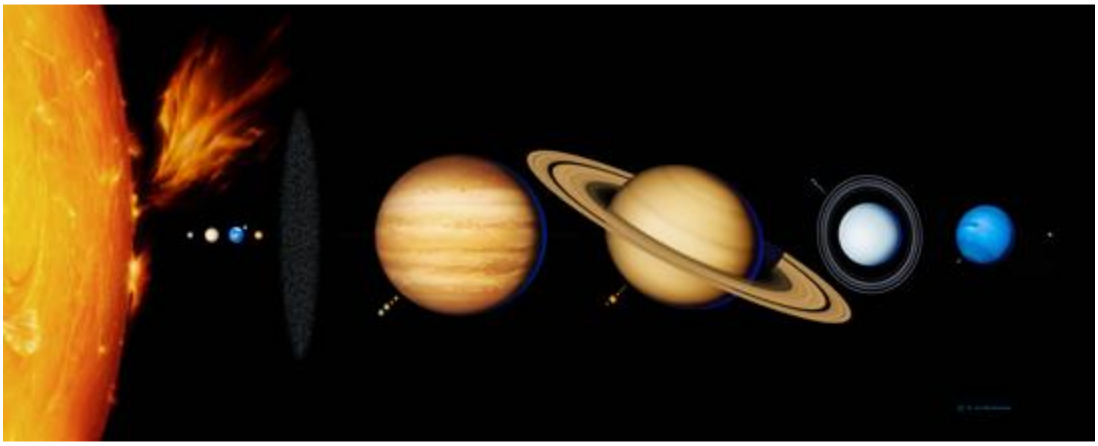
Meteors are small rocks. They burn up if they enter a planet's atmosphere, forming a 'shooting star'.

The Solar System

Solar systems consist of:

- a star
- planets and dwarf planets in orbit around the star
- satellites (moons) in orbit around most of the planets
- comets and asteroids in orbit around the Sun.

The star in our solar system is the Sun. Eight planets orbit the Sun, including the Earth, and smaller dwarf planets such as Pluto, Ceres and Eris.



The Solar System showing from left to right from the Sun - Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto

You need to know the position of the planets in order from the Sun. Starting with the closest to the sun, the order is:

- Mercury
- Venus
- Earth
- Mars

- Jupiter
- Saturn
- Uranus
- Neptune

It may help to remember **M**y **V**ery **E**asy **M**ethod **J**ust **S**peeds **U**p **N**aming.

Exploring space

Stars are very far away from each other. The distances are measured in light years. One light year is the distance that light travels in one year. Since the speed of light in space is about 300,000,000 m/s, this is a very large distance indeed - about 9.5 million million km.

Radio signals also travel at the speed of light. This means that they take a long time to travel through the Solar System. For example, it takes just over one second for a signal to reach the Moon from the Earth, and up to 21 minutes to reach Mars.

Space travel

The space between planets is called interplanetary space. These are some of the conditions there:

- no atmosphere
- the temperature varies from very cold - away from the sunshine - to very hot - in sunshine
- the gravitational field strength is close to zero, so objects are effectively weightless
- there is a lot of cosmic radiation - radiation from the Sun and distant objects in space.

If astronauts are to explore space, scientists and engineers must design systems to protect them from these conditions. Spacecraft provide the conditions needed for astronauts to survive. They provide:

- an atmosphere and equipment to remove waste gases such as carbon dioxide
- insulation and heating to provide a suitable temperature for life
- exercise equipment to reduce the effects of weightlessness, such as weakened bones

The walls and windows of spacecraft are designed to withstand the impact of 'micrometeorites' (tiny pieces of fast-moving rock). But they cannot protect astronauts from all the cosmic radiation in space, which can cause cancer. This limits how long a mission can last without damaging the health of the astronauts.

Space probes

Space probes are spacecraft that can visit other planets without the need for astronauts. They can send back information about things such as the:

- temperature, magnetic field strength and radiation levels

- gravitational field strength
- the surroundings, including the composition of any atmosphere.

Some of the missions undertaken by such craft include:

- **Viking 1** and **Viking 2** (landed on Mars in the 1970s, took photographs and analysed soil samples)
- **Mars Global Surveyor** (went into orbit around Mars in 1997 and mapped the surface in 3D)
- **Spirit** and **Opportunity** (two robot vehicles that landed on Mars in 2004).

