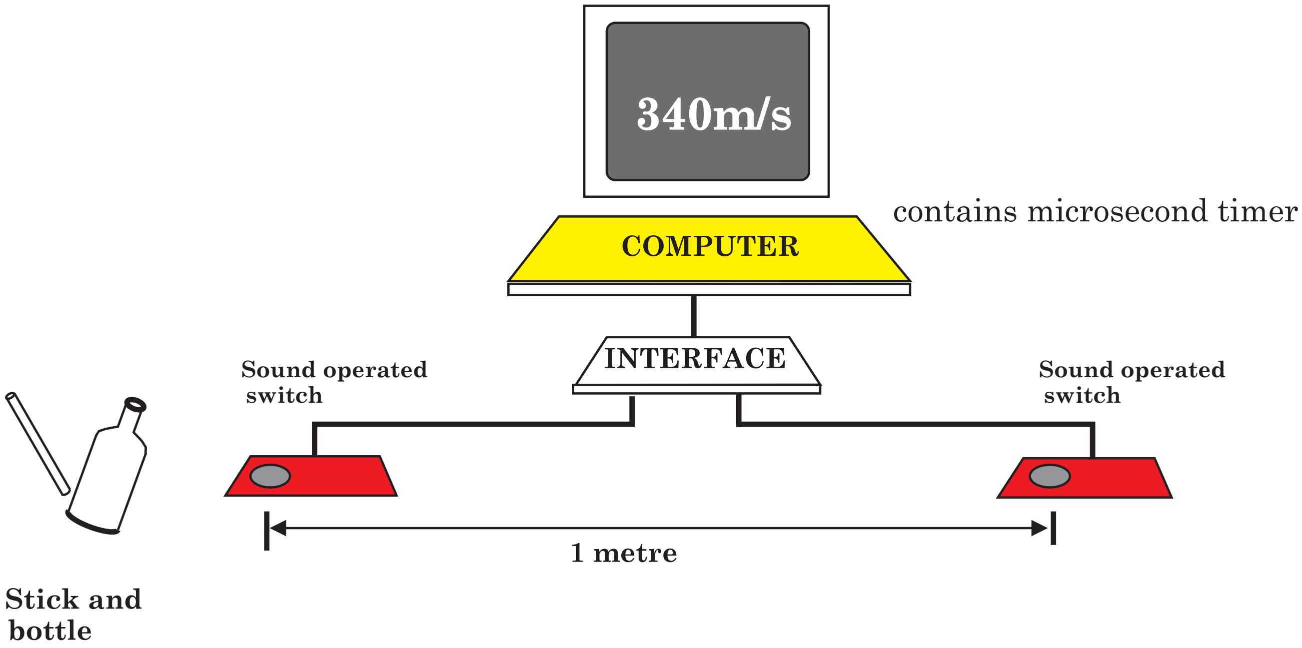
TELECOMMUNICATION

SUMMARY NOTES

SECTION	DESCRIPTION of CONTENTS
1. Communication using waves	Speed of sound. Waves.
2. Communication using cables	Communication with wires between transmitter and receiver. Telephone. Electrical signals in the communicating wires. Optical fibre communications. Fibres vs Electrical cables. Laws of reflection. Signal transmission.
3. Radio and Television	Radio: Receiver, aerial, tuner, decoder, amplifier. Television: Receiver, aerial, tuner, decoders, amplifiers, picture tube, black and white picture, colour picture.
4. Transmission of Radio waves	Transmission and reception Waves, wavelength, frequency band. Dish aerials, curved reflectors. Satellites. Geostationary satellites and ground stations.

Section 1: SPEED OF SOUND



Measuring the speed of sound waves in air.

The apparatus used is shown above. The distance between the two sound operated switches is measured using a metre stick and entered in the computer programme.

A sharp sound is produced by the stick hitting the bottle. When the sound reaches the first sound operated switch, it turns on the timer in the computer. When it reaches the second sound operated switch, the timer is turned off.

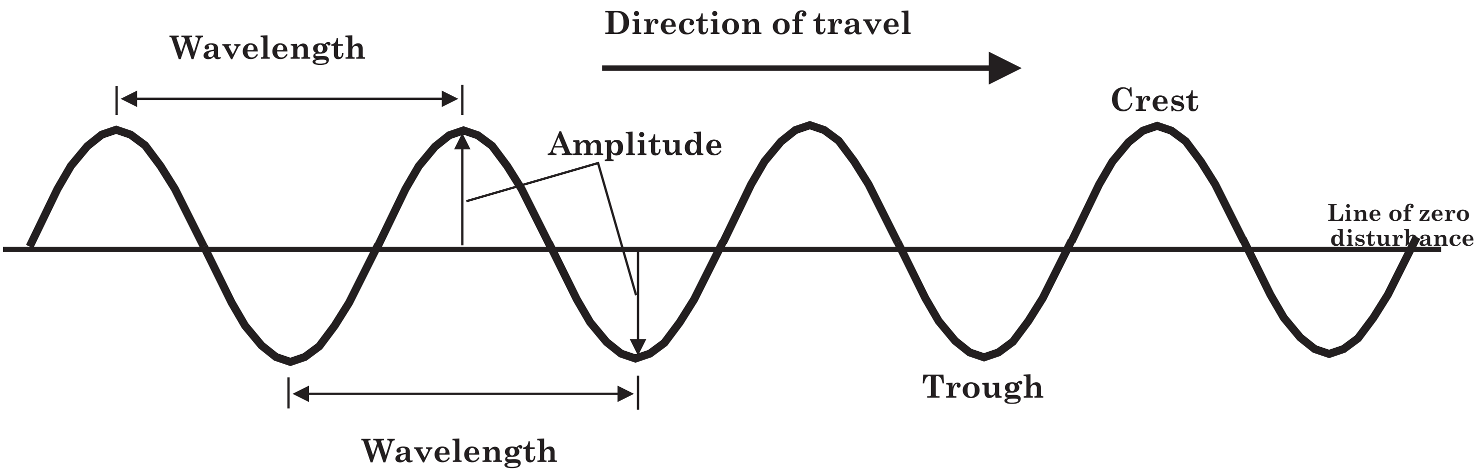
The speed of sound is calculated from:

$$\textit{speed of sound} = \frac{\textit{distance between the sound switches}}{\textit{time taken}}$$

Sound travels at 340 m/s in air.
Light travels at 300,000,000 m/s in air.

During thunder storms we see the flash of lightning before we hear the thunder,

Section1: THE WAVE EQUATION



DEFINITIONS

Wavelength(λ) The wavelength of a wave is the distance between two successive peaks, or two successive troughs. Wavelength is measured in metres.

Frequency(*f*) The frequency of a wave is the number of waves produced each second by the source of the wave. It can also be defined as the number of waves passing a point in a second. Frequency is measured in hertz (Hz).

Speed(*v*) The speed of a wave is the distance travelled by one wave in a second. Speed is measured in metres per second (m/s).

Amplitude The amplitude of a wave is the maximum movement, up or down, given to particles as the wave passes.

THE WAVE EQUATION

SPEED = FREQUENCY x WAVELENGTH

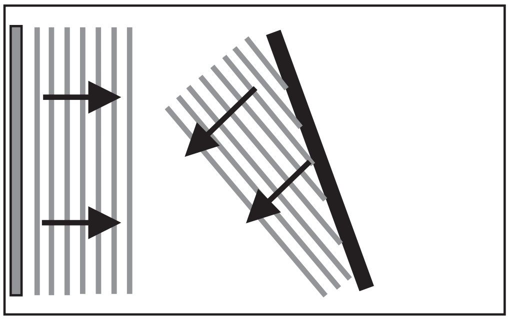
$$\boxed{v = f \times \lambda}$$

The speed of the wave is the speed of a particular wave in the wave. The speed of a wave can also be expressed in the relationship

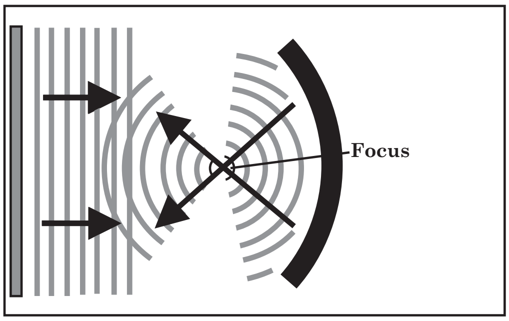
$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

Where the distance is the distance covered by a particular wave.

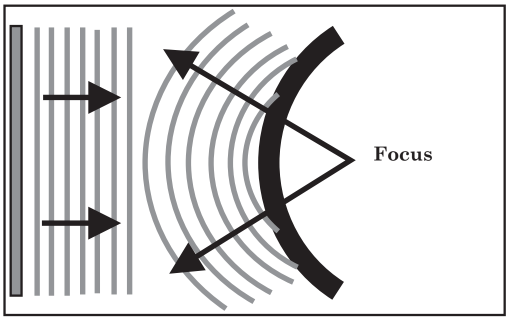
Section 1; WATER WAVES



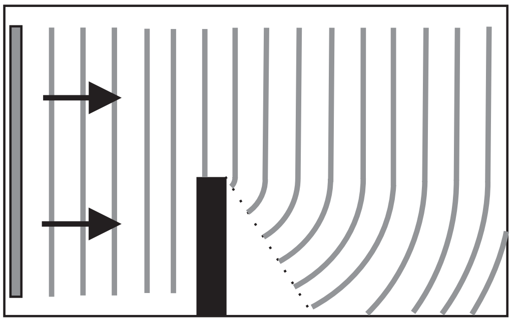
1. Reflection from straight barrier



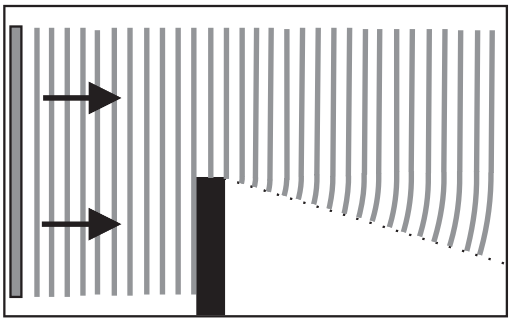
2.Reflection from curved barrier



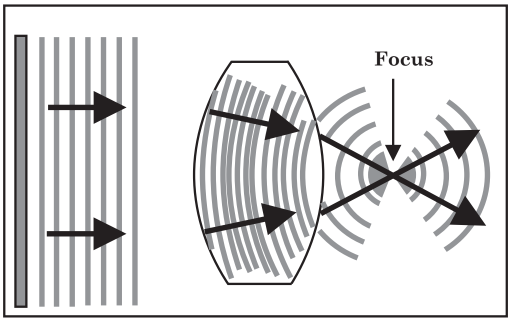
3. Reflection from curved barrier



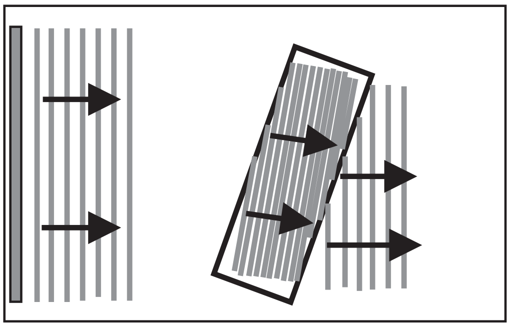
4. Diffraction - Long wavelength



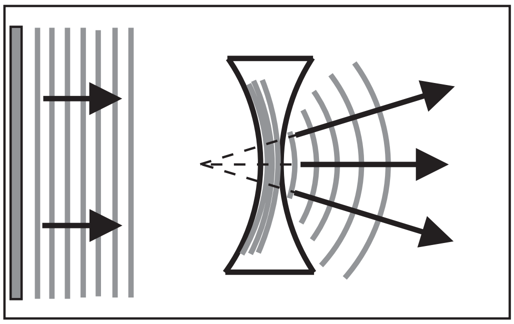
5. Diffraction - Short wavelength



6. Refraction - Convex lens

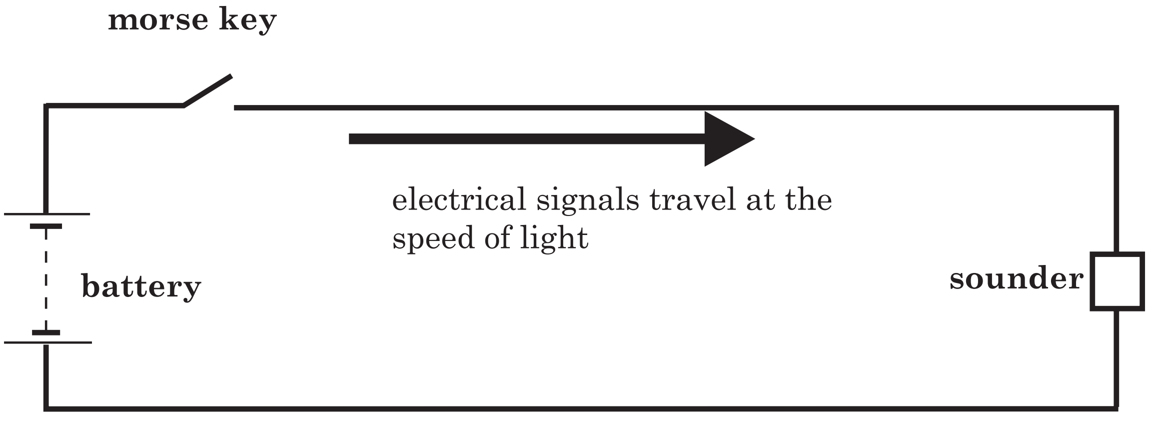


7. Refraction - Rectangle

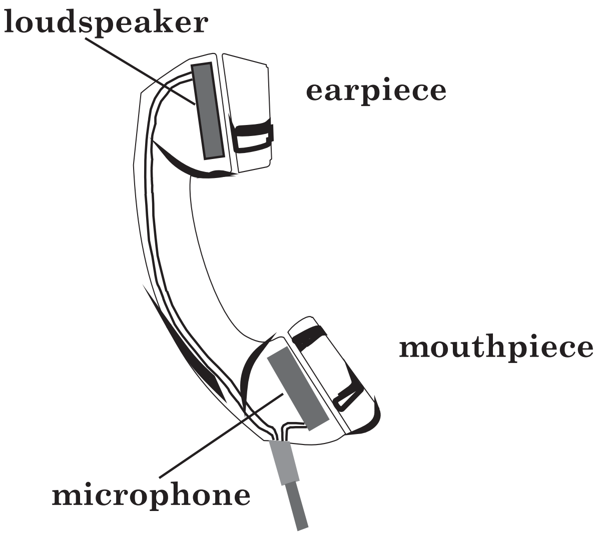


8. Refraction - Concave lens

Section 2: COMMUNICATION USING CABLES



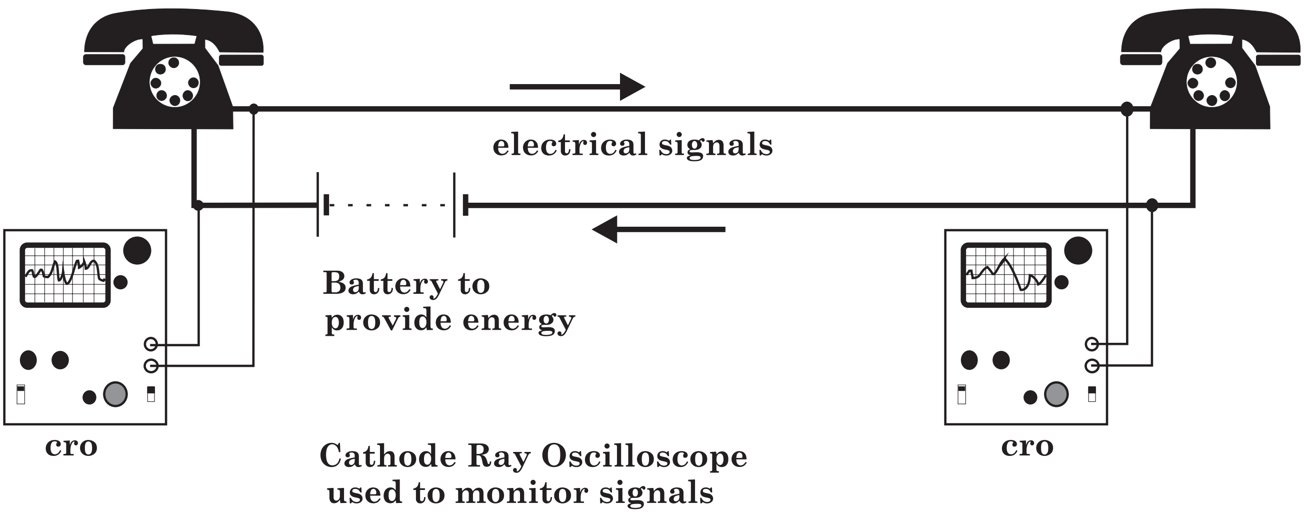
The Morse Telegraph



A telephone handset contains both a ***TRANSMITTER*** (mouthpiece) and a ***RECEIVER*** (earpiece).

Mouthpiece converts ***Sound energy*** into ***Electrical energy***

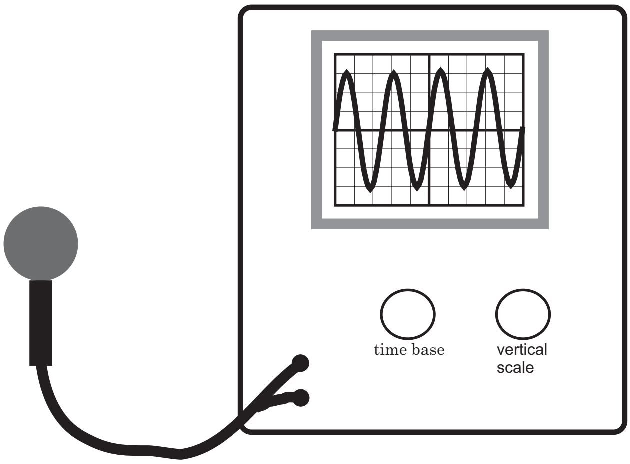
Earpiece converts ***Electrical energy*** into ***Sound energy***

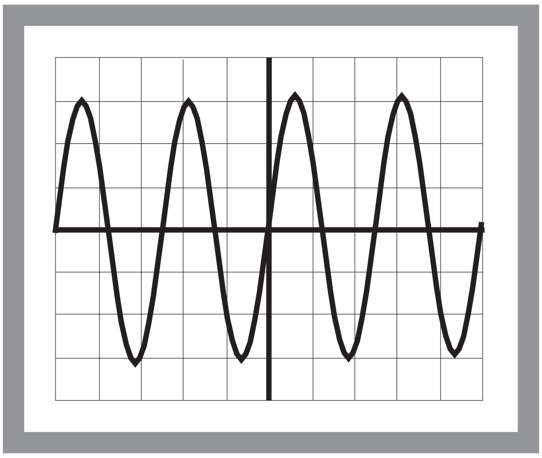


Section 2: COMMUNICATION USING CABLES

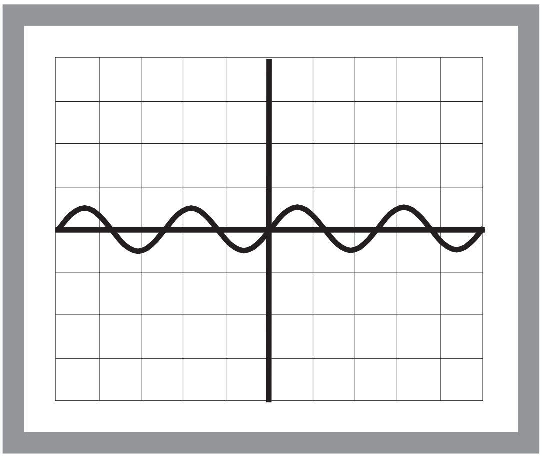
Signals in wire

We can examine electrical signals in wires using a CRO. If we connect a microphone to a CRO, we can observe the signals generated by sound waves.
The louder sounds generate a stronger signal. This increases the amplitude of the signal displayed by the CRO. The electron beam which 'writes' the signal on the CRO screen takes a set time to move across the screen. Higher frequency sounds will give a larger number of 'waves' across the screen.

