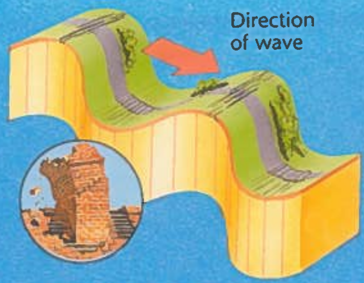
LIGHT, SOUND AND ELECTRICITY

WAVES

All **waves** carry energy. There are two main types of waves – mechanical and electromagnetic. **Mechanical waves**, including water waves and sound waves, are vibrations in a solid, liquid or gas. Electromagnetic waves, such as light waves and radio waves, are vibrations of a different kind. For more about these waves see pages 212-213.



Earthquakes are waves that travel through rock. The vibrations can be strong enough to destroy buildings.

TRANSFERRING ENERGY

Any substance through which waves travel is called a **medium**. Water, glass and air are different types of medium. A mechanical wave carries energy through a medium by making its particles vibrate. Each vibrating particle makes its neighbor vibrate, so passing the energy through the substance.

Waves such as those shown in the pictures below are caused by the water's particles vibrating up and down. The particles don't travel onwards with the wave.

*

Like the water particles themselves, the bird isn't moved forward by the passing wave.

A wave does not permanently disturb the medium it travels through. Each particle gradually stops vibrating and settles in its original position.

*

The particles in a wave vibrate less as they lose energy, and the water becomes still.

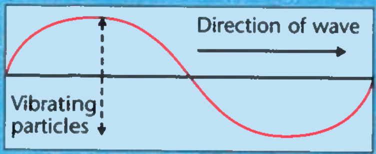
As these droplets fall into the water, waves spread out in a circle, carrying energy away from the disturbed area.

The ripples on this pond are water waves. As they move away from the source of the disturbance they lose energy, and so become smaller.

TYPES OF WAVES

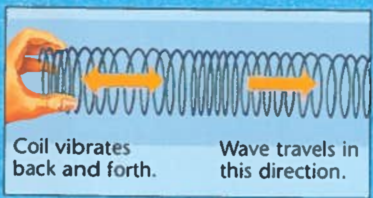
All waves can be described as either transverse or longitudinal, depending on the direction of their vibrations.

Transverse waves are waves in which the particles vibrate at right angles to the direction the wave is traveling. Water waves are transverse waves.



Particles in a transverse wave vibrate at right angles to the direction of the wave.

In **longitudinal waves**, the particles vibrate in the same direction as the wave is traveling. The particles of the medium vibrate forward and backward, acting like the coils in a spring as they are squeezed together and then spread out. Sound waves are longitudinal waves.



The coils in this moving spring show how longitudinal waves travel.

MEASURING WAVES

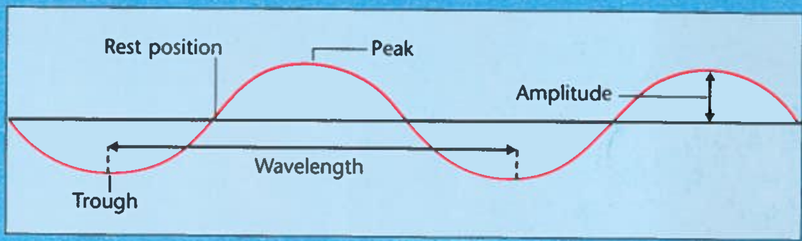
Transverse waves create a regular pattern of high points, called **peaks**, and low points, called **troughs**. A complete wave is known as a **cycle**. It has one peak and one trough.

The number of complete waves that pass a point in one second is called the **frequency**. This is measured in **hertz (Hz)**, named after the German scientist, Heinrich Hertz (1857-1894), who was the first person to discover and use radio waves.

The distance between a point on one wave and the same point on the next, for example, between two troughs, is called the **wavelength**.

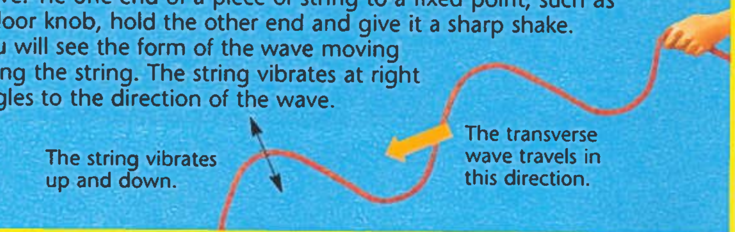
The height from a particle's rest position to a peak is called **amplitude**. This becomes less as a wave moves away from its source and loses energy.

A wave is measured by its frequency, wavelength and amplitude.



See for yourself

You can use this experiment to see the form of a transverse wave. Tie one end of a piece of string to a fixed point, such as a door knob, hold the other end and give it a sharp shake. You will see the form of the wave moving along the string. The string vibrates at right angles to the direction of the wave.



Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Watch animated explanations of waves and calculate their measurements.

Website 2 Follow an online lesson on how waves behave then try a test-yourself quiz.

Website 3 Watch animations that show how seismic waves affect fault zones in the Earth's crust and cause earthquakes.

Website 4 Find out more about earthquakes and how seismic waves are measured, with animations and diagrams.

Website 5 Learn about types of waves and their properties in an online lesson, with quizzes to test your knowledge.

Website 6 Watch animations about ocean waves and how they behave.

Website 7 More about ocean waves, with pictures and an online quiz.

Website 8 Definitions of waves and their characteristics, with a mini quiz and animations.

WAVE BEHAVIOR

When a wave hits an obstacle, or passes from one substance (medium) to another, it can change in speed, direction or shape. Before the change, the wave is called the **incident wave**. The examples on these pages show water waves, but all waves behave in the same way.

Tsunami are giant waves that slow down and rapidly increase in height as they enter shallow water.

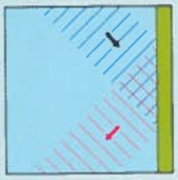
REFLECTION

When an incident wave hits an obstacle, for example when a water wave hits a sea wall, it bounces back. This is called **reflection**. The wave is reflected back at an angle equal to its angle of approach. It is then called a **reflected wave**.

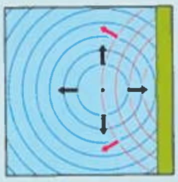
*

The angle of reflection of a wave is the same as the angle of approach of the incident wave.

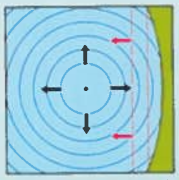
The shape of a reflected wave depends both on the shape of the incident wave and the shape of the obstacle it hits. The diagrams below show what happens when straight and curved incident waves hit differently shaped obstacles.



Straight waves hitting a straight barrier produce straight reflected waves.



Circular waves hitting a straight barrier produce circular reflected waves.



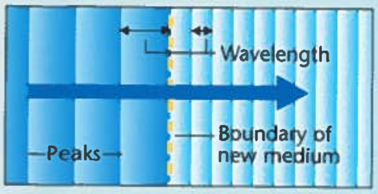
*

Circular waves hitting an inward-curving barrier produce straight reflected waves.

Waves at sea are relatively straight. As they approach the shallow waters of a beach, they bend until they match the curves of its shoreline. This is an example of refraction.

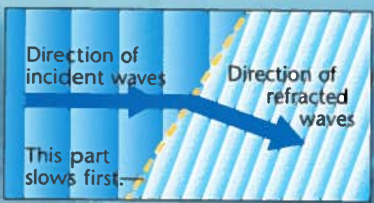
REFRACTION

When an incident wave enters a new medium it changes speed. Its wavelength* changes, but its frequency* doesn't. In the diagram below, the waves slow down in the new medium. Their wavelength gets shorter, but the number of peaks passing in a second (the frequency) stays the same.

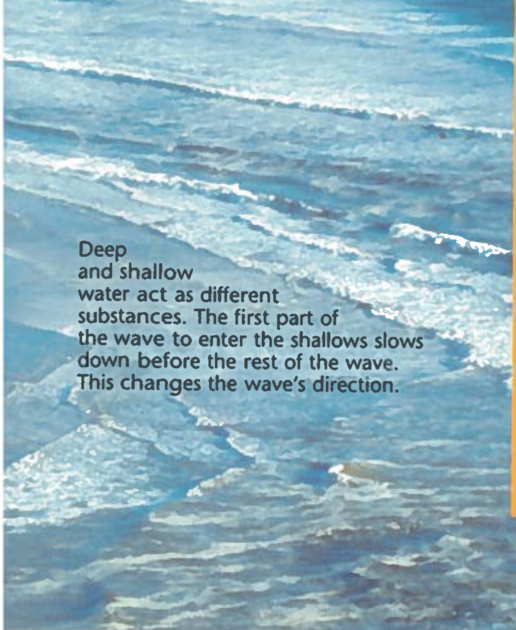


Waves change speed as they enter a new medium. *

If a wave enters a new medium at an angle, it changes both speed and direction. This is called **refraction**. A wave that has undergone refraction is called a **refracted wave**.



Waves change speed and direction as they enter a new medium at an angle. *



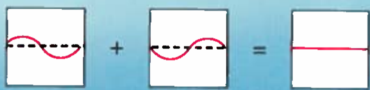
Deep and shallow water act as different substances. The first part of the wave to enter the shallows slows down before the rest of the wave. This changes the wave's direction.

INTERFERENCE

If two or more waves meet, they have an effect on each other. This effect is called **interference**. The kind of interference depends on which parts of the waves coincide.

If two peaks of the same amplitude* arrive in the same place at the same time, they combine to form a peak twice as large. This is an example of **constructive interference**.

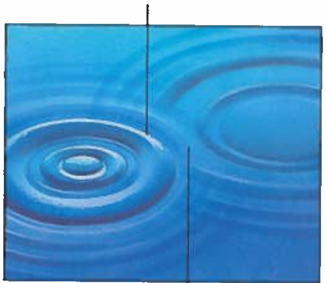
If a peak meets a trough of the same size, they cancel each other out and the wave disappears. This is an example of **destructive interference**.



See for yourself

To see wave interference, hold a small pebble in each hand and drop them, at the same time, into a bath filled with water. The ripples made by the pebbles will move out in circles. Where they cross each other you might see, very briefly, both constructive and destructive interference.

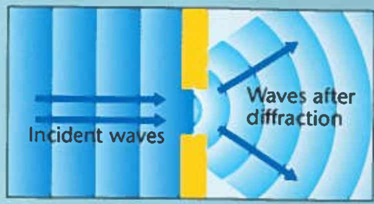
Constructive interference



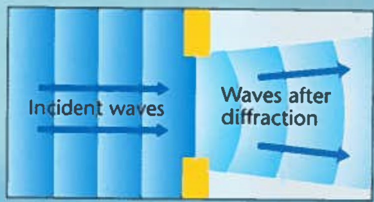
Destructive interference

DIFFRACTION

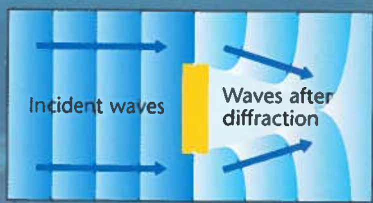
When an incident wave passes through a gap, it spreads out and bends. This is an example of **diffraction**. The smaller the gap compared to the wavelength of the wave, the more it is diffracted.



A wave passing through a gap smaller than its wavelength is diffracted a lot.



A wave passing through a gap larger than its wavelength is hardly diffracted at all.



Waves can also be diffracted when striking the edge of an obstacle. *

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Watch how waves behave and experiment online with reflection, refraction and diffraction.

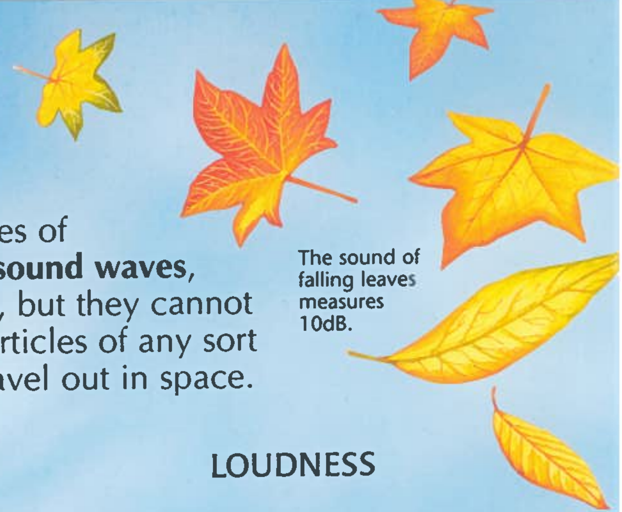
Website 2 Follow an online lesson with lots of animations that help to demonstrate interference.

Website 3 An interactive lesson on how waves behave.

Website 4 Review wave behavior and find out more about interference.

* *Amplitude, Frequency, Wavelength, 203.*

SOUND



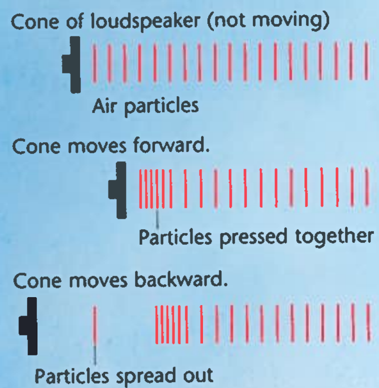
Sound is a form of energy carried by waves of vibrating particles. These waves, called **sound waves**, can travel through solids, liquids and gases, but they cannot travel through a vacuum as there are no particles of any sort to vibrate. For this reason, sound cannot travel out in space.

The sound of falling leaves measures 10dB.

SOUND WAVES

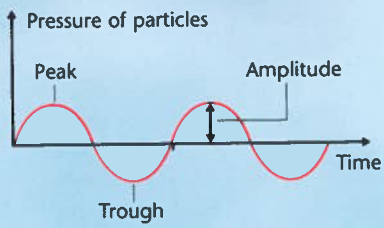
Sound waves are longitudinal waves. This means that the particles vibrate in the same direction as the wave travels.

For instance, inside a loudspeaker a paper cone vibrates forward and backward, sending sound energy into the air. As the cone moves forward, it presses together air particles in front of it. As it moves backward, it leaves an area where the particles are more spaced out.



Sound waves can be shown as a wavy line. The peaks show where particles have been squashed. The troughs show where particles are spread out. Wave diagrams show the number of waves per second (frequency) and their strength (amplitude).

Diagram showing sound waves



Wave frequency is measured in hertz (Hz). Sound waves with frequencies between about 20 and 20,000 hertz can be heard by the human ear and are commonly described as sound. Sound waves below this range are known as **infrasound**, and above it are **ultrasound**.

High sounds, such as birdsong, have high-frequency waves.

Low sounds, such as the rumble made by the engine of a heavy truck, have low-frequency waves.

See for yourself

You can feel sound vibrations with a balloon and a radio. Turn on a radio and hold a balloon about 4in away from the speaker. The vibrations of the sounds make the air in the balloon vibrate.

LOUDNESS

Loud sounds are waves with a large amplitude. Soft sounds are waves with a small amplitude. As a sound travels further away from its source, the amplitude becomes smaller and so the sound becomes quieter.

The loudness of sound is measured in **decibels** (**dB**). The blue whale is the loudest animal in the world. It makes sounds of up to 188dB.

Aircraft make such loud sounds that ground crew wear ear protectors to avoid hearing damage.

SPEED OF SOUND

Sound waves travel at different speeds in different substances. They travel more quickly in solids than in liquids, and more quickly in liquids than in gases.

The speed of sound waves as they travel through dry air at 0°C is 331 meters per second. This speed increases if the air temperature goes up, and decreases if the temperature of the air goes down.

A speed that is faster than the speed of sound in the same conditions is known as a **supersonic speed**. One that is slower is a **subsonic speed**.

As it reaches supersonic speed, an aircraft makes a deafening bang called a **sonic boom**. In this photo, the sound waves can be seen as they disturb the misty air.

The sound of an aircraft landing measures about 120dB.

ECHOES

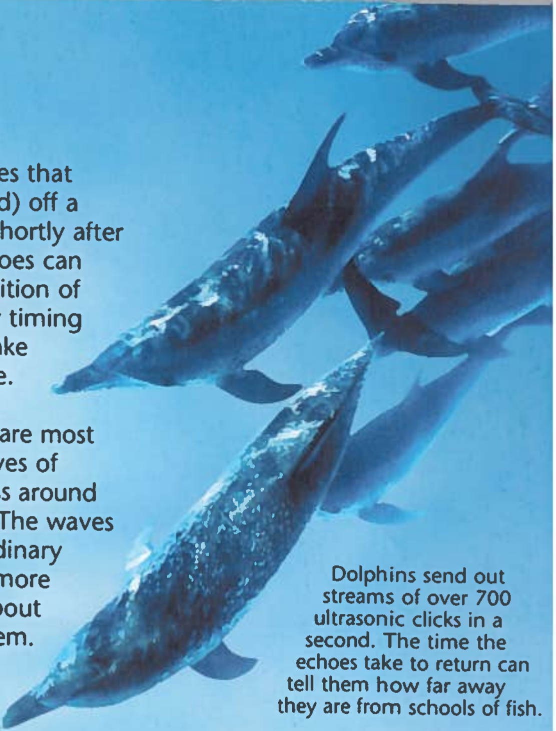
Echoes are sound waves that have reflected (bounced) off a surface and are heard shortly after the original sound. Echoes can be used to find the position of objects. This is done by timing how long the echoes take to return to their source.

Ultrasonic sound waves are most often used because waves of high frequency bend less around obstacles in their path. The waves spread out less than ordinary sound waves and give more accurate information about the surface reflecting them.

When animals such as bats and dolphins use echoes, it is called **echo location**. They use it to find their way around or to locate prey.

Sonar is the name given to the method used by ships to measure the depth of sea water, or to detect underwater objects, such as shipwrecks or schools of fish. The echoes are detected by equipment on board the ship.

Ultrasound waves sent from the ship bounce off the wreck. A computer times the echoes to find the wreck's position.



Dolphins send out streams of over 700 ultrasonic clicks in a second. The time the echoes take to return can tell them how far away they are from schools of fish.

Echoes are also used in **ultrasound scanning** to see inside the body – for example to check on the growth of an unborn baby inside its mother. Bone, muscle and fat all reflect ultrasonic waves differently. A computer uses this information to make a picture.

Ultrasound scan of an unborn baby

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Follow an animated guide to sound and sound waves.

Website 2 Online sound experiments.

Website 3 Find out more about sonic booms and what causes them, then try an online challenge.

Website 4 Listen to and compare the sounds made by bats and dolphins.

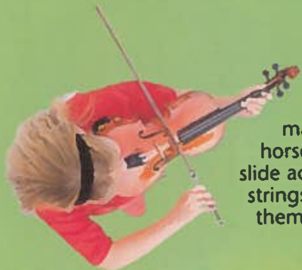
MUSICAL INSTRUMENTS

Musical instruments work by making sound waves. The shape and size of the instrument and the material of which it is made affect the sound. Some instruments have a soundbox that **resonates**. This means that it vibrates at the same frequency as the air vibrations created by the original sound, making the sound fuller and richer.

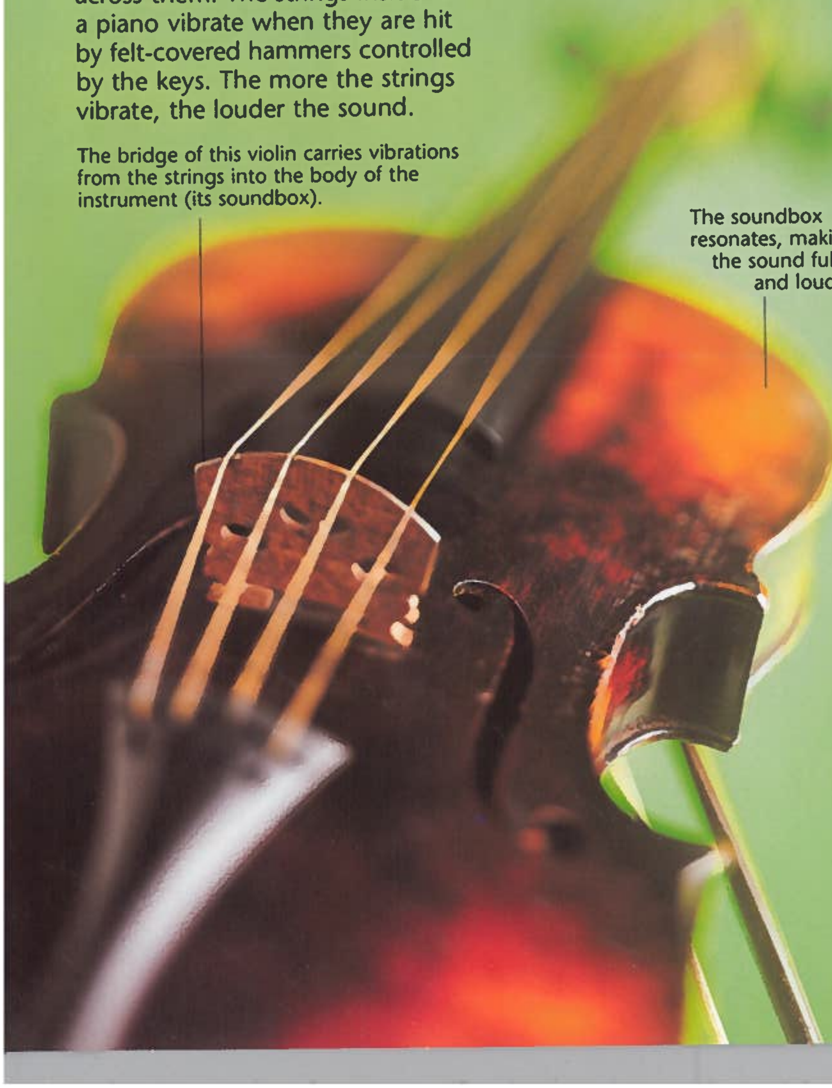
A French horn is a wind instrument. Air vibrates inside it, making sound.