Unmanned space probes do not need to carry food, water or oxygen. They can withstand conditions that would be lethal to astronauts.

Image of NASA Spirit robot vehicle courtesy of NASA

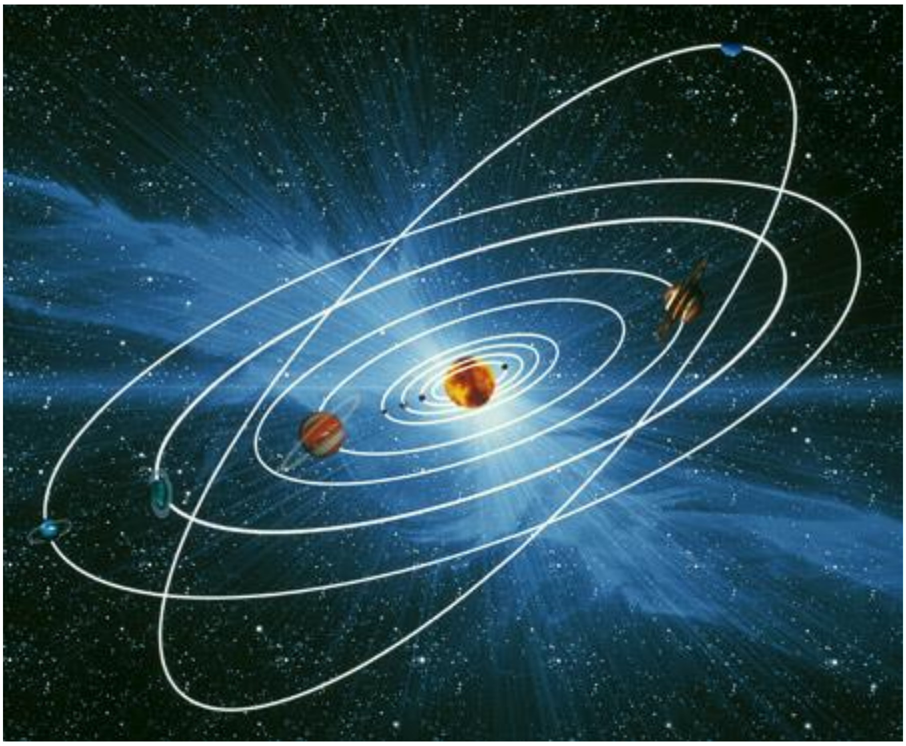
Manned vs unmanned spacecraft

Unmanned spacecraft are cheaper than manned spacecraft, and safer, as they do not carry any astronauts. It is very difficult to repair an unmanned spacecraft in Earth's orbit, and impossible once it leaves orbit. So the components are designed to be rugged and reliable. But history shows that systems in unmanned spacecraft do fail. This may mean that parts of the mission cannot be completed. Sometimes the whole mission is lost.

Gravity and orbits - Higher tier

Identifying the type of radiation

The orbits of the planets in the Solar System are almost circular, with the Sun near the centre. Many diagrams (including these here) show the orbits very squashed from top to bottom. This is to give a sense of perspective, or to fit the diagram into a page in a book.



The orbits of the eight planets and Pluto

Circular motion requires a centripetal force. Without it, the object will fly off in a straight line. The Sun's gravity keeps the planets, dwarf planets, comets and asteroids in orbit. The gravity of a planet keeps its satellites in orbit.