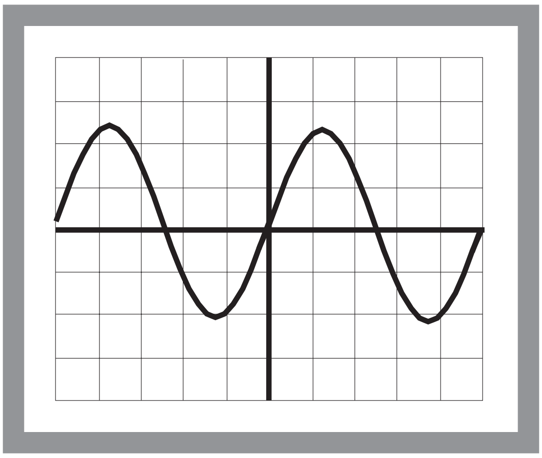




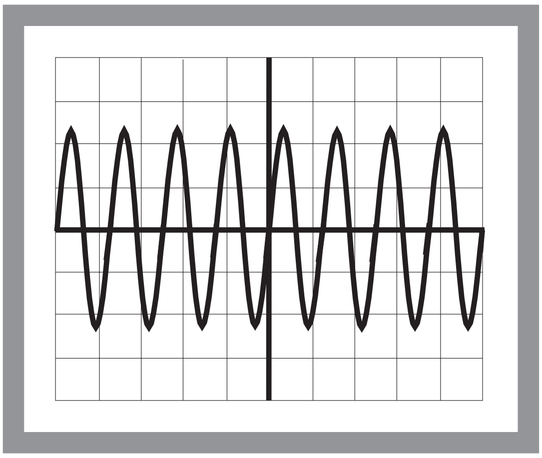
Loud Sound



Quiet Sound

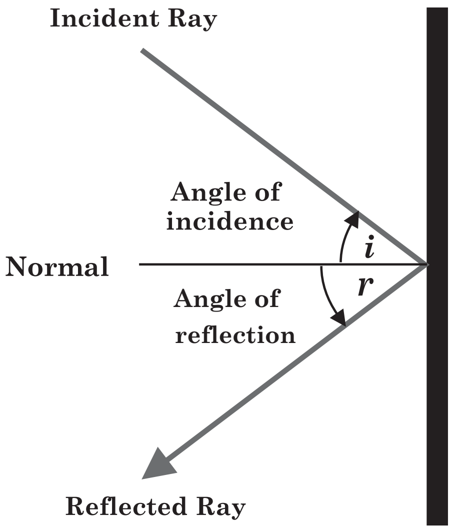


Lower Frequency



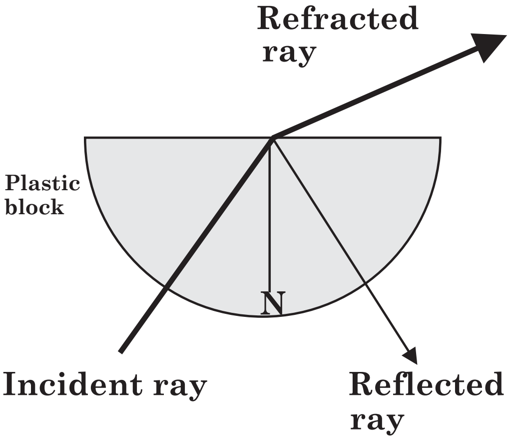
Higher Frequency

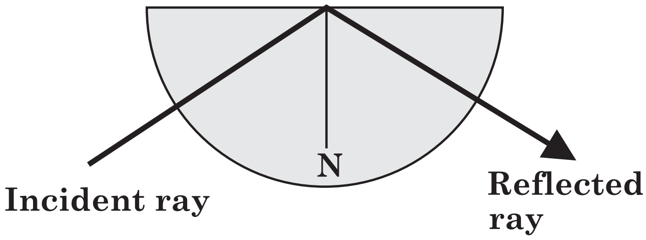
Section 2: COMMUNICATION USING CABLES



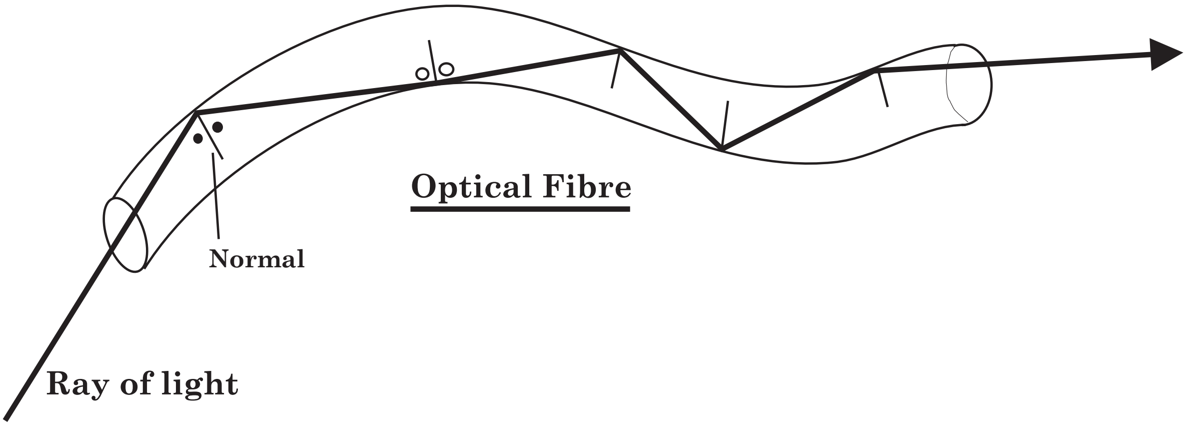
Law of REFLECTION

Angle of Incidence = Angle of Reflection



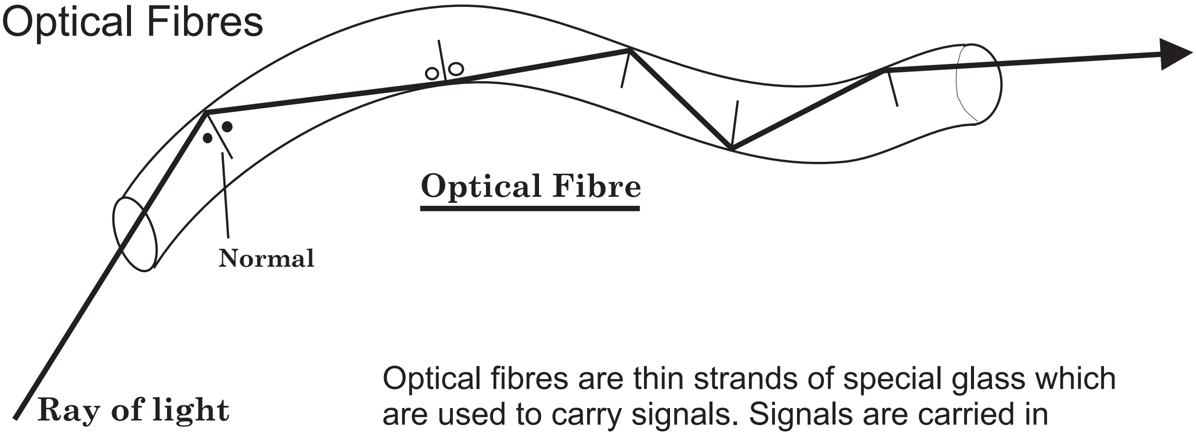


Total Internal Reflection



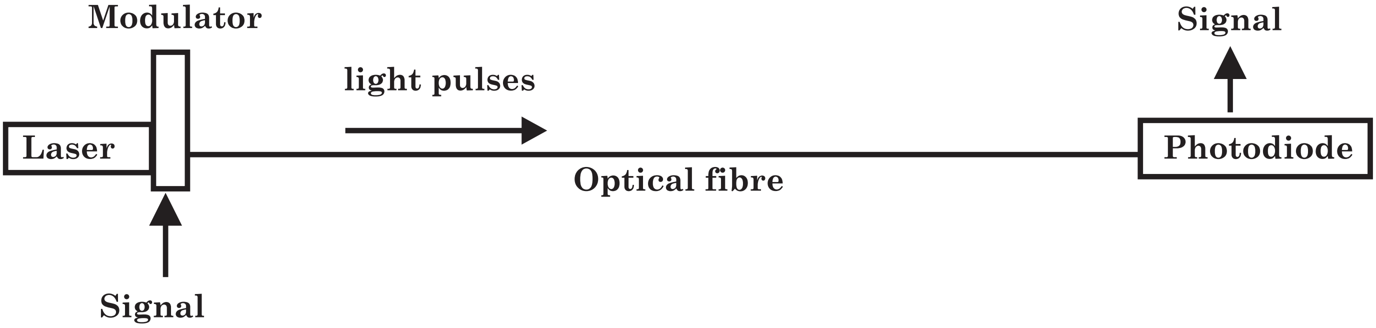
Optical Fibre

Optical Fibres

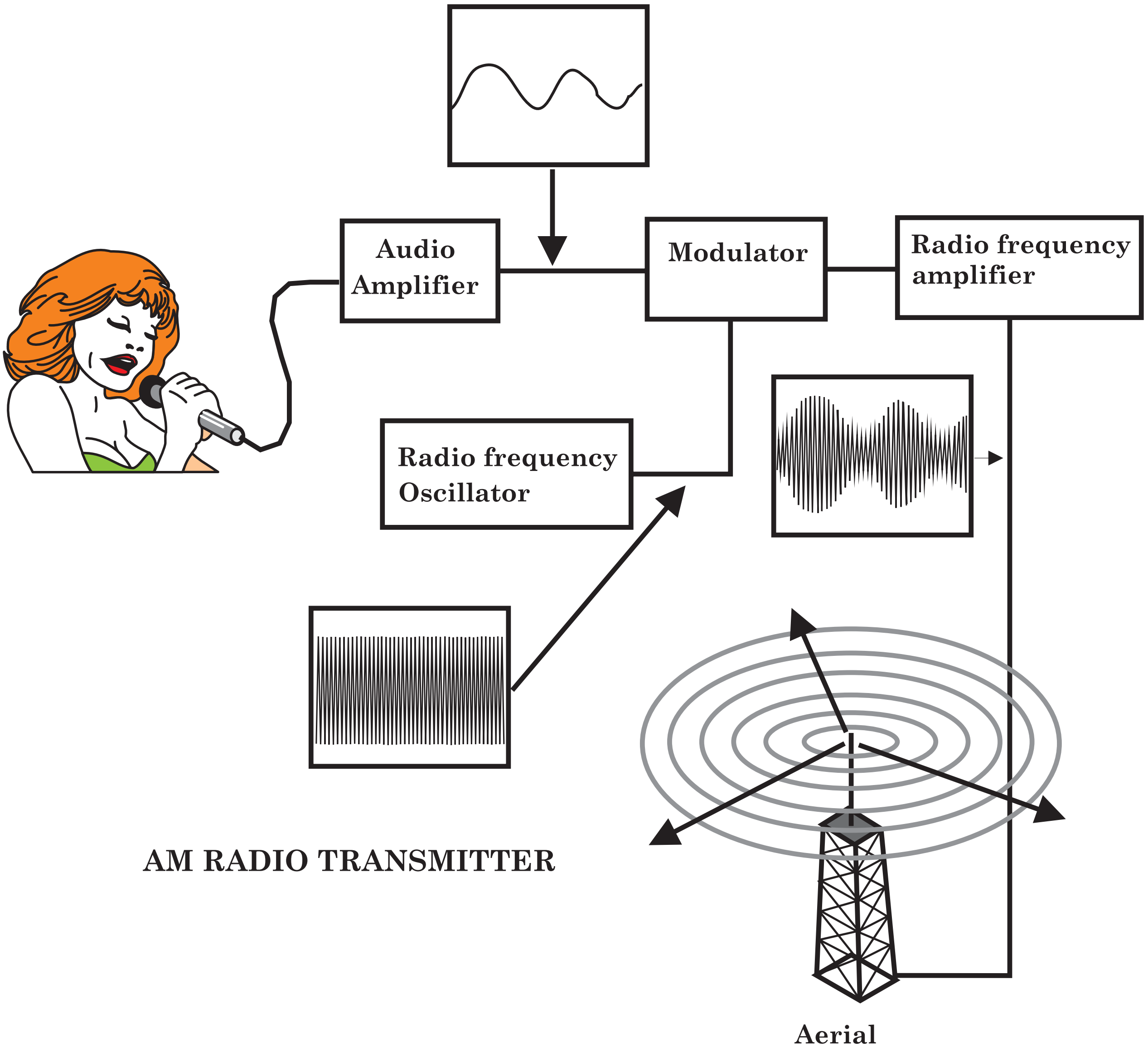


Optical fibres are thin strands of special glass which are used to carry signals. Signals are carried in pulses of light (digital signals). The light is provided by a laser.

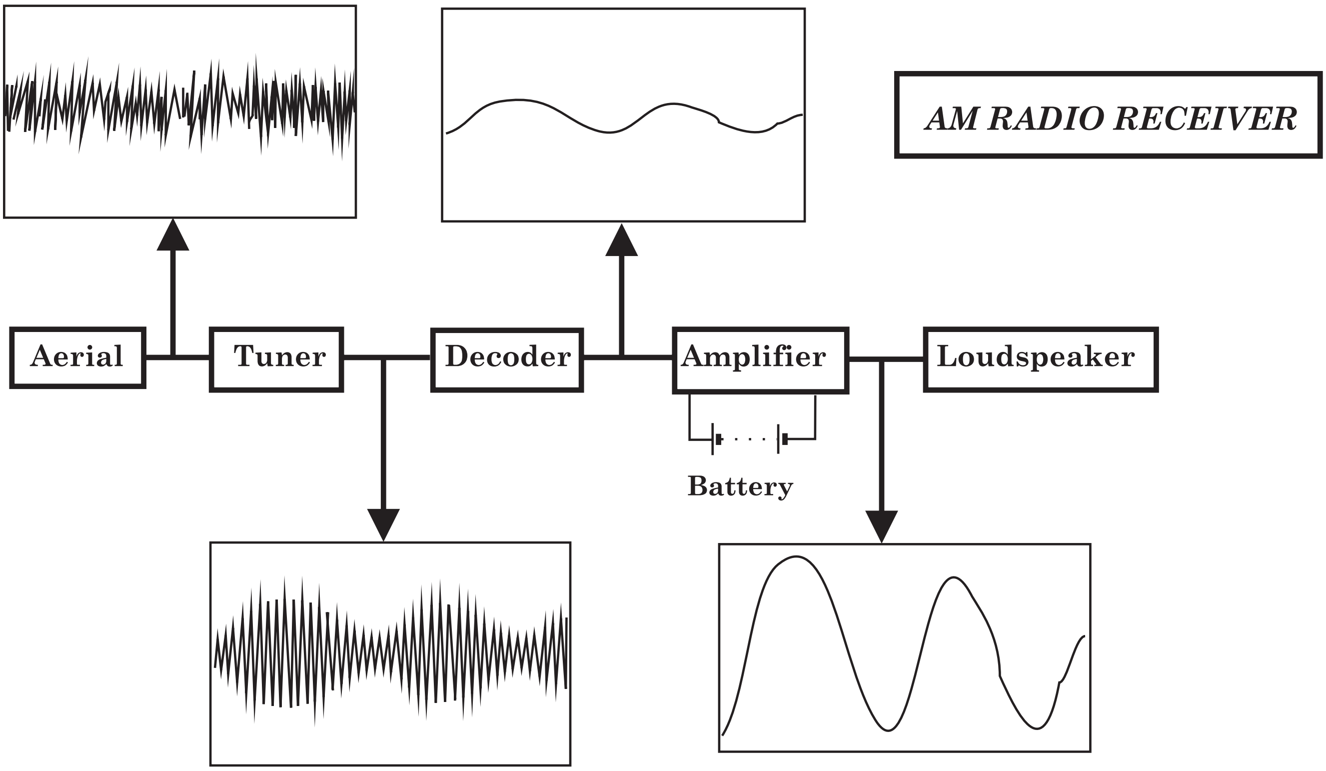
Optical fibres can carry light for up to 100 km before they need boosted. Optical fibres are replacing electrical cables in modern telephone systems.



Optical Fibres	Copper Cable
Very high signal rate (1000Mbit/s +)	High signal rate (140Mbit/s -max)
Low material cost	High material cost
Small cable size	Large cable size
Boosters every 100km	Boosters every 4km
No interference	Signals affected by electrical interference
Difficult to 'tap'	Easily 'tapped'



AM RADIO TRANSMITTER



AM RADIO RECEIVER

Section 3: RADIO AND TELEVISION

Radio Waves.

Radio waves are generated by pushing electric current up and down an aerial. The waves cause tiny 'copy' electric currents in any wire they cross. Radio waves are from the same family of waves as light and travel at the same speed as light (300,000,000m/s)

Radio waves can be adapted, or modulated, to carry information in two ways. The information can be superimposed on the amplitude of the wave (AM) or by modifying the frequency of the wave (FM). We shall concentrate on AM radio.

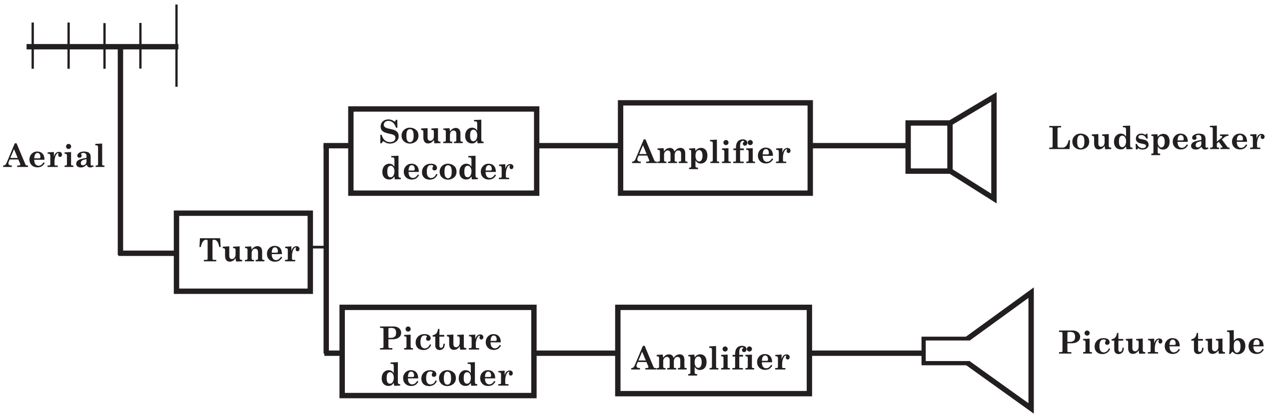
AM transmitters transmit radio waves at a constant set frequency. Each transmitter has its own particular frequency. The radio wave which carries the transmitter signal is called the CARRIER WAVE.

AM Radio Receiver

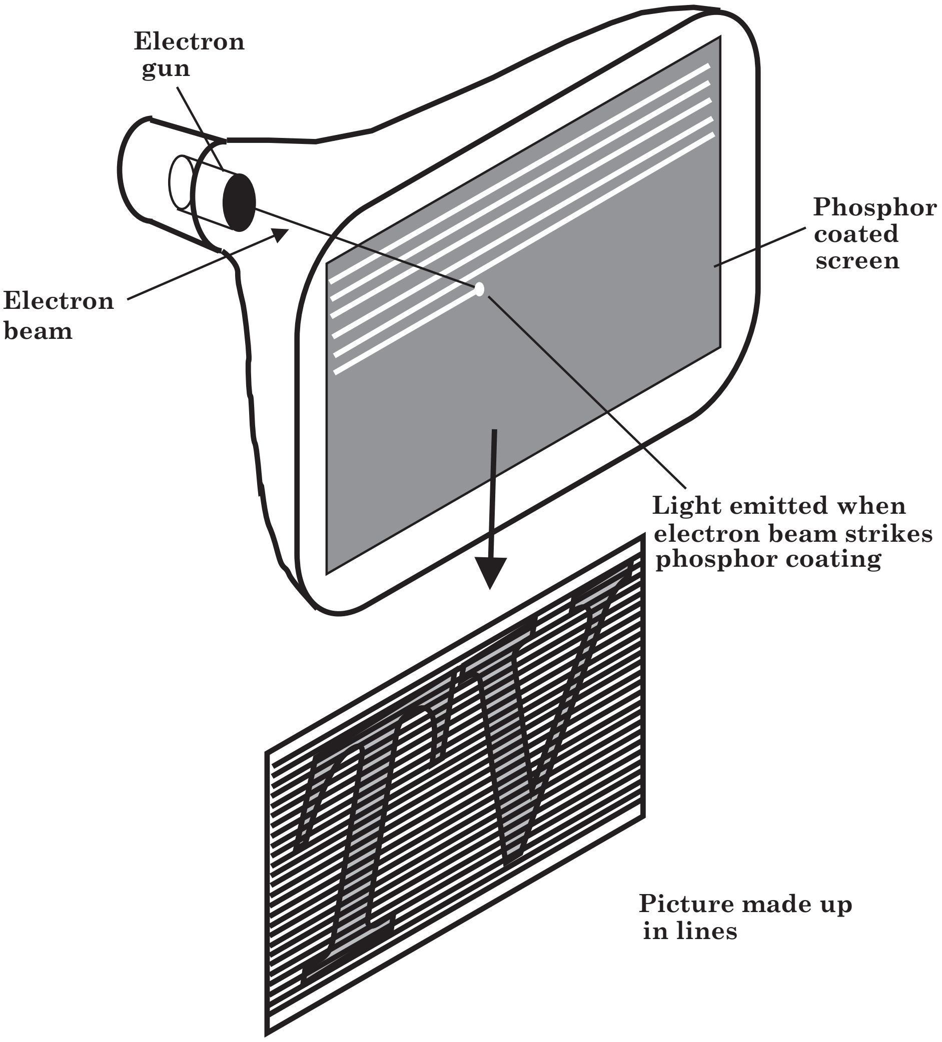
A simple AM receiver can be divided into different stages;

Aerial: The aerial picks up any radio wave that crosses it. The electric signal from the aerial is a meaningless hiss; noise.
Tuner: The tuner selects a particular radio frequency. This is the frequency of the station you wish to listen to.
Decoder: The decoder removes the radio frequency signal and restores the audio signal.
Amplifier: The amplifier boosts the weak signal from the decoder using energy from a battery or mains. The signal is now strong enough to drive a loudspeaker.
Loudspeaker: The loudspeaker converts the electrical signal back into sound.

Radio waves cannot pass through metal. In cars, for example, the aerial must be situated outside the metal body of the car. The same applies to boats and aeroplanes.

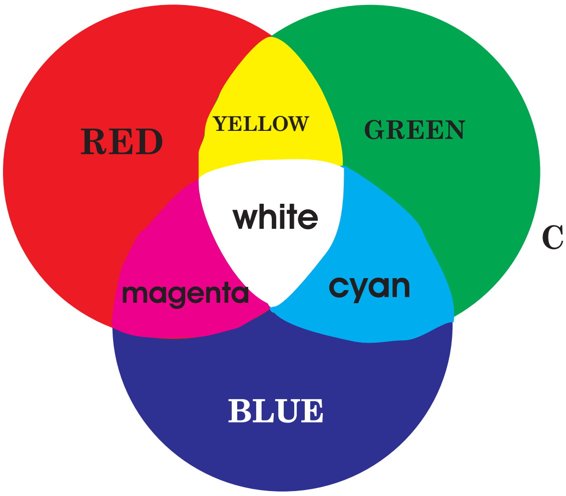


The radio waves carrying television signals are more complex than those carrying radio signals. Both sound and pictures are carried.
The black and white TV receiver contains an aerial and a tuner circuit just like a radio. The signal from the tuner is fed to two decoders. One selects the sound information, the other selects the picture information. The sound signal is amplified and fed to a loudspeaker. The picture signal is amplified and fed to the picture tube.



The Picture

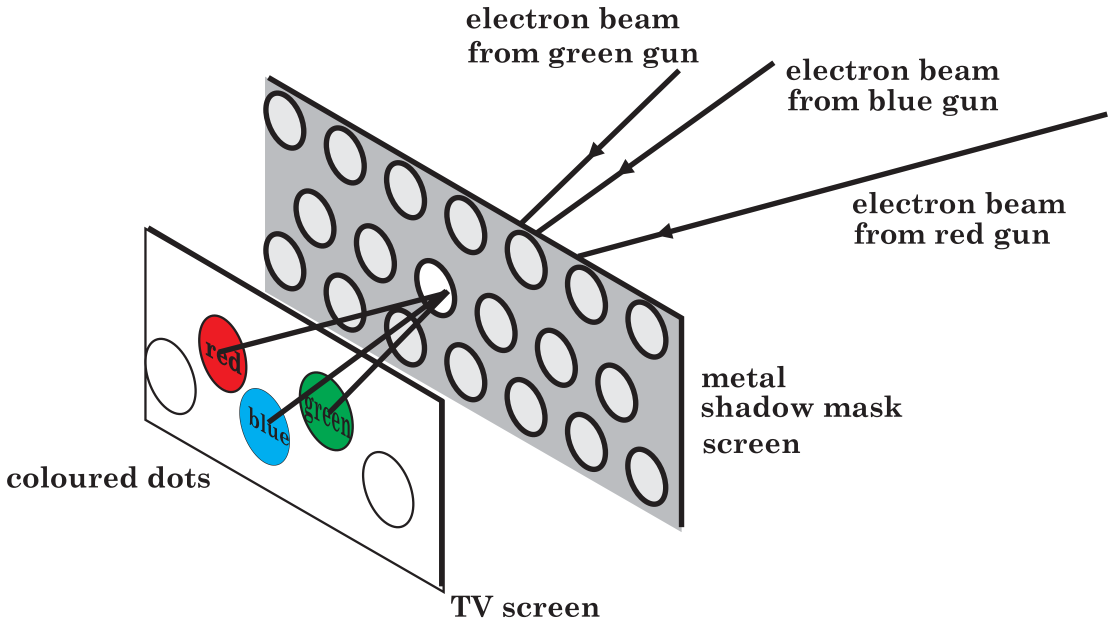
The picture is built up on screen using lines. The lines are created by a beam of electrons which scan backwards and forwards across the back of the screen. The back of the screen is coated in phosphors which emit light when struck by the electrons.
The brightness of the light from the phosphor is altered by changing the number of electrons carried in the beam. This changes the colour from black, through the greys, to white.
A new picture is made every 0.04 seconds (25 pictures per second) . We cannot see the change due to PERSISTENCE OF VISION, so the motion on screen appears smooth.



Colour Mixing

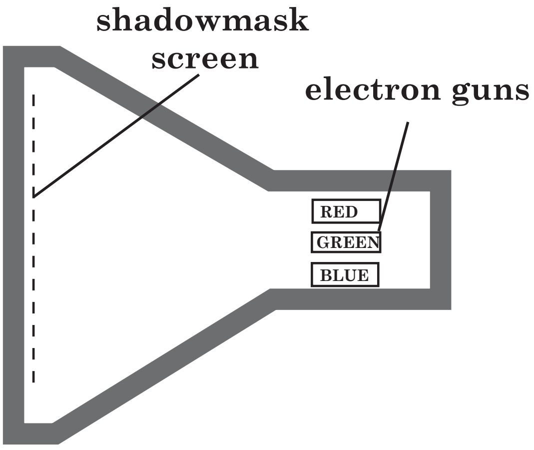
Colour.
Our brains interpret the wavelength of visible light as colour. The retina, in the back of our eye, contains 3 types of colour sensor (rods). One set detects red light, one set green light and the other blue light. The brain uses the signals from these sensors to put colour into the picture we see.