TYPES OF INSTRUMENTS

Musical instruments can be divided into groups depending on the way they make sounds. **Stringed instruments**, such as harps and violins, have stretched strings that vibrate when you pluck or slide a bow across them. The strings inside a piano vibrate when they are hit by felt-covered hammers controlled by the keys. The more the strings vibrate, the louder the sound.



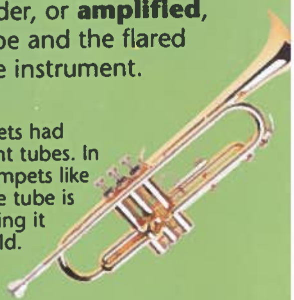
The bow strings are made of horsehairs. They slide across the strings, making them vibrate.



The bridge of this violin carries vibrations from the strings into the body of the instrument (its soundbox).

The soundbox resonates, making the sound fuller and louder.

Wind instruments work by making a column of air vibrate inside them. The vibrations are produced in different ways. For example in a trumpet, the player's lips vibrate in a cup-shaped mouthpiece. This sound is then made louder, or **amplified**, by the tube and the flared end of the instrument.



Early trumpets had long, straight tubes. In modern trumpets like this one, the tube is coiled, making it easier to hold.

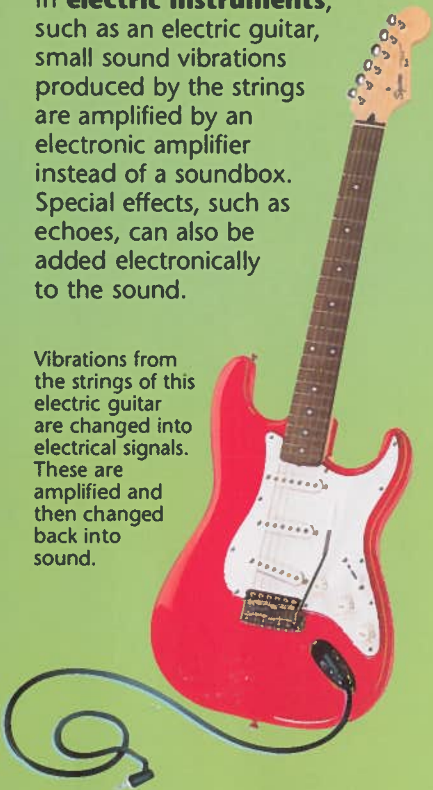
Clarinets and oboes have a mouthpiece that contains one or two pieces of reed. These vibrate as air is blown past them.

Percussion instruments produce sound when they are beaten, scraped or shaken. A drum, for example, has a tight skin which you beat with your hand or a stick. The vibrations make the air inside the drum vibrate, and the hollow shape of the drum amplifies the sound.

The vibrations of a drum skin resonate inside the drum and are amplified.

ELECTRIC INSTRUMENTS

In **electric instruments**, such as an electric guitar, small sound vibrations produced by the strings are amplified by an electronic amplifier instead of a soundbox. Special effects, such as echoes, can also be added electronically to the sound.



Vibrations from the strings of this electric guitar are changed into electrical signals. These are amplified and then changed back into sound.

SYNTHESIZED SOUND

A **sound synthesizer** is an instrument that stores sound waves as binary code* in its electronic memory. The synthesizer can reproduce a sound by converting the code for the sound into an electric current and sending it to a loudspeaker.

The sounds of musical instruments, as well as other noises, such as dogs barking, can be stored as binary code and reproduced by a synthesizer.

This keyboard synthesizer contains binary code for the sound waves of many different instruments.

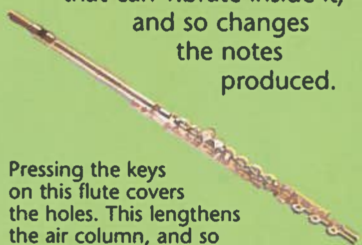
PITCH

The highness or lowness of a sound is known as its **pitch**. Sound waves with a high frequency produce sounds of a high pitch, those with a low frequency, a low pitch. Musical sounds of a specific pitch are called **notes**. For example, the note known as **Middle C**, which is the C nearest to the middle of a piano keyboard, has a frequency of about 262 hertz*. The next C above it has a higher frequency – about 523 hertz.

The size of an instrument affects the pitch of the notes that can be played on it. For example, in a stringed instrument, the longer the string, the lower the pitch. This is why a double bass makes lower notes than a violin.

A harp has strings that vibrate as they are plucked. Strings of different lengths make notes of different pitches.

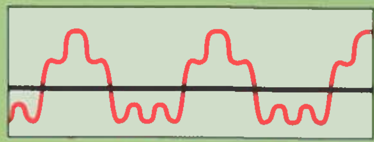
Players can change the pitch of the sounds an instrument makes. For example, a guitar or violin player presses down on the strings. This shortens the length of string that can vibrate, and so it makes higher notes. On a flute or recorder, the player covers and uncovers holes. This alters the length of the column of air that can vibrate inside it, and so changes the notes produced.



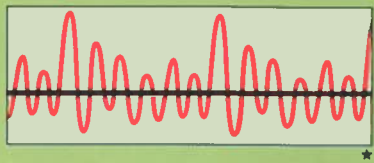
Pressing the keys on this flute covers the holes. This lengthens the air column, and so lowers the pitch of the note.

HARMONICS

Most instruments produce complex sound waves that have higher, quieter sounds mixed in. These sounds are called **harmonics**. They give an instrument its individual sound quality, or **timbre**.



On a sound wave diagram, harmonics look like extra little waves. This diagram shows the waves made by an instrument.



These are the sound waves of the same note played by a different instrument.

See for yourself

Try blowing across the top of an open, empty bottle. If you get it right, you will make the air column inside the bottle vibrate, producing a musical note. Now pour some water into the bottle and blow again. The water will have reduced the size of the air column, so the note that you produce will be higher.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Listen to instruments.

Website 2 Watch a movie on how an orchestra finds a common pitch before it performs.

Website 3 Find out how guitars work.

Website 4 Try an instrument quiz.

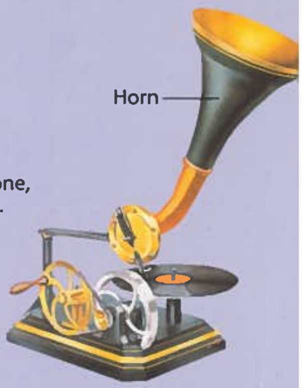
Website 5 Mix music online and learn more about pitch and frequency.

Website 6 Try to solve sound puzzles about pitch.

* *Binary code, 238; Hertz 203.*

SOUND REPRODUCTION

By changing sound energy into electrical energy, sounds can be recorded and stored, to be played back at another time. In this form, sounds can also be sent over long distances, for example, over the Internet.

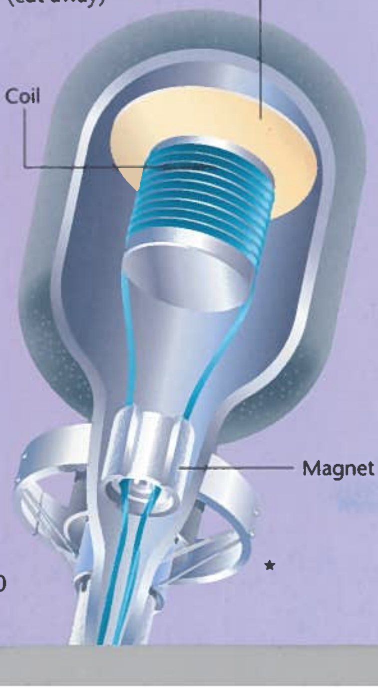


An early gramophone, made in the 1890s. Grooves on a disk made a needle vibrate, creating sound waves that were amplified (made louder) by the horn.

MICROPHONES

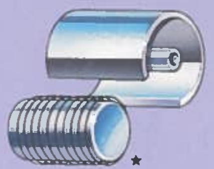
Sounds can be converted into an electric current by a device called a **microphone**. This contains a thin metal disk called a **diaphragm**, which is attached to an electromagnet*, that is, a coil of wire and a ring-shaped magnet.

When sound waves hit the diaphragm, it vibrates at the same frequency* as the waves. The diaphragm makes the wire coil vibrate. When the coil moves near the magnet, it creates an electric current which flows along the wire. The current produced varies according to the size and frequency of the sound waves.



LOUDSPEAKERS

A **loudspeaker** turns an electric current from a source such as a microphone back into sound waves. Inside the loudspeaker there is an electromagnet. When an electric current flows through the coil in the electromagnet, it becomes magnetic. The coil is attached to a cone-shaped paper diaphragm.

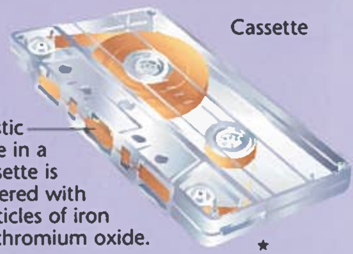


When a varying current produced from a sound wave flows through the coil, the force between the coil's magnetic field and that of the magnet makes both the coil and the diaphragm vibrate.

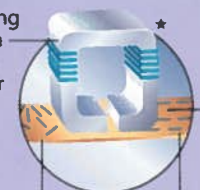
The air in front of the diaphragm vibrates to create sound waves of the same frequency as the original sound.

CASSETTE RECORDERS

In a **cassette recorder**, sounds are recorded as a pattern of magnetized particles of iron or chromium oxide on plastic tape.



This is done by a part called the **recording head**, which is an electromagnet. A varying current produced from a sound wave passes from a microphone through a metal coil in the recording head. This causes variations in the head's magnetic field which arrange the metal particles on the tape into different patterns.



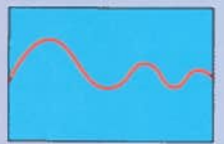
The patterns of particles on the tape can be read by a part called the **playback head**. It produces a varying current which is converted back into sound by a loudspeaker.

* *Electromagnet, 233; Frequency, 203.*

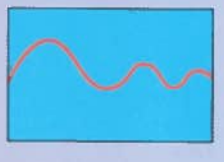
ANALOG RECORDING

The varying current from a microphone produces a varying pattern of magnetic particles on a cassette tape. This is a continuous record of the position of the microphone's diaphragm as it vibrates back and forth in response to the sound waves, and is an example of **analog recording**.

Original sound wave



Recorded analog sound wave



One problem with analog recordings is that they can be changed by repeated use. For example, the playback heads on a cassette recorder gradually wear away the magnetic particles on the tape. This means that the sound heard becomes less like the original sound that was recorded.

See for yourself

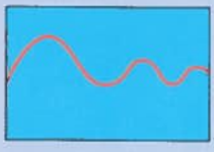
You can hear the effect of magnetism on tape if you record something on a blank cassette. Wind the tape back to the start and take the cassette out of the machine. Unravel part of the tape and run a magnet over it a few times. Wind the tape back into the cassette and play it back. You will find that the magnet has rearranged the particles on the tape and has distorted the sound.

DIGITAL RECORDING

In **digital recording**, an electric current representing a sound is described by a code made up of the numbers 0 and 1 (binary code*). This is done by measuring the current at different points, a process called **sampling**.

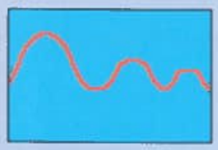
The more points that are sampled, the closer to the original sound the recording is when played back. For example, in CD recording, 44,100 samples are taken every second. This produces a **high-fidelity recording** – one that sounds very similar to the original.

Analog sound wave



Low-fidelity digital sound wave

High-fidelity digital sound wave

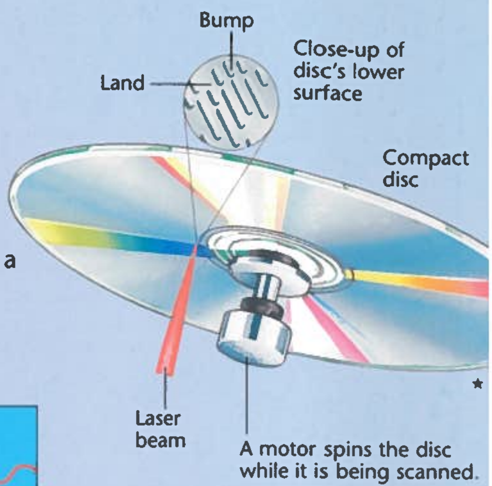


With a digital recording, the same series of numbers is used to make up the sound each time it is played back. This means that it always sounds the same as when it was first recorded and is known as **perfect sound reproduction**.

Digitally recorded information can be stored as a file on computer. It can then be used in many ways, for example it can be transferred onto a CD, or sent across the Internet.

COMPACT DISCS

A **compact disc**, or **CD**, uses digital methods to store sound or other information. The binary code is represented by tiny **bumps**, and flat areas called **land**, on the surface of the disc.



Inside a CD player, a laser beam scans the disc's shiny underside. As light hits the edge of each bump, a light detector reads an electric pulse as a binary 1. As light hits the flat areas on and between the bumps, this is read as a 0. The stream of pulses is turned into sound by a loudspeaker.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Explore a recording studio and discover the science behind microphones, CDs, loudspeakers and more.

Website 2 An interactive diagram of a microphone.

Website 3 A good summary of the basics of sound reproduction.

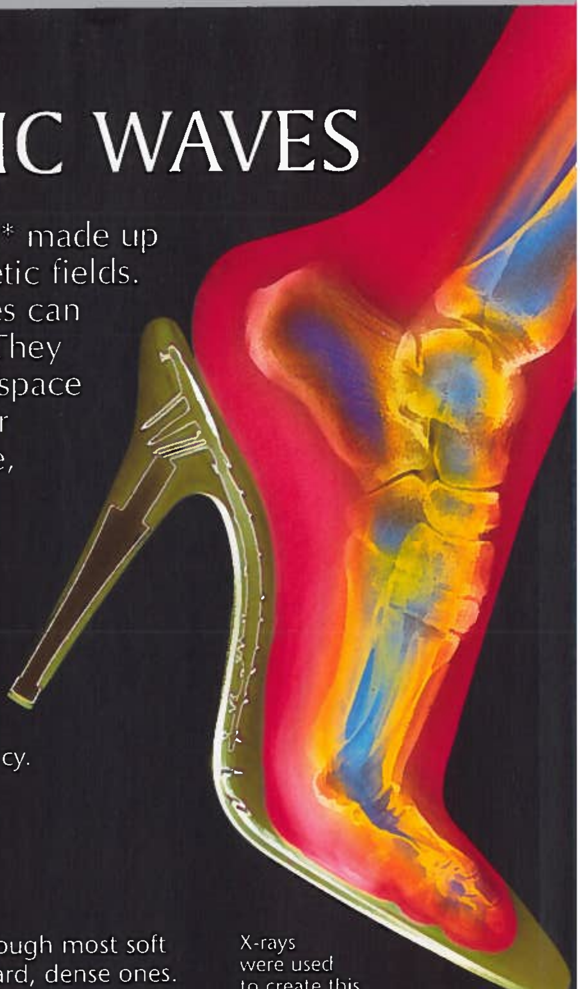
Website 4 Lots about electrical energy, with short animated tutorials on how CDs, DVDs and other devices work.

Website 5 Watch an animated movie about MP3 files.

* *Binary code, 238.*

ELECTROMAGNETIC WAVES

Electromagnetic waves are transverse waves* made up of continually changing electric and magnetic fields. Like mechanical waves, electromagnetic waves can travel through most solids, liquids and gases. They can also travel through a **vacuum** – an empty space where there are no particles of air or any other matter. All electromagnetic waves are invisible, except for those that make up light.



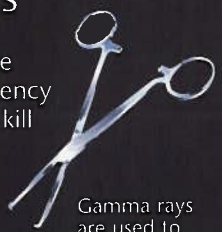
ELECTROMAGNETIC SPECTRUM

The complete range of electromagnetic waves, arranged in order of their wavelength* and frequency*, is known as the **electromagnetic spectrum**. At one end are waves with a short wavelength and high frequency, and at the other are waves with a long wavelength and low frequency. They all travel at the same speed – approximately 300,000 kilometers per second. This is known as the **speed of light**.

X-rays were used to create this image of a woman's foot in a shoe. The bones and metal shoe parts show up most clearly because the X-rays could not pass through them.

GAMMA RAYS

Gamma rays are short, high-frequency waves. They can kill living cells and are used to sterilize medical equipment by destroying any germs on them.

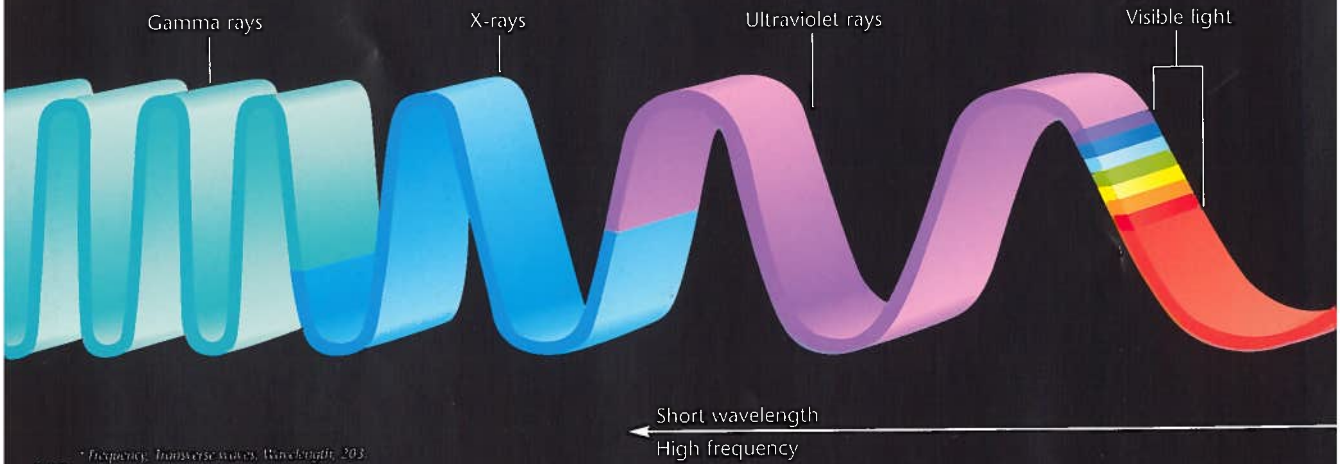


Gamma rays are used to keep these forceps free of germs.

X-RAYS

X-rays can travel through most soft substances but not hard, dense ones. X-rays are used in hospitals to make shadow pictures of parts of the body. They travel through soft tissue, such as skin and muscle, but not through hard bone. X-rays are also used for security at airports to check what may be hidden in people's luggage.

The electromagnetic spectrum



* Frequency, Transverse waves, Wavelength, 203

UV RAYS

Ultraviolet (UV) rays have more energy than visible light (see below) and can cause chemical reactions to take place.

Sunscreen protects skin by blocking out harmful UV rays.

For example, UV rays from the Sun cause the skin to increase its production of a brown chemical called **melanin**. This makes the skin tanned. Too much exposure to UV rays can result in high levels of melanin, and may lead to skin cancer.

VISIBLE LIGHT

There is a narrow section of the electromagnetic spectrum that humans can see. This is called the **visible light spectrum**. You can find out more about visible light and the way it behaves on pages 214-217.

INFRARED RAYS

Infrared rays are given out by anything hot. For example, heat from the Sun travels to the Earth as infrared rays.

RADIO WAVES

Radio waves are those with the longest wavelength and lowest frequency. You can read more about them on page 226.

Microwaves are radio waves with a relatively short wavelength. They are easy to control and direct, and have many different uses.