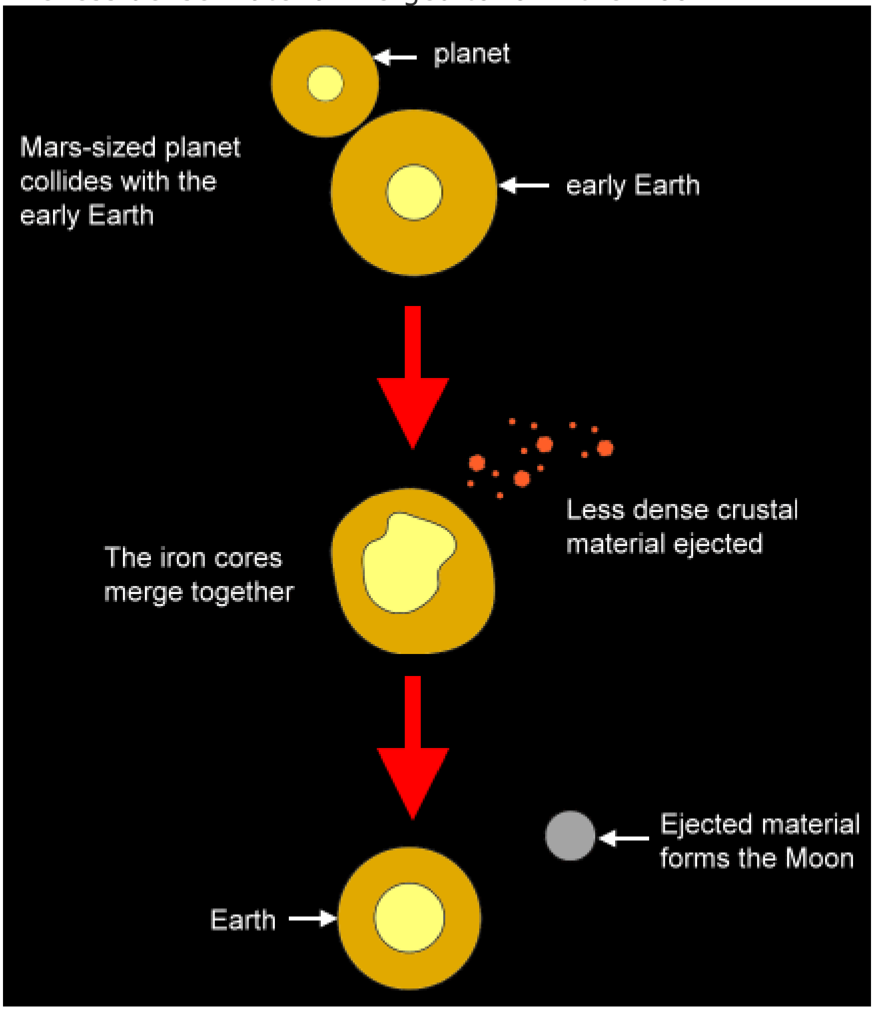
7. Threats to Earth

The Moon may be the remains of a planet that collided with the Earth during the early years of the Earth's existence. Asteroids are rocks in space, while comets are balls of dust and ice in space. There would be serious consequences if a large asteroid collided with the Earth.

The Moon

The Moon is the Earth's natural satellite. It may be the remains of a Mars-sized planet that collided with the early Earth as it was forming billions of years ago.

- The iron cores of the two planets merged.
- Less dense material was ejected by the collision.
- The less dense material merged to form the Moon.



How the moon was formed.

Evidence for collision

Here is some evidence for the collision theory.

- The Earth has a relatively large iron core but the Moon has a much smaller one.
- Moon rocks from the crust are similar in composition to rocks found on Earth.

Asteroids

Asteroids are smaller than planets. They are rocks left over from the formation of the Solar System. Most are found in an 'asteroid belt' in orbit around the Sun between Mars and Jupiter. The minor planet Ceres is found here, too.

Asteroids can crash into each other. When they do, they can break apart and change orbit.

The orbits of some asteroids cross the Earth's orbit. At various times during the Earth's history, asteroids have hit it. A tremendous amount of energy was released, throwing up billions of tonnes of dust and hot rocks. Together with smoke from widespread fires, this blocked heat and light from the Sun. It changed the Earth's climate, making it very cold.

It is thought that an asteroid colliding with the Earth helped to drive the dinosaurs to extinction. Scientists worry that an asteroid could hit again and cause a global catastrophe. The chances of this happening are very small, but the damage caused by a large asteroid would be huge.

Comets

Comets are balls of ice and dust that orbit the Sun. Their orbits are different to those of planets: they are highly **elliptical** (an oval).

A comet's orbit takes it very close to the Sun, then far away, beyond the planets. The time to complete an orbit varies - some comets take a few years, others millions of years.

The speed of a comet increases as it approaches the Sun. This is because the strength of gravity increases.

Comets are often visible from Earth when they get close to the Sun. This is because the Sun's heat vaporises material from their surface, forming a tail of debris.

NEOs and collisions with Earth

An NEO is a **N**ear **E**arth **O**bject. Asteroids or comets on a possible collision course with the Earth are NEOs.