We can use mixtures of red, green and blue light to create any colour, including white.

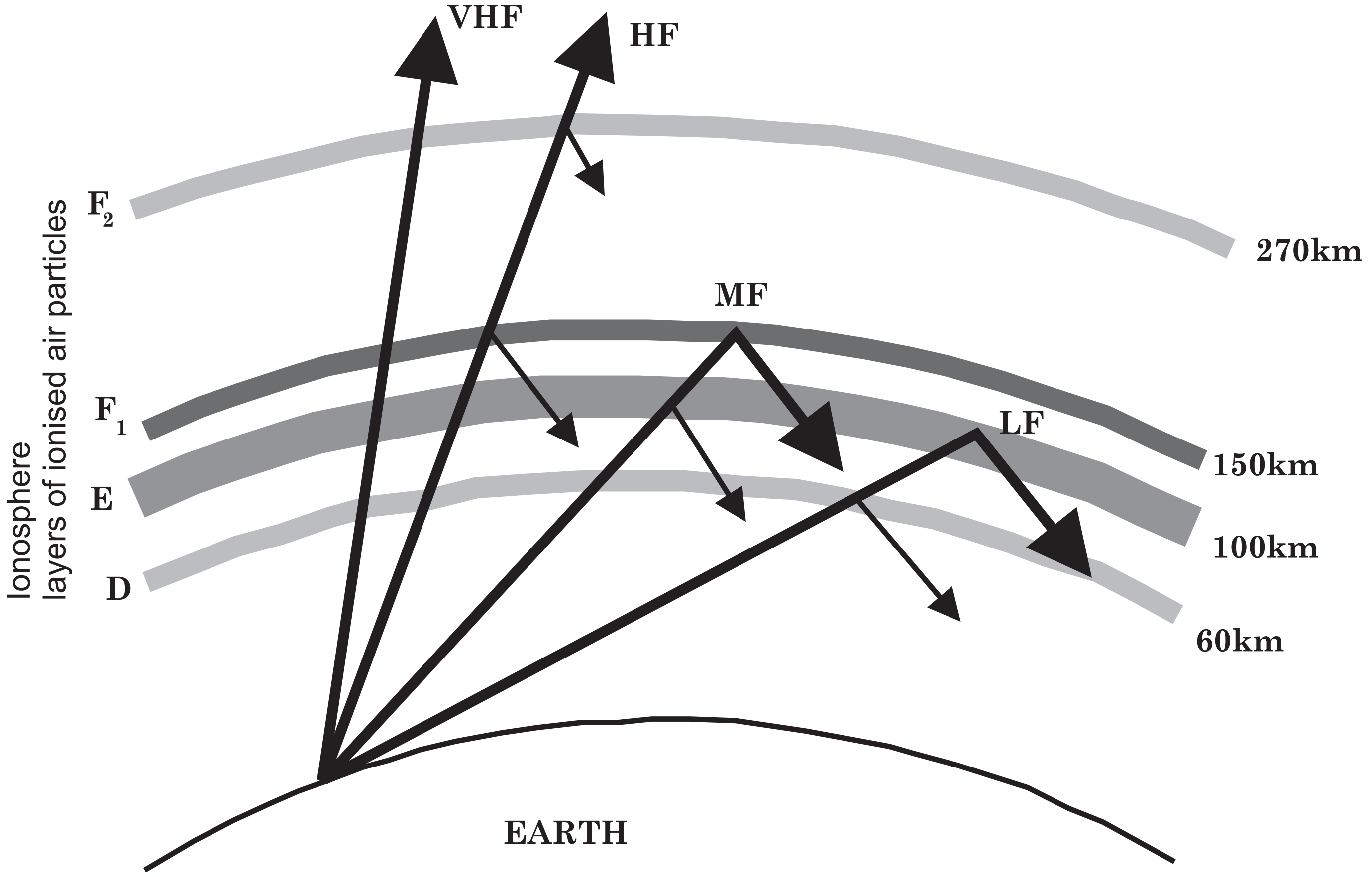


Colour TV.

The colour television camera uses filters to separate the picture into its red, green and blue components.
The transmitted TV signal contains sound and the three picture components.
The coloured TV receiver has a special tube containing three electron guns. One gun for the red component, one for the green and the other for the blue. The screen has three sets of phosphor dots. One set glows red, one glows green and one glows blue when struck by electrons.
Behind the screen is a special metal screen full of tiny holes; the shadowmask. The electron beams from the three guns are focussed on the screen so that when they pass through the holes they strike the correct phosphor dots. In this way the beam from the red electron gun strikes the red phosphor dots. The same for the other two guns.
The red, green and blue components are recombined on the screen to produce the original coloured picture.



Section 4; TRANSMISSION OF RADIO WAVES



Frequency	Name	Wavelength metres	Range km	Main uses
30Hz -3kHz	ELF	> 100000	> 1500	Links to submarines
3 - 30kHz	VLF	100000 -10000	> 1500	Military Long Range
30 - 300kHz	LF	10000 - 1000	> 1500	Military Long Range LW radio
300kHz - 3MHz	MF	1000 - 100	< 1500	Sound Broadcast MW
3MHz - 30MHz	HF	100 - 10	World Wide	Sound Broadcast SW
30MHZ - 300MHz	VHF	10 - 1	Horizon	High Quality Sound FM
300MHz - 3GHz	UHF	1 - 0.1	Horizon	TV, Car phones.
> 3GHZ	Microwave	< 0.1	Horizon 36000k	Satellite, microwave links

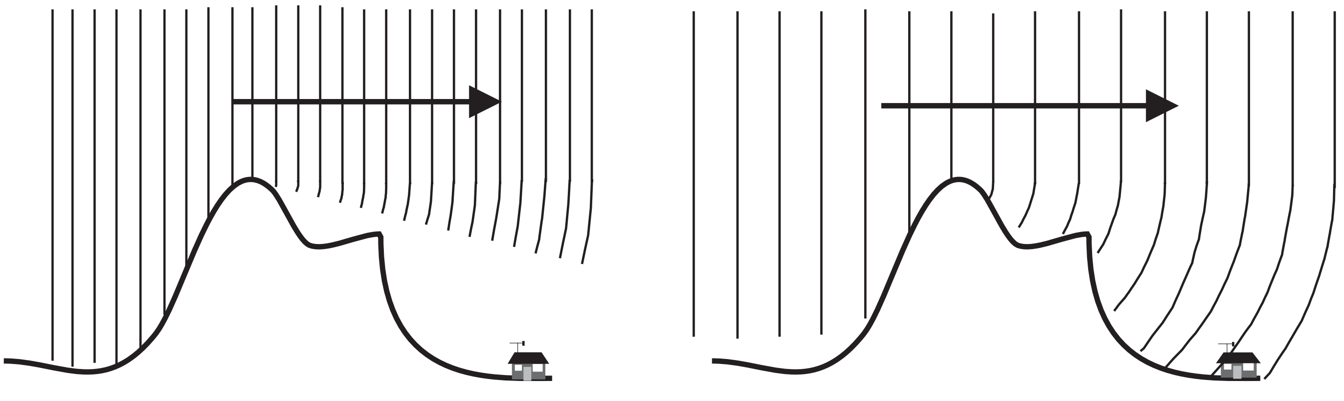
Section 4: TRANSMISSION OF RADIO WAVES

Radio Waves.

Radio waves are part of the electromagnetic spectrum of waves which contain light waves.
Radio waves travel at 3×10^8m/s.
Radio waves are generated by electric current moving up and down an aerial, and have a range of frequencies from 30 hertz to around 20 gigahertz.
Radio waves can pass through normal air quite easily but cannot pass so easily through ionised air (air containing charged particles) or metals. Wrapping a transistor radio in foil stops it receiving any signal (this is why car aerials are on the outside of the car).
Different frequency bands have different transmission properties and uses. The table above summarises these.

The Ionosphere.

The Earth's atmosphere contains regions where the gases have been ionised by radiation from the Sun. Ions are charged particles so these regions of space reflect radio waves back to Earth, particularly the lower frequencies. This allows these frequencies to cover longer distances.
Higher frequencies can pass through into space. Short Wave radio is used by radio amateurs to talk to the Space Shuttle.



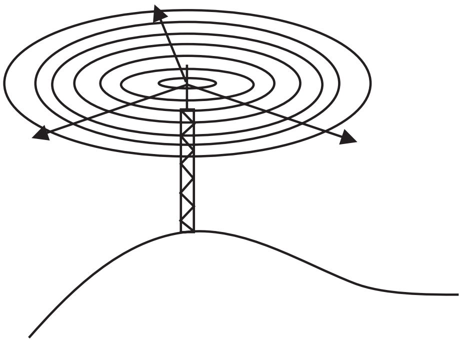
Short Wavelength **Long Wavelength**

DIFFRACTION

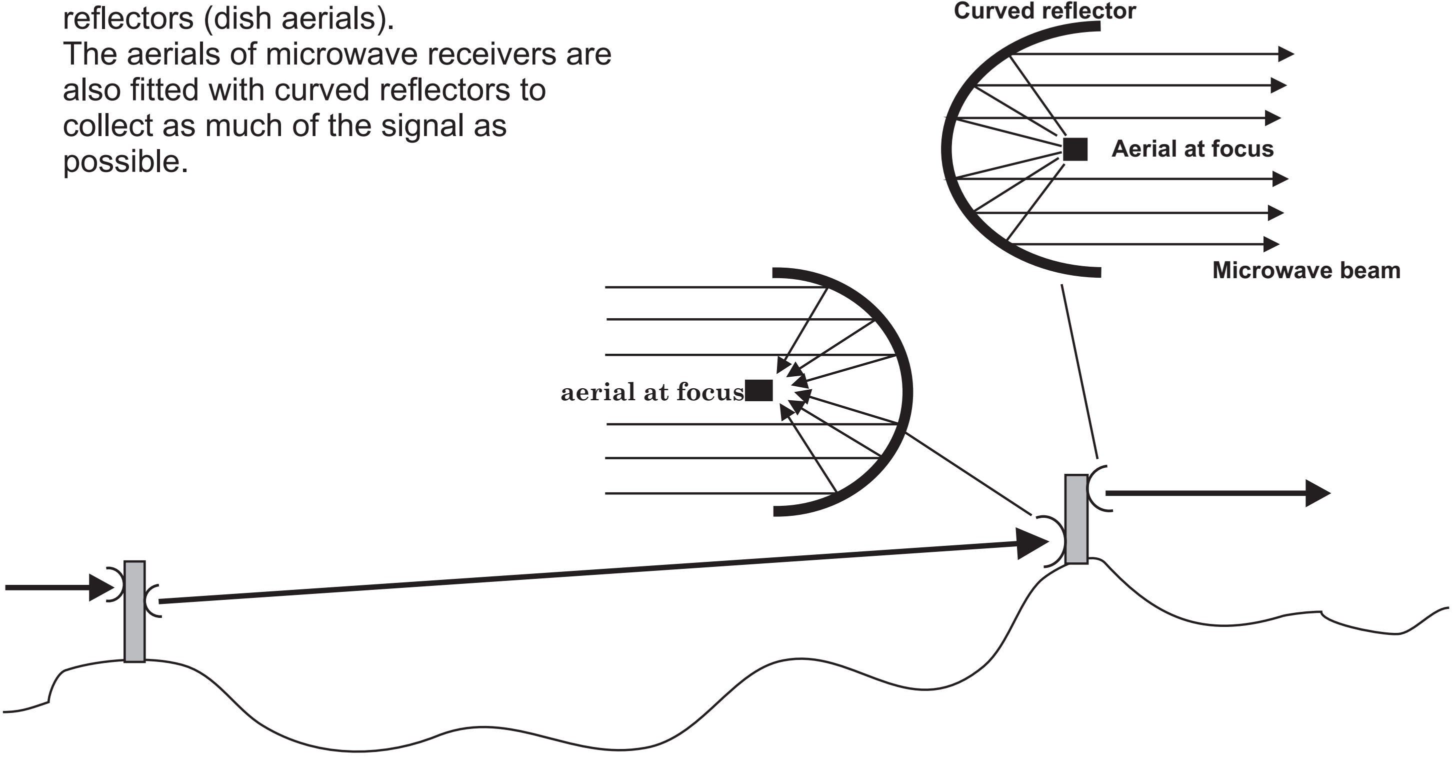
Hilly areas create problems for radio and TV reception. Short wavelengths cannot diffract round hills and so the residents in the valleys cannot receive short wave broadcasts. This means that FM and TV are difficult to receive without expensive aerials. LW and MW radio are able to diffract round hills so these are easily received.

Section 4: TRANSMISSION OF RADIO WAVES

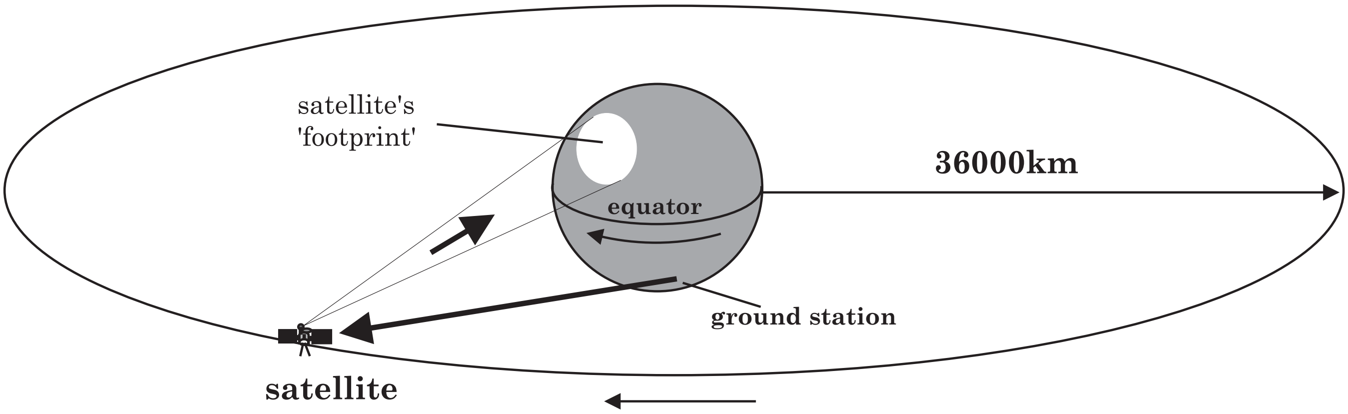
MW and LW radio stations transmit radio waves from powerful transmitters.
The waves spread out over hundreds of kilometres but even over long distances the signal is strong enough to be picked up clearly.
FM stations are high frequency and can only reach to the horizon (30km). FM transmitters do not need to be as powerful as MW or LW ones.



Microwaves are not transmitted with high power. Instead, microwaves are concentrated into beams using curved reflectors (dish aerials).
The aerials of microwave receivers are also fitted with curved reflectors to collect as much of the signal as possible.

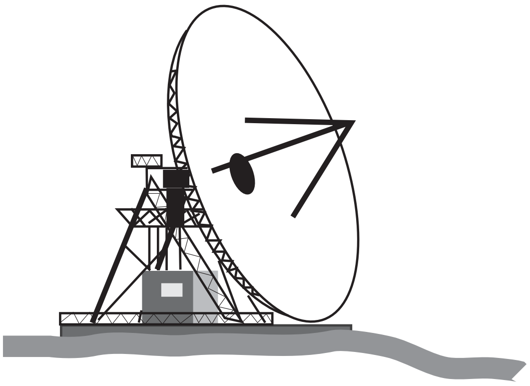


Microwave links are used to carry information all over the country. Microwaves are beamed from hill to hill using transmitter/receiver stations. These have sets of dish aerials mounted so that microwaves can be received and then passed on to the next station.



Communication Satellites.

The period of a satellite is the time it takes to orbit once round the Earth.
The period increases with the satellite'qs height above the Earth. At a height of around 36000km, the period of a satellite is 24 hours. If this satellite is positioned directly above the equator, it will remain above the same spot on the Earth and appear stationary to an observer on the Earth. Such a satellite is called GEOSTATIONARY, and is used for communications.


satellite ground station

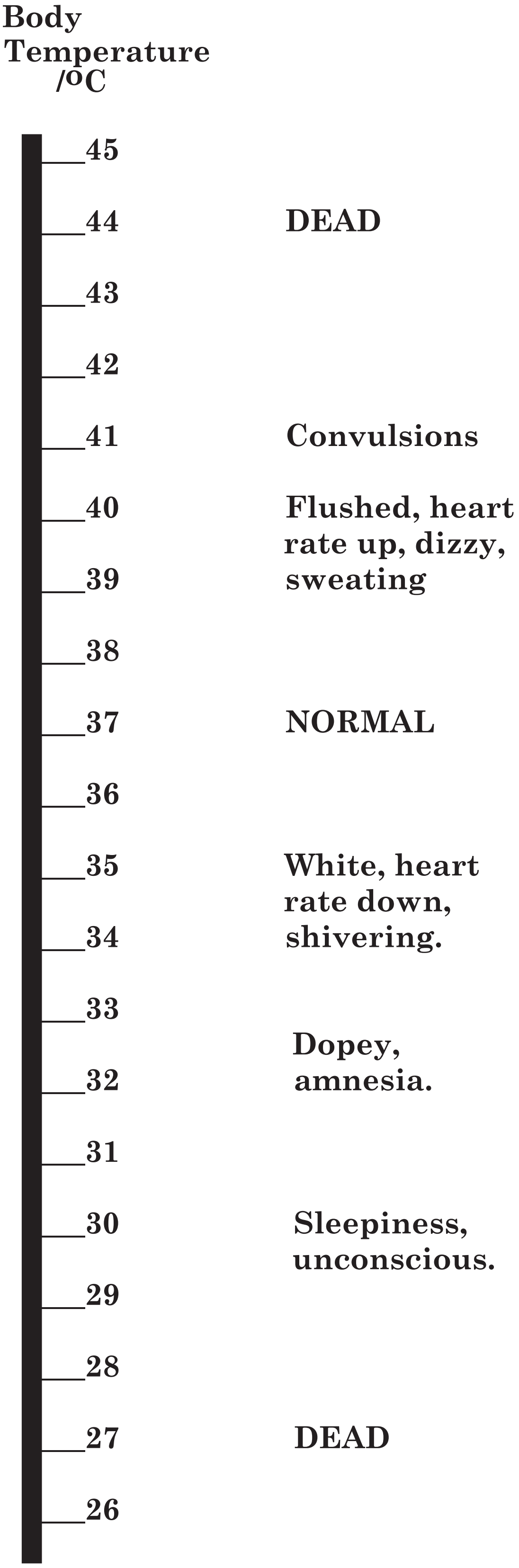
Signals are sent to and from the satellite using microwaves.
Powerful transmitters on the ground transmit signals to the satellite using curved reflectors.
The satellite transmits the signal back to Earth using a different frequency.
Communication satellites transmit their signals to a particular area of the Earth's surface. This is the satellite's 'footprint'.
Receivers on the ground pick up the signal using dish aerials. The aerials at the edge of the 'footprint' have a larger reflecting dish as the signals are weaker.

HEALTH PHYSICS

Summary Notes

Section	Content
1. The use of thermometers	Thermometers and body temperature
2. Using Sound	The stethoscope Ultrasonic scanning Noise pollution
3. Light and sight	Refraction Image formation Correction of eye defects The use of fibre optics in medicine
4. Using the spectrum	Uses of Laser, X-rays, ultra violet and infra-red in medicine.
5. Nuclear radiation - Humans and Medicine	The uses of radioactivity in medicine The properties of radioactivity The effects of radioactivity on living things and the special precautions needed in handling radioactive materials

Section 1: BODY TEMPERATURE



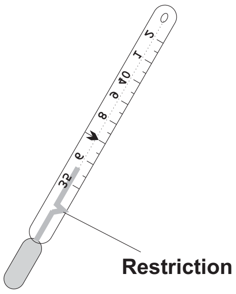
Body temperature

Our normal body temperature is 37°C.
The brain works to keep our temperature at the normal level. If we get too hot, we sweat. If we get too cold, we shiver.
When we become ill our temperature changes. Doctors can use measurements of body temperature to monitor our illness. It also indicates the effectiveness of the treatment.

Clinical thermometers

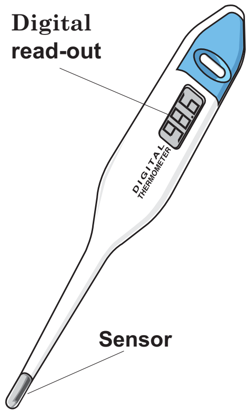
Clinical thermometers are thermometers designed to measure body temperature. They have a scale of roughly between 30°C and 40°C, and can be read to the nearest 0.1°C; (compare this with the normal laboratory thermometer).
To measure body temperature accurately, a thermometer must be inserted into the body. Usually it would be inserted under the tongue. The thermometer must be removed for reading so it is designed to hold onto the maximum temperature it measures.

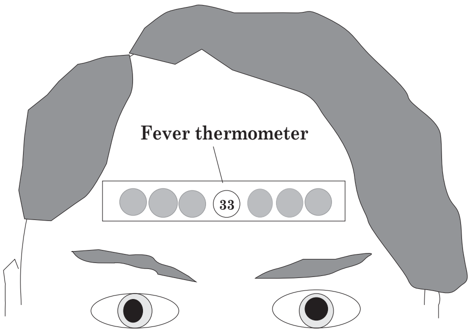
Section 1: Clinical Thermometers



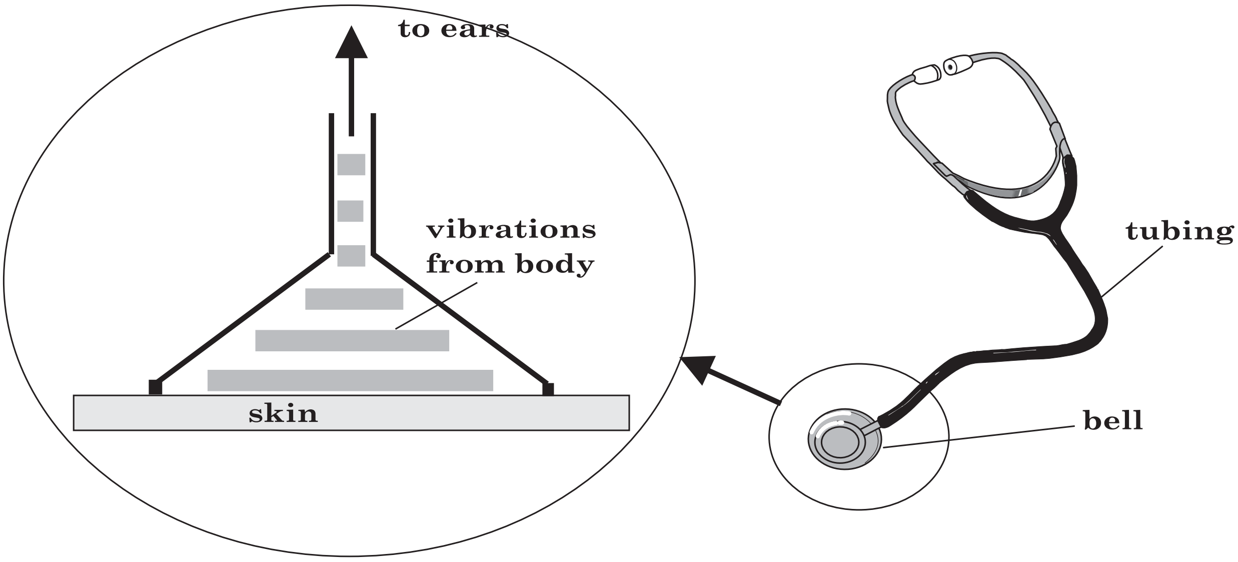
Mercury clinical thermometer
The thermometer is placed under the tongue and left for several minutes to allow for an accurate reading. The thermometer is removed to read it. The restriction in the mercury thread prevents the mercury returning to the bulb so it keeps the temperature measurement. The thermometer has to be shaken to force the mercury down.