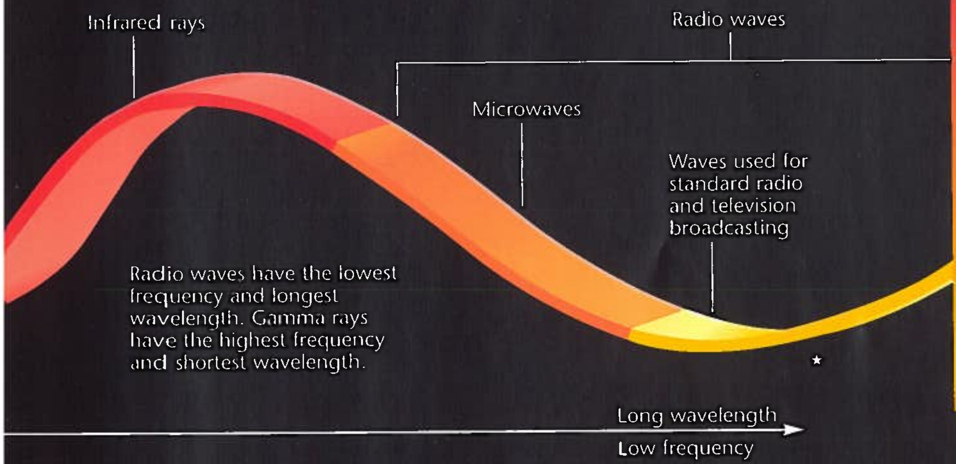
In an ordinary oven, heat is passed from molecules at the edge of the food to ones in the middle. Microwave ovens work by making all the molecules in a food substance vibrate at the same time. This heats and cooks the food more quickly.

Microwave oven (cut away)

RADAR

Radar (which stands for **ra**dio **d**etection **a**nd **r**anging) uses microwaves to find the position of distant objects, such as ships and aircraft. A transmitter sends out a beam of microwaves that is reflected off a solid object and picked up again by a receiver. This information is transformed into a screen image that shows the distance and direction of the object.

Radio telescope dishes like this one can pick up microwaves that travel from distant stars and planets. They can detect things that are too dark or too far away to be seen with normal telescopes.



Radio waves have the lowest frequency and longest wavelength. Gamma rays have the highest frequency and shortest wavelength.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 An online lesson about electromagnetic waves.

Website 2 Take a virtual tour of the electromagnetic spectrum.

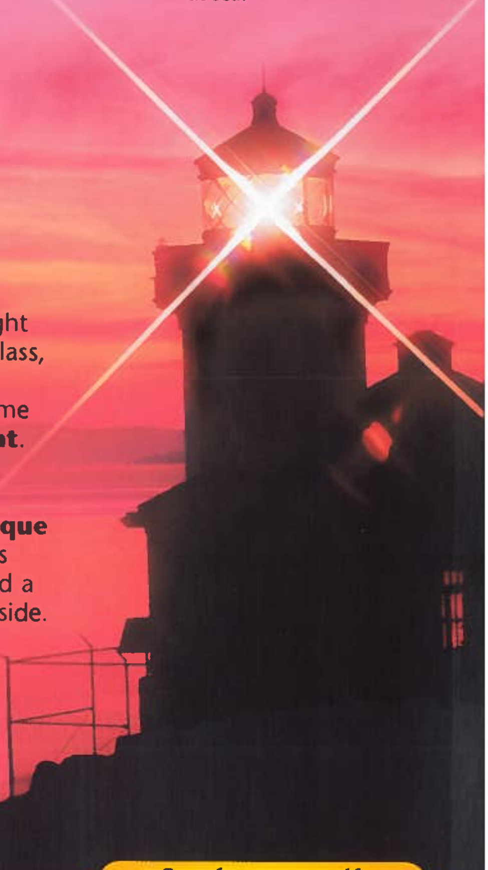
Website 3 Experiment online and learn more about electromagnetic waves.

Website 4 Use a virtual X-ray machine and read about X-rays and how they work.

Website 5 See infrared pictures of everyday objects.

LIGHT AND SHADOW

Light is a form of energy. It is made up of electromagnetic waves which are part of the electromagnetic spectrum*. This part is known as **visible light** because it can be seen.



The beacon in this lighthouse rotates, flashing with intense bright light that can reach ships many miles out at sea.

LIGHT

Light waves are a type of transverse wave*. Like other waves, they transport energy from a source to its surroundings.

Any object that gives off light, for example the Sun or a light bulb, is said to be **luminous**. Most objects are non-luminous and can be seen only because they are reflecting the light from something luminous. For example, the Moon can only be seen when light from the Sun bounces off it.

Light from the Sun reflects off the surface of the Moon, enabling it to be seen.

Some luminous objects give off more light than others. The level of brightness is called **intensity**. The further you are from a source of light, the less intense the light is. This is because light waves spread out as they travel away from the source.

The bright flashlight gives more intense light than the small candle.

The light fades as the vibrations of the light waves become gradually smaller.

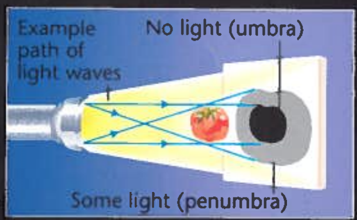
SHADOWS

Different types of substances allow different amounts of light to pass through them. Substances through which light can pass fully, such as clear glass, are said to be **transparent**. Substances which only let some light through are **translucent**. Frosted glass is translucent.

When light shines on an **opaque** object, the waves cannot pass through, so a dark area, called a **shadow**, forms on the other side.

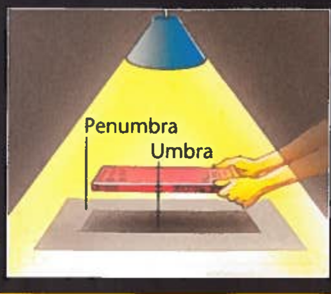
Light cannot pass through this ball, so a shadow is formed.

Opaque objects cast two types of shadow. If no light reaches an area, a dark shadow, called an **umbra**, is formed. If some light reaches an area, gray shadow is formed. This is called a **penumbra**, and it forms around the edge of the umbra. The smaller the light source, the more umbra and less penumbra it creates.



See for yourself

To see the two different kinds of shadow, hold a book over a piece of white paper under the light of a lamp. Notice the types of shadow it casts. If you move the book closer to the paper, you will see more umbra and less penumbra.



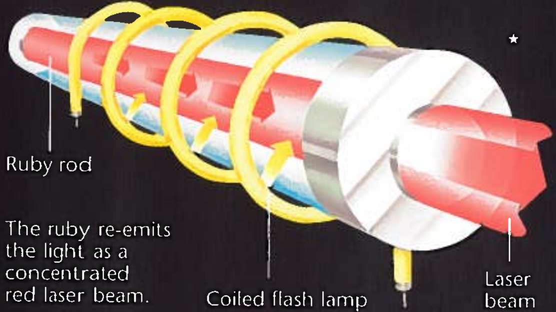
* Electromagnetic spectrum, 212-213; Transverse waves, 203.

LASERS

Visible light is made up of several colors of different wavelengths* and frequencies*. Machines called **lasers** create beams of intense, pure color of one wavelength and frequency.

In a simple laser, a ruby rod absorbs light energy from a bright lamp. Atoms in the ruby gain the energy and give off bursts of light of a certain wavelength and frequency. Each burst of light causes other atoms in the ruby to give off light waves of the exact same type. Together they form a **laser beam**.

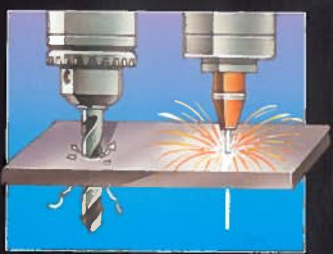
In this laser, a rod of ruby absorbs light from a coiled flash lamp.



The ruby re-emits the light as a concentrated red laser beam.

The waves in a laser beam are **coherent**. This means that they travel in step with each other as everything about them is exactly the same. They stay together in a narrow, concentrated beam, making them easy to direct.

Some powerful lasers produce extremely hot beams of infrared light*. These are used in industry for melting through metals, diamonds and other tough materials. Less powerful lasers are used in certain types of eye surgery, such as replacing a detached retina. The laser makes a small heat scar which welds the detached part back into place.



The drill (far left) makes a rough hole in the metal and produces waste shavings.

The powerful laser beam, by contrast, melts a clean hole.

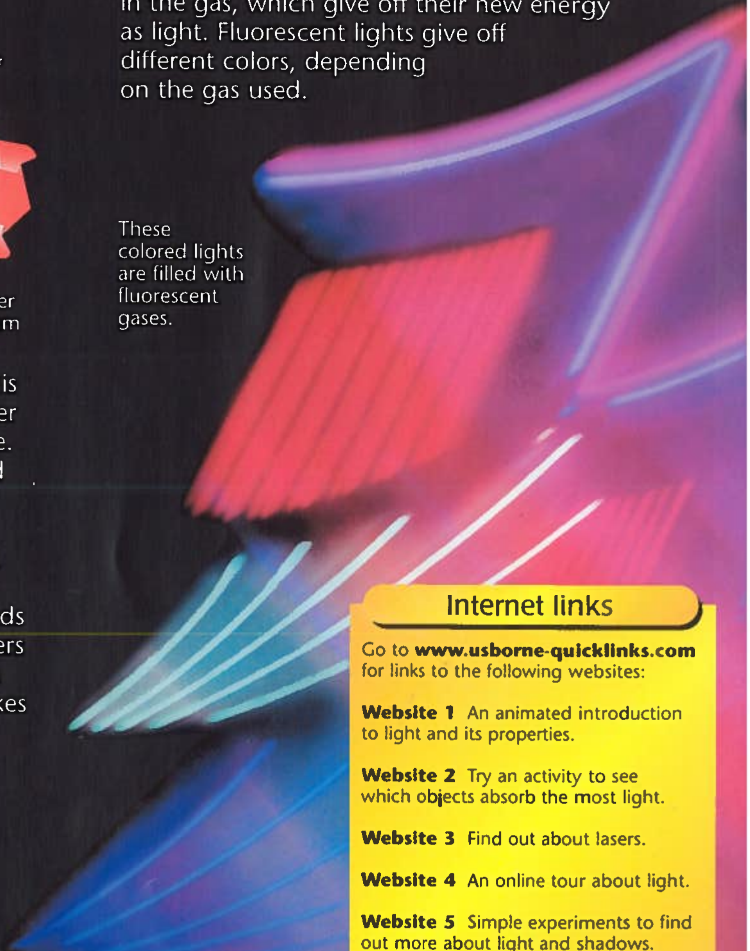
*Frequency, 203; Infrared rays, UV rays, 213; Wavelength, 203.

FLUORESCENCE

Some substances can absorb energy, such as electricity or ultraviolet (UV) rays*, and give it out as light. They are described as **fluorescent** substances. They are widely used in advertising and paints as they make colors seem to glow.

This T-shirt has been washed with a washing powder containing fluorescent substances that absorb UV rays from the Sun and make white clothes look whiter.

Fluorescent lights consist of a tube filled with a gas such as neon. When electricity is passed through the tube, it gives energy to particles in the gas, which give off their new energy as light. Fluorescent lights give off different colors, depending on the gas used.



These colored lights are filled with fluorescent gases.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 An animated introduction to light and its properties.

Website 2 Try an activity to see which objects absorb the most light.

Website 3 Find out about lasers.

Website 4 An online tour about light.

Website 5 Simple experiments to find out more about light and shadows.

Website 6 Visit an online exhibition about lasers and discover how they are used today.

COLOR

Rainbows, like this one, form when light hits tiny drops of water in the air and splits up into separate colors.

Visible light appears colorless. It is also known as **white light**. In fact, it is made up of seven different colors: red, orange, yellow, green, blue, indigo and violet. Each color has a different wavelength* and frequency*. Together they make up the **visible light spectrum**. Colors of the spectrum are called **chromatic colors**.

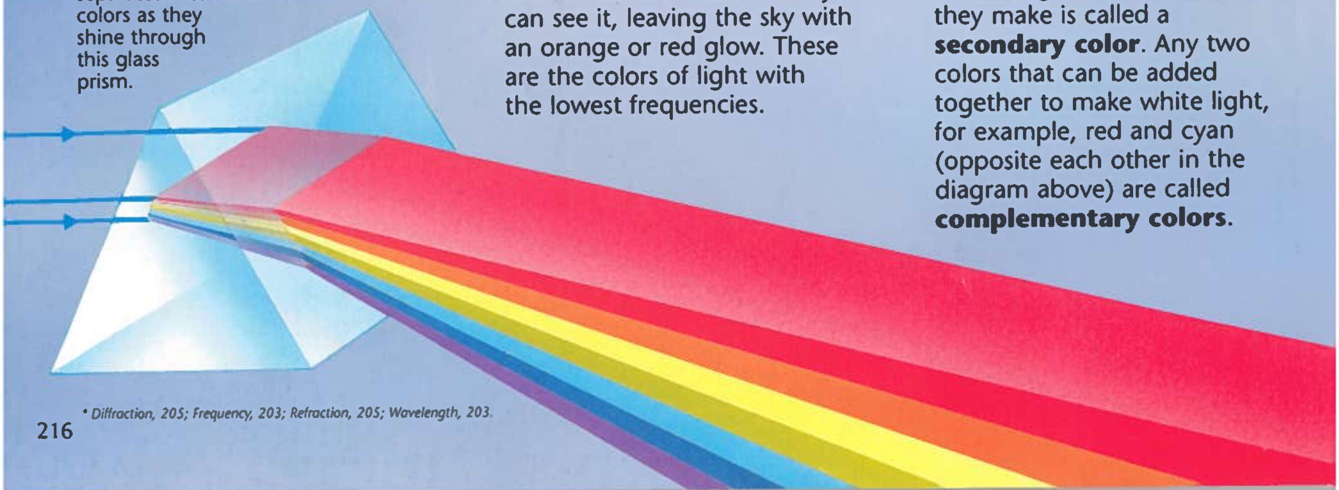
DISPERSION

In 1666, scientist Isaac Newton discovered that white light could be divided into separate colors. This process is called **dispersion**. He dispersed light using a **prism** – a transparent solid with two flat surfaces at an angle to each other.

The picture below shows a prism. As light hits the first surface, the colors in it are bent (refracted*) by various amounts. This splits up the light into its separate colors. This dispersed light is refracted further when it hits the second surface. Colors with the shortest wavelengths, namely blue and violet, are refracted the most.

A rainbow is a result of dispersion that happens naturally. Water particles in the air act like prisms, separating sunlight into colors.

Rays of white light are separated into seven colors as they shine through this glass prism.



COLOR OF THE SKY

The color of the sky is a result of sunlight being scattered by small particles in the atmosphere. They reflect and diffract* sunlight, scattering high-frequency light waves, such as blue, most of all. When you look up at the sky, it appears blue because some of this scattered blue light reaches your eyes.

The different colors of this evening sky are caused by light scattering.

At sunrise and sunset, the light has to travel through more of the atmosphere before reaching your eyes. This means that the blue is scattered out before you can see it, leaving the sky with an orange or red glow. These are the colors of light with the lowest frequencies.

MIXING LIGHT

Almost any color of light can be made by **additive mixing**, that is, by using different combinations of red, green and blue light. For this reason red, green and blue are known as the **primary colors** of light.

Red, blue and green are the primary colors of light.

Cyan, magenta and yellow are the secondary colors of light.

When two primary colors are added together, the color they make is called a **secondary color**. Any two colors that can be added together to make white light, for example, red and cyan (opposite each other in the diagram above) are called **complementary colors**.

** Diffraction, 205; Frequency, 203; Refraction, 205; Wavelength, 203.*

SEEING IN COLOR

You can see colors when light reflecting off objects is detected by color-sensitive cells in your eyes.

All colored objects and paints contain **pigments**. These are substances that absorb certain colors and reflect others. You can see the color of an object because it reflects only light of that color. For example, a red flower reflects red light and absorbs all the other colors of the spectrum.

This bottle looks blue because it reflects only blue light and absorbs all the other colors.

White objects appear white because they reflect all the colors of light equally. Black objects absorb all the colors, so hardly any light is reflected, making the object look black. Black and white are known as **achromatic colors**.

The white feathers on this penguin reflect all the light that hits them.

The black feathers absorb all the light that hits them.

MIXING PIGMENTS

Pigments mix by a process called **subtractive mixing**. For example, the pigment in yellow paint absorbs blue light and the pigment in cyan paint absorbs red light. So when you mix yellow and cyan paints, the mixture can only reflect green light, making it look green. The primary colors of pigments are cyan, yellow and magenta. Red, blue and green are the secondary colors.

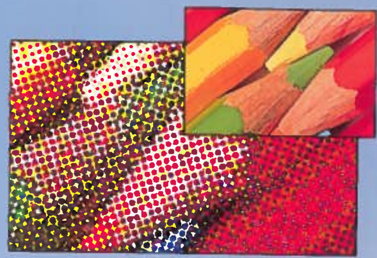
Yellow and cyan pigments mix to make green because they absorb blue and red light.

See for yourself

You can see the colors of the spectrum form white light by making a color spinner. Draw around the bottom of a jar on some stiff cardboard. Cut out the circle, divide it into seven sections and paint them with the colors of the rainbow. Push a pencil through the middle and spin it on a table. As it spins, the colored light reflecting off it merges to make white.

COLOR PRINTING

Color printing in books and magazines uses dots of magenta, yellow and cyan ink, along with black ink to make the pictures look sharper. This process is called **four-color printing**.



This magnified picture shows how all the colors are made up of tiny dots of magenta, yellow, cyan and black.

If you look through a magnifying glass at any picture in this book, you will see the dots which make up the image.

Colors used in four-color printing

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Lots of information about rainbows, including how to make an indoor rainbow.

Website 2 See what happens to the Sun's light as it passes through the atmosphere.

Website 3 Animated explanation of how we see colors.

Website 4 Mix colors online and compare light and pigments.

Website 5 Design the lighting for a concert and discover the science behind it.

LIGHT BEHAVIOR

Like all electromagnetic waves, light travels incredibly quickly – about 300,000 kilometers per second when measured in a vacuum. The direction in which light waves travel is shown in diagrams by arrows. These are called **light rays**. Light waves usually travel in a straight path but may change direction when they meet an obstacle, or move from one substance into another.

The colors on the surface of soap bubbles are caused by light interference.

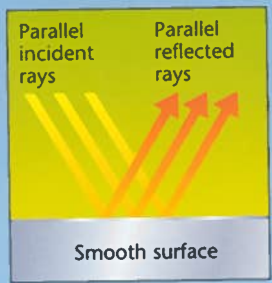
REFLECTION OF LIGHT

Light rays traveling toward an object are known as **incident rays**. If they hit the object and bounce off it, they are then called **reflected rays**. Each ray is reflected at the same angle as it hits the object.

When parallel light rays hit a smooth, shiny surface, they are reflected so that the reflected rays are also parallel. This is called **regular reflection**.

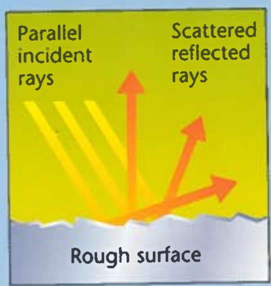
When parallel light rays hit a rough surface, the reflected rays are scattered in different directions. This is **diffuse reflection**. It is the most common type of reflection as most surfaces are rough (though they may not seem so unless seen with a microscope).

Regular reflection of light rays



*

Diffuse reflection of light rays



*

When you look at an object, the light that reflects off it goes directly into your eyes, so you see the object where it really is. If you look at an object in a mirror, the rays bounce off the object and then bounce off the mirror before entering your eyes. What you are looking at is the **image** of the object. In this case the image appears to be behind the mirror.

REFRACTION OF LIGHT

If light rays pass from one substance to another of a different density, their speed will change. If they are also bent, they are known as **refracted rays**. The amount of speed change and refraction depends on the change in density. Light rays speed up on moving into a less dense substance, and slow down on moving into a denser one.

For instance, light rays bouncing off objects in water can make the objects look distorted. This is because the rays are refracted as they pass out of the water into the less dense air. You can find out more about refraction on page 205.

See for yourself

To see light refraction, look at a straw in a glass of water from all sides. It seems to bend in different ways. The unbroken lines in the diagram show the real path of the light rays looking from above. But the brain assumes they travel straight, so it sees the end of the straw at X.

*

The rays of sunlight breaking through these clouds show that light travels in straight lines.

LIGHT DIFFRACTION

When light rays pass through tiny gaps, or meet the edge of an opaque object, they are diffracted, or spread out. For more about diffraction, see page 205.

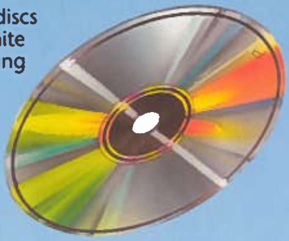
LIGHT INTERFERENCE

When light rays are reflected or diffracted, their paths may cross, causing interference. See page 205 for more about interference.

As light rays interfere with each other, some wavelengths of light are strengthened and some are weakened, so certain colors become visible. The colors on a compact disc and on the surface of soap bubbles, for example, are caused by interference.

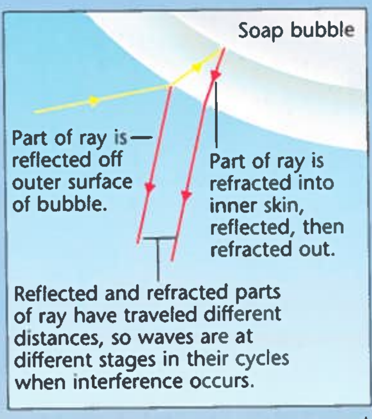
The metallic sheen on the wings of this butterfly is caused by light interference.