NEOs are difficult to observe because they are smaller, and darker, than planets. But scientists are actively observing many with telescopes. It is possible to calculate the **trajectory** (path) of an NEO if enough observations are taken over time.

Evidence for past collisions with Earth

Asteroid collisions leave craters behind. These are obvious on the Moon, but on the Earth craters are usually eventually weathered away or covered over by natural processes.

Other evidence for past impacts comes from studying layers of rock built up over millions of years. For example, some adjacent layers show abrupt changes in the type and number of fossils. This shows the possible effect on living organisms of an asteroid hitting the Earth.

Iridium is a rare metallic element on Earth, but it is relatively abundant in space. There is a layer of iridium-rich rock dating from around 65 million years ago. This is evidence of an asteroid collision.

Comets and asteroids - Higher tier

The asteroid belt

Most asteroids lie in the asteroid belt located between Mars and Jupiter.

Jupiter is a very large planet with a very large gravitational field strength. Its gravity stops rocks from coming together to form a planet. Instead, they orbit the Sun as asteroids.

Reducing the threat of NEOs

Scientists are searching for NEOs using telescopes. Over 4,000 have been detected, varying in size from a few metres to over a kilometre across. NEOs could also be monitored using satellites.

If an NEO were to be detected on a collision course with Earth, it may be possible to deflect the NEO using explosions. If enough force could be applied early enough, the NEO could be nudged into a different trajectory that missed the Earth. NASA’s Deep Impact mission in 2005 showed that we can send a probe to an asteroid and hit it.

8. The Big Bang

Scientists believe the Universe began in a hot 'big bang' about 13,600 million years ago. The Universe continues to expand today. The evidence for the Big Bang theory includes the existence of a microwave background radiation, and red-shift. Stars do not remain the same, but change as they age.

The Big Bang theory

Scientists have gathered a lot of evidence and information about the Universe. They have used their observations to develop a theory called the Big Bang. The theory states that about 13.7 billion years ago all the matter in the Universe was concentrated into a single incredibly tiny point. This began to enlarge rapidly in a hot explosion, and it is still expanding today.

Evidence for the Big Bang includes:

- all the galaxies are moving away from us
- the further away a galaxy is, the faster it is moving away.

These two features are found in explosions - the fastest moving objects end up furthest away from the explosion.

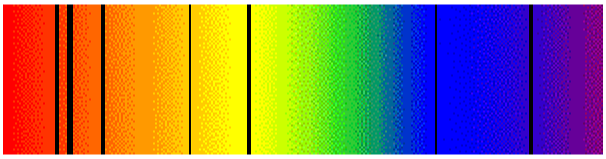
Scientists have also detected a cosmic microwave background radiation or CMBR. This is received from all parts of the Universe and is thought to be the heat left over from the original explosion.

Evidence for the Big Bang - Higher tier

Red-shift

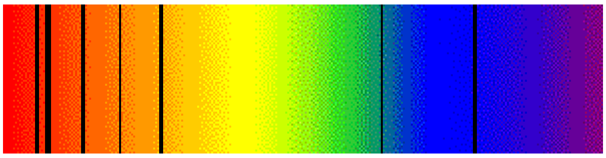
You may have noticed that when an ambulance or police car goes past, its siren is high-pitched as it comes towards you, then becomes low-pitched as it goes away. This effect, where there is a change in frequency and wavelength, is called the Doppler effect. It happens with any wave source that moves relative to an observer.

This happens with light, too, and is called 'red-shift'. Our Sun contains helium. We know this because there are black lines in the spectrum of the light from the Sun where helium has absorbed light. These lines form the absorption spectrum for helium.



Spectrum of the sun

When we look at the spectrum of a distant star, the absorption spectrum is there, but the pattern of lines has moved towards the red end of the spectrum, as you can see below:



Spectrum of a distant star

This is called **red-shift**. It is a change in frequency of the position of the lines.

Astronomers have found that the further from us a star is, the more its light is red-shifted. This tells us that distant galaxies are moving away from us, and that the further away a galaxy is, the faster it is moving away.