Digital clinical thermometers
This type of thermometer is used in exactly the same way as the older mercury type. It requires less time to reach an accurate temperature and the reading is held electronically.
There are several different types of sensors which can be used to measure temperature. The most common are thermistors, resistors and thermocouples (look them up!).
Electronic thermometers, connected to computers, are used to record the temperature of patients in hospital.





Fever thermometer
A fever thermometer is a plastic strip which is placed on the forehead.
Printed on the strip are a series of patches.
Each patch changes colour at a certain temperature, usually revealing the temperature as it does so.
Fever thermometers are a convenient means of monitoring temperature in the home as they require no training to use.
They are not as accurate as a standard clinical thermometer.

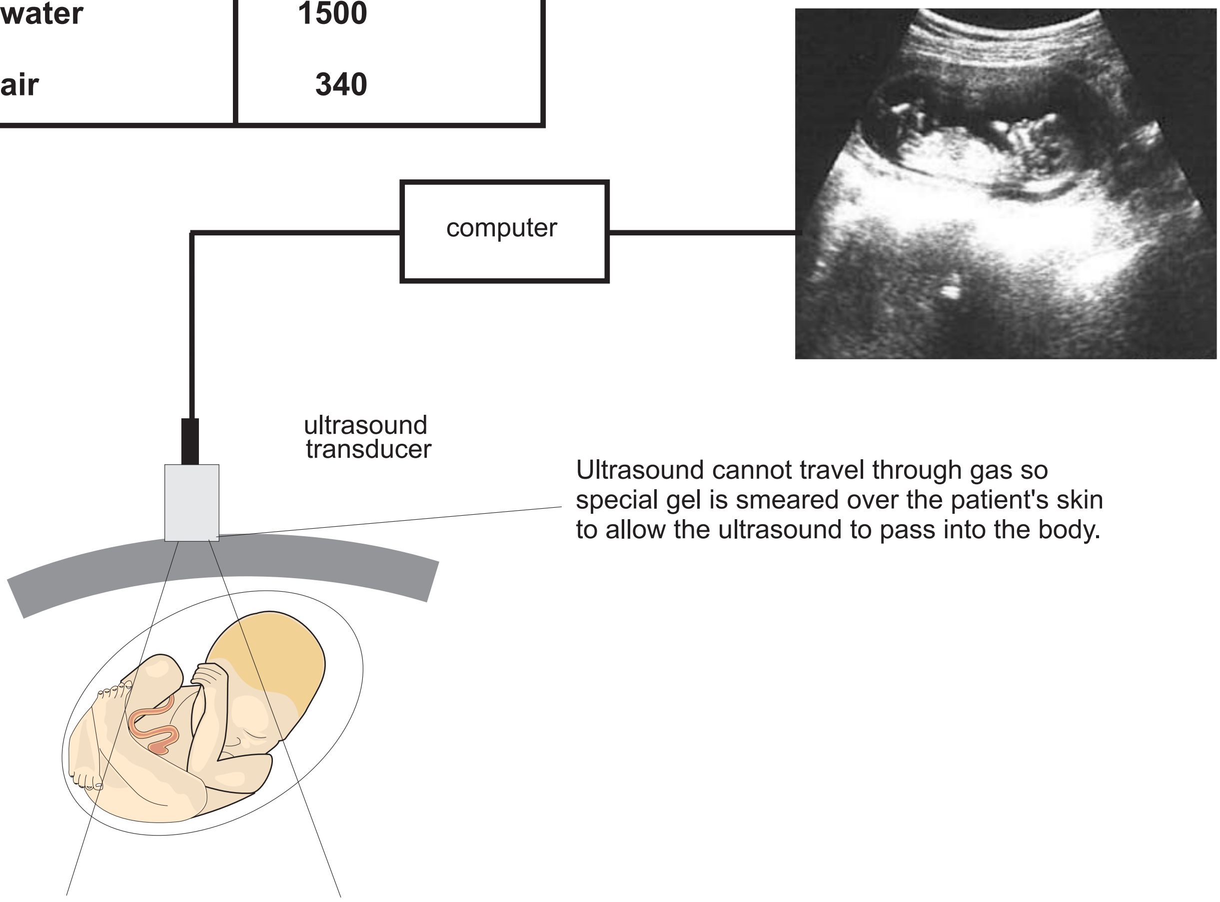


STETHOSCOPE

The stethoscope
The stethoscope is used to listen to the sounds generated inside the body. Sound vibrations are collected by the bell and channeled up tubes into the ears. No sound energy is lost, so the listener can hear even the faintest sound.
Stethoscopes usually have two bells, an open one and a closed one. The open bell is used to listen to the low frequency sounds from the heart. The closed bell is more useful for listening to the higher frequency sounds from the lungs.

Section 2: ULTRASOUND

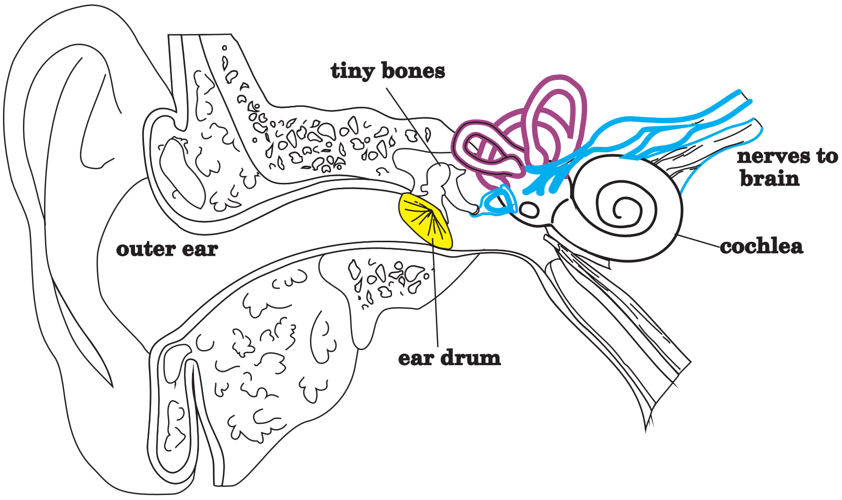
Substance	Speed of sound in m/s
bone	3000
muscle	1600
soft tissue	1500
water	1500
air	340



Ultrasound cannot travel through gas so special gel is smeared over the patient's skin to allow the ultrasound to pass into the body.

Ultrasound scanning
Ultrasound is sound with a frequency greater than 20000Hz.
Ultrasound is used to look inside the body. High frequency sound, with frequencies in megahertz, is directed into the body. The reflected sound from the body is used to build up a picture. Ships use the same techniques to look under the sea using ordinary sound.

Ultrasounds with high frequencies have very short wavelengths inside the body and so can see small details. Ultrasound is much safer than the alternative X-rays, where long exposures may be required. Ultrasound is the preferred option for examining unborn babies while in the womb.

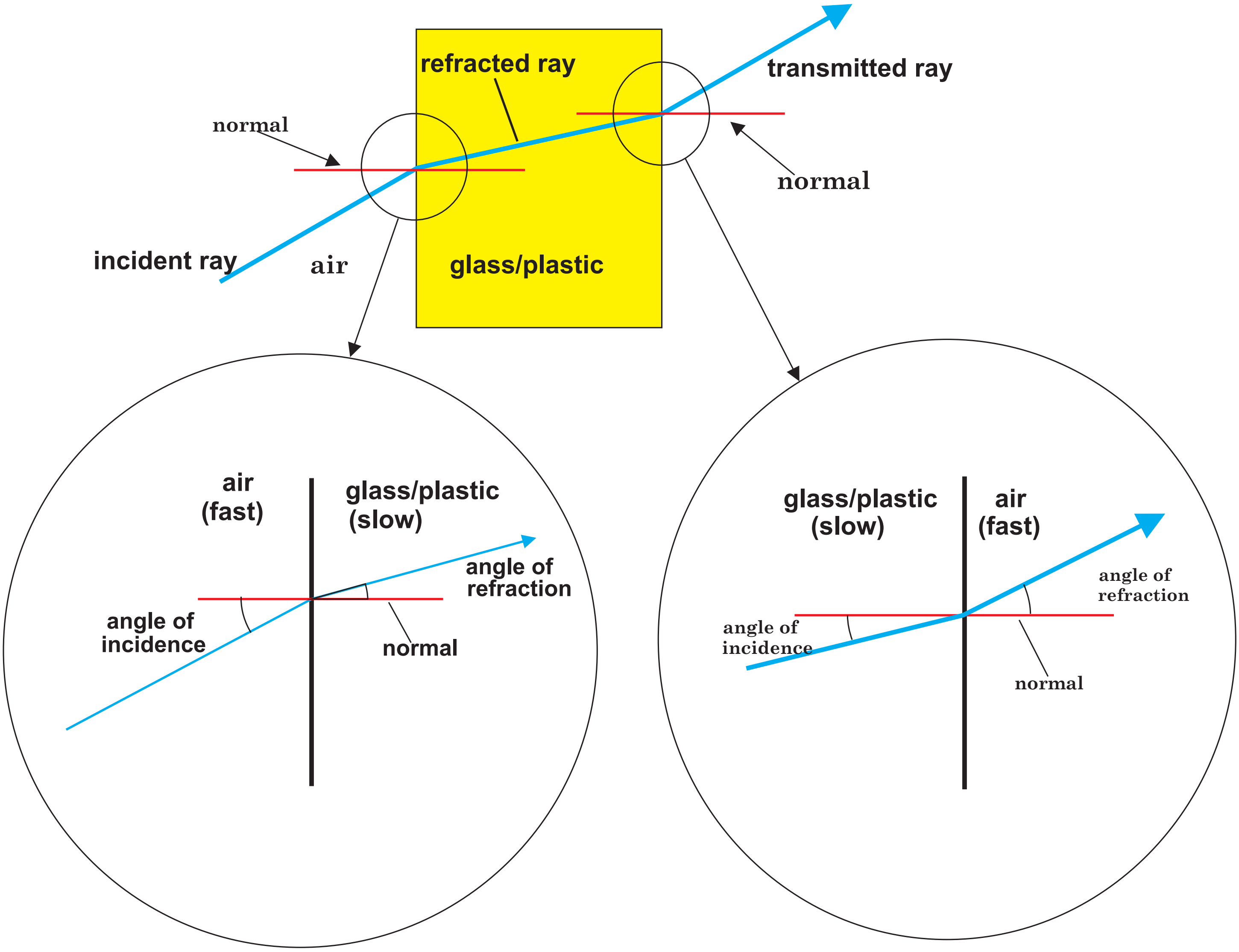


The ear

Sound waves are collected by the outer ear and channeled to the ear drum. The ear drum vibrates in response. The vibrations are transferred to the cochlea, in the inner ear, by tiny bones. In the fluid filled cochlea, the vibrations are picked up by tiny hairs. Each hair is tuned to are particular frequency and sends its own signal to the brain. The hairs lining the cochlea are easily broken by heavy vibration. The ones tuned to the higher frequencies are very fragile and easily damaged. We tend to lose the ability to hear higher frequencies as we get older.
A new born baby can hear sounds with a frequency range between 20Hz and 20000Hz. A 50 year old may only hear up to 12000Hz.

Sound and Effect	Level /dB
Rifle close to ear (ear drum bursts)	160
Jet aircraft at 25m (pain)	140
Disco close to speakers (discomfort)	120
Very noisy factory	100
Road drill at 7m (legal limit)	90
Busy street	70
Quiet street	50
Quiet conversation	40
Whisper, ticking watch	30
Blood pulsing	20
Threshold of hearing	0

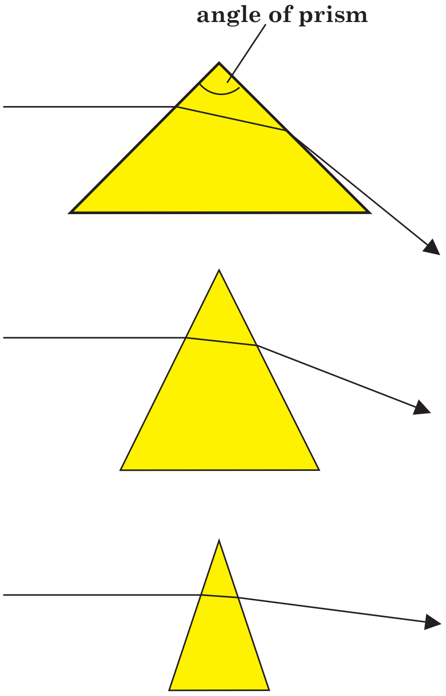
Section 3 REFRACTION



Refraction

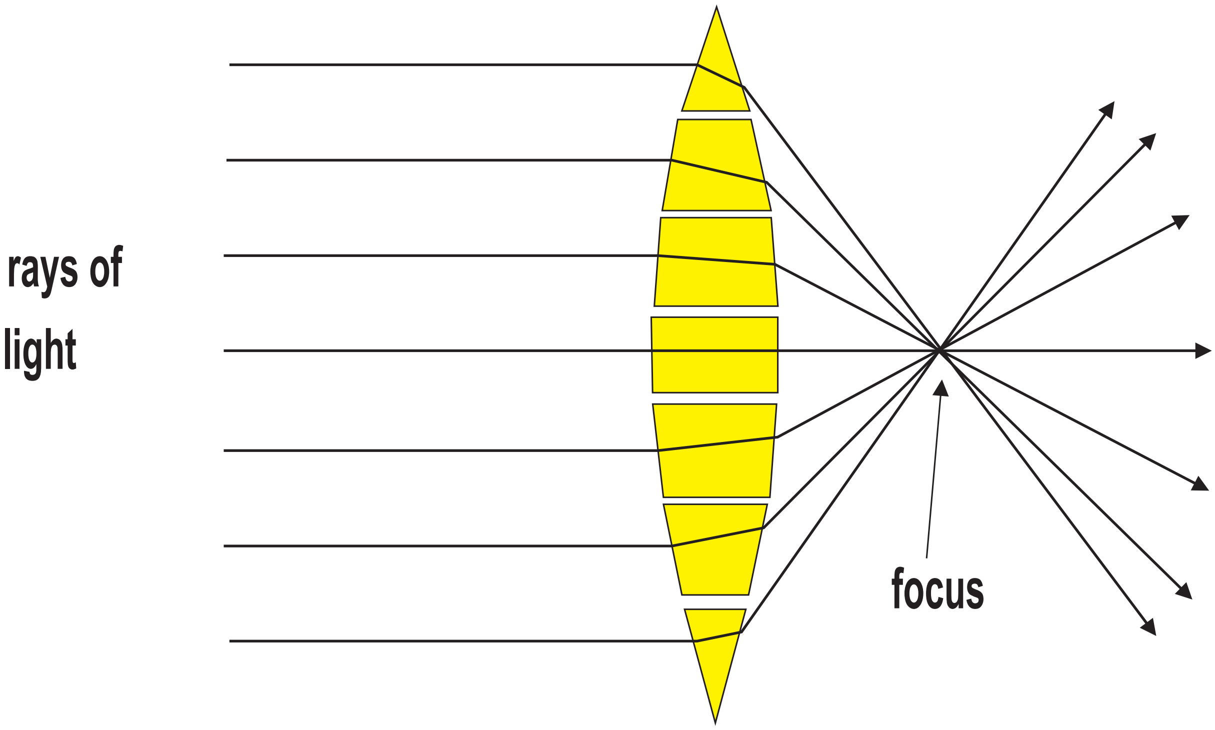
The speed of light depends on the material it is travelling through. It has a higher speed in air than it does in glass or plastic.
When light rays pass from one material into another, the change in speed can cause the ray to change direction: if it strikes the boundary at an angle other than along the normal.
When passing from air into a slower material like glass or plastic, the direction of the ray is changed towards the normal. When passing from glass or plastic into air, the direction is changed away from the normal.

Section 3 : REFRACTION



Prisms

Triangular prisms change the direction of light rays. For rays coming from the same direction, the size of the direction change depends on the angle of the prism. The larger the angle, the greater the change of direction.



Lens

A lens can be considered to be built up from a number of prisms.
The outer edge of the lens has the greatest angle of prism and so a ray of light, passing through the edge, changes direction by the greatest amount.
The change of direction gets less as we move towards the centre of the lens.
The net effect is that the rays, passing through the lens, change direction and pass through a focus.

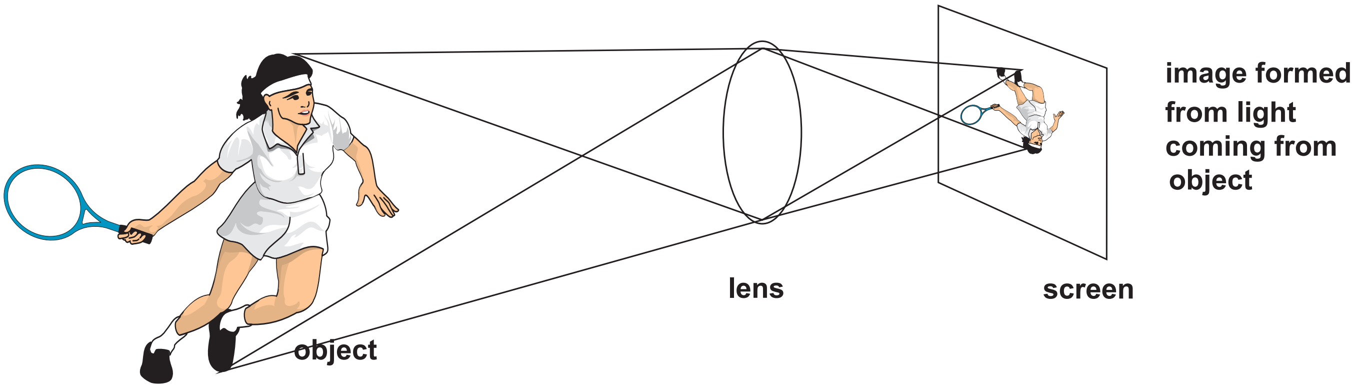
Section 3 : FORMING AN IMAGE

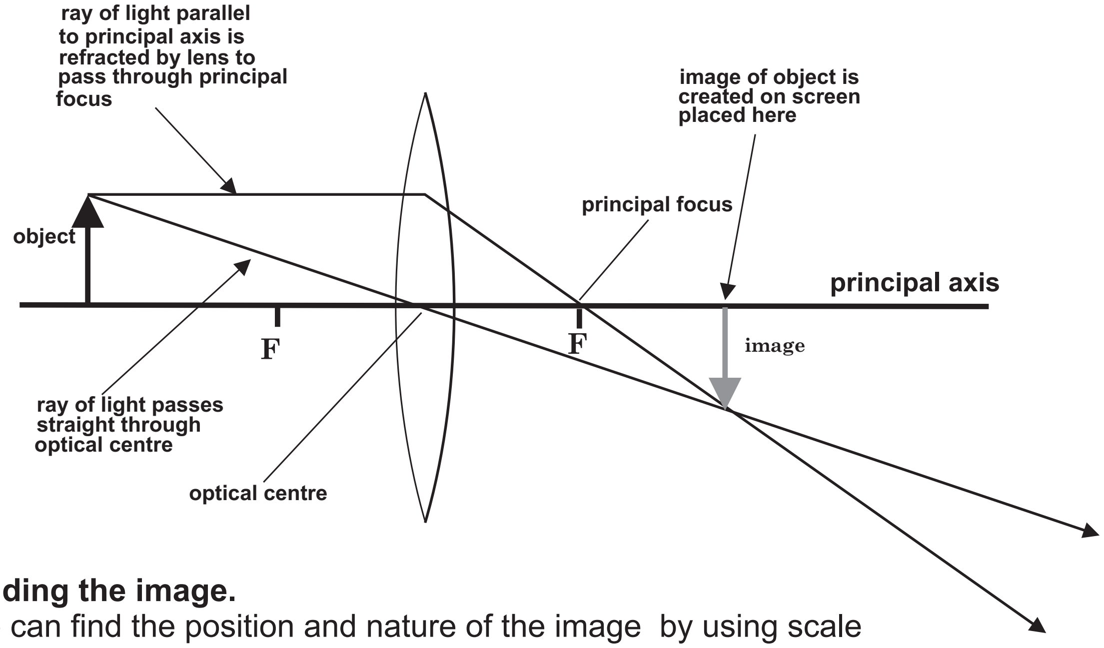
Forming an image.

Objects reflect light. A convex lens can be used to collect some of this light and focus it on a screen to produce an image of the object.

The image is formed from the light collected by the lens. The larger the lens the greater the amount of light collected and the brighter the image.

The image formed by the lens is upside down and left to right compared to the object (inverted and laterally inverted).

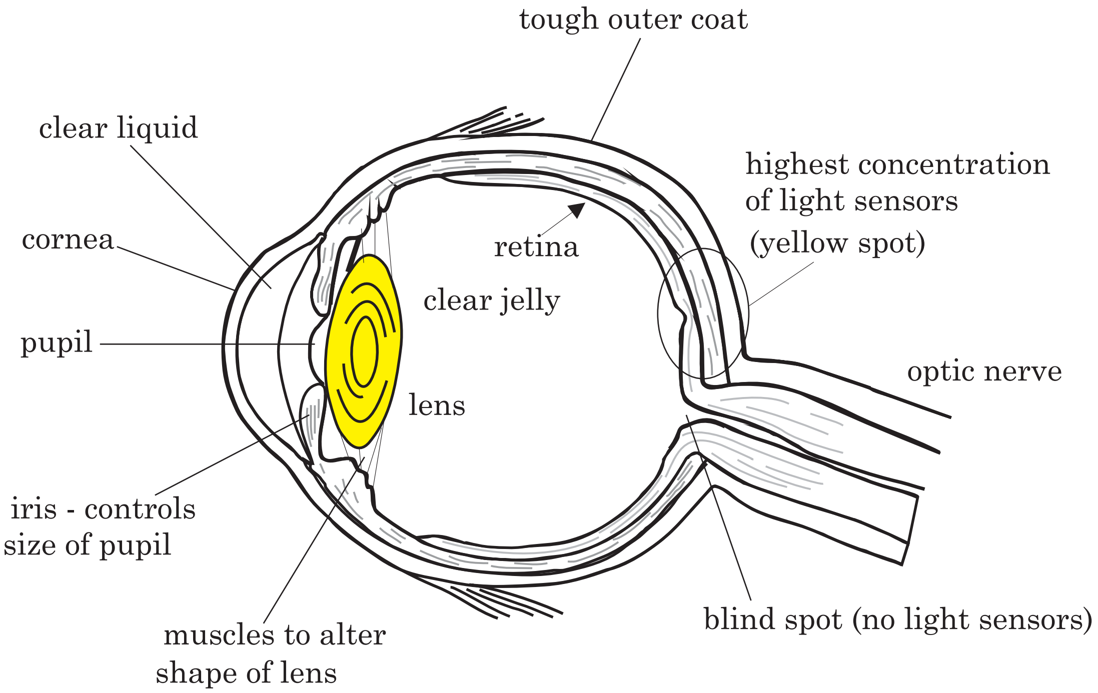




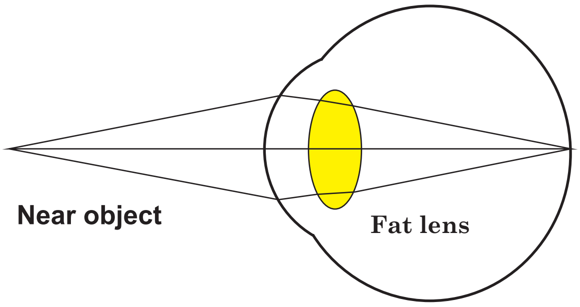
Finding the image.