The shiny side of a compact disc has tiny bumps on it. When light enters the gaps between them, the waves are diffracted and interfere, so certain colors are seen at different angles.



Compact discs diffract white light, making its colors visible.

The rainbow colors on a soap bubble appear when light reflected off the outer surface of the bubble interferes with light reflected off the inner surface.

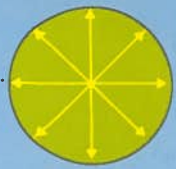


*

The colors are constantly changing, giving a shimmering effect called **iridescence**. This is also seen on the wings of some insects and birds.

POLARIZATION

Light waves are made up of vibrations in electric and magnetic fields. The vibrations change direction many millions of times per second, but are always at right angles to the direction the wave is traveling.



Imagine a normal light wave traveling directly into your eye. Its vibrations are in many directions, as shown here.

When light is **polarized**, the vibrations only occur in one direction, such as up and down.

A polarized light wave is filtered so that its vibrations are in just one direction, as shown here.

Polarizing sunglasses work by filtering out all light wave vibrations that are not in a certain direction. This shields the eyes from excessive glare.

Polarizing sunglasses only allow light vibrations through in one direction.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Try a reflection experiment with mirrors and a laser.

Website 2 Online lesson of how light behaves, with a test-yourself quiz.

Website 3 An animated explanation of refraction.

Website 4 Find out why diamonds sparkle.

LENSES AND MIRRORS

A **lens** is a piece of transparent substance with curved surfaces, that makes light passing through it bend in a particular way. A **mirror** is a shiny surface that reflects nearly all of the light that hits it. Lenses and mirrors have many uses, for example in cameras and telescopes.

LENSES

Lenses are shaped so that light passing through them is bent (refracted*) in a particular way. There are two main shapes of lens: convex and concave. In a **convex lens**, one or both surfaces curve outwards. In a **concave lens**, one or both surfaces curve inwards.

This photograph of New York City was taken through a fish-eye lens. This curved lens creates a distorted, circular image, covering an angle of 180°.

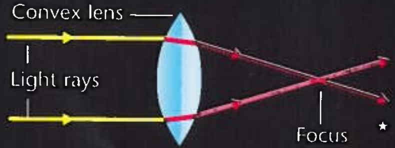
Types of convex lenses

Types of concave lenses

Lenses are described as converging or diverging lenses, depending how the light rays are refracted. For example, a glass convex lens in air acts as a converging lens and a glass concave lens in air acts as a diverging lens.

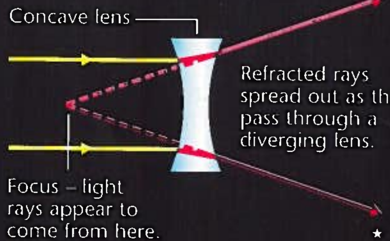
Any point where light rays come together or appear to come from is called a **focus**. A **converging lens** causes parallel rays of light passing through it to come together at a focus.

Converging lens

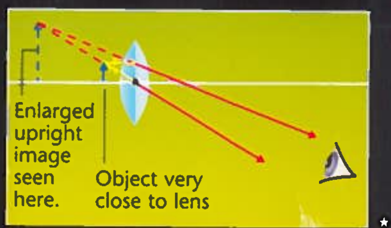


A **diverging lens** makes parallel rays of light spread out.

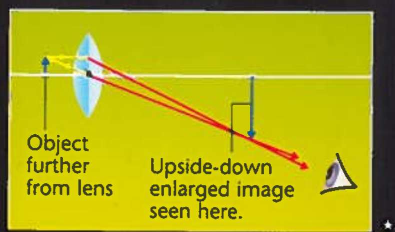
Diverging lens



The size and position of an image seen through a converging lens depends how far the object is from the lens. If the object is very close to a converging lens, the image is upright and enlarged.



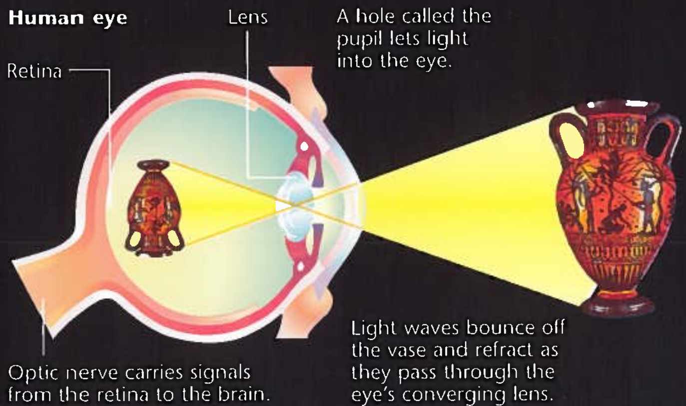
If the object is further away from a converging lens, the image is upside down.



* Refraction, 205.

EYES AND EYESIGHT

Your eye turns light reflected from an object into an image that can be recognized by your brain. The front part of the eye is a convex converging lens. It focuses the light rays so that they form an image on a layer called the **retina**, at the back of the eye. The image formed is upside down, but your brain then corrects this so you see things right-side up.

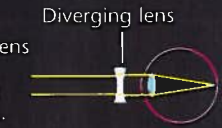


Distant objects are blurred for people with short sight. This is because the lenses in their eyes bend the light rays too much and the image forms in front of the retina.

Short sight

Rays from a distant object focus in front of the retina.

A diverging lens corrects this, focusing rays on the retina.

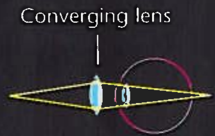


Far-sighted people can't see nearby objects well. This is because the lens does not bend the light rays enough so the rays focus behind the retina.

Far sight

Rays from a near object focus beyond the retina.

A converging lens corrects this, focusing rays on the retina.



See for yourself

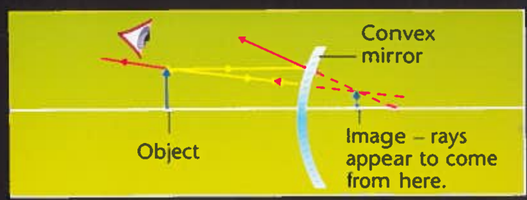
Look at your reflection in the bowl of a shiny metal spoon. If you hold the spoon very close to your face, the reflection will be enlarged. If you hold it a little further away, the reflection will be upside down. Look at the two diagrams at the bottom of the column on the right to see why this happens.

MIRRORS

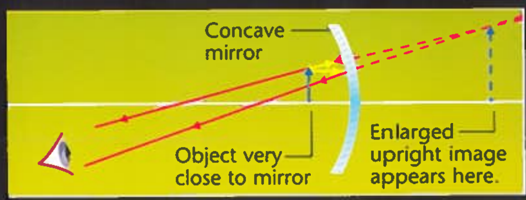
When light from an object hits a flat mirror straight on, it is reflected straight back. The image produced is the same size and same way up as the object but the left and right sides are switched around. The image is the same distance behind the mirror as the object is in front of the mirror.

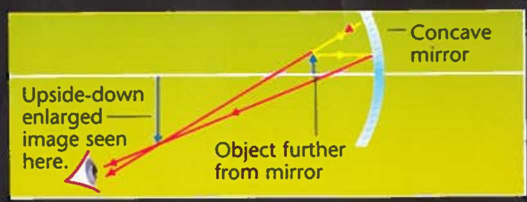
Curved mirrors bounce light off at an angle, producing different kinds of images. A **convex mirror** curves outward. The image formed is upright and reduced in size.

Car wing mirrors are convex.



Concave mirrors curve inward. If an object is very close to the mirror, an enlarged image is produced. If the object is further away, the image is upside down. The bowl of a shiny metal spoon acts like a concave mirror.





Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 See animations of how the human eye works.

Website 2 Learn about the basics of lenses and mirrors.

Website 3 Experiment online with lots of mirror and reflection activities.

OPTICAL INSTRUMENTS

Optical instruments use combinations of lenses and mirrors to produce a particular type of image, for example, an image that appears larger than when viewed with the eye alone. These pages show some of the many kinds of optical instruments.

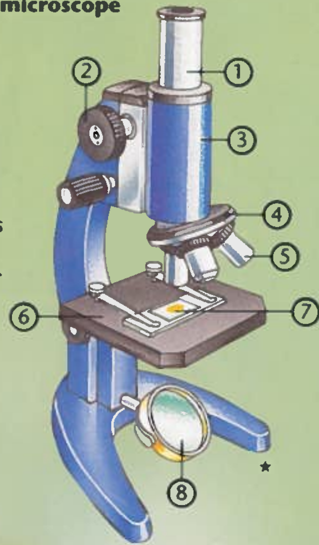
Binoculars use lenses to magnify objects.

OPTICAL MICROSCOPES

Optical microscopes use lenses to make small objects look bigger. Simple ones, such as a magnifying glass, have only one lens. More complex ones use two lenses or more.

Inside a **compound optical microscope**, the object is first magnified by the **objective lens**. It is further magnified by the **eyepiece**, which produces the final image. Some optical microscopes can magnify up to 2,000 times.

A compound optical microscope



1. **Eyepiece**. This refracts (bends) light from the objective lens, turns the image right-side up, and makes it look much bigger.

2. **Focusing knob**. This controls the sharpness and clarity of the image.

3. **Body tube**

4. **Nosepiece**. This holds three objective lenses, each giving a different magnification. It is swiveled around to change between them.

5. **Objective lens**. This refracts light from the object to form a larger, upside-down image. The eyepiece then further magnifies this image.

6. **Stage**. The object to be magnified goes on here.

7. **Object**

8. **Mirror**. This reflects daylight or lamplight through a hole in the stage onto the object.

Using magnifying lenses, scientists can learn about the structure of tiny living things, such as this ladybug.

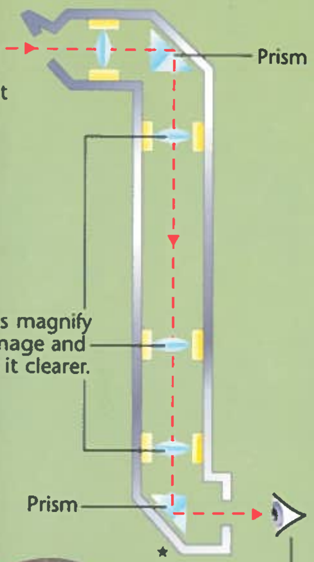
On its own, the eye can only see small objects separately if they are at least a quarter of a millimeter apart. A microscope can show you objects separately that are up to 1,000 times closer together than this.

The tiny hairs on the ladybug's mouthparts are too small to be seen with the eye alone, but are easy to make out under a microscope's magnifying lens.

PERISCOPES

A **periscope** is an upright tube with prisms at each end. Prisms are glass shapes with two flat surfaces at an angle to each other. In a periscope they are used to reflect light around corners, which allows you to see something when you are far below it. For instance, periscopes are used in submarines to look above the surface of the water.

Diagram of a periscope

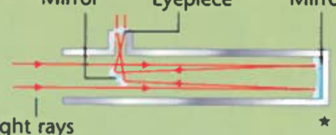


TELESCOPES

Telescopes are used to make distant objects appear closer and therefore larger. They are often used for looking at the stars. There are two main types: reflector and refractor telescopes.

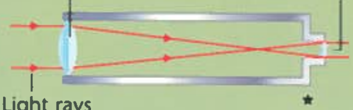
A **reflector telescope** uses a curved mirror to collect light. The light then reflects off a second mirror and an image is focused in front of the eyepiece, which magnifies it.

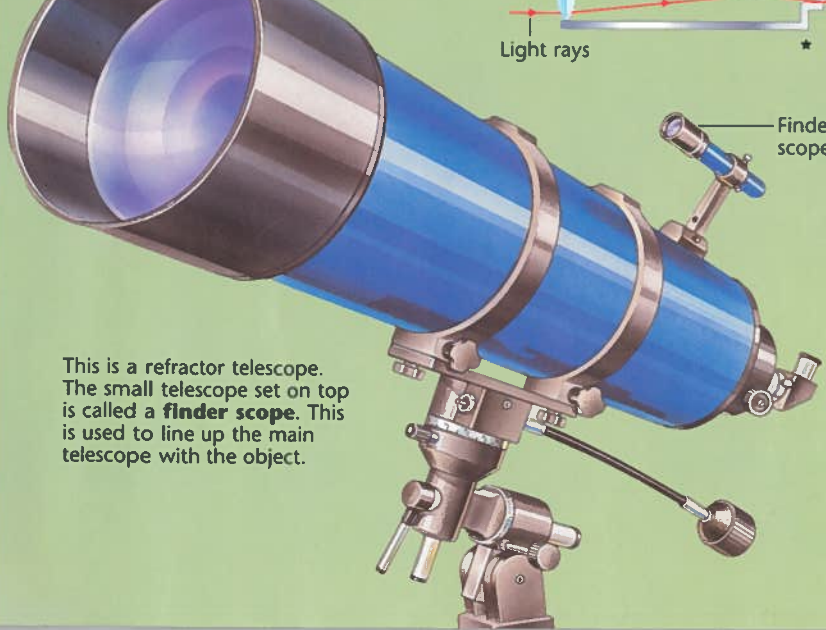
This diagram shows the path of light rays in a reflector telescope.



A **refractor telescope** uses lenses. The objective lens collects the light but, like the mirror in a reflector telescope, it does not magnify the object. This is done by the eyepiece.

This diagram shows the path of light rays in a refractor telescope.





This is a refractor telescope. The small telescope set on top is called a **finder scope**. This is used to line up the main telescope with the object.

See for yourself

You could use a pair of binoculars to look at the stars.

Binoculars are made in various sizes and powers, shown by a pair of numbers, such as 7 x 35 or 10 x 50. The first number is the magnification. The second is the diameter, in millimeters, of the front, objective lenses. The larger the lenses, the more light they can collect, so the fainter the starlight they can pick out.

Stars seen with the eye alone are tiny pinpoints.

Seen through binoculars, more details are visible.

It is a good idea to rest your binoculars on a steady surface, such as a wall or fence. This will keep them from shaking in your hand and give you a clearer view of the stars.

A good telescope can show the stars in even greater detail.

Many more distant stars can be seen through a good telescope.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 A simple introduction to optics, with diagrams.

Website 2 Find out about Galileo, who invented the first optical telescope.

Website 3 How telescopes work.

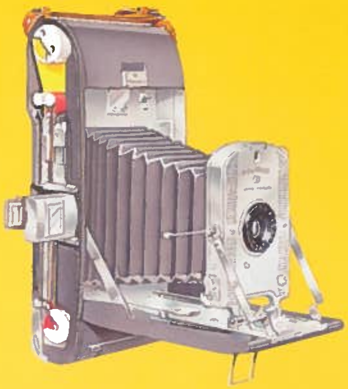
Website 4 Try to assemble an optical microscope online.

Website 5 Microscopes from 1660 to the present day, with animations.

Websites 6–8 Find out how to make your own periscope, telescope and kaleidoscope and see how they work.

CAMERAS

Cameras are optical instruments that record pictures. They use lenses to focus light onto film or some other device that saves the picture so that you can look at it again later. Early cameras stored pictures on sheets of glass or metal coated with light-sensitive substances. Today, most cameras use light-sensitive film. Digital cameras, invented in the 1990s, store pictures electronically.



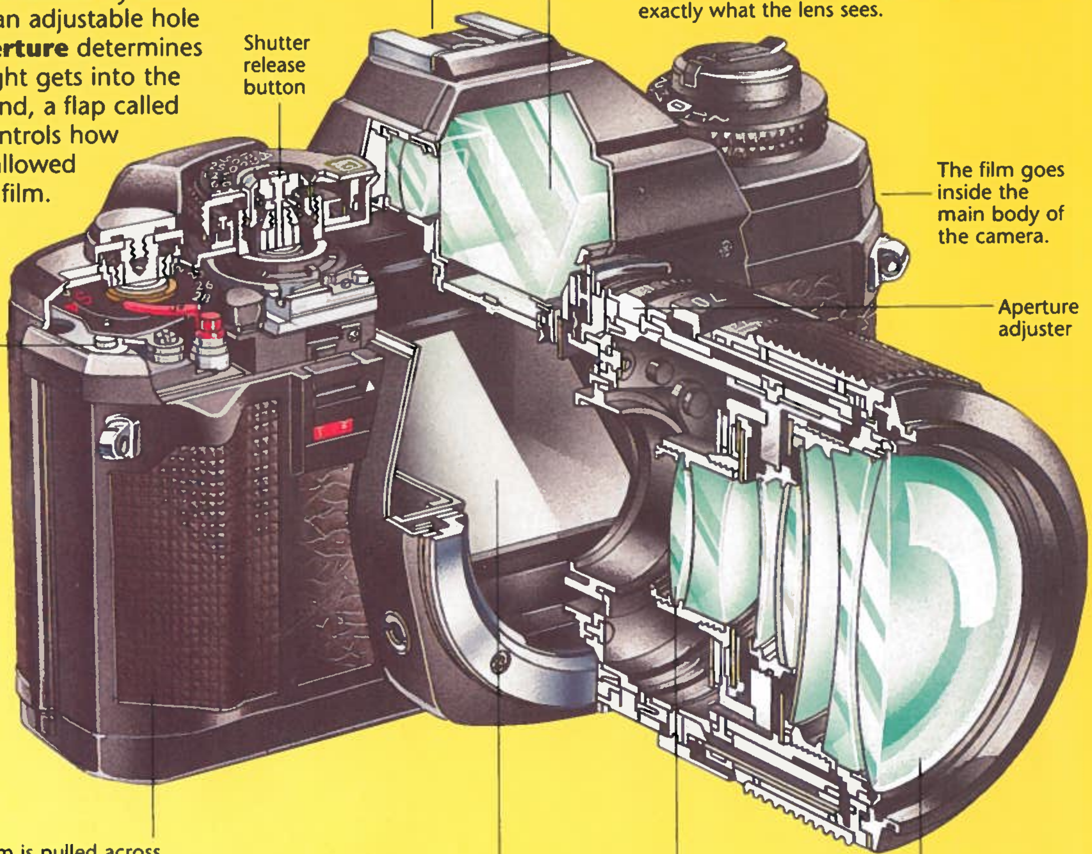
This is an early Polaroid camera. Polaroid film develops rapidly, so you see the picture just after you take it.

CAMERA PRINCIPLES

Light enters a camera through a lens. The amount of light that is let in is called the **exposure**. Exposure is controlled by two things. First, an adjustable hole called an **aperture** determines how much light gets into the camera. Second, a flap called a **shutter** controls how long light is allowed to fall on the film.

Single-lens reflex (SLR) camera

In this type of camera, light entering the lens is reflected off a mirror and refracted through a prism to a little window called the **viewfinder**. This lets the photographer see exactly what the lens sees.

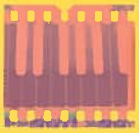


PHOTOGRAPHIC FILM

Photographic film is coated with silver nitrate, a light-sensitive chemical. How the film reacts depends on the amount of light that reaches it.

The exposed film is dipped into chemicals to produce the images and stop the film from being sensitive to any more light. This process is called **developing**.

Positive film (also called **transparency** or **slide film**). This shows images with the correct colors.



Negative film. The light parts of the piano keyboard in the picture appear dark and the dark parts appear light.

Developed negative film is projected onto light-sensitive paper to make the final print.

MOVING PICTURES

Motion-picture cameras record images on very long strips of photographic film. They take 25 separate pictures, called **frames**, every second. The film is developed in the same way as film from a normal camera.

The film is held in a cassette which clips onto the camera.

To watch the film, it is wound through a projector at a rate of 25 frames per second. The frames move so fast that you see the next frame before the last one fades in your brain. This is called **persistent vision**.

See for yourself

You can demonstrate persistent vision by making your own "movie" flip book.

On the back page of a small pad of paper draw a simple character. Turn over the page and trace this image, making slight changes to show the character moving. Draw at least 20 more images, changing each one a little.

When you flip the pad, the images appear as one moving picture.

TELEVISION CAMERAS

Television cameras do not use film, but turn the light that enters them into a series of electrical signals. These signals are sent down a cable and are either transmitted as a live broadcast, or recorded onto tape or computer to be transmitted at another time.

A television studio camera is heavy and is supported by a stand.

CAMCORDERS

A **video camcorder** is a combined TV camera and video recorder. Lenses direct an image onto a tiny light-sensitive electronic part called a **charge-coupled device** (**CCD**). The CCD produces electrical signals which are recorded onto videotape.

This small camcorder can fit in the palm of your hand.

DIGITAL CAMERAS

Digital cameras record images onto a CCD. The images are broken down into tiny colored squares called **pixels**. Information about the pixels is stored in the camera's memory as binary code*. To print the picture or see it on a computer screen, the pixels recombine, forming a complete picture.

The degree of detail in a picture is called its **resolution**. The more pixels that a digital camera creates in an image, the higher the image's resolution.

Low-resolution image

High-resolution image

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Find out about digital cameras and learn how to make a pinhole camera.

Website 2 An online museum of photography, film and television.

Website 3 Explore a virtual exhibit about photography and light.