Since we cannot assume that we have a special place in the Universe, this is evidence for a generally expanding Universe. It suggests that everything is moving away from everything else

Interpreting the evidence

Summary of some of the evidence of the Big Bang and its interpretation

Evidence	Interpretation
light from other galaxies is red-shifted	other galaxies are moving away from us
The further away the galaxy, the more its light is red-shifted	The most likely explanation is that the whole Universe is expanding and this supports the theory that the start of the Universe could have began with a single explosion

The birth of a star

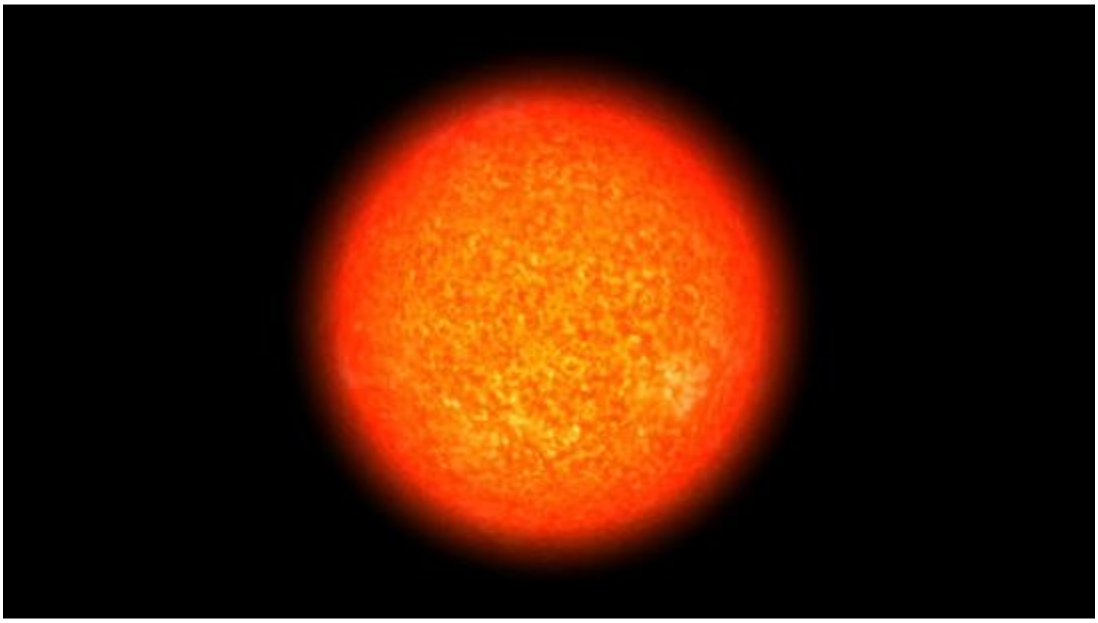
You are expected to know how stars are formed.

Dust and gas

Stars form from massive clouds of dust and gas in space.

Gravity pulls the dust and gas together.

As the gas falls together, it gets hot. A star forms when it is hot enough for nuclear reactions to start. This releases energy, and keeps the star hot. The outward pressure from the expanding hot gases is balanced by the force of the star's gravity. Our sun is at this stable phase in its life. Gravity pulls smaller amounts of dust and gas together, which form planets in orbit around the star.



The Sun is halfway through its 10 billion year stable phase

The Sun is halfway through its 10 billion year stable phase.

Changing models of the Universe

The explanations and models for the shape and size of the Universe have changed over time. They have developed as new evidence has been found, and technology has advanced. For example, astronomers do not just have telescopes that detect visible light. They have telescopes sensitive to other parts of the electromagnetic spectrum, such as gamma rays, radio waves and X-rays.

Ptolemy

Ptolemy was a Greek philosopher who lived almost 2000 years ago. He believed that the Universe was arranged rather like layers of an onion, with the Earth at the centre and the stars at the outermost layer.

Copernicus

Five hundred years ago, Copernicus suggested that the Earth was not the centre of the Universe. Instead, he suggested that the Sun was at the centre of a solar system, with the Earth and other planets in orbit around it. This was a very different idea to Ptolemy's theory and it was not widely accepted.

Galileo

Around a hundred years after Copernicus, the Italian physicist, astronomer and philosopher Galileo used telescope observations to support Copernicus' theory. Unfortunately for Galileo, the Catholic Church was very powerful at the time and it did not support the idea that the Earth was not at the centre of the Universe. Galileo was tried for heresy and sentenced to house arrest for the rest of his life. It took many years for the ideas of Copernicus and Galileo to be widely accepted.