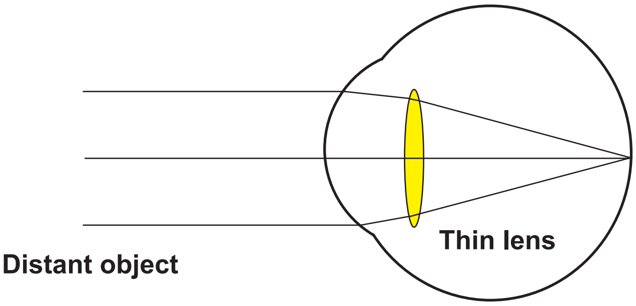
We can find the position and nature of the image by using scale drawing.

We select two rays of light; one from the top of the object passing straight through the optical centre of the lens; the other from the top and parallel to the principal axis, which passes through the principal focus after refraction. The image is formed where the rays cross.



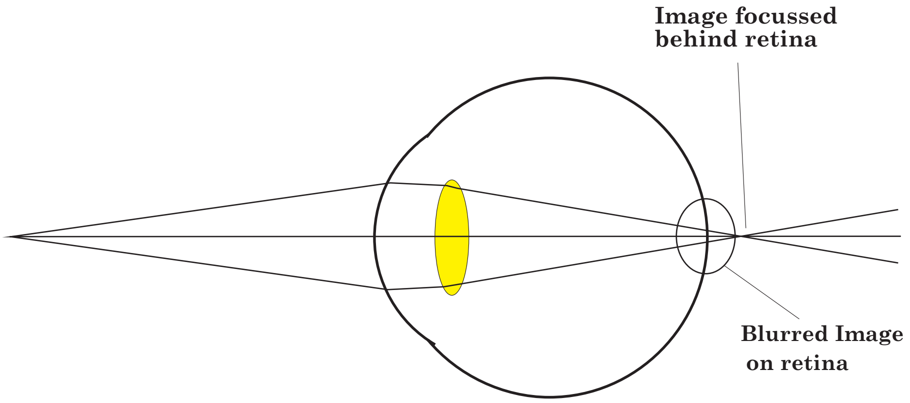
The Eye

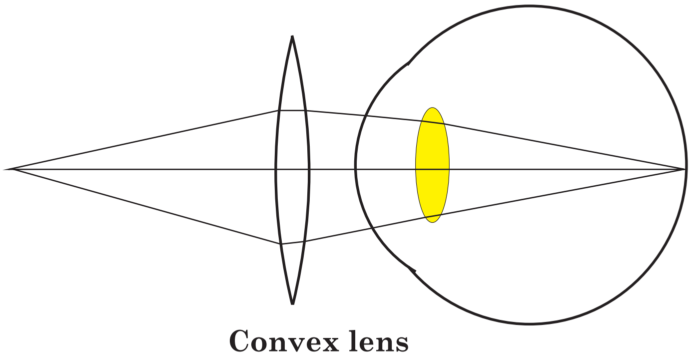




The eye.
The eye is designed to project a sharp image of the outside world onto the retina at the back of the eye. The retina is covered in special cells which sense both light and colour. These convert the image to electrical signals which are sent to the optical centre in the brain. The brain provides us with the coloured pictures.
The eye can focus on both near and distant objects by changing the shape of the lens: fatter, to give more power, for near objects: thinner for distant objects. The cornea provides most of the focusing power, the lens provides the extra adjustment.

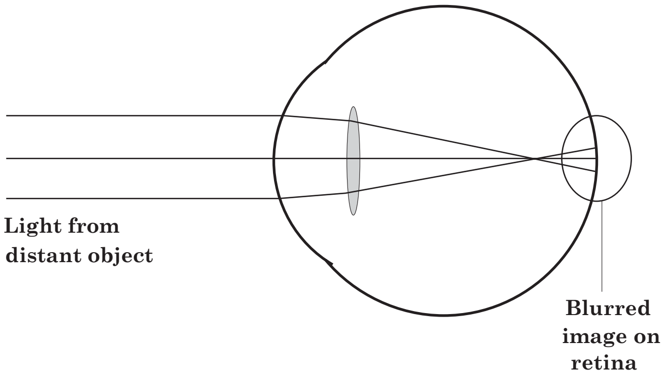
Section 3: EYE DEFECTS

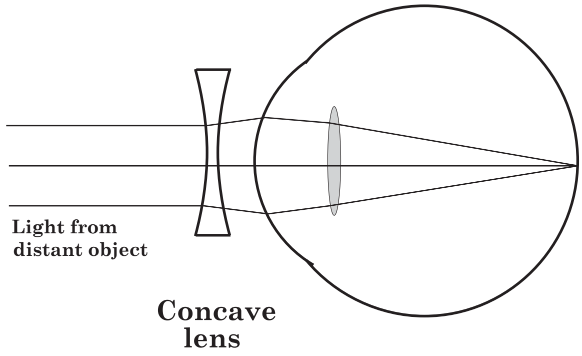




Long sightedness
A person suffering from long sightedness can see distant objects clearly but near objects appear blurred.
The eye is not powerful enough to focus the light from near objects onto the retina. Instead the light is focused behind the eye, producing a blurred image on the retina.
An optician can correct this defect by using spectacles containing convex lenses. These provide the extra focusing power required.

Short sightedness
A person, suffering from short sightedness, can see near objects clearly but distant objects appear blurred.
Short sightedness is caused by the eye being unable to reduce its focusing power so that light from distant objects is focused in front of the retina.
An optician can correct this defect by using spectacles fitted with concave lenses. These reduce the focusing power of the eye.





Section 3: THE POWER OF A LENS

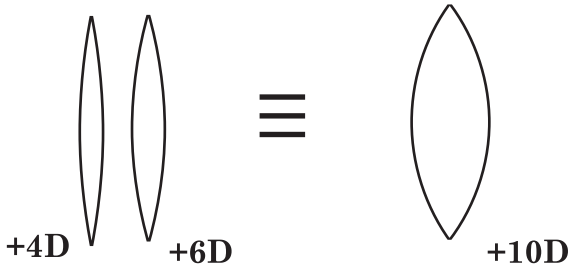
Power of a lens (P)
Scientists would normally use the focal length of a lens when describing the focusing power of a lens. Opticians prescribe lenses by quoting the power of the lens required.
The power of a lens is given by the relationship;

$$\text{Power} = \frac{1}{\text{focal length(m)}}$$

$$P = \frac{1}{f}$$

The power of a lens is measured in dioptres.
Convex lenses have positive powers: Concave lenses have negative powers.

When two lenses are used together, their combined power is equal to the sum of their individual powers.

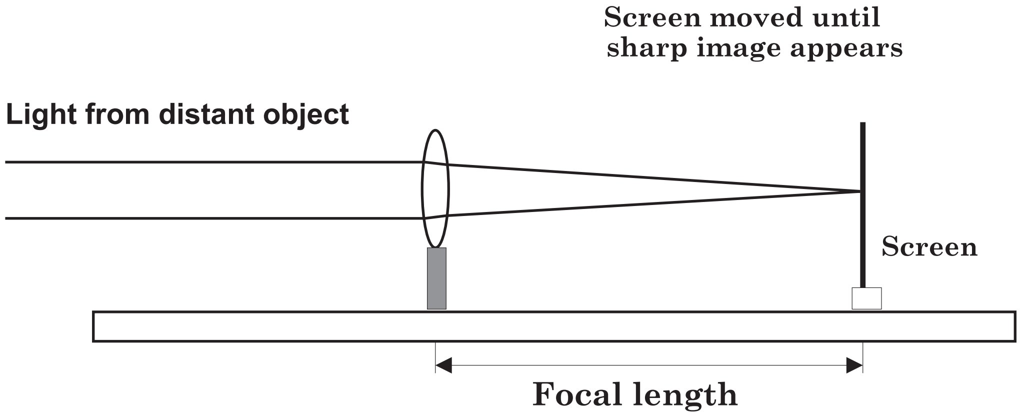


The human eye has a diameter of 4cm.
When focused on distant objects the power of the human eye is:

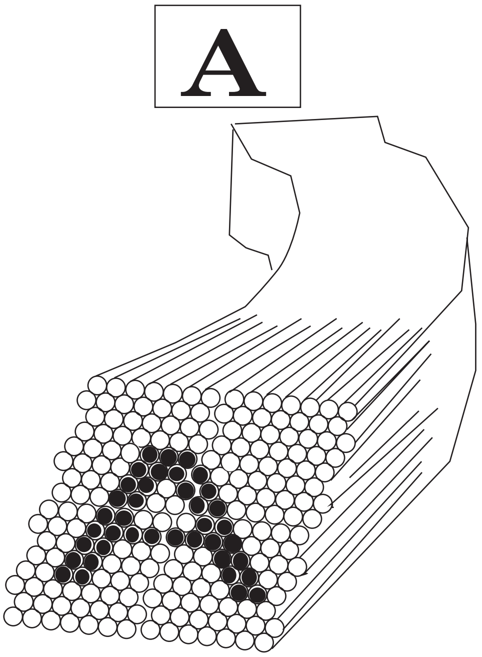
$$P = \frac{100}{4}$$
$$= 25 \text{ Dioptres}$$

The internal lens in the eye only provides an extra +10 Dioptres maximum adjustment for near objects.

Measuring Focal length



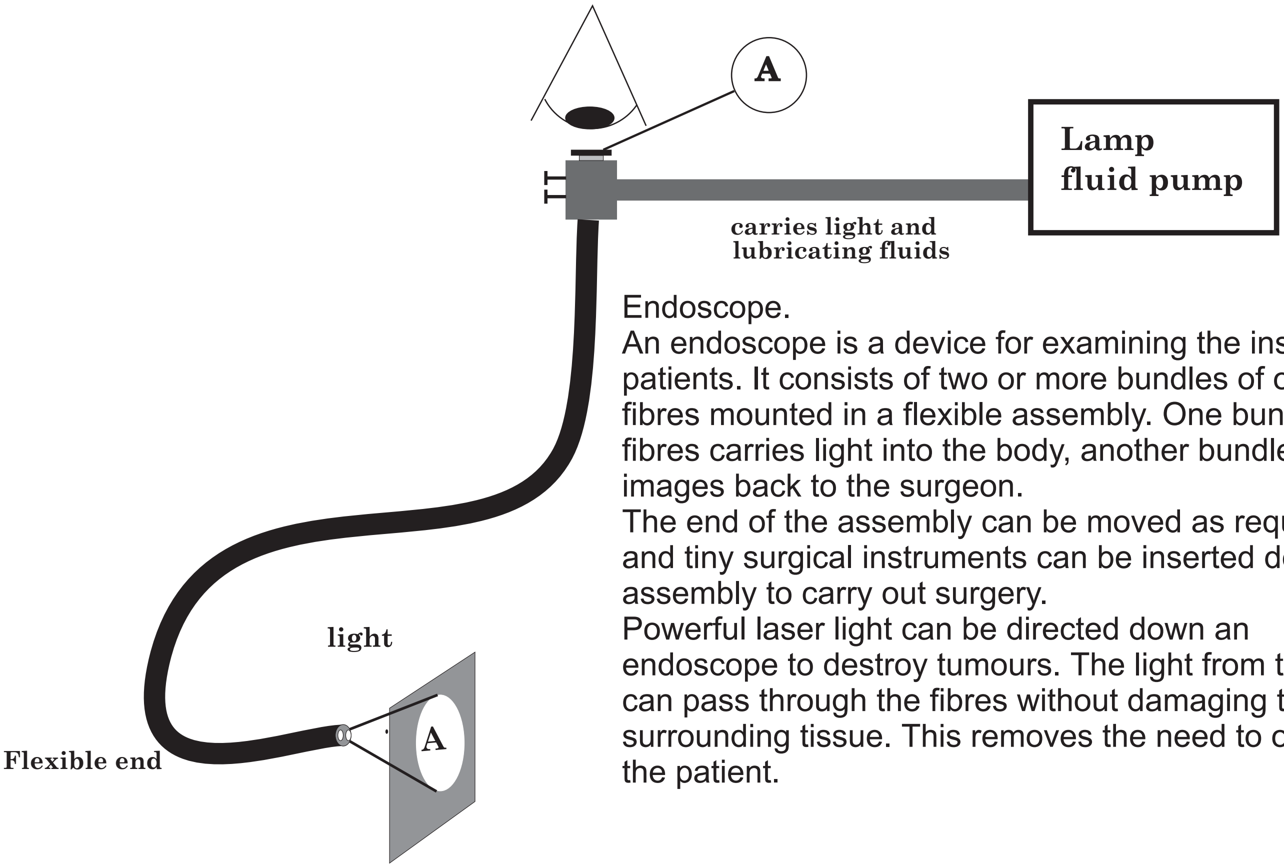
Section 3: FIBRE OPTICS IN MEDICINE



Images can be transmitted using COHERENT bundles of optical fibres. Each optical fibre transmits a tiny part of the image. As long as each fibre maintains its position in the bundle, a composite image will be transmitted from one end to the other.

The more fibres packed into the bundle, the more detail can be transmitted.

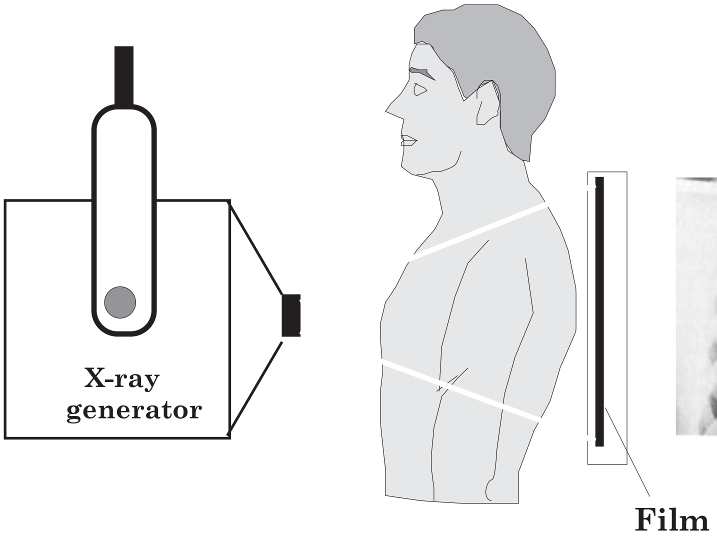
The endoscope uses a coherent bundle of fibres to transmit images from inside the body.

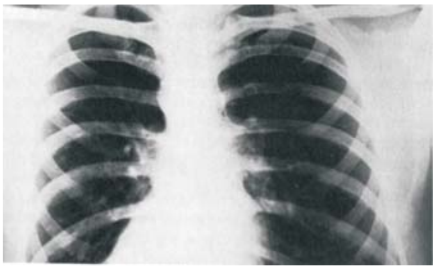


Endoscope.
An endoscope is a device for examining the inside of patients. It consists of two or more bundles of optical fibres mounted in a flexible assembly. One bundle of fibres carries light into the body, another bundle carries images back to the surgeon.
The end of the assembly can be moved as required and tiny surgical instruments can be inserted down the assembly to carry out surgery.
Powerful laser light can be directed down an endoscope to destroy tumours. The light from the laser can pass through the fibres without damaging the surrounding tissue. This removes the need to open up the patient.

Section 4: X-RAYS

Ionising Radiation



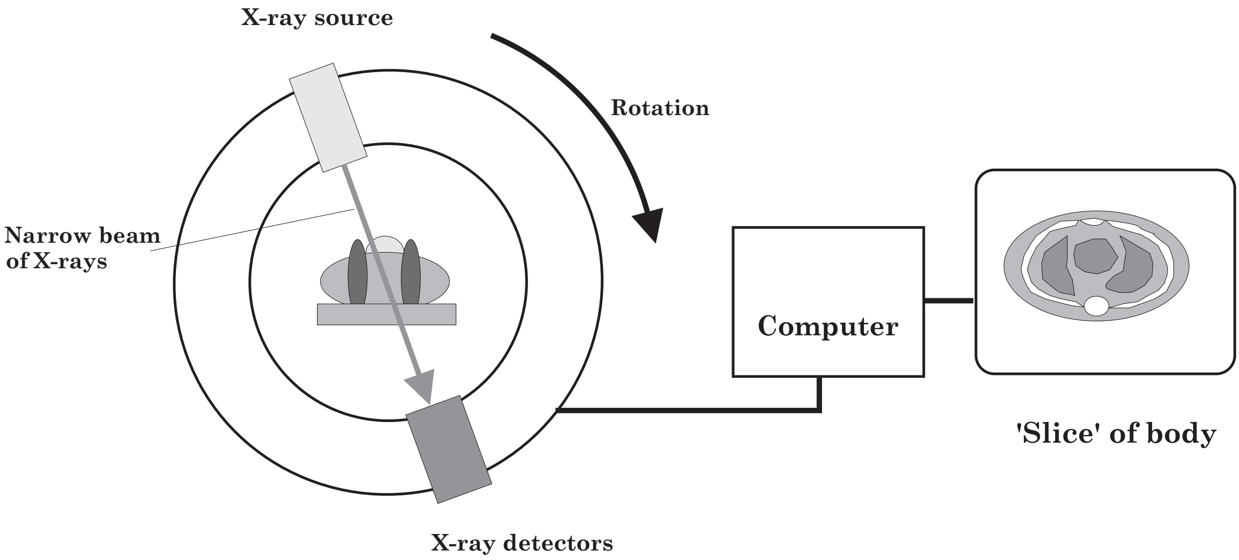


Developed Negative

X-rays are high frequency, short wavelength electromagnetic waves. X-rays are created by bombarding heavy metals with high energy electrons.

X-rays pass through human flesh but are absorbed by the denser bones. X-rays fog photographic film (airport security!). When X-rays are passed through the body onto film, the bones cast a shadow. When the negative is developed, the shadows cast by the bones appear white (if the film was printed the bones would appear black!)

X-rays are ionising radiation. Long exposure to them could cause cancers. Radiologists are more at risk than patients so they operate with lead-lined aprons and from behind lead screens.



CAT scanner.

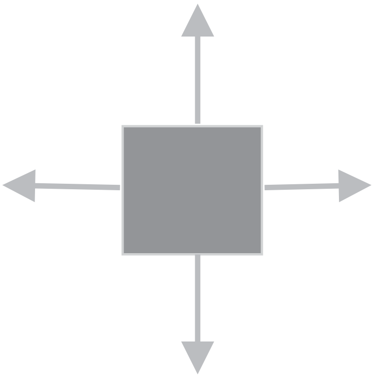
Normal X-ray 'shadow' photographs cannot be used to locate objects in the body.Computer-Aided-Tomography(CAT) scanners use a rotating X-ray machine to view the body from different angles. It uses an extremely narrow beam of X-rays (mm) to 'slice' the body. The X-rays are picked up by electronic detectors. The signals from the detectors are processed by a powerful computer to provide a series of 'slices' of the body.

CAT scanners pick up minute details; even of soft tissue, that an ordinary X-ray would miss.

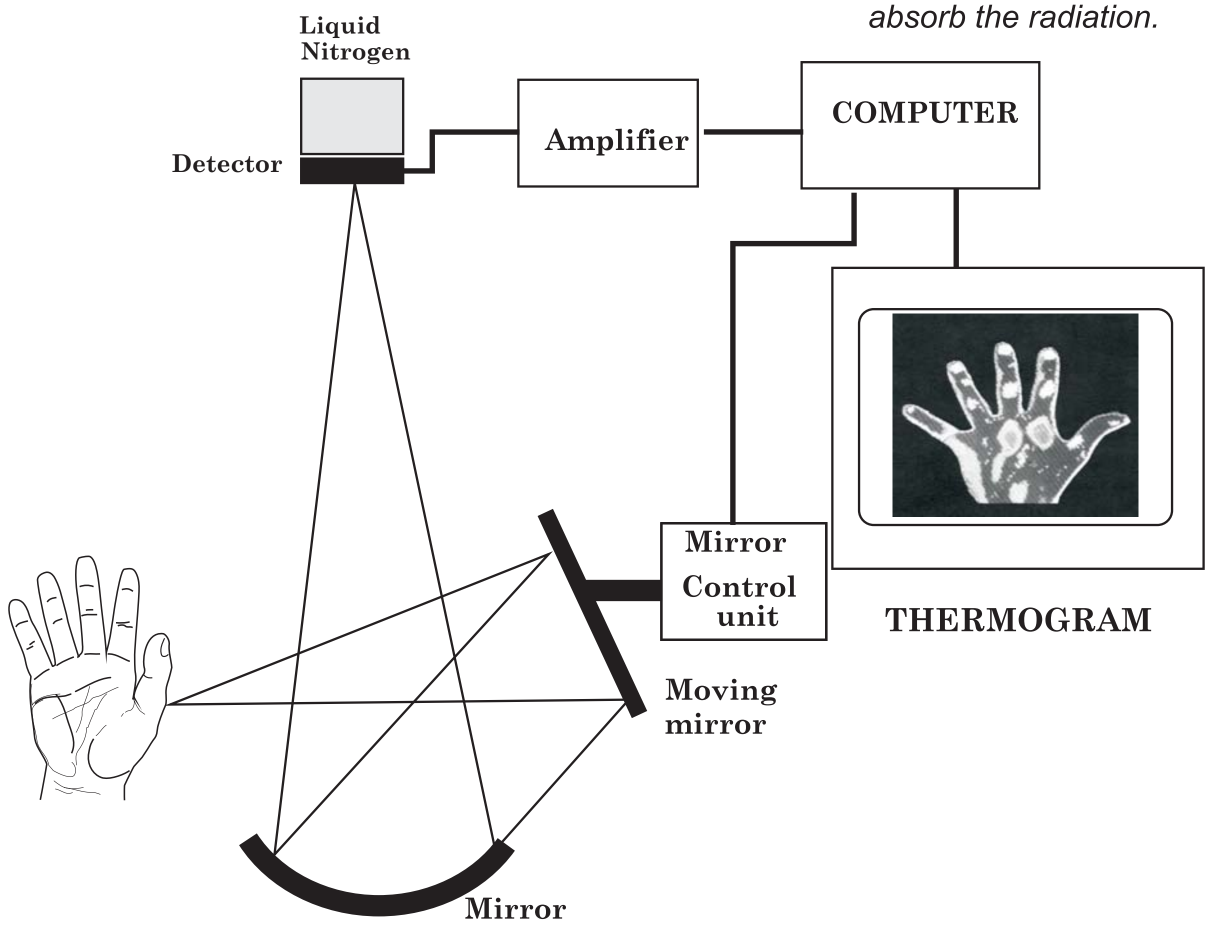
CAT scans take much longer than normal X-rays and so the patient receives a larger than normal dose of ionising radiation. To reduce the risk, X-rays used in CAT scans are reduced in intensity.

Section 4: INFRA RED

All hot objects emit invisible Infrared radiation. Infrared can be focused using mirrors and special lenses. As with visible light, we can produce an image of an object from the infrared radiation it emits.
The hotter the object, the brighter the image. If the temperature of the object is uneven, then the hotter parts will appear brighter.
We cannot see an image produced in infrared. We have to convert the infrared image to electrical signals and use a computer, or use special photographic film which is sensitive to infrared.

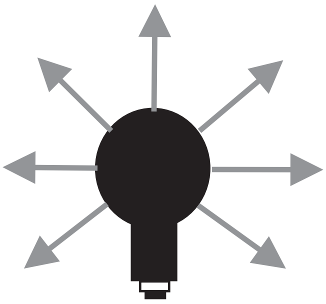


Infra red is detected using thermopiles, photodiodes or a sensitive thermometer with a blackened bulb to absorb the radiation.