Website 4 Visit the websites of famous camera manufacturers, learn about the latest innovations and find helpful tips and advice.

Website 5 Visit an online camera museum.

* *Binary code, 238.*

TV AND RADIO

The first radio transmissions were made about 100 years ago. Television was invented in 1926. The first signals could only be sent over very short distances, but today satellites can instantly broadcast clear signals around the world.

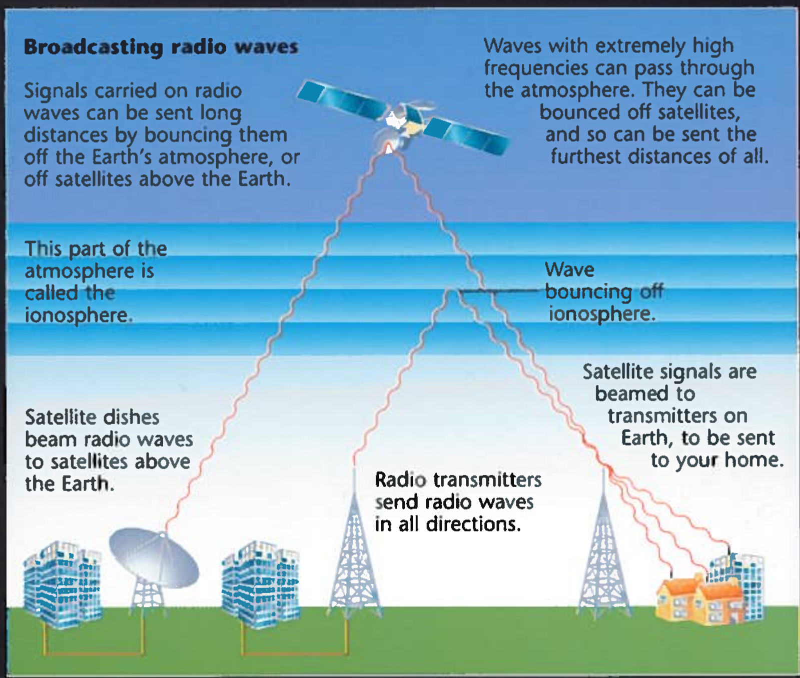
This early radio was invented by Marconi. It was called a marconiphone.

BROADCASTING

Most radio and television shows are broadcast as **radio waves**. These are a band of waves in the electromagnetic spectrum* with a range of different frequencies* and wavelengths*.

Radio waves are the longest waves in the electromagnetic spectrum.

Before broadcasting, sounds and images first have to be converted into electrical signals. Sounds are made into electrical signals by microphones. Cameras create electrical signals from images.

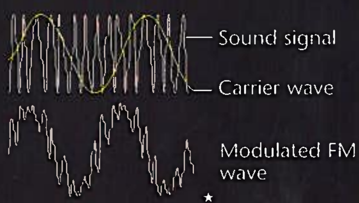


MODULATION

To enable them to be broadcast, electrical signals have to be altered, using a method called **modulation**. This is done by mixing the electrical sound and picture signals with radio waves, called **carrier waves**.

As a result of modulation, the shape of the carrier wave varies depending on the electrical sound and picture signals. The picture on the right shows an example of this.

With **frequency modulation** (**FM**) the electrical signals are altered to match the frequency of the carrier wave. With **amplitude modulation** (**AM**) the electrical signals are altered to match the amplitude* (strength) of the carrier wave.



HOW A RADIO WORKS

A radio works by receiving modulated radio waves through its antenna, and then converting them back into very weak electrical signals.

Radio receives many different signals. Tuner is adjusted to select wavelength of broadcast required.

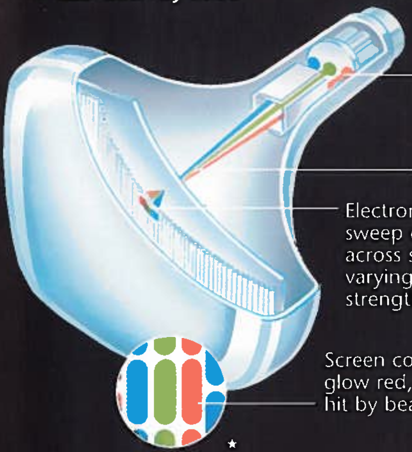
The signal is strengthened (amplified) and a loudspeaker turns it into a sound that can be heard.

* *Amplitude, 203; Electromagnetic spectrum, 212-213; Frequency, Wavelength, 203.*

HOW TV WORKS

Television signals are carried by radio waves. As well as the sound signals, the waves carry picture signals. A television converts these signals into sound and pictures. The sound is converted in the same way as in a radio. The picture signals are converted into pictures by a **cathode ray tube**. The pictures are built up from about 350,000 tiny shapes called **pixels** (short for picture elements).

A cathode ray tube



CABLE BROADCASTING

TV and radio signals can be carried along cables, too. The cables can convey more signals than when they are transmitted through the air, so more channels are available. A vast network of underground cables exists. These can also be used to carry phone signals.

Fiber-optic cables are used for carrying television and radio signals.

DIGITAL BROADCASTING

By 2010 most radio and television broadcasting will be done **digitally**. Digital signals are electrical signals which carry information as a code made up of millions and millions of just two components: either "on" (1) or "off" (0).

The digital code is mixed onto – and then carried by – radio waves. Digital information can be compressed (see *Transmission Speed*, page 245, for an example) so far more can be sent. As a result, broadcasters can offer more channels than previously.

INTERACTIVE TV

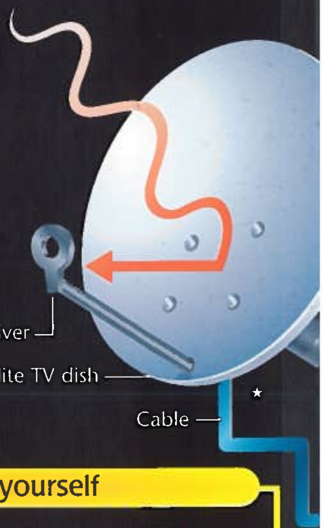
Digital broadcasting makes it possible to communicate in two directions. As a result, you can send information back through your TV, to order programs to watch whenever you want, or to buy things, or even to take part in games and competitions. This is called **interactive TV**.

This TV shows an interactive game to play during a soccer game.

Competitors predict the scorers of goals and the game's outcome. Their predictions are registered with the TV company and if they are right they win instant prizes.

SATELLITE TV

Satellite TV companies bounce signals off space satellites, to be received directly by a small dish that is fixed to the side of your home.



The dish focuses the TV signal onto a receiver. The signals travel along a cable to a television set.

See for yourself

Put a magnifying glass up close to your TV set while it is on. Look carefully and you'll be able to see the pixels that make up the picture.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Discover the origins of radio and broadcasting.

Website 2 The journey of a sound wave in a radio transmission.

Website 3 A simple explanation and quiz on how radio works.

Website 4 Digital TV, with a brief history of television.

Website 5 Find out how TV and computer screens work.

ELECTRICITY

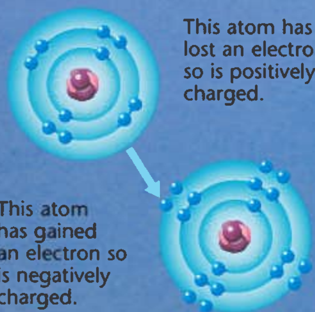
Lightning is a form of electricity.

Electricity is a useful form of energy. It can easily be converted to other forms of energy, such as heat or light, and it can flow along cables, which makes it easy to transport. Electricity is used to power many devices, from kettles to computers, and to provide heat and light in homes, offices and factories.

ELECTRIC CHARGE

All matter is made up of tiny units called **atoms**. In the middle of each atom is a **nucleus**. This contains particles called **protons** which have a positive charge and **neutrons** which have no charge. Negatively charged particles called **electrons** whizz around the nucleus. Normally, the number of protons and electrons is equal. Their charges cancel each other out so the atom is electrically neutral.

An atom can gain or lose electrons. If it gains electrons, it becomes negatively charged (–). If it loses electrons, it becomes positively charged (+).



If charged particles are close enough to each other, they have an effect on each other known as an **electric force**. The area in which this force has an effect is called an **electric field**.

Particles with opposite charges (positive and negative charges) attract each other. Particles with the same type of charge, for example two positively charged particles, push each other away.

Atoms with opposite charges attract each other.

Atoms with the same charge push each other away.

Electricity is the effect caused by the presence or movement of charged particles.

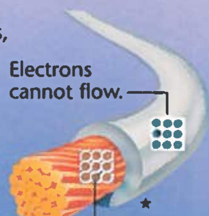
ELECTRIC CURRENT

In certain substances, such as metals, some electrons are not held tightly by the atoms and can move between them. If they are made to move, there is a flow of electric charge called an **electric current**. Substances through which current can flow are called **conductors**. Those substances, such as plastic, which cannot conduct current, are called **insulators**.

Wood and plastic are insulators.

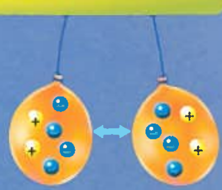
Aluminum foil is a conductor.

Insulated wires are electrical wires, usually made of copper, covered with plastic to insulate them.



See for yourself

To see how charges affect each other, tape two equal lengths of nylon thread to the top of a door frame, spaced about 1in apart. Tie a balloon to each thread, so that they touch and hang at the same height. Rub the balloons with a wool scarf or sweater. The balloons become negatively charged and move away from each other. If you put your hand in between the balloons, they move toward your hand, which has a positive charge.



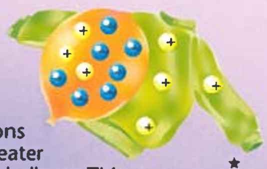
Matching charges repel each other.

STATIC ELECTRICITY

Some insulating materials become charged when rubbed. This happens because electrons from one material are transferred to the other. The charge cannot flow away because there is no conductor, so it builds up on the surface of the material. Electrical charge that is held by a material is called **static electricity**.

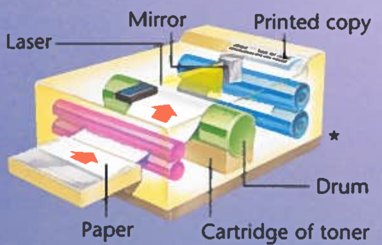
The diagrams below show how static electricity builds up if you rub a balloon on a wool sweater.

Before they are rubbed, the balloon and the sweater are electrically neutral.



As they are rubbed, some electrons from the sweater move to the balloon. This becomes negatively charged, and the sweater becomes positively charged. They cling together because their opposite charges attract each other.

Equipment such as laser printers and photocopiers use static electricity as part of their printing process.



In a laser printer, a laser beam reflected by a mirror makes dots of static electricity on a drum. Toner clings to the dots of static and is pressed onto the paper.

LIGHTNING

Lightning is caused by static electricity that builds up when falling water droplets and rising ice crystals rub against each other in storm clouds.

Water droplets and ice crystals become charged as they rub against each other and the air.

Positive charges gather at the top of the cloud and negative charges in the base. As this happens, positive charges collect together on the ground beneath the cloud.

A giant spark, called a **leader stroke**, flashes out from the cloud, seeking a point with the opposite charge on the ground. When it finds it, it makes a path which is followed by a powerful stroke of lightning from the ground to the cloud. This is called the **return stroke**.

Lightning contains a vast amount of electrical energy, which is changed into light, heat and sound (thunder).

A stroke of lightning branches out in many directions as it seeks its way to the ground.

A build-up of negative charge at the base of a storm cloud causes a build-up of positive charge in the ground below.

When lightning strikes, an electric current flows between the cloud and the ground, leaving them both electrically neutral.

The air heated by the flashes of lightning expands very rapidly. This makes the noise that we hear as **thunder**. Light travels faster than sound, so unless the storm cloud is directly overhead, you see the lightning before you hear the thunder.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 A guide to electricity.

Website 2 Meet the energy pioneers and find out about important inventions.

Website 3 Fun online activities about electrical conductors and insulators.

Website 4 Learn about atoms, electricity and different types of electricity.

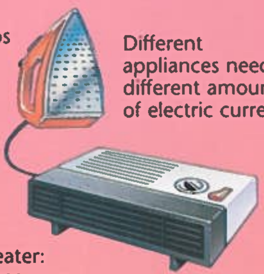
Website 5 Read about the discovery of the electron.

Website 6 Try some fun electricity experiments.

Website 7 Learn all about lightning.

CIRCUITS

An electric current flows from one place to another as a result of something called **potential difference**. This is similar to the pressure difference that causes water to flow through pipes. Potential difference is measured in **volts (V)** and is also called **voltage**. Current is measured in units called **amperes (amps)**.



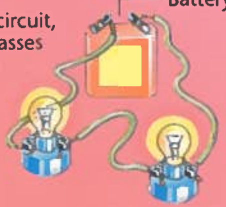
Different appliances need different amounts of electric current.

For an electric current to keep flowing there must be a power source, such as a battery (see opposite page), joined to an unbroken conducting pathway, such as a loop of copper wire. This pathway is called an **electric circuit**. The power source has two ends with opposite charges, called **poles** or **terminals**. These are where the circuit starts and finishes.

A potential difference exists between the terminals of a battery. When they are joined, a circuit is formed and a current flows.

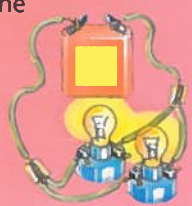
Components, such as bulbs, can be added to a circuit. These convert the electrical energy carried by the current into other forms of energy such as light and heat. The components in a circuit can be arranged in two ways: in series or in parallel.

In a **series circuit**, the current passes through the components one after the other. If one component is not working, it breaks the circuit and no current flows. For example, in a chain of Christmas lights, if one bulb fails, the current to the others is cut off.



In this series circuit, the current passes through each component in turn.

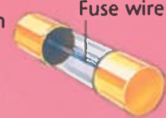
A **parallel circuit** has more than one path for the current. If a component in one path does not work, current continues to flow through the other path.



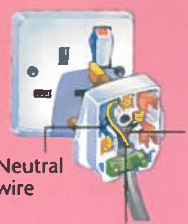
In this parallel circuit, the current passes through the components by different paths at the same time.

ELECTRICITY AT HOME

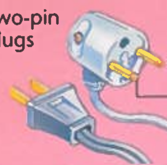
Household electricity is 240V in some countries and 110V in others. These large voltages can give you a deadly electric shock. Appliances are protected by **fuses** containing very thin pieces of wire. These melt, and cut off the current if it is too large.

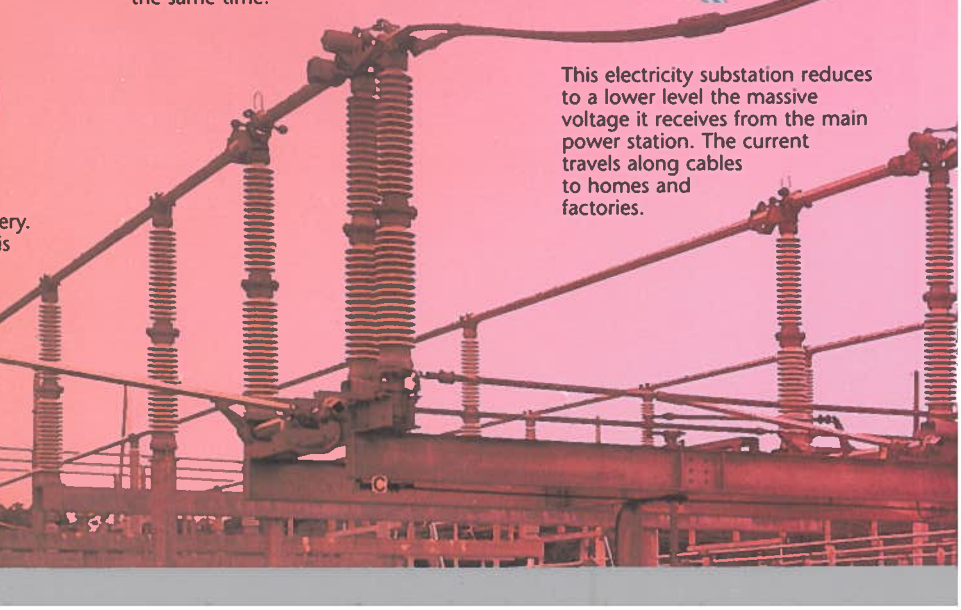


Electricity is carried to different parts of a house by parallel circuits. These circuits contain two wires called the **live** and **neutral wires**, which carry the current. In some countries there is also an **earth wire**. This is a safety device. It provides a path to the ground through which electric current can escape if the plug develops a fault.



When a plug is put into a socket, the pins connect with the live and neutral points in the circuit.





This electricity substation reduces to a lower level the massive voltage it receives from the main power station. The current travels along cables to homes and factories.

BATTERIES

A **battery** is a store of chemical energy that can be converted to electrical energy. The most common type of battery used at home is called a **dry cell**. It contains a paste called an **electrolyte** which contains charged particles that can move. Chemical reactions make the charges separate. Positive charges move to one terminal and negative ones move to the other.

Batteries produce an electric current that moves in a single direction. This is called **direct current** (**DC**).

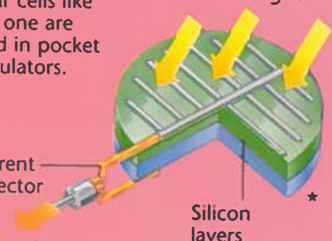
Cutaway view of a dry cell

A 1.5V battery, such as the type used in a personal stereo, is called a **single cell**. Larger batteries are made up of several single cells.

Dry cells are **primary cells**. When the chemicals in the electrolyte run out, the battery is finished. **Secondary cells**, or **accumulators**, are batteries that can be recharged. A car battery is a type of secondary cell. It is continually recharged with electric current generated from the car.

Cutaway view of a car battery

A **solar cell** converts the Sun's energy into electricity. Sunlight falling on the layers of silicon makes the electrons move, creating a potential difference between the two layers.



See for yourself

To make a simple battery, draw around a coin to make twelve circles each on a sheet of foil and a paper towel, then cut them out. Dampen the paper circles in a cup of water with ten teaspoons of salt stirred in.

You need 12 copper coins. Pile the circles in groups of three (a cell), made up of one foil, one paper and one coin. Tape the bare end of a piece of insulated copper wire to the bottom of the pile, and another wire to the top. Touch the other two ends together. In a dark room you should see a spark.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Online introductions to electricity, circuits and currents.

Website 2 Animations that explain electricity, circuits, lightning and static.

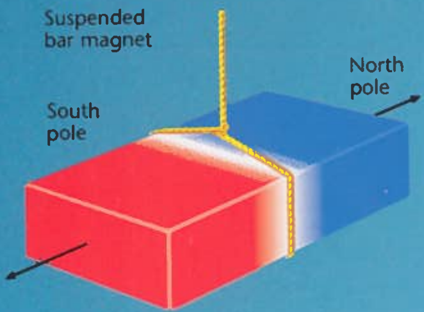
MAGNETISM

Magnetism is an invisible force that attracts some metals, especially iron and steel. Materials that create this force are said to be **magnetic** and are called **magnets**.

Migrating terns like these may use the Earth's magnetic field to guide them.

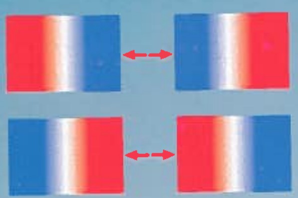
POLES

If you float a magnet in water or hang it from a thread tied around its middle, it will always point in a north-south direction. The part of the magnet that points north is the **north** or **north-seeking pole**. The other is the **south** or **south-seeking pole**.

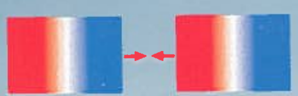


A north and a south pole of two magnets will pull toward or **attract** each other. Two north or two south poles will push each other away. This is called **repulsion**.

Like poles repel each other.



Unlike poles attract each other.



TYPES OF MAGNETS

Materials that can easily be magnetized (turned into magnets) are said to be **ferromagnetic**. They can be described as hard or soft.

Soft ferromagnetic materials such as iron quickly lose their magnetic properties. Magnets made from these materials are called **temporary magnets**. Hard ferromagnetic materials such as steel keep their magnetic properties for much longer. They are used to make **permanent magnets**.

Each paper clip in this chain has become magnetized by contact with the magnet. Each is a temporary magnet.

If the magnet is removed, the clips will lose their magnetism.

A compass needle is a permanent magnet. It points to the Earth's magnetic north pole.

DIPOLES AND DOMAINS

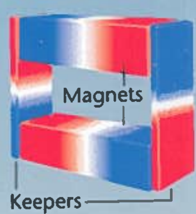
A ferromagnetic material has molecules which behave like tiny magnets. They are known as **dipoles** and are grouped in **domains**, in which they all point the same way. When the material is magnetized, all the domains become ordered and point the same way. The material loses its magnetism if its domains become jumbled up again.

When magnetic material is in a non-magnetized state, the domains are jumbled up.

When it is magnetized, the domains line up, with their poles all pointing the same way.

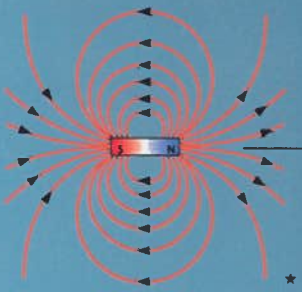
Ordered dipoles collectively form a magnet, but individually, each one is trying to flip round, as its poles are attracted to the opposite poles of the whole magnet. As they turn, the magnet loses its magnetism.

A metal **keeper** across a magnet's ends helps it to stay magnetic. The keeper becomes magnetized and attracts the magnet's dipoles to its poles.



MAGNETIC FIELDS

The region around a magnet in which objects are affected by its magnetic force is called a **magnetic field**. The strength and direction of the magnetic field are shown by **magnetic flux lines**. The arrows on the lines show the direction. The magnetic field is strongest where the lines are close together.



Magnetic flux lines showing the direction of the magnetic field around a bar magnet

The lines are closest near the poles, where the field is strongest.

The Earth itself has a magnetic field. It acts as though it has a giant bar magnet through its middle. The north pole of a compass points towards a point called **magnetic north**, its south pole points to **magnetic south**. These are different from the geographical North and South Poles.

These magnetic flux lines show the direction of the magnetic field around the Earth.

See for yourself

To see magnetic flux lines, sprinkle some iron filings onto a sheet of clear plastic or a piece of white paper, then hold a magnet underneath. The iron filings will move to show the pattern of the magnetic field.

Clear plastic sheet

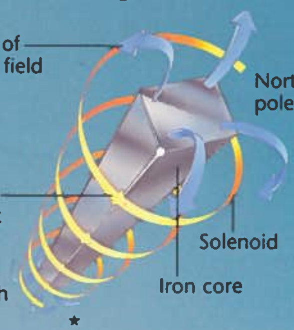
ELECTROMAGNETISM

When an electric current flows through a wire, it produces a magnetic field around it. This effect is called **electromagnetism**.

The magnetic field of the wire can be made stronger if the wire is wound in a coil. When a current is passed through the coil, the coil behaves like a bar magnet and is called a **solenoid**. The region inside the coil is called the **core**.

If a solenoid has a rod of a soft ferromagnetic material such as iron placed inside it, the rod is quickly magnetized and adds its own magnetic field to that of the solenoid. Together the solenoid and the ferromagnetic core make an **electromagnet**. You can find out more about the uses of electromagnets over the page.

A simple electromagnet



The position of the north and south poles in an electromagnet depends on the direction of the current flowing through the wire.

Viewed end-on, current flowing counterclockwise gives a north pole.

Current flowing clockwise gives a south pole.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Find out more about Earth's magnetic field and make a compass.

Website 2 Learn about the properties of magnets and find some experiments to try at home.

Website 3 Investigate the use of magnets in an everyday kitchen.

Website 4 An animated guide to magnetic fields, with a quiz.

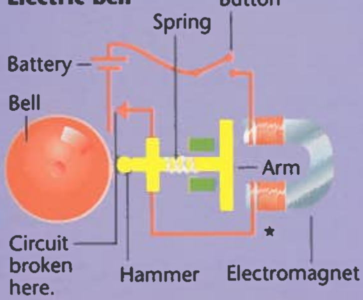
Website 5 Interactive activities about electricity and magnetism.

USING ELECTROMAGNETS

Electromagnets often contain iron, a soft ferromagnetic material. The iron loses almost all of its magnetism when the current through the electromagnet is switched off. For this reason, electromagnets have many uses, such as in switches, bells and buzzers.

When you press the button of an electric bell, for example, current flows through the coils of an electromagnet and attracts a metal arm. As the arm moves closer to the electromagnet, it loses touch with the contact through which the current is flowing, breaking the circuit. The arm is pulled back by a spring, making a hammer hit a bell. This completes the circuit and the cycle begins again.

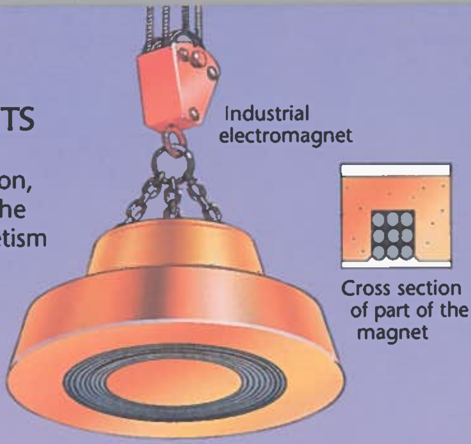
Electric bell



See for yourself

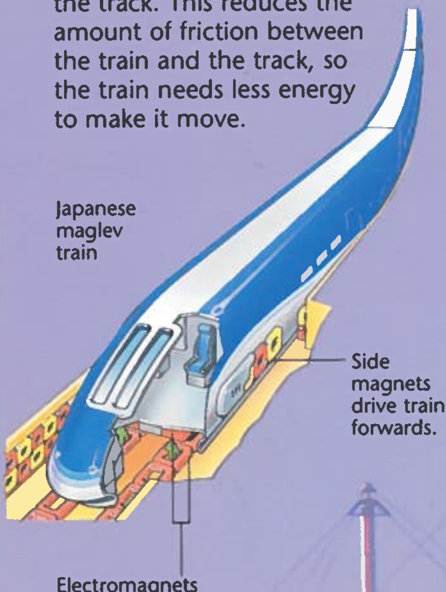
You can make an electromagnet using a 4.5V battery, a pencil, a large iron nail and some insulated copper wire. To make a solenoid*, wind the wire tightly around the pencil, and tape both ends to the battery. Your electromagnet should be strong enough to affect a compass needle, but too weak to pick anything up. If you replace the pencil with the nail, you will have an electromagnet that can pick up paper clips.

* *Solenoid, 233.*



Very powerful electromagnets are used in steelworks to lift heavy loads. When current flows through the coil of wire, the iron becomes magnetized. It attracts steel, which can be moved from one place to another. When the current is switched off, the electromagnet releases its load.

Magnetic levitation (maglev) trains have electromagnets on the bottom. They run on tracks with electromagnets on them. The magnets repel each other, so the train hovers just above the track. This reduces the amount of friction between the train and the track, so the train needs less energy to make it move.

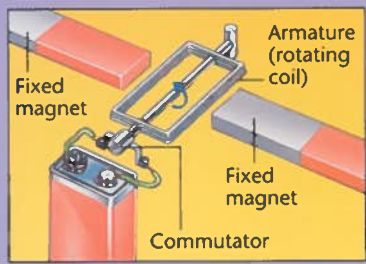


ELECTRIC MOTORS

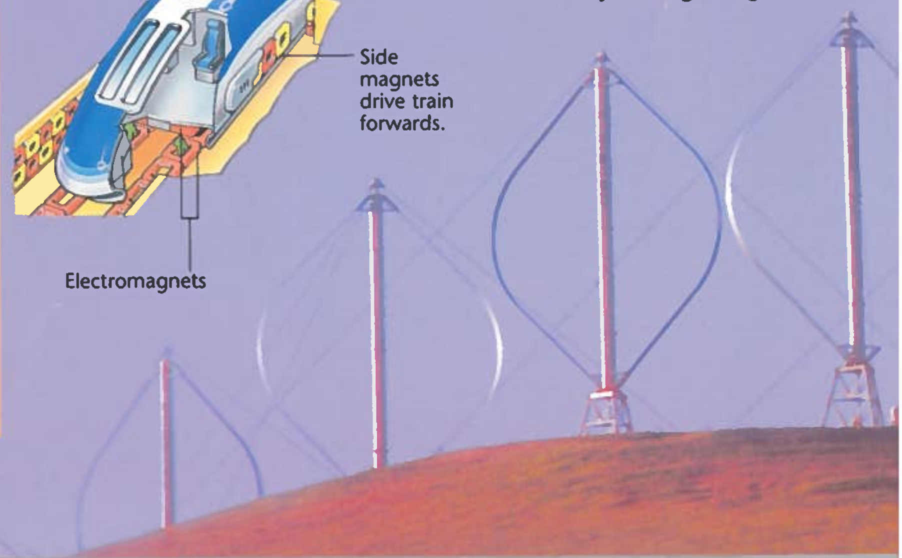
Electric motors change electrical energy into movement. A simple electric motor (see picture below) contains a flat coil of wire called an **armature** between two magnets.

When current flows through the armature, the combination of the electromagnetic field of the armature and the magnetic fields of the magnets pushes one side of the armature up and the other side down.

A simple electric motor

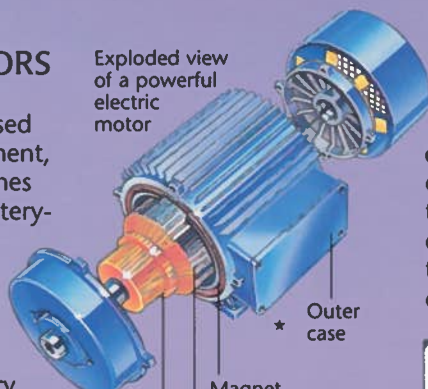


When the armature is in an upright position, a device called a **commutator** causes the direction of the electric current to be reversed, so the magnetic field of the armature is reversed. The side of the armature that was pushed up is now pulled down. The armature completes its circle and the cycle begins again.

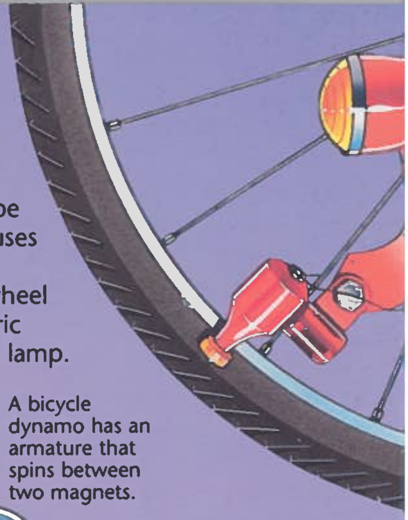


USES FOR MOTORS

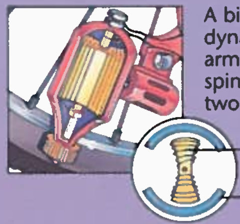
Electric motors are used in all kinds of equipment, from washing machines and hairdryers to battery-driven toy cars and model trains. Tiny **micromotors** (see picture below) are being developed for use in microsurgery and space research.



This Toshiba micromotor is 0.8mm wide – about the same as the eye of the needle next to it.



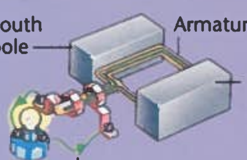
A **bicycle dynamo** is a type of generator. It uses the movement energy from a wheel to produce electric current to light a lamp.

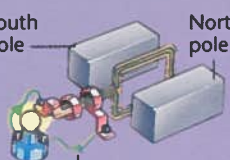


A bicycle dynamo has an armature that spins between two magnets.

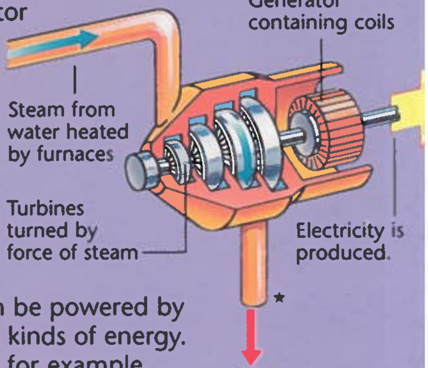
GENERATING ELECTRICITY

A **dynamo** or **generator** is a machine for converting movement energy into electrical energy. It works rather like an electric motor in reverse. The diagrams below show how a generator produces electricity. As the armature turns between the two magnets, an electric current starts to flow. As the armature passes through its upright position, the direction of the current changes. This type of current is called **alternating current (AC)**.





Electricity is generated on a larger scale in **power stations**. Many power stations use heat energy from burning coal to boil water and turn it to steam. The pressure of the steam is used to spin the shaft of a machine called a **turbine**. This then turns the shaft of a huge generator and produces alternating current.



Cutaway of steam turbine

Generators can be powered by many different kinds of energy. Wind turbines, for example, use the energy of moving air (wind) to generate electricity.

The shafts of these wind turbines are made to spin by the wind. The movement energy is used to generate electricity.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Find out more about how electric motors work.

Website 2 Interactive animations that show how an electric motor and an electric generator work.

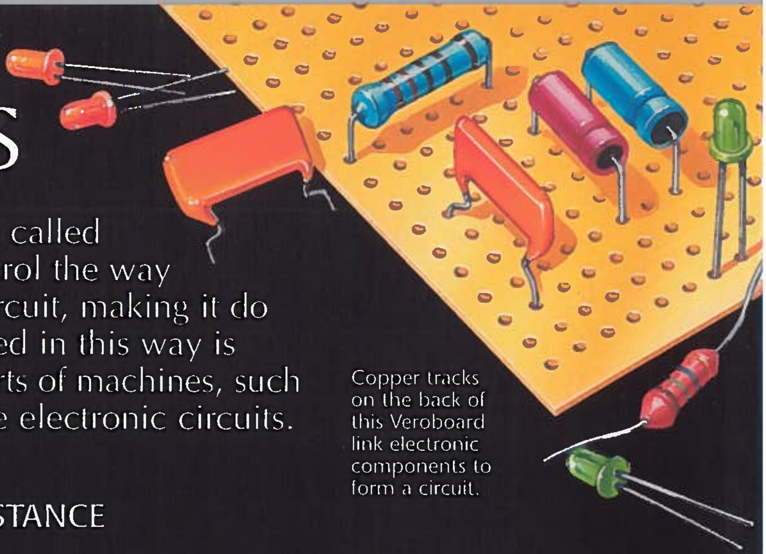
Website 3 Review the principles of magnets, electromagnets and electric currents, with animated diagrams.

Website 4 See how an alternating current works.

Website 5 Animations that show how Maglev trains work.

Website 6 Learn how a turbine works then build one online.

ELECTRONICS

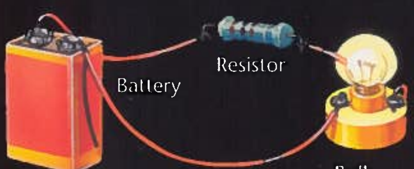


Copper tracks on the back of this Veroboard link electronic components to form a circuit.

Electronics is the use of devices called **electronic components** to control the way electric current flows around a circuit, making it do particular tasks. A circuit controlled in this way is called an **electronic circuit**. All sorts of machines, such as TVs, robots and computers, use electronic circuits.

BUILDING CIRCUITS

Electronic circuits can be made up using different components. The simple circuit below, for instance, contains a resistor (see right).



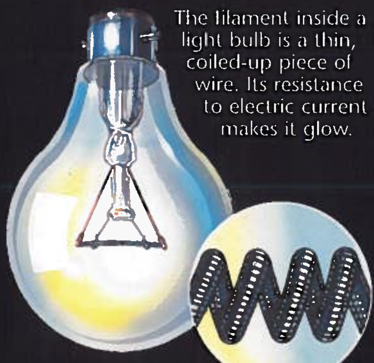
Circuits can be mapped out using diagrams like the one below. Each component is shown using a different circuit symbol. The main circuit symbols can be found together on page 409.

Circuit diagram of circuit above

You can make simple circuits using **Veroboard**. This has rows of holes and copper tracks on the back. Components are pushed through from the front, then their legs are soldered onto the tracks to form a circuit. **Printed circuit boards (PCBs)** are plastic boards which are imprinted with metal tracks. They are used, for example, in televisions. **Integrated circuits** are tiny circuits engraved onto small slices of silicon.

RESISTANCE

The ability of a substance to restrict the flow of electric current is known as **resistance**. All the parts in an electric circuit have a certain amount of resistance, and this reduces the amount of current that is able to flow around it in a certain time. When a substance resists an electric current, it converts some of the electrical energy into heat or light.



The filament inside a light bulb is a thin, coiled-up piece of wire. Its resistance to electric current makes it glow.

Close-up of filament

Resistance is measured in units called **ohms**, named after Georg Ohm, a nineteenth-century physicist.

The Greek letter omega is used as a symbol for ohms.

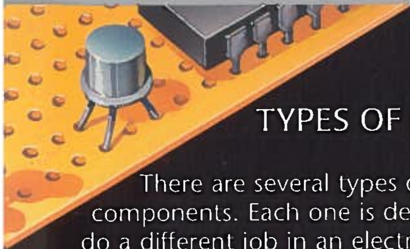
Resistors are electronic components which reduce the flow of current. Resistors have three or four color-coded stripes on them which show how much resistance they give.

The first two stripes on a resistor stand for numbers. The third tells how many zeros to put on the end. The fourth stripe tells you the rating's range. The stripes on the resistor below, for example, are blue (6), red (2), black (0) and gold (±5%), so it has a resistance of 62 ohms, plus or minus 5%.

The stripes on this resistor show that it gives between 58.9 and 65.1Ω of resistance.

See for yourself

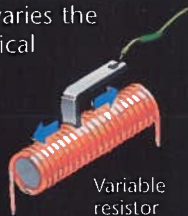
Using the color code chart above, try to determine which of these two resistors has the highest ohm rating. (Answer on page 447.)



TYPES OF COMPONENTS

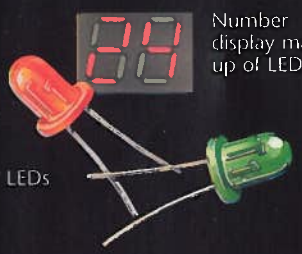
There are several types of electronic components. Each one is designed to do a different job in an electronic circuit. For example, different kinds of resistors are designed to resist current by greater or lesser amounts in different conditions.

A **variable resistor**, or **rheostat**, can be adjusted to give different amounts of resistance. The volume control on a radio uses a variable resistor to change the amount of current. This varies the amount of electrical energy that is converted to sound energy.



A **thermistor** is a heat-sensitive resistor. Its resistance falls as the temperature rises, and rises as the temperature falls. They are used in some fire alarms to sense when a room is too hot.

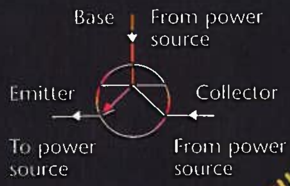
Diodes allow the current to flow through them in only one direction. A **light-emitting diode** (**LED**) glows when current flows through it.



This pocket radio contains many electrical components arranged in a circuit called an **amplifier circuit**.

Transistors are electronic switches. A transistor has three legs, called the **base**, the **collector** and the **emitter**. When a small current flows into the base leg, the transistor allows a larger current to flow between the collector and the emitter. The transistor is then switched on. When no current flows to the base leg the transistor is off.

This diagram shows the currents (white arrows) that flow through a transistor in a circuit.



Capacitors store up electrical energy and release it when it is needed. A television uses capacitors to build up and store very high voltages.

There are different kinds of capacitors.

On this printed circuit board, the black oblong shapes contain integrated circuits. They are connected to each other and to other components by metal tracks.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 A very good introduction to electronics.

Website 2 Learn the symbols used for circuits then build a circuit online.

Website 3 Find out more about resistance and resistors, with exam questions.

Website 4 Interactive electronics activity about resistance.

Website 5 Another activity about resistor color codes.

Website 6 A brief history of electronics.

DIGITAL ELECTRONICS

Digital electronics is a form of electronics that uses pulses of electricity instead of continuously flowing, or **analog**, electricity. All sorts of electronic equipment, from digital watches and calculators to computers, use digital electronics.

Pocket calculators contain digital electronic circuits.

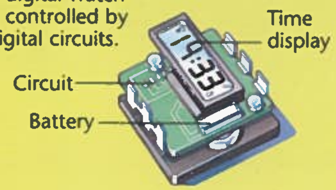
DIGITAL CIRCUITS

In a **digital circuit**, the electricity exists in pulses at either high voltage* or low voltage. Tiny electronic components* change and redirect these pulses as they flow around the circuits.

In an analog circuit, electricity flows continuously.

In a digital circuit, the electricity is broken up into a series of pulses.

A digital watch is controlled by digital circuits.



The pulses of electricity can be used to represent information in **binary code**. This expresses information using numbers made up of the digits 0 and 1. Words, sounds and pictures can be translated into binary, too. As there are only two options (0 and 1), devices that use digital electronics can process information very quickly.

Wave form of digital current

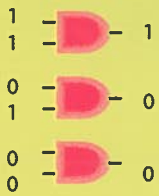
A pulse at high voltage represents a 1 and a pulse at low voltage represents a 0.

LOGIC GATES

A **logic gate** is an arrangement of transistors* used to carry out calculations in digital electronic circuits. Logic gates change or redirect the pulses that flow through them. Most logic gates have two **inputs**, which receive signals, and one **output**, which gives out a signal.

There are three main types of logic gates, and they are each represented by a different circuit symbol, as shown below.

AND gate



An AND gate gives out a 1 if it receives two 1s. Otherwise, it gives out a 0.

NOT gate

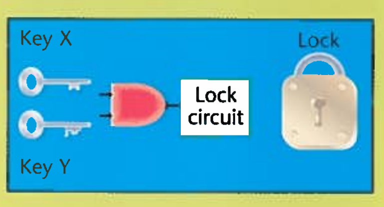
A NOT gate has one input and one output. It changes a 1 to a 0 and a 0 to a 1.