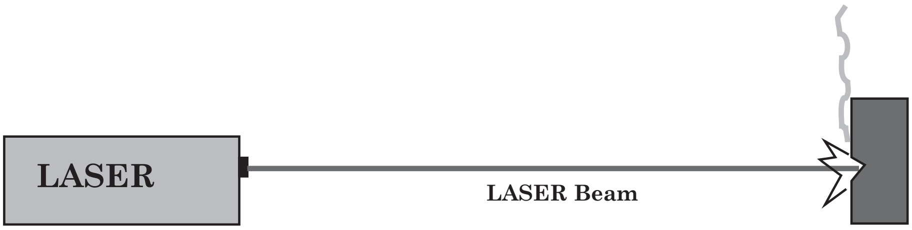
Thermography.
Images of the body created from the infrared radiation emitted by the body can be used in diagnosis. A computer is used to colour the image according to temperature. Hot spots on the image represent areas where the blood supply is close to the surface. This can be an indication of a hidden tumour. An image created from infrared radiation is called a Thermogram.
In the apparatus above a controlled mirror is used to focus infrared from each point on the hand onto a special electronic detector. The detector has to be cooled to low temperature using liquid nitrogen. The computer builds up the thermogram on a screen from the signal.

Section 4: ULTRA VIOLET



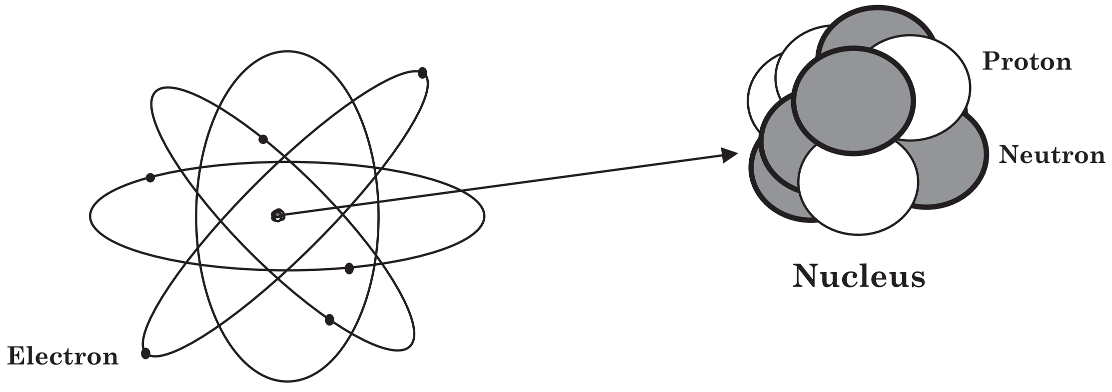
UV Lamp

Ultraviolet Radiation.
UV is generated using special discharge lamps (black lights). UV is invisible, but can be detected through the fluorescence it creates in certain materials.
UV causes our skin to tan in the summer. This is now regarded as unhealthy as exposure to UV can lead to skin cancers.
Doctors use UV to treat skin conditions, where it kills skin cells. It is also used to sterilise equipment as it also kills germs.



LASER - Light Amplification by Stimulated Emission of Radiation

Lasers are devices which generate narrow beams of intense light. Lasers are used in medicine to destroy cells. The heat generated when a laser beam strikes a cell is enough to vaporise the cell.
Lasers can be used to treat skin conditions directly or can be used via optical fibres to treat internal tumours. The Laser does not transfer energy to the fibre so it does not heat up. The Laser beam can be passed safely down the fibre to where it is required.

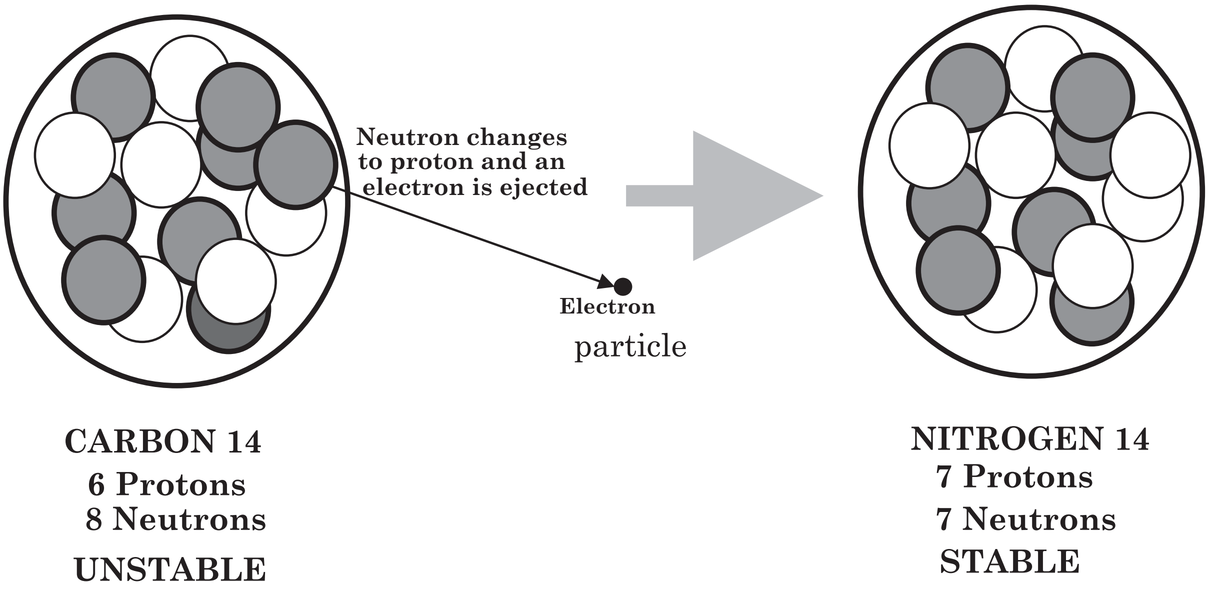


Atom

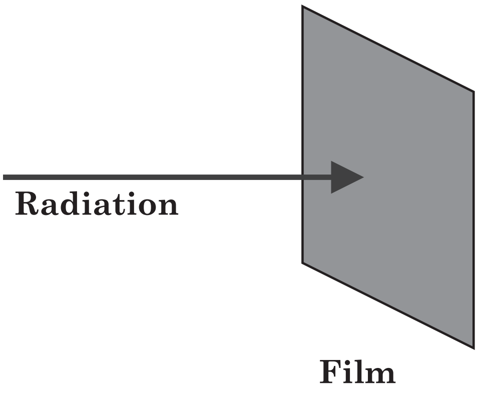
Atoms consist of a nucleus composed of protons and neutrons, surrounded by electrons. The electrons are tiny particles with a negative charge. The protons are 2000 times larger with a positive charge which is equal in size to the charge on the electron. There are equal numbers of protons and electrons in an atom so from a distance the atom would appear to have no charge.

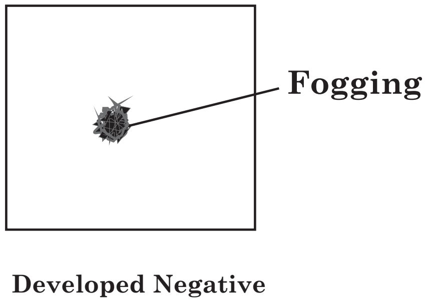
The protons are closely packed together and have the same charge so they should fly apart (like charges repel). They are held together by the neutrons which are the same size as protons but have no charge.

Whether a nucleus stays together depends on the balance of protons and neutrons. In some types of atom there is an imbalance and the nucleus is unstable. The nucleus will eject a radioactive particle to become more stable. This process gives rise to radioactivity.



Section 5: DETECTING RADIOACTIVITY

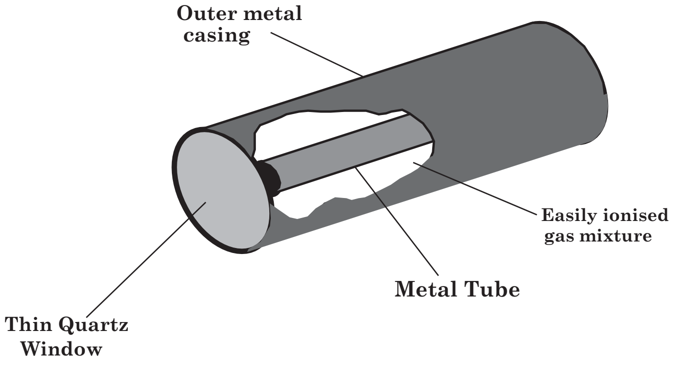


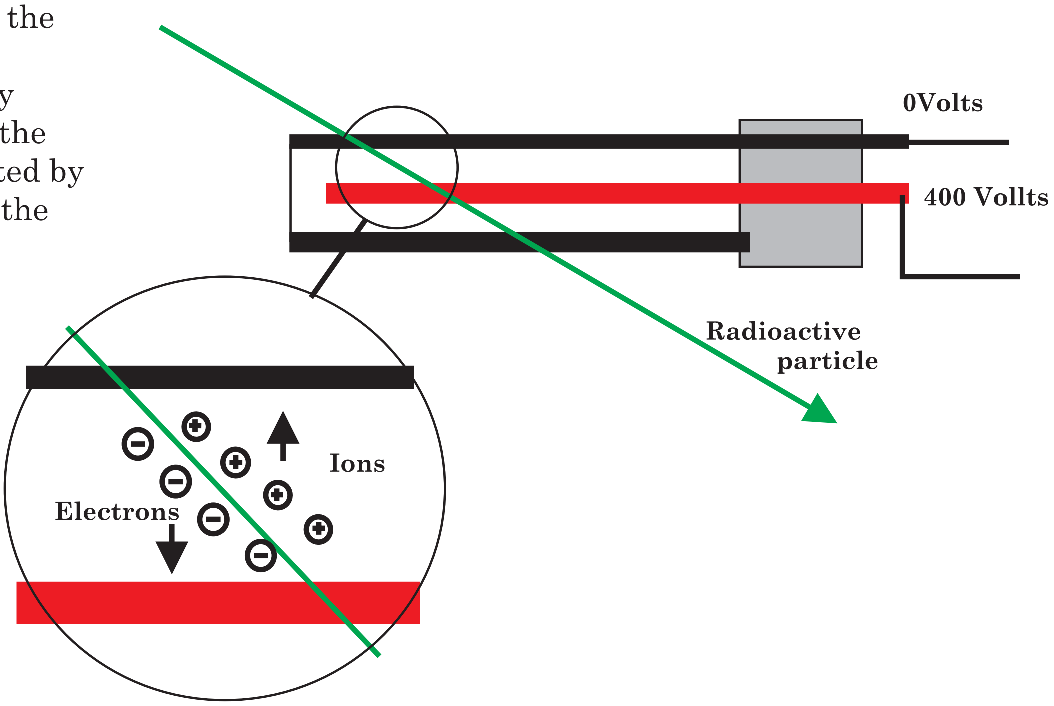


All ionising radiation, including radioactive particles, affects photographic film. It causes fogging; blackened film negatives.
Film is used in the personal badge Dosimeters carried by workers dealing with radioactivity. The film in the badges is regularly developed to check how much radiation the worker has been exposed to.

Geiger-Muller Tube

Most methods of detection rely on the ability of radioactive particles to ionise the substances through which they pass.
The Geiger-Muller tube contains inner and outer electrodes surrounded by a gas which is easily ionised. The electrodes have a high voltage across them. When a particle enters the tube, the gas is ionised and can conduct electricity. A tiny current passes between the electrodes. This is detected by the equipment to which the tube is connected.





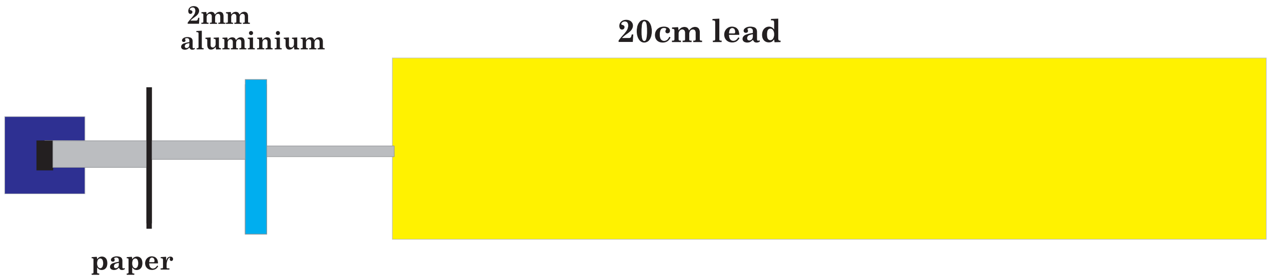
Section 5: ALPHA, BETA, GAMMA

There are three distinct types of radioactive emissions.

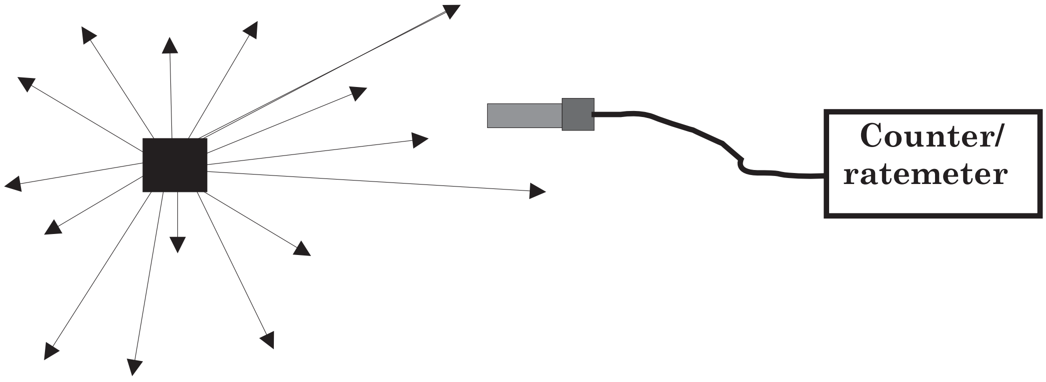
Alpha (α) particles are composed of 2 protons and 2 neutrons. They are heavy and strongly ionising. Alpha particles have a range of only a few centimetres in air and can be stopped by a sheet of paper. Even so, Alpha particles are regarded as the most hazardous of the radioactive particles, due to their ability to ionise.

Beta (β) particles are simply electrons with high energy. They are much lighter than alpha particles and are only moderately ionising. Beta particles have a range of around 15 centimetres in air and can be stopped be 2 millimetres of aluminium.

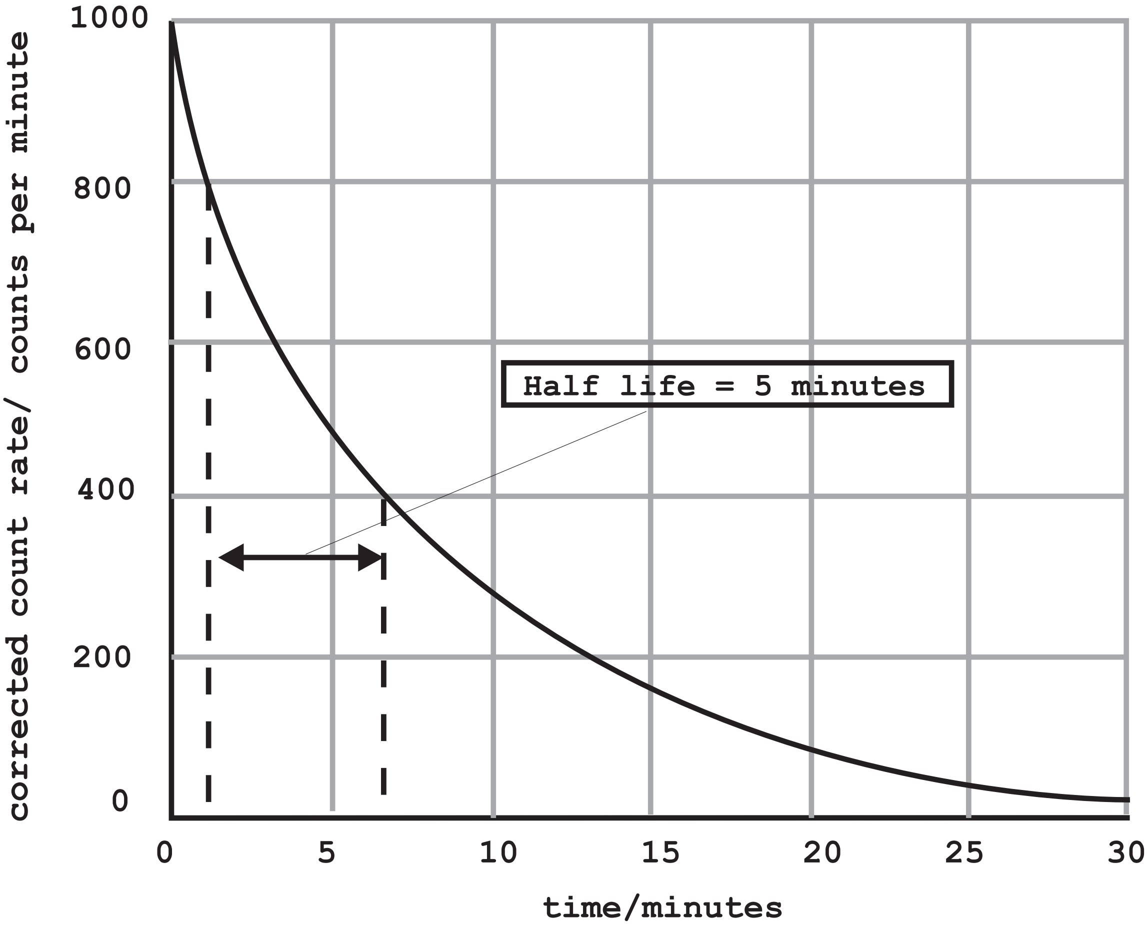
Gamma (γ) rays are bursts of electromagnetic radiation emitted after a beta or alpha particle. They have no mass and are less ionising than beta particles. Gamma rays have a range of many metres in air and are stopped by 20 centimetres of lead.

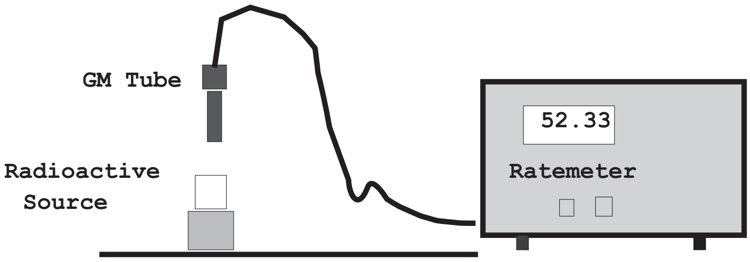


The Activity of a radioactive source is the number of radioactive decays per second. Activity is measured in becquerels(Bq).
Radioactivity is a random process and radioactive particles are emitted in any direction from the source. Radioactivity cannot be affected by any physical means.
It is difficult to measure the activity of a radioactive source. Normally we would place a detector close to the source and measure the number of particles entering the detector in a given time: the count rate.
The measured count rate is directly related to the activity of the source.



Half Life of a Radioactive Source





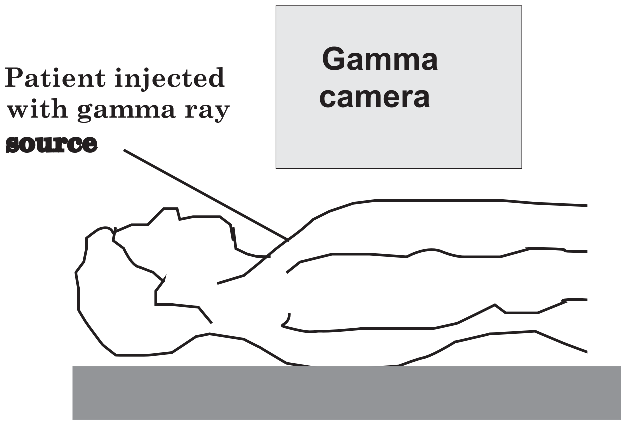
The ACTIVITY of a radioactive source decreases with time as atoms emit radioactive particles and change to more stable forms. The time taken for the ACTIVITY to fall to half its value is called the HALF LIFE of the source.

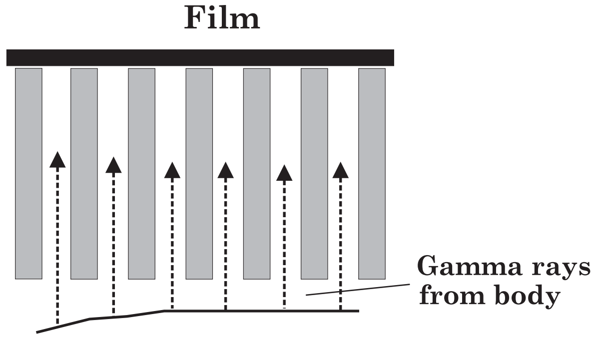
Each type of isotope has its own particular half life which can be used as an identity for that isotope.

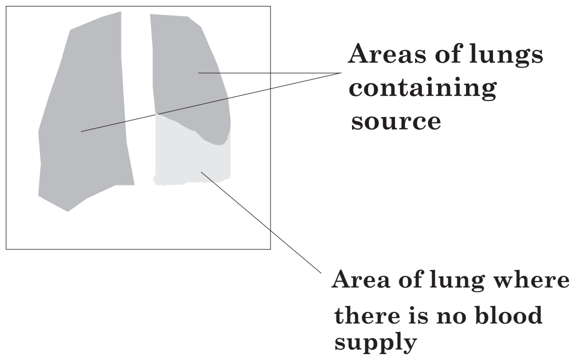
We can measure half life using the apparatus shown above. Firstly we measure the background count rate without the source. The count rate of the source is measured over a length of time. The background rate is subtracted from each measurement to give a corrected count rate. This is the count rate from the radioactive source.

The corrected count rate is graphed as above and the half life measured from the graph.

Section 5: RADIOACTIVITY IN MEDICINE



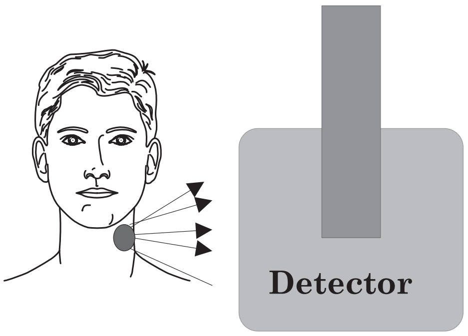




Gamma Camera.

Radioactivity can be used to diagnose internal problems. A patient is injected with a gamma ray source and placed under a special camera which photographs those areas of the body emitting gamma rays: those areas where blood is flowing. In this case, it shows that part of the lungs is not receiving blood.

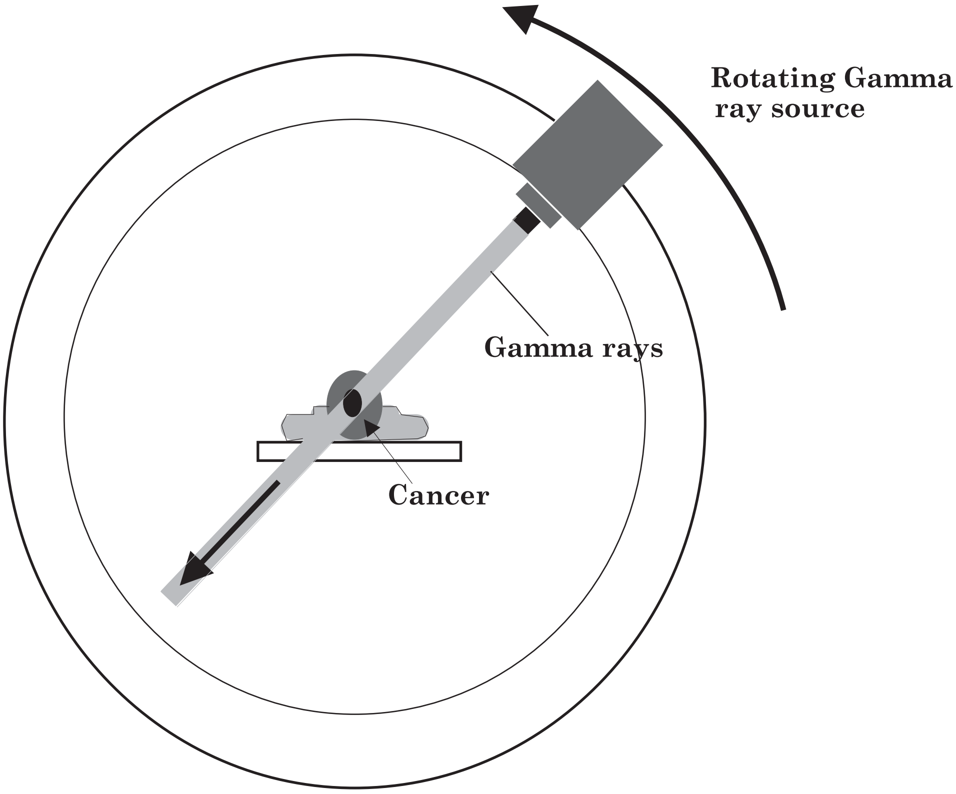
Gamma ray sources are used because alpha and beta radiation will not pass out of the body. The source will decay in a few hours and will pass out the body through the kidneys.



The patient has been injected with radioactive iodine. The thyroid gland in the neck collects iodine. The detector measures the amount of radiation emitted by the iodine collected by the thyroid. In this way it is possible to see if the gland is normal or diseased.

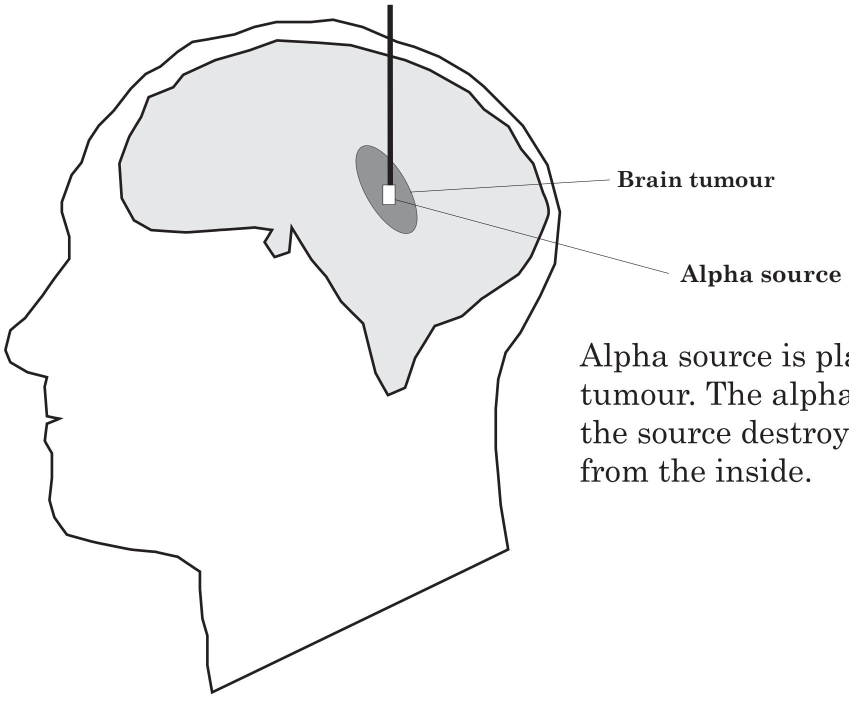
All radioactive sources injected into the body are chosen to be safe. Their activity is low and they have a short half life. All the sources used are beta-gamma emitters (Gamma rays are not emitted on their own, but with either alpha or beta particles). The chemicals used do not affect body chemistry and are passed safely out of the body in urine.

Section 5: KILLING CANCERS



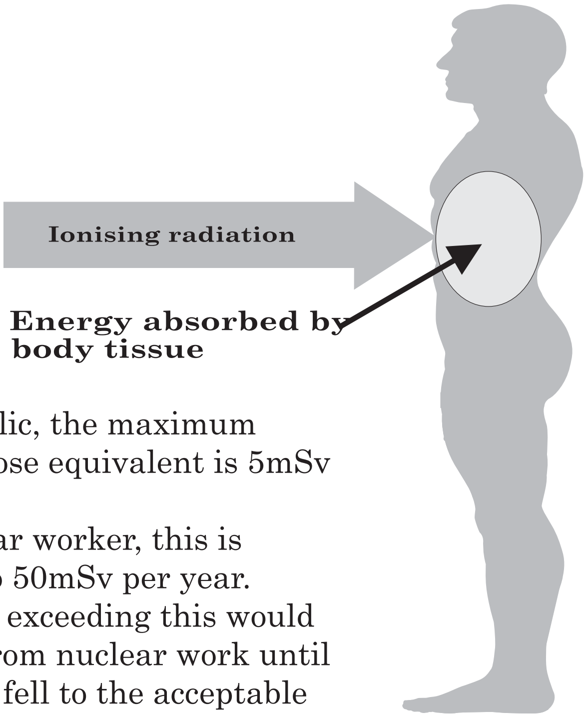
The major difficulty with using radiation to destroy cancer tumours is the need to safeguard the healthy cells surrounding the tumour.

The gamma ray source is mounted on a rotating assembly, so that it is directed at the tumour. The tumour receives a lethal dose of radiation while the dose to the surrounding tissue is reduced to a safe level. Nowadays, in Scotalnd, X-rays are used instead of gamma rays.



Alpha source is planted inside tumour. The alpha particles from the source destroy the tumour from the inside.

Section 5: THE SIEVERT

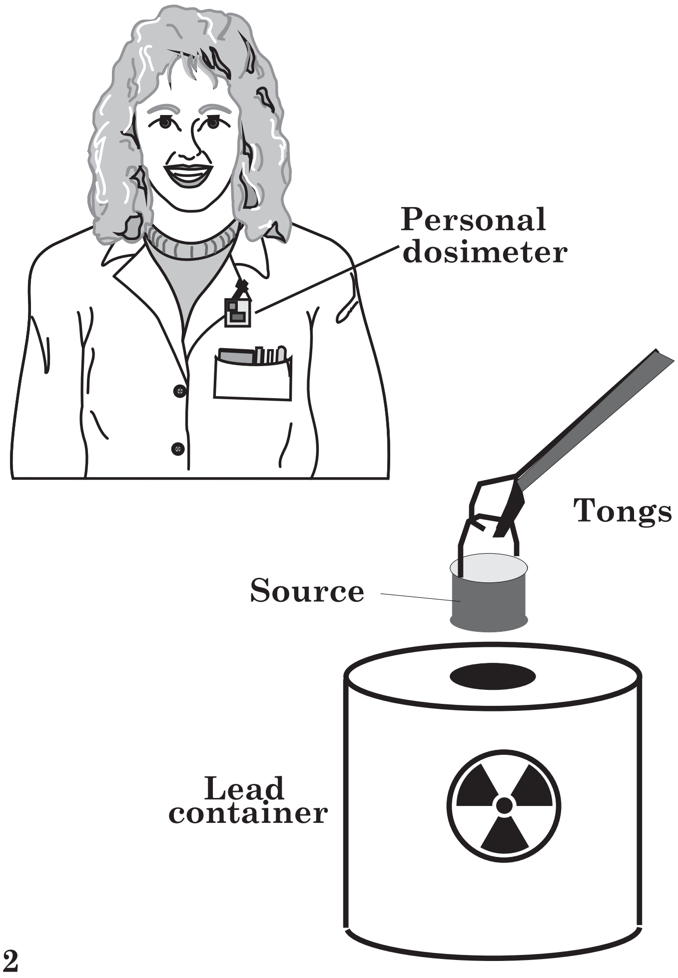


Ionising radiation damages living cells and causes cancers.
When ionising radiation passes into the body, energy is absorbed by the body tissues.
The damage created depends on the amount of energy absorbed and the type of radiation involved. Alpha particles are heavily ionising and cause more damage.
All the factors are included in the DOSE EQUIVALENT which is measured in SIEVERTS(Sv)

For the public, the maximum allowable dose equivalent is 5mSv per year.
For a nuclear worker, this is increased to 50mSv per year.
Any worker exceeding this would be retired from nuclear work until his average fell to the acceptable limit.

Handling Radioactive Sources.

All radioactive sources are kept in sealed containers which are thick enough to prevent the particles escaping. They are only removed when they are needed.
Sources are not handled. They are moved using long tongs so that the handler is exposed to only minimal amounts of radiation. Strong sources are handled by machines.
All workers handling radioactive sources carry dosimeters which record the amount of radioactivity the worker is exposed to. These are checked regularly. All radioactive leaks are reported and investigated by the government inspectorate.

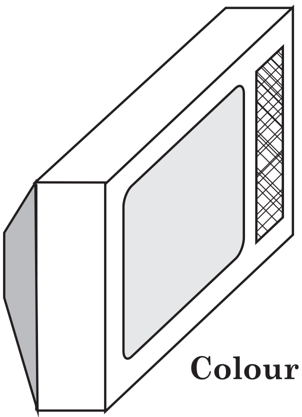


Using Electricity

Summary Notes

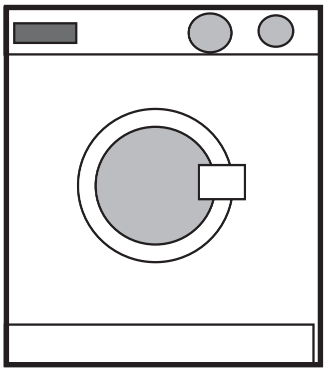
Section	Content
1. From the Wall Socket	Household appliances. Earth wire and safety.
2. Alternating and Direct Current	Battery and transformer. Circuit diagrams. Current and voltage.
3. Resistance	Resistance. Variable resistors and their uses. Electrical power. Lamps and heaters.
4. Useful Circuits	Series and parallel. Fault finding.
5. Behind the Wall	The mains supply. Domestic electricity meter.
6. Movement from Electricity	Electric motor.

Section 1: FROM THE WALL SOCKET



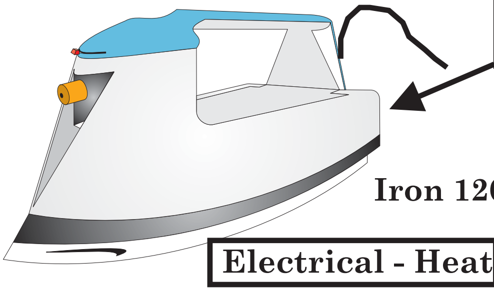
Colour TV 700 Watts

Electrical - Light + Sound



Washing machine 3000 Watts

Electrical - Heat + Kinetic



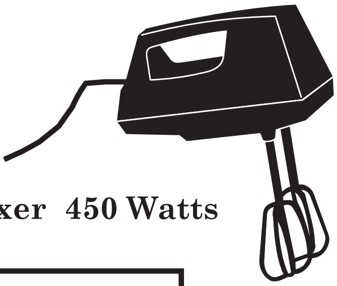
230V 50Hz

1200W

Energy label

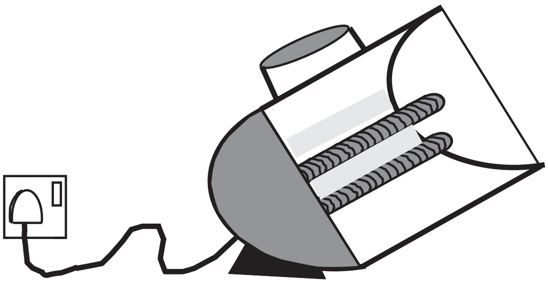
Iron 1200 Watts

Electrical - Heat



Mixer 450 Watts

Electrical - Kinetic

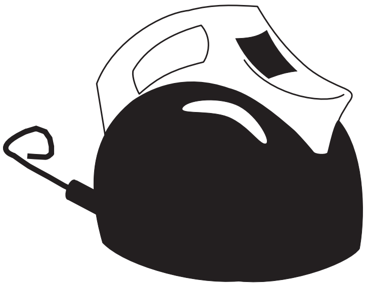


Heater 3000 Watts

Electrical - Heat

Lamp 60 Watts

Electrical - light



Electric Kettle 2500 Watts

Electrical - Heat

Section 1: FROM WALL TO SOCKET

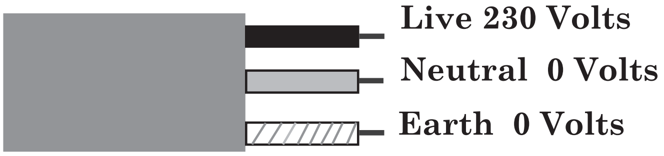
Electricity is so useful because it can easily be converted into other forms of energy.

Electricity is potentially dangerous for two reasons. Firstly, it can cause electric shock. Secondly, because electric current generates heat when flowing in cable, it can cause fires.

Portable appliances are plugged into wall sockets using 3-pin plugs. The plug contains a fuse. The fuse is a device which limits the current which can flow through it. A fuse rated at 3 amps will melt and break the circuit if more than 3 amps flows through it. The fuse is there to protect the flex to the appliance.

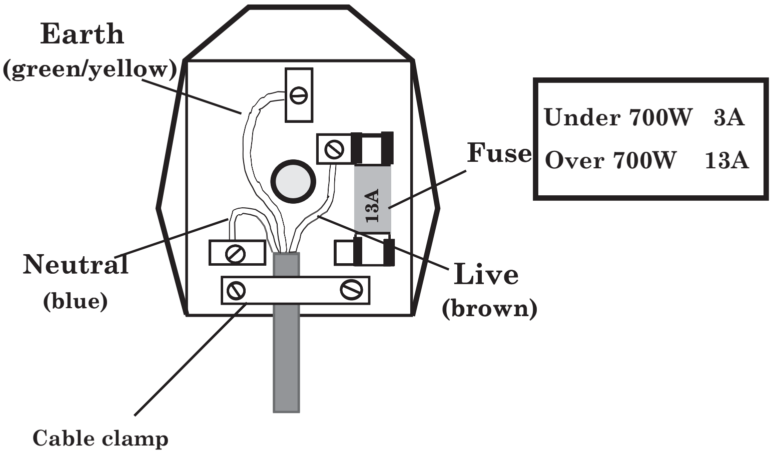
The flex to the appliance must be chosen to suit the current which will be flowing through it. The higher the current the thicker the cable.

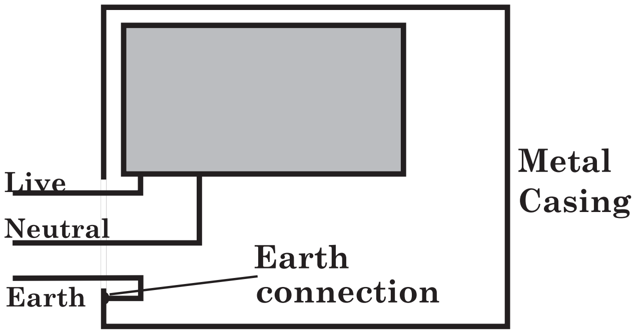
The Earth Wire



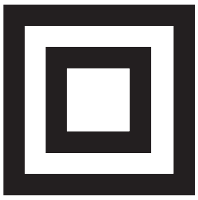
The Earth wire is connected directly to the metal casing on certain appliances. The other end of the Earth wire is connected to the house via the cold water pipes.

In the event of the live wire coming into contact with the metal casing, current will flow directly to Earth and melt the fuse. Even if someone is touching the casing at the time, there will be no electric shock as the voltage on the casing will always be low.





NOTE !!!
All the fuses and switches are in the LIVE side of the circuit. This ensures that, when the current is either switched off, or a fuse has blown, the appliance is safe to touch. The neutral carries a safe low potential (voltage).

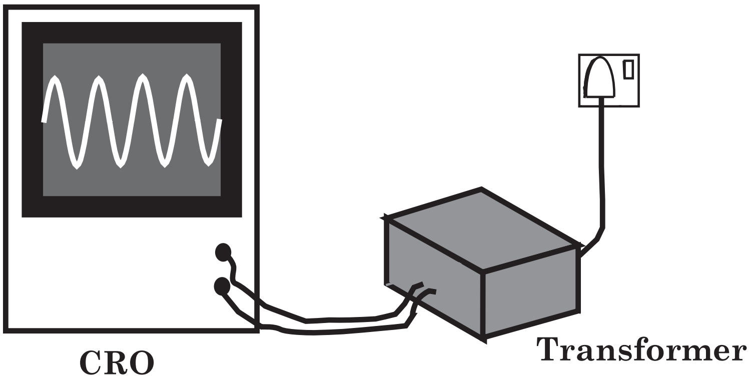


Double Insulation Symbol

Does not need Earth connection as it has a plastic casing

Section 2: ALTERNATING AND DIRECT CURRENT

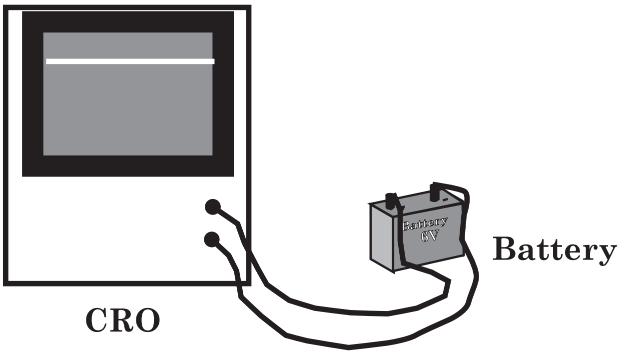
AC CURRENT



Alternating Current - AC

Alternating Current is produced by a rotating generator. It flows first one way then the other.
Alternating Current produces a sine wave trace on the CRO.
Mains supply is AC.

DC CURRENT

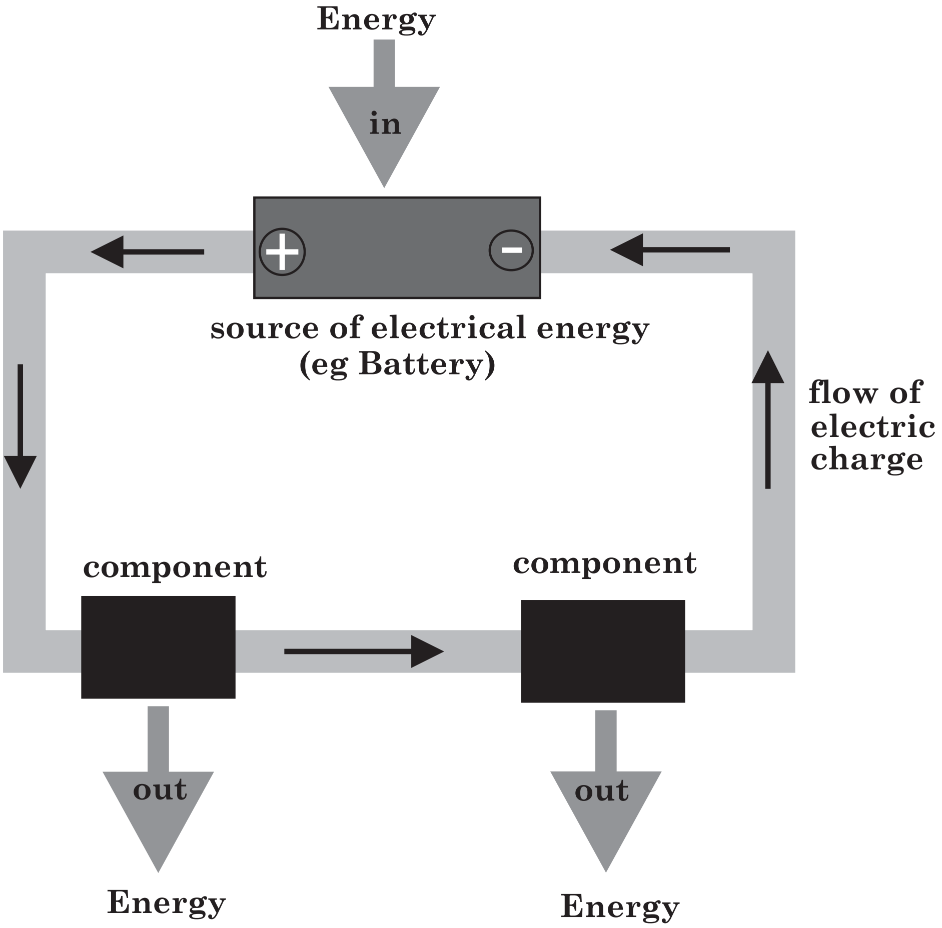


Direct Current - DC

Direct Current is produced by batteries and rectified power supplies.
Direct Current flows in the same direction and produces a straight line on the CRO.

MAINS SUPPLY is 230 Volts 50Hz

Mains electricity is supplied at a voltage of 230 volts and a frequency of 50 hertz.
This value is less than its peak value of around 330 volts.
230 volts can be regarded as the equivalent DC value.



The Electric Circuit

An electric circuit consists of wires and components. A source of electrical energy (battery or mains) within the circuit supplies energy to pump electric charge round the circuit. The supply of energy gained in the source is used up going round the circuit; mostly in the components.

The Conservation of Energy applies in that the energy lost by the charge moving round the circuit is equal to the energy supplied to the charge by the source.

Conductors and Insulators.

Electric cable is usually made from copper. Copper is a good electrical conductor. Conducting materials like Copper contain electrons; tiny particles with a negative charge. In conductors, electrons are moved easily with only tiny amounts of energy being used. In insulating materials like plastics, electrons need large amounts of energy to move.

Conductors are used to make wires and components. Insulators are used to stop the movement of electricity.

Section 2: ALTERNATING AND DIRECT CURRENT

CURRENT

Current is the rate of flow of electric charge in a circuit,

Electric charge (Q) is measured in coulombs (C), so current (I) should be measured in coulombs per second (C/s). However, current is important enough to be given its own special unit, the ampere (A), or amp for short, where:

1 amp = 1 coulomb per second

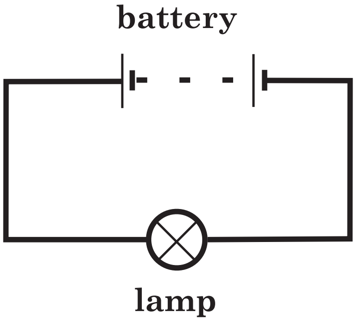
Current is related to the charge flowing round a circuit:

$$\text{Current} = \frac{\text{Charge}}{\text{time}}$$

$$\boxed{I = \frac{Q}{t}}$$

Example.

The current flowing through a lamp is 0.6 amps. If the lamp is turned on for 2 minutes, how much charge has flowed through it?



$$I = \frac{Q}{t}$$

$$Q = I.t$$

$$= 0.6 \times 120$$

$$= 72$$

Charge = 72 C

I = 0.6 amps

t = 2 minutes

= 120 seconds

Q = ?

Section 2: ALTERNATING AND DIRECT CURRENT

Voltage.

When charge moves between two points in a circuit, it loses energy. This loss of energy is measured as the voltage between those two points.

Voltage(V) is measured in volts(V), where the voltage between two points is 1 volt if 1 joule of energy is lost in moving 1 coulomb of charge between these points.

The voltage across a source is a measure of the energy given to charge as it moves through the source.

Voltage, Current and Power.

A current of I amps flows between two points in a circuit. The current flows for t seconds and the voltage between the points is V Volts.

The charge Q which flowed between the points $Q = I.t$ Coulombs

The energy lost $E = Q.V$

$= I.t.V$

Rewriting $\frac{E}{t} = V.I$

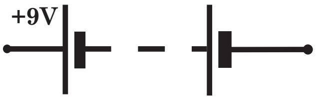
$$Power\ P = \frac{E}{t} = V.I$$

The rate at which energy is lost between two points in a circuit, the dissipated power, is given by the relationship;

Power = Voltage x Current

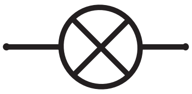
NOTE This proof is not required for Standard Grade

CIRCUIT SYMBOLS



Battery

Fuse

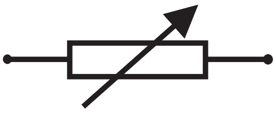


Lamp

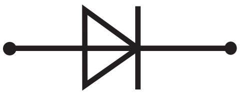
Switch

Resistor

Capacitor



Variable Resistor

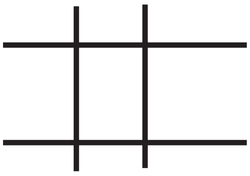


Diode

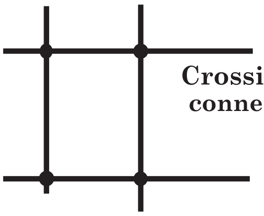
Ammeter

Voltmeter

Ohmmeter



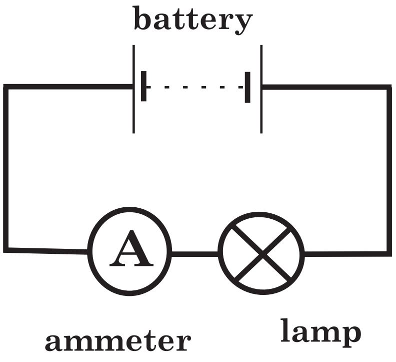
Crossing wires
not connected



Crossing wires
connected

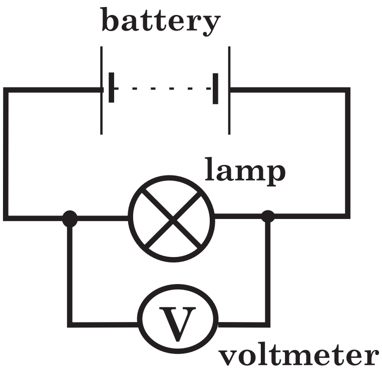
Section 3: RESISTANCE

Measuring Current.



Current is measured using an ammeter. An ammeter measures the current flowing through it. In order to measure the current flowing through a component, the ammeter is connected in series with the component. Ammeters have low resistance so they do not change the current in any circuit they are placed.

Measuring Voltage



Voltage is measured using a voltmeter. A voltmeter measures the difference in the energy carried by current between two points in a circuit. Voltmeters are connected across the circuit (in parallel) between the two points it is measuring the voltage across.
Voltmeters have very high resistance so they have no effect on the currents in circuits

RESISTANCE

The resistance of a circuit or a component is the opposition it provides to the flow of current.
The higher the resistance, the lower the current, for a given source.
Resistance is given by the relationship;

$$\boxed{\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}}$$

In symbol form $\boxed{R = \frac{V}{I}}$

Where

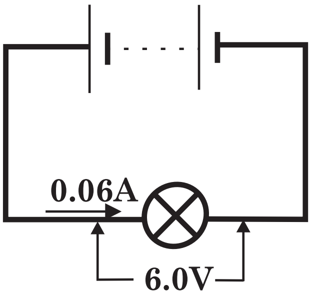
V is the voltage in volts (V)
I is the current in amps (I)
R is the resistance in ohms (W)

The relationship can also be written

$$\boxed{\begin{array}{l} V = IR \\ I = \frac{V}{R} \end{array}}$$

Section 3: RESISTANCE

Example: Find the resistance of a lamp if a current of 0.06 amps flows through it when the voltage across it is 6.0 volts.



$$R = \frac{V}{I}$$

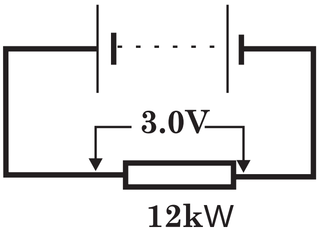
V = 6.0 volts
I = 0.06 amps

$$= \frac{6.0}{0.06}$$

$$= 100\text{W}$$

Resistance of lamp = 100 ohms

Example: A resistor has a resistance of 12 kilohms. What current will flow through it if a voltage of 3.0 volts is placed across it?



$$R = \frac{V}{I}$$

V = 3.0 volts
12 k
= 12000 W

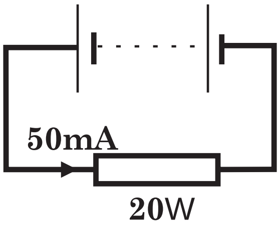
$$12000 = \frac{3.0}{I}$$

$$I = \frac{3.0}{12000}$$

$$= 0.00025 \text{ amps}$$

Current in resistor = 0.25mA

Example: Find the voltage across a 20 ohm resistor when 50 mA current flows through it.



$$R = \frac{V}{I}$$

I = 50 mA
= 0.05 A
R = 20 W

$$20 = \frac{V}{0.05}$$

$$V = 20 \times 0.05$$

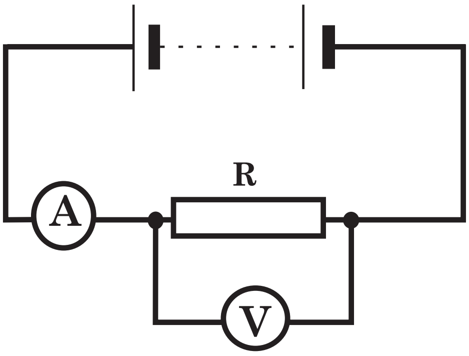
$$= 1.0 \text{ volts}$$

Voltage across resistor = 1.0 volts

Section 3: RESISTANCE

Measurement of resistance

Voltmeter/Ammeter method

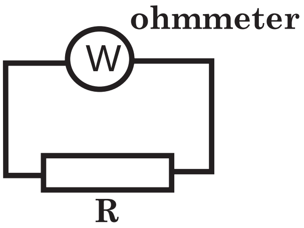


The resistance of a resistor can be measured by using an ammeter to measure the current through it and a voltmeter to measure the voltage across it. The resistance is found by using

$$R = \frac{V}{I}$$

Several measurements are made and an average result worked out.

The Ohmmeter

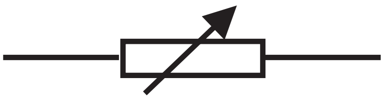


We can measure resistance directly using an ohmeter. This instrument carries its own power supply so, when it is used, the circuit power must be turned off.
Most multimeters contain an ohmmeter.

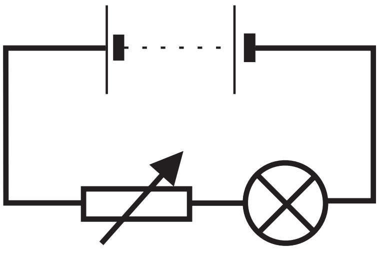
Resistors.

Resistors are components with a known resistance. They are designed to add measured amounts of resistance to circuits to control current and voltage.
The resistance of a resistor will remain reasonably constant for different currents as long as the resistor does not overheat.
A variable resistor is a resistor with an adjustable resistance. These are used in control circuits where current adjustment is required.
We can use variable resistors to adjust the brightness of a small lamp or the speed of a small motor.

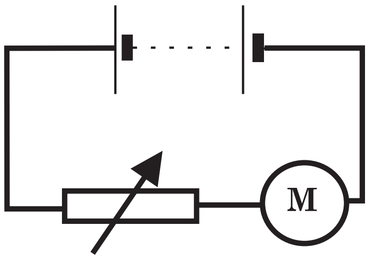
resistor



variable resistor



lamp

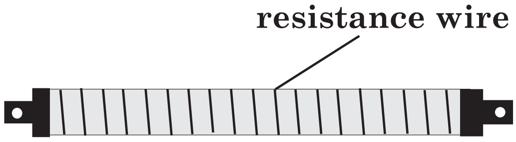


electric motor

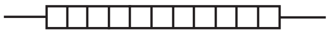
Section 3: RESISTANCE

The Electric Heater

When electric current flows through a wire, some of the electrical energy carried by the current is converted to heat energy.
This effect is used in cookers, toasters, water immersion heaters and electric fires.
Special high resistance wire is used to make heating elements. This is usually wound round insulators which can withstand the high temperatures.



heating element



circuit symbol

Electrical Power.

The quantity of electrical energy converted into heat energy each second, is given by;

$$\text{Energy/second} = \text{Voltage} \times \text{Current}$$

The rate of conversion, or transfer of energy is the definition of power. So the electrical power used by a circuit or a component is given by;

$$\text{Power} = \text{Voltage} \times \text{Current}$$

$$P = VI$$

Power is measured in watts (W). The amount of electrical power used by an appliance is called its wattage, or power rating.

V 230V 50Hz
2000W
ser no 234/577

$$P = VI$$

$$R = \frac{V}{I} \quad \text{so} \quad V = IR \quad \text{and} \quad I = \frac{V}{I}$$

Substituting for V and I

$$P = VI$$

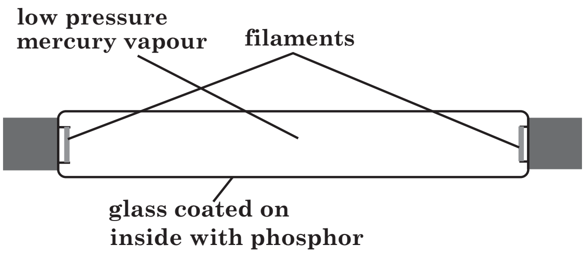
$$P = I^2R$$

$$P = \frac{V^2}{R}$$

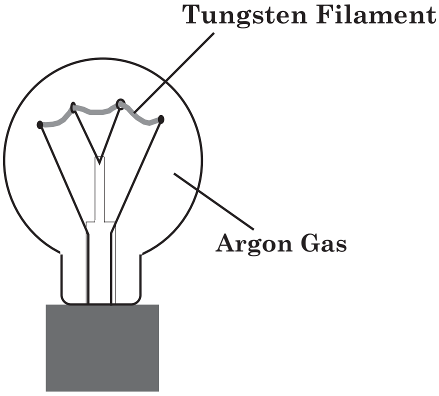
Equivalent expressions

Section 3: RESISTANCE

Lamps



fluorescent lamp



filament lamp

A filament lamp bulb contains a fine tungsten filament. The bulb is filled with argon gas which prevents the tungsten oxidising when it is hot. When a current is passed through the filament, electrical energy is converted to heat energy and the filament glows white hot.

A fluorescent lamp contains mercury vapour at low pressure. The small filaments at either end heat up and produce electrons which are passed through the vapour. When an electron collides with a mercury atom, UV light is emitted. The UV strikes the phosphor coating on the glass and it glows white. The lamps are safe because UV does not pass through the glass.

Most of the electrical energy used by a fluorescent lamp is emitted as light. Only a small amount of heat energy is produced.

Most of the electrical energy used by a filament lamp is converted to heat energy; only about 10% is converted to visible light.

Filament lamps can be replaced by fluorescent lamps with a much lower power rating. Fuorescent lamps last much longer than filament lamps so, even though they cost much more, they save energy and money in the long run.

Section 4: USEFUL CIRCUITS

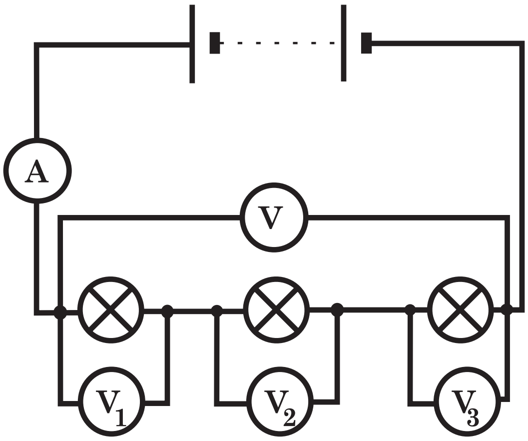
Series and Parallel

Connected in Series

Components connected in series are connected into a circuit one after the other.
The same current flows through all components connected in series.
The components share the voltage across all of them.

I is the same for all

$$V = V_1 + V_2 + V_3$$

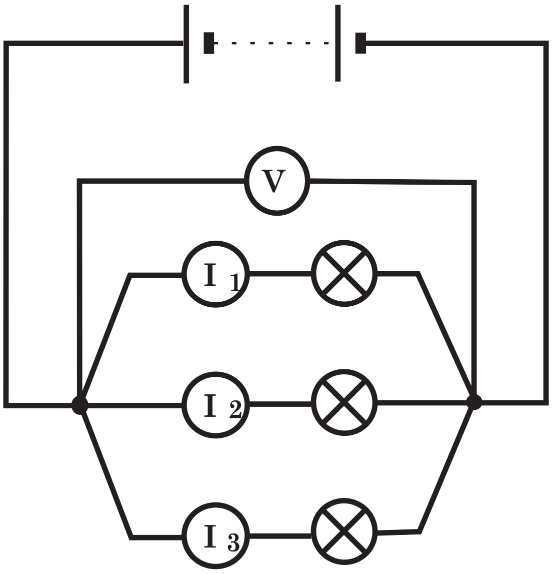


SERIES

Connected in Parallel

Components connected in parallel are connected between the same two points in a circuit.
The voltage across them is the same for all of them.
They share the total current flowing into the parallel arrangement

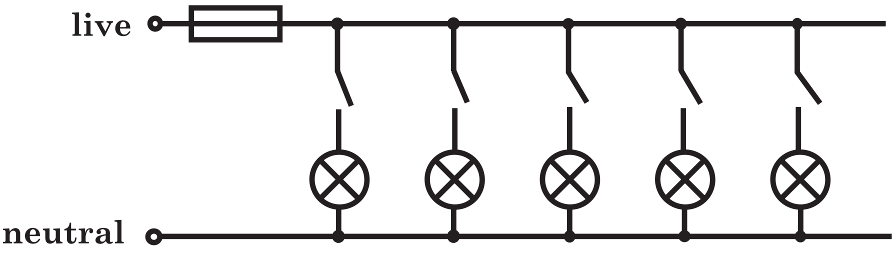
V is the same for all



PARALLEL

Section 4: USEFUL CIRCUITS

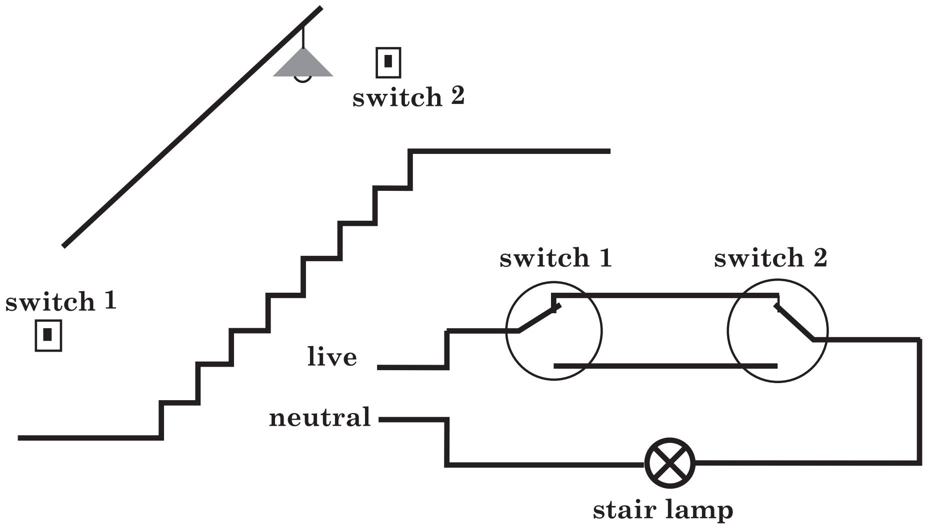
Lighting Circuits



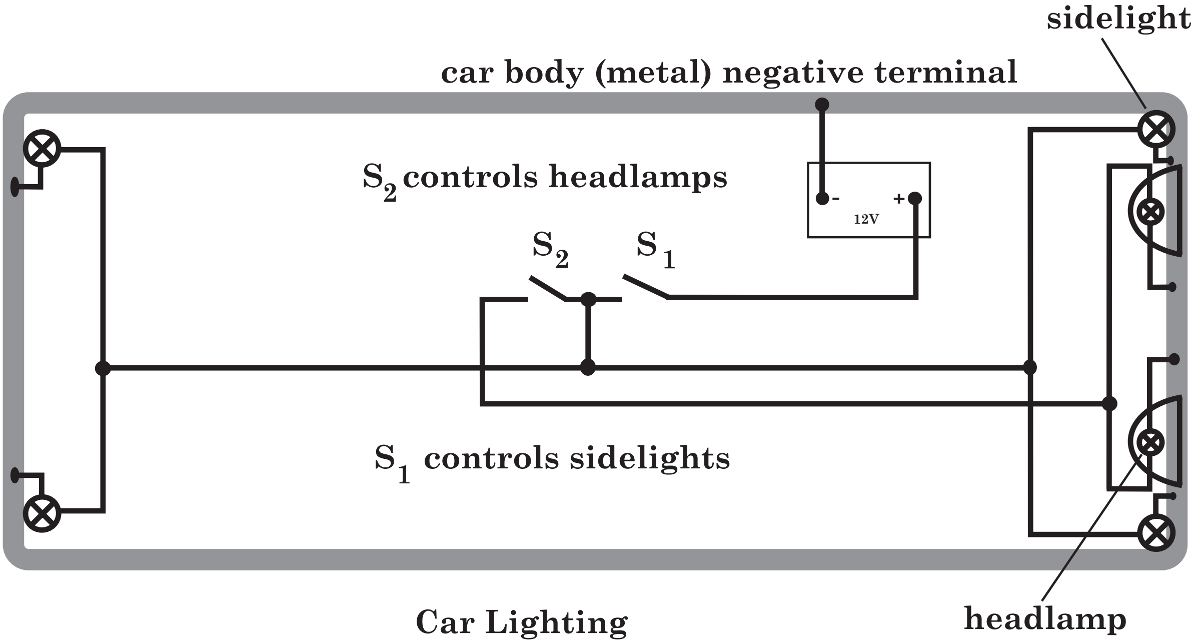
Lighting Circuit

Lighting Circuits

The ceiling lights in houses are usually connected in parallel across the mains. This allows each light to be individually switched on and off, and, if one lamp fails, the others stay working.



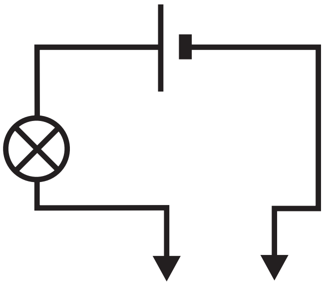
Lighting can be controlled from two switches. These are quite common on stairs and in corridors. This is an example of a situation where two switches are connected in series. The switches are special changeover switches.



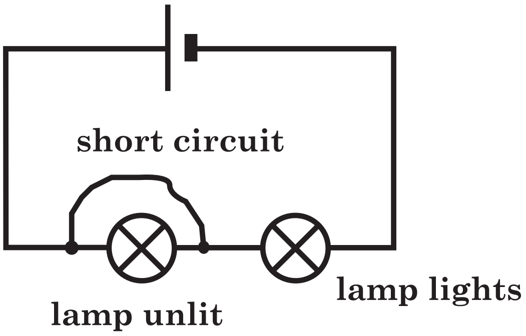
Car Lighting

Secion 4: USEFUL CIRCUITS

Fault Finding

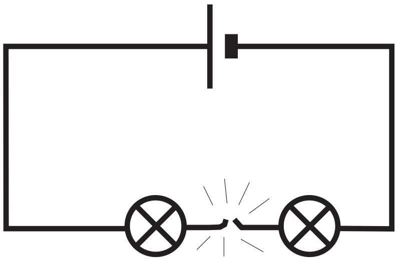


Continuity testers are devices which are used to check if two points in a circuit are connected together.
In its simplest form, it consists of a circuit containing a battery and lamp. The lamp indicates whether the two points being tested are connected. It can be used to check fuses.
The ohmeter is a more sophisticated circuit tester and can be used in situations where the lamp would not light.
In both cases, circuits are tested with the power to the circuit turned off.



Short Circuit
A short circuit is created when a low resistance path is formed across the terminals of a component. The current flows round the component rather than through it.
When an ohmeter is placed across the terminals the resistance reading will be unusually low.
There will still be circuit continuity however.

Broken Circuit
A broken circuit is a break in the conductive path round the circuit. Current cannot flow across a break in a circuit.
When tested with an ohmeter, the resistance will be extremely high. There will be no continuity.



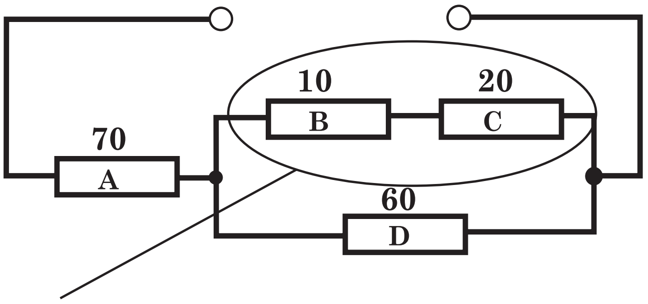
both lamps unlit

Section 4: USEFUL CIRCUITS

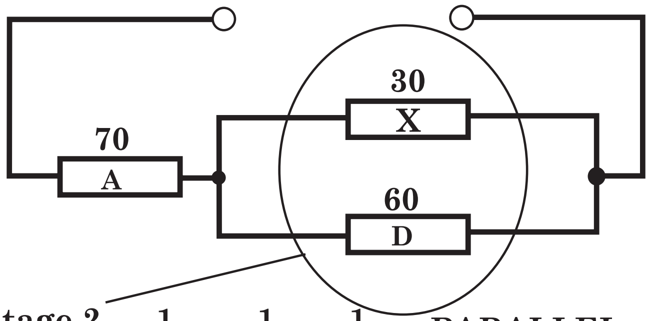
Combining Resistance

Circuits can be made up from many combinations of components, each with its own resistance. How do we find the total resistance of a number of components? Components are either connected in series, or in parallel or a combination of both.

Example. Find the combined resistance of the arrangement shown below.



Stage 1 B + C 10 + 20 = 30 = X



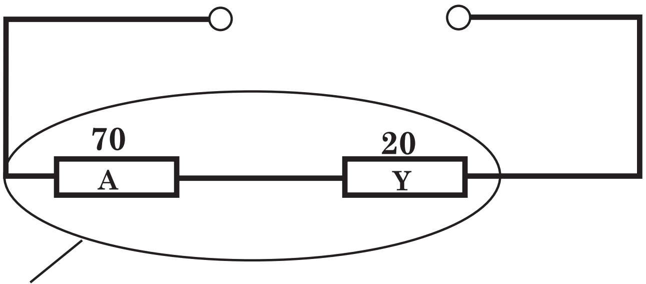
Stage 2

$$\frac{1}{X} + \frac{1}{D} = \frac{1}{Y} \qquad \text{PARALLEL}$$

$$\frac{1}{30} + \frac{1}{60} = \frac{1}{Y}$$

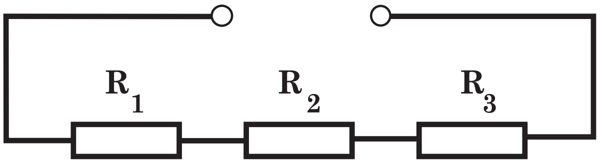
$$\frac{3}{60} = \frac{1}{Y}$$

$$Y = 20$$



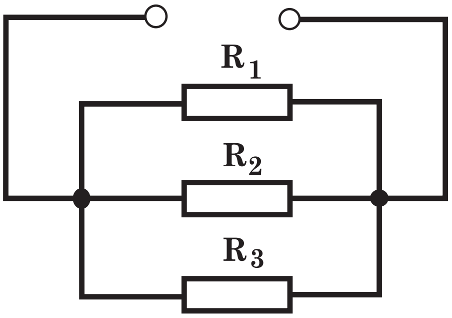
Stage 3 A + Y 70 + 20 = 90

<u>Total combined resistance = 90</u>



$$R_T = R_1 + R_2 + R_3$$

SERIES