OR gate

An OR gate gives out a 1 if it receives a 1 in either of its inputs.

Logic gates have many uses. For example, an AND gate might be used in a security system, such as that used in a bank, where two officials must turn keys at the same time to open a safe. Only when both keys are turned would two 1s pass through the AND gate, and so open the lock.

This security circuit uses an AND gate so that the lock only opens when keys X and Y are both turned.



If the output is 1, current flows through the lock circuit and the lock opens.

FLIP-FLOPS

Logic gates are usually combined to make up more complex devices, such as **flip-flops**. Electric pulses circulate back and forth inside flip-flops in a process called **feedback**. This enables the flip-flops to "remember" pieces of binary information.

Integrated circuits in computers (see opposite) often contain many thousands of flip-flops. These are joined together to make the computer's memory.

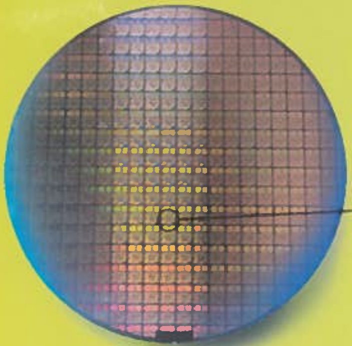
* *Electronic components, 237; Transistors, 237; Voltage, 230.*

INTEGRATED CIRCUITS

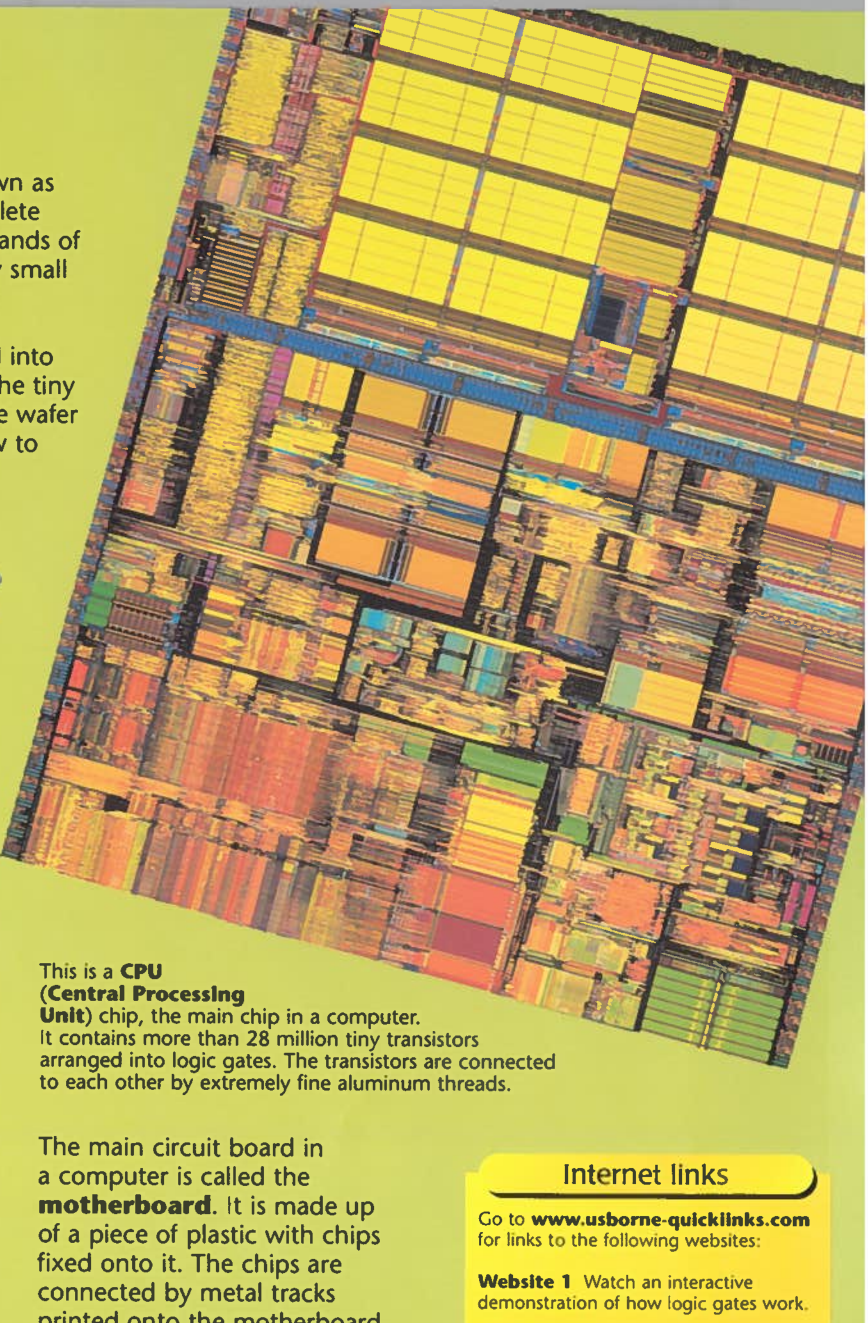
An **integrated circuit**, also known as a **silicon chip** or **chip**, is a complete electronic circuit containing thousands of tiny components etched on a very small piece of an element called silicon.

Large cylinders of silicon are sliced into thin sections called **wafers**, and the tiny circuits are printed onto them. The wafer is then cut up with a diamond saw to make the individual chips.

To make chips, silicon cylinders are sliced into thin wafers.



Many circuits are printed onto each wafer. The wafer is then cut up into individual chips.



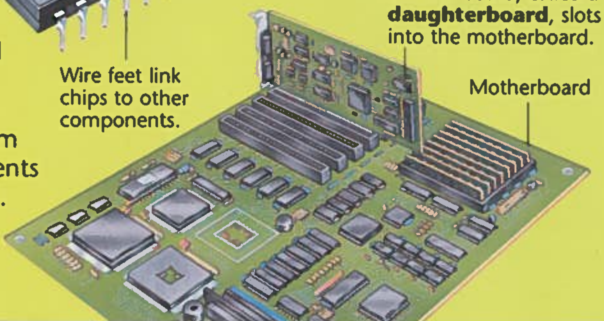
This is a **CPU** (**Central Processing Unit**) chip, the main chip in a computer. It contains more than 28 million tiny transistors arranged into logic gates. The transistors are connected to each other by extremely fine aluminum threads.

Silicon is used because it is a **semiconductor** – a type of material that acts as a conductor* or an insulator*, depending on its temperature. The components that make up the circuits are also semiconductors, made of silicon mixed with tiny amounts of elements such as phosphorus or boron.

When the chips are made, they are mounted in plastic fittings which have wire feet to attach them to other components on a circuit board.

Wire feet link chips to other components.

The main circuit board in a computer is called the **motherboard**. It is made up of a piece of plastic with chips fixed onto it. The chips are connected by metal tracks printed onto the motherboard. Other components on the board control the amount of electricity flowing through the chips.



Smaller board, called a **daughterboard**, slots into the motherboard.

Motherboard

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Watch an interactive demonstration of how logic gates work.

Website 2 Simple animations about different types of logic gates.

Website 3 Select the ingredients for making a microprocessor.

Website 4 Zoom in on the circuits on a silicon wafer then follow an online lesson to see how microprocessors are made.

Website 5 Illustrated guide to digital electronics, with exam questions.

Website 6 View the history of microprocessors and how they have become more powerful.

* *Conductor, Insulator, 228.*

COMPUTERS

At their most basic, **computers** are machines that do calculations and sort information. When they were invented in the late 1940s, computers were so big they filled whole rooms. Since then, they have been continuously improved and made smaller. Today, computers with more power than the early ones are no bigger than this book.

The Analytical Engine, a forerunner of the computer, built over a hundred years ago.

HARDWARE

The pieces that make up a computer are called **hardware**. Items of hardware that sit outside the case containing the computer's main electronic circuits are called **peripherals**. The screen, keyboard and mouse are all peripherals.

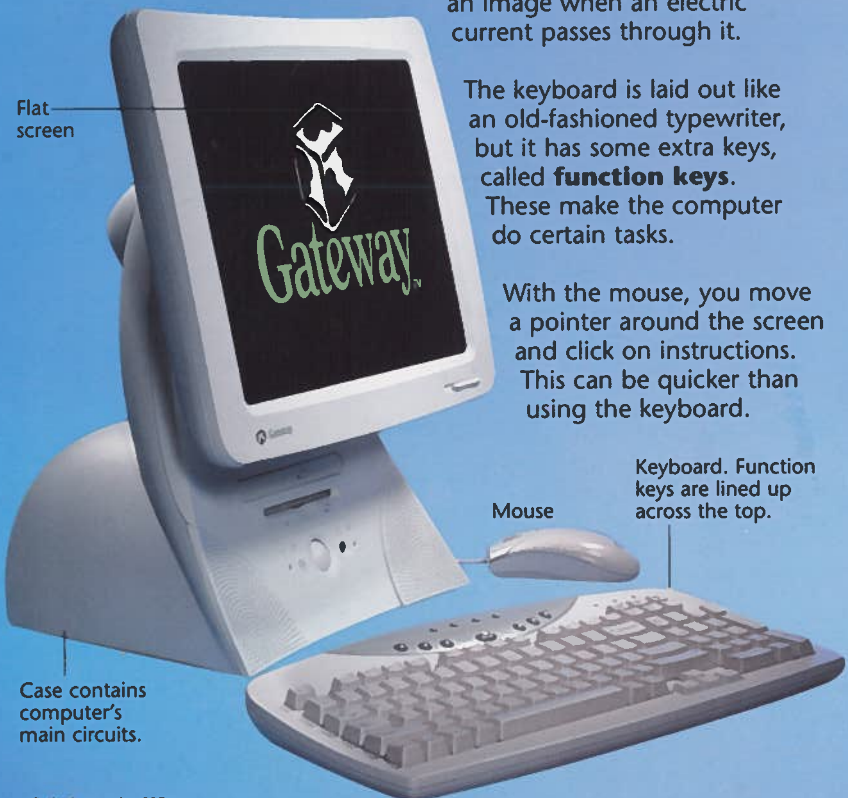
The type of computer shown below is called a **personal computer**, or **PC**.

This computer has a cathode ray tube* screen. It makes a picture in a similar way to a television.

Portable computers, called **laptops**, and handheld computers, called **palmtops**, have flat screens. They contain a thin layer of liquid crystal solution, which darkens to form an image when an electric current passes through it.

The keyboard is laid out like an old-fashioned typewriter, but it has some extra keys, called **function keys**. These make the computer do certain tasks.

With the mouse, you move a pointer around the screen and click on instructions. This can be quicker than using the keyboard.



Flat screen

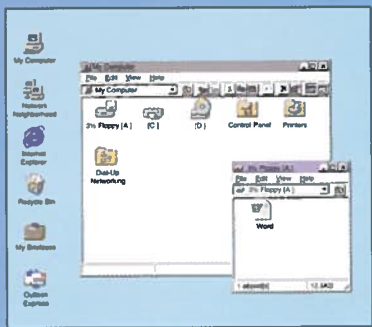
Case contains computer's main circuits.

Mouse

Keyboard. Function keys are lined up across the top.

SOFTWARE

A computer won't work unless it has a set of instructions called a **program**, or **software**, loaded into its memory. Software that controls how the computer works is called the **operating system**. Windows®, made by Microsoft®, is an operating system.



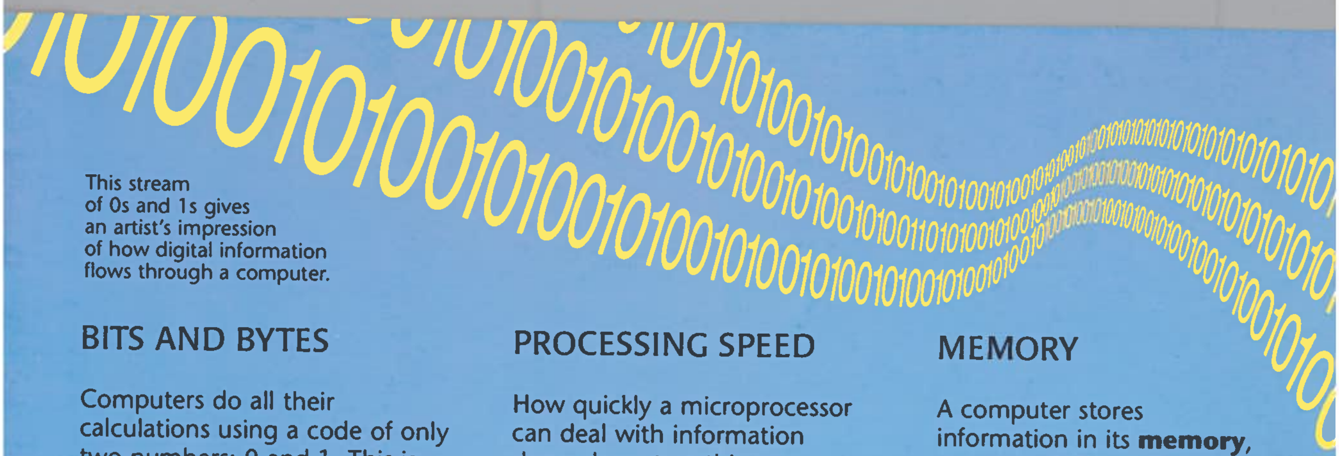
This screen shows files containing Windows software and documents.

Further software is needed to let you use the computer for particular activities such as playing games or connecting to the Internet.

See for yourself

When you start up a PC, watch for lines of information which flash past your eyes. This is the computer checking through its own hardware and software, making sure that everything is working correctly.

* Cathode ray tube, 227



This stream of 0s and 1s gives an artist's impression of how digital information flows through a computer.

BITS AND BYTES

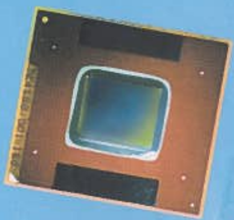
Computers do all their calculations using a code of only two numbers: 0 and 1. This is known as **binary code**. Each 0 or 1 is called a **bit** (short for **bi**nary dig**it**). Binary code is easy to express by pulses of high (1) or low (0) electrical voltage through the computer's circuits.

A group of eight bits, called a **byte**, is used to represent a small piece of data (information). Lots and lots of bytes together can represent complex data.

This byte stands for the keyboard letter B.

PROCESSING

Calculations in a computer are done by **microprocessors**. In a personal computer, the most important is called the **central processing unit**, or **CPU**. CPUs can deal with several million calculations per second.



A microprocessor

Bytes travel around a computer along tiny electronic pathways, called **buses**. These take information between the CPU and other parts of the computer.

* *Silicon chip, 239*

PROCESSING SPEED

How quickly a microprocessor can deal with information depends on two things:

- the number of bytes that it can process at once, called **bandwidth**;
- the number of instructions it can deal with in one second, called **clock speed**. This is measured in megahertz (MHz). A CPU that can process 500,000 calculations per second is said to have a clock speed of 500MHz.

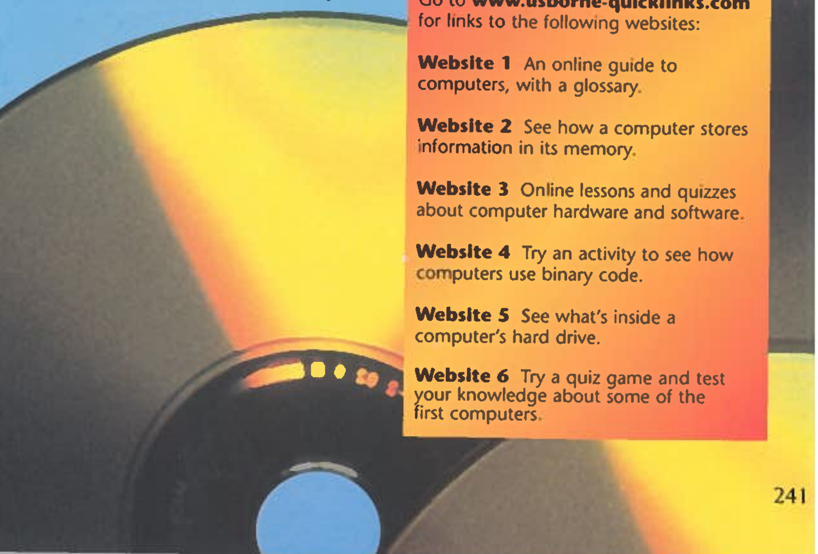
A CPU microprocessor made by Intel

MEMORY

A computer stores information in its **memory**, on a set of disks called the **hard disk**. This information is retained when the computer is switched off. Information can also be stored for later use, or moved between computers, on cassette tapes, floppy disks or CDs.

A computer's **RAM** (**random access memory**) stores data on silicon chips* while other calculations are done by the CPU. RAM is emptied when the computer is shut down.

A floppy disk can hold a small quantity of data.



CDs can hold 450 times more information than floppy disks.

Computer CDs look just like music CDs. All CDs store information in a similar way.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 An online guide to computers, with a glossary.

Website 2 See how a computer stores information in its memory.

Website 3 Online lessons and quizzes about computer hardware and software.

Website 4 Try an activity to see how computers use binary code.

Website 5 See what's inside a computer's hard drive.

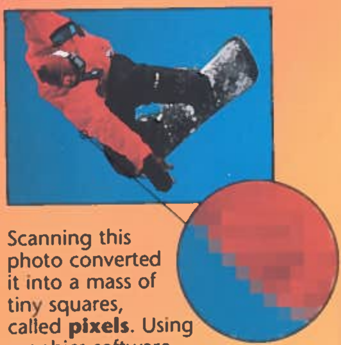
Website 6 Try a quiz game and test your knowledge about some of the first computers.

SOFTWARE PACKAGES

There are hundreds of different types of software available. These range from simple programs that let you type letters, to super-sophisticated packages that are used to design modern jets.

This picture of an Airbus was made using design software only. When the image was created, no real versions had been built.

There is software available for almost every type of work. In advertising and publishing, for instance, graphics software is used to manipulate pictures to create special effects.



Scanning this photo converted it into a mass of tiny squares, called **pixels**. Using graphics software, the pixels were altered to give the result on the right.

Close-up of pixels

Software comes loaded on floppy disks or, if it takes up a lot of memory, on CDs. These are downloaded (copied) onto the computer's hard disk.

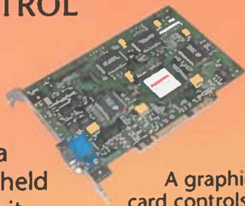
See for yourself

Windows® contains simple graphics software called Paint®. Although it is not as powerful as the software used to create the images on these pages, you can use it to alter an image's colors and shapes.

A color-selection panel from Paint®

HARDWARE CONTROL

How a piece of computer hardware, such as the screen, works is controlled by a set of microprocessors held on a small printed circuit board called a **card**.



A graphics card controls how pictures appear on the screen.

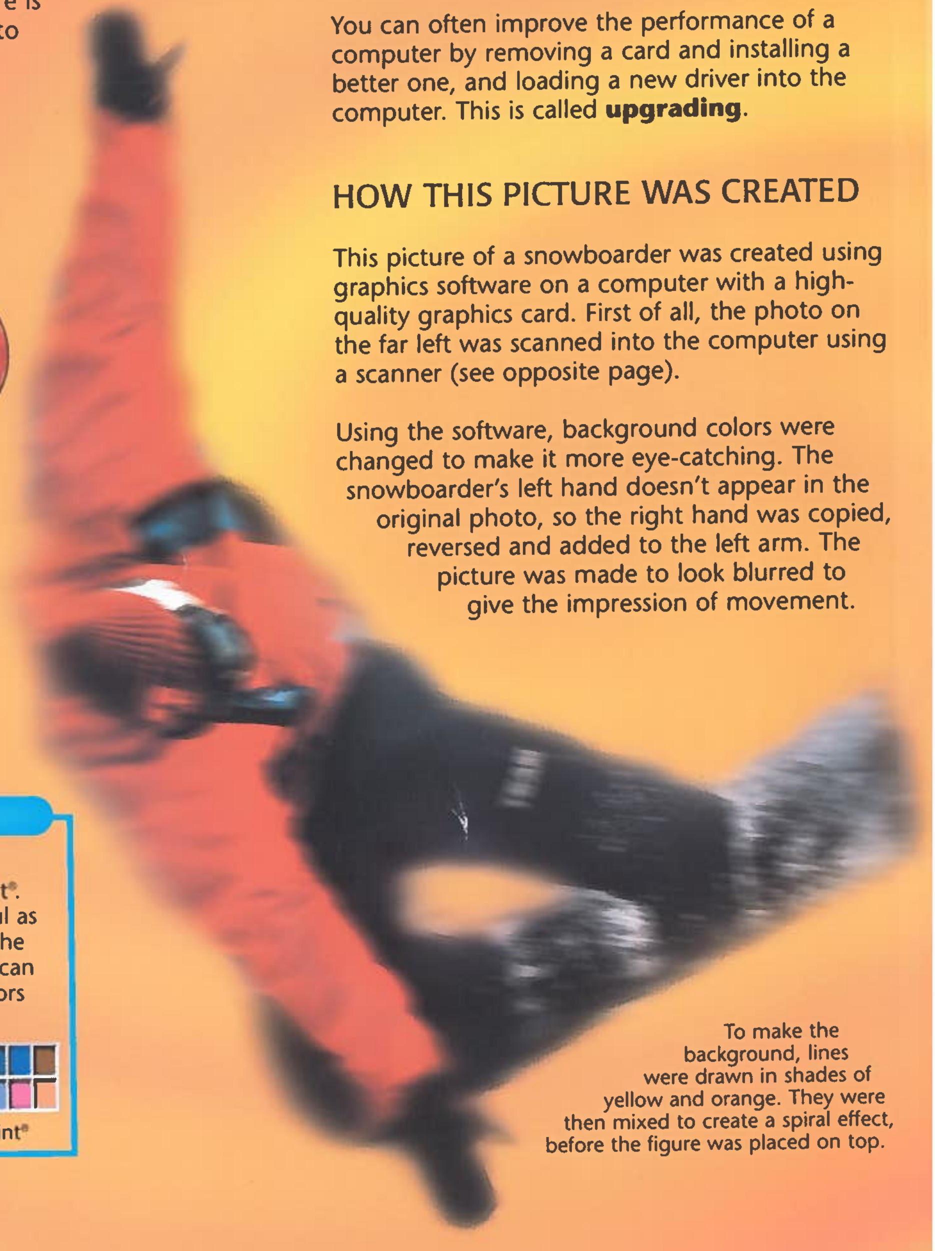
Each card slots into the computer's main circuit board. It is controlled in turn by software called a **driver**, which needs to be installed on the computer's hard disk.

You can often improve the performance of a computer by removing a card and installing a better one, and loading a new driver into the computer. This is called **upgrading**.

HOW THIS PICTURE WAS CREATED

This picture of a snowboarder was created using graphics software on a computer with a high-quality graphics card. First of all, the photo on the far left was scanned into the computer using a scanner (see opposite page).

Using the software, background colors were changed to make it more eye-catching. The snowboarder's left hand doesn't appear in the original photo, so the right hand was copied, reversed and added to the left arm. The picture was made to look blurred to give the impression of movement.



To make the background, lines were drawn in shades of yellow and orange. They were then mixed to create a spiral effect, before the figure was placed on top.

EXTRA HARDWARE

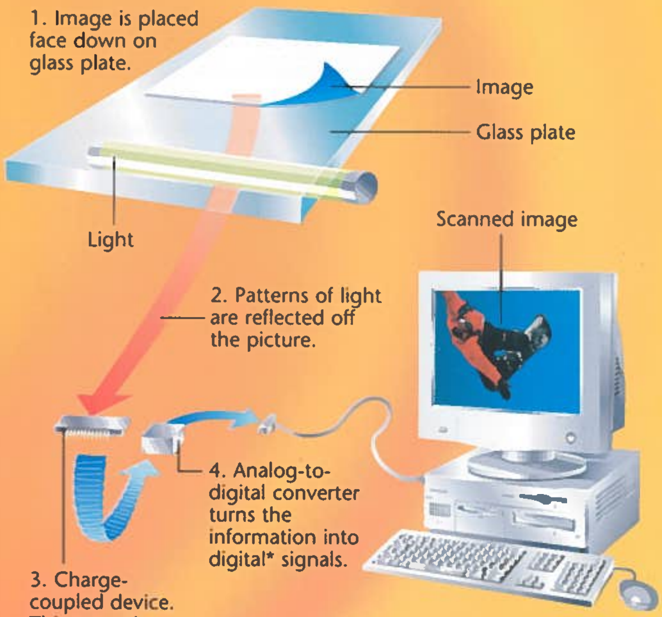
As well as basic hardware such as a screen, keyboard and mouse, other peripherals can be attached to a computer. These include printers, scanners and devices such as CD recorders for storing lots of information.

Speakers let you listen to music or speech on software, or downloaded from the Internet.

This steering wheel and foot pedal attach to the computer and make computer driving games more realistic and exciting.

A scanner turns text and pictures into digital information which can be stored in the computer.

How a scanner works



* *Analog, Digital, 238.*

NETWORKS

Connecting computers to each other is called **networking**. It allows information to be shared easily. A network can consist of computers that are close to each other or thousands of miles apart.

The simplest LAN consists of just two computers in the same room.

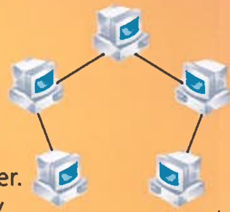
A network consisting of computers that are close together, for example all in the same room, is called a **local-area network**, or **LAN**.

A network of computers that are far apart is called a **wide-area network**, or **WAN**.

A WAN can join computers anywhere in the world.

TYPES OF NETWORKS

The simplest kind of network is called **peer-to-peer**. This means that the network is not controlled by any one computer. Peer-to-peer networks are fairly easy to set up.



A peer-to-peer network setup

In **client/server** networks, one computer, called the **server**, has control of the network. Important programs and data are held on the server. Other computers (the **clients**) collect these from the server to work on. If the server is not working, the clients can't use the data, so the network doesn't function.

A client/server network setup

Client/server networks can process more information than peer-to-peer networks.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Take an informative journey inside computers.

Website 2 An online ICT lesson, with a test-yourself quiz.

Website 3 Explore a clickable timeline about the history of the computer.

TELECOMS

Since the invention of the telephone in 1876, there have been continual improvements to telephone systems. Used with computers, there is now a whole range of ways that people can send and receive information. This branch of technology is called **telecommunications**, or **telecoms**.

This telephone handset is attached by a cord to its base unit. Cordless phones communicate with their base unit using radio waves.

TELEPHONE LINES

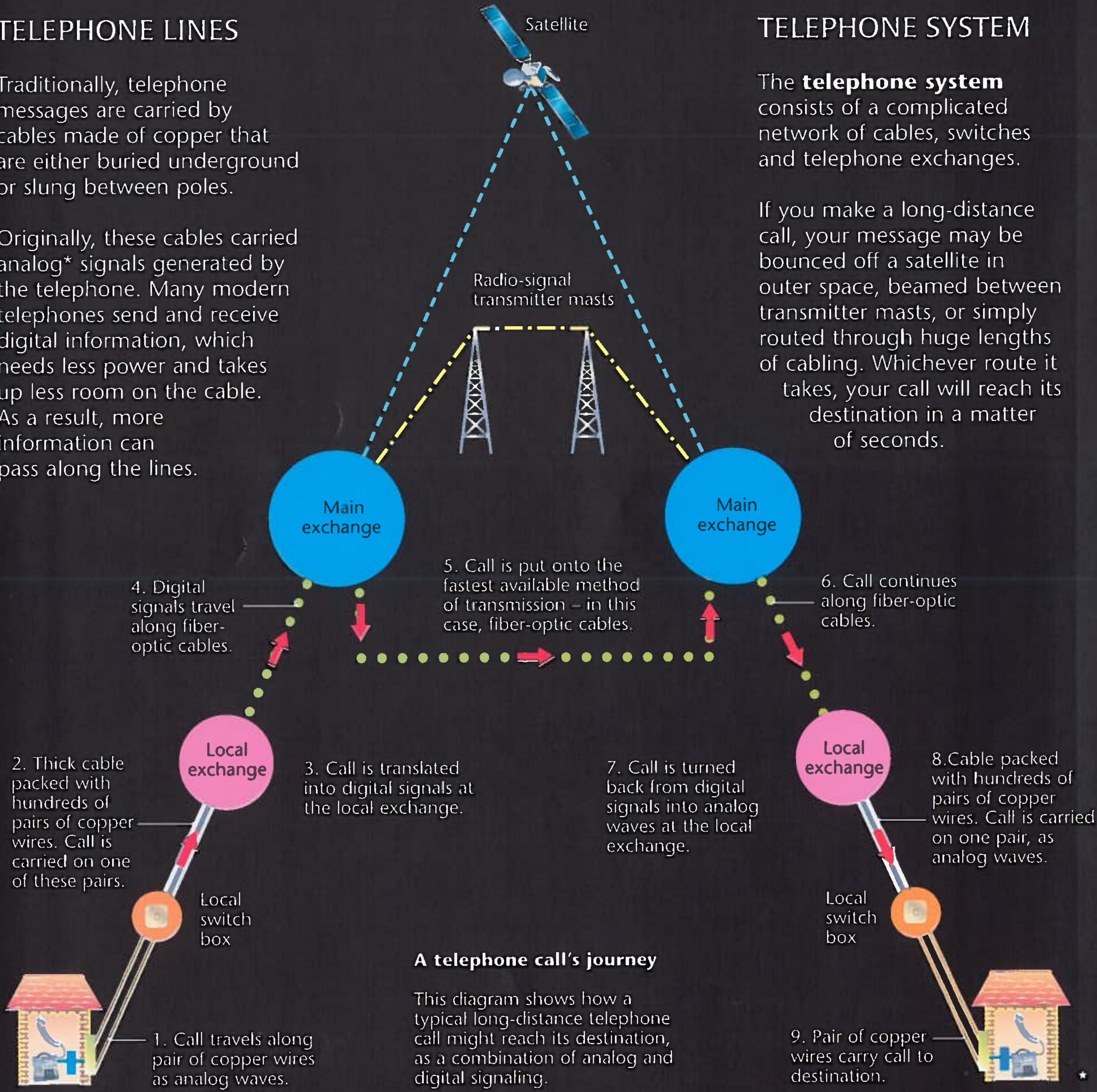
Traditionally, telephone messages are carried by cables made of copper that are either buried underground or slung between poles.

Originally, these cables carried analog* signals generated by the telephone. Many modern telephones send and receive digital information, which needs less power and takes up less room on the cable. As a result, more information can pass along the lines.

TELEPHONE SYSTEM

The **telephone system** consists of a complicated network of cables, switches and telephone exchanges.

If you make a long-distance call, your message may be bounced off a satellite in outer space, beamed between transmitter masts, or simply routed through huge lengths of cabling. Whichever route it takes, your call will reach its destination in a matter of seconds.



A telephone call's journey

This diagram shows how a typical long-distance telephone call might reach its destination, as a combination of analog and digital signaling.

* Analog, 238.

MODEMS

A **modem** allows a computer or fax to send and receive information along telephone lines. "Modem" stands for **mo**dulator-**dem**odulator.

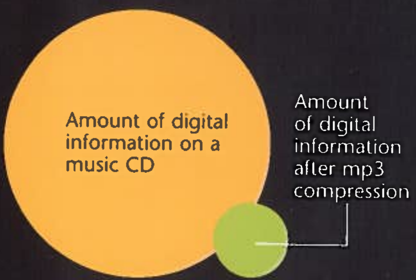
The modem converts, or modulates, digital information produced by a computer or fax into analog waves. The modem receiving the information demodulates (turns back) the waves into digital code which is understood by another computer or fax.

Modem

TRANSMISSION SPEED

The amount of information that can be sent by a modem is limited by the speed at which it can process information. **Data compression** can speed this up by cutting out any information that is not vital.

For example, music can be compressed using **mp3** software. This removes parts of sound that your ears can't detect. A stripped-down version is left, which is quicker to send.



Mp3 software cuts out any very high or very low frequency soundwaves that are out of the range of sounds that you can hear. It also cuts out sounds that are masked by other sounds.

BANDWIDTH

The amount of information that can be processed each second by a telephone line is called its **bandwidth**. Copper cabling has a limited bandwidth. **Fiber-optic cables**, made of glass or plastic fibers, have a much greater bandwidth. However, they are expensive to install.

MOBILE PHONES

Mobile telephones do not make use of telephone lines. Instead, they send digital radio signals through the air to nearby transmitter masts, called **base stations**. These pass the signal on to the next station, and on and on, until they reach the phone that you are calling.

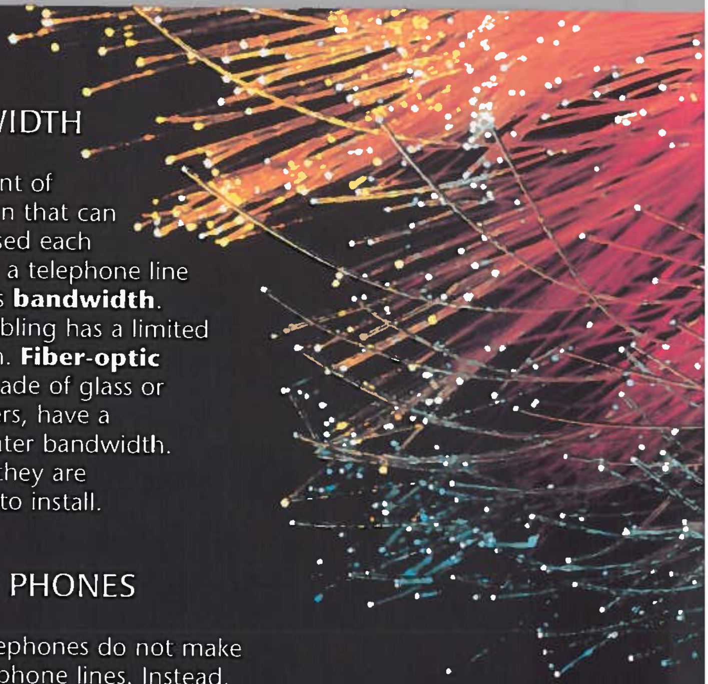
How a mobile phone works

1. You dial a number and press the call key.

2. Your phone chooses an available radio channel and sends a digital radio signal of the phone number to the nearest base station.

3. The base station sends the signal around the network of base stations, until it finds the phone you are calling.

4. The phone you are calling sends a message back via the base stations, saying whether it is available. Only now do you hear a ringing tone.



Here you can see light shining out of the ends of a bundle of fiber-optic cables. Fiber-optic cables carry digital information as pulses of light.

See for yourself

Try dialing a fax number from a telephone. When the fax answers your call, you will hear a high-pitched warbling sound. This is its internal modem sending a little message. The message is to establish whether a fax is calling it, and if so, to tell the other fax to start transmitting its information.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Interactive presentations on the history and development of the telephone.

Website 2 A clickable timeline of key events in communications history.

Website 3 Follow the development of mobile phones.

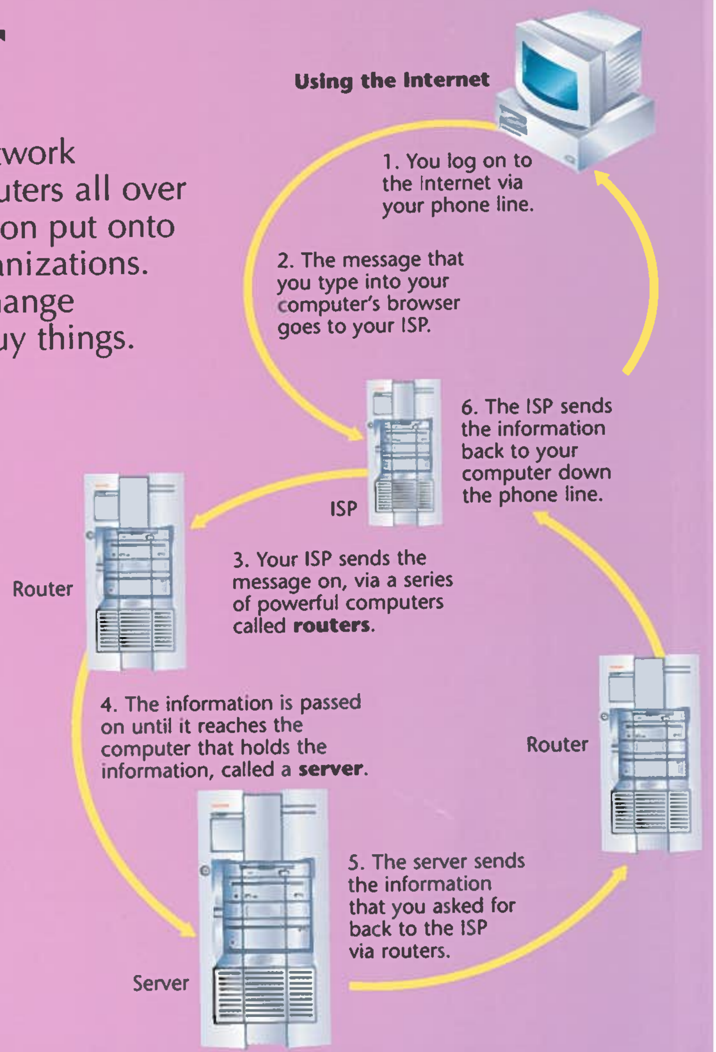
Website 4 Communications pioneers.

Website 5 See what's inside a phone.

Website 6 Read about communications satellites, then try to build one.

THE INTERNET

The **Internet** is a vast computer network linking together millions of computers all over the world. It gives access to information put onto it by individuals, companies and organizations. The Internet can also be used to exchange information, send messages and to buy things.



INTERNET BASICS

Most people connect, or **log on**, to the Internet using software called a **browser**.

The basic structure of the Internet is provided by telephone companies. Their phone lines carry the information that you send and receive when you use the Internet.

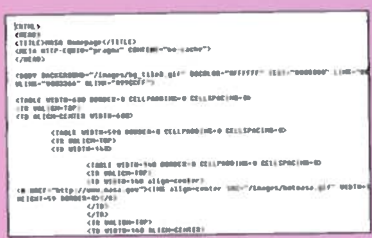
Most home users use **Internet service providers (ISPs)** to access the Internet. When you are **online** (connected to the Internet) messages go from your computer down the phone line to the ISP's powerful computers. The computers work like electronic post offices, automatically sorting and sending things on in a matter of seconds.

The World Wide Web is the most well-known, and most widely used, part of the Internet.

WORLD WIDE WEB

The **World Wide Web** (**www**) is a huge information resource and a place to conduct ecommerce (see opposite page). It consists of thousands of individual Web sites. Each site is made up of individual documents, called Web pages.

HTML



Web pages are written using a computer language called **HyperText Markup Language** (**HTML**). If you are looking at a Web page, you can view the HTML code by clicking on the "View" button and then choosing "Source".

HYPERLINKS

On Web pages, some words or pictures are highlighted. Click on them and a new page with related information is shown, or **downloaded**. This is a **hyperlink**. These links enable you to jump really quickly from page to page all over the Web.

INTERNET NAMES

Each piece of information on the Internet has an address, called a **URL** (**Uniform Resource Locator**). A URL enables you to call up the exact piece of information you want. It also defines the format (called the **protocol**) in which the messages are sent.

A URL

http://www.howstuffworks.com/web-server.htm

http:// This is the **protocol name**. "http" stands for **hypertext transfer protocol**.

www.howstuffworks.com/ is the **domain name**. This identifies the name of the site and the Web server it is held on.

web-server.htm is the **file path**. This is the name of the file in which the page is stored. The *.htm* part shows that the file is written in HTML code.

DOT COM

The final part of a domain name is called the **top-level domain**. Here are some examples and what they indicate:

- .com - commercial organization
- .edu - school or educational establishment
- .gov - government agency
- .org - non-profit organization (such as a charity)

Some domain names have an extra two letters to identify which country they are based in. For example:

- .es - Spain
- .th - Thailand
- .uk - United Kingdom

EMAIL

Email stands for **electronic mail**. It is a way of using your computer to send messages to other Internet users. You write and read emails using special email software, such as Outlook Express®, made by Microsoft®.

Email is sent down the phone line to your ISP. It is sent on to the recipient's ISP via the Internet, where it waits for delivery the next time the recipient logs on to the Internet.

Email addresses have three parts. Here's a typical one:

joeschmo@slugpost.com

joeschmo is the name that the person has decided to use when sending and receiving emails.

@ stands for "at".

slugpost.com is the domain name. For home computer users, this is normally the name of your ISP.

ECOMMERCE

The Internet can be used to buy and sell things. This is called **ecommerce**. Goods and services that are offered for sale on a Web site can be ordered directly by filling in an order form which appears on the Web page.

Ecommerce enables people to shop for just about anything, at any time, and from anywhere. However, it means that you can't inspect the goods or try them out before you buy.

MOBILE INTERNET

There is a part of the Internet that can be accessed by some mobile telephones. It displays Web pages that are written in a different protocol and have few pictures. The pages are simpler than regular Internet pages because mobile phone lines can't carry the amount of digital information contained in a regular Web page quickly enough.

You can access the Internet and send emails from this mobile phone.

See for yourself

To see just how quickly email zips from place to place, try sending yourself an email. Write your own address in the "To:" window and then click "Send". (You don't need to add a subject name, even if the email software asks for one.)

The email should come back from your ISP (which could be in another country) in seconds. However, it may take longer, depending on how busy the Internet is at the time.

Internet links

Go to **www.usborne-quicklinks.com** for links to the following websites:

Website 1 Find out how the Internet works, with definitions of key terms such as HTTP, IP and domain.

Website 2 Browse questions and answers about email, mobile phones, the Internet and much more.

Website 3 An interactive guide to the Internet.

Website 4 An animated introduction to the Internet.

Website 5 Find out how email works and send yourself a message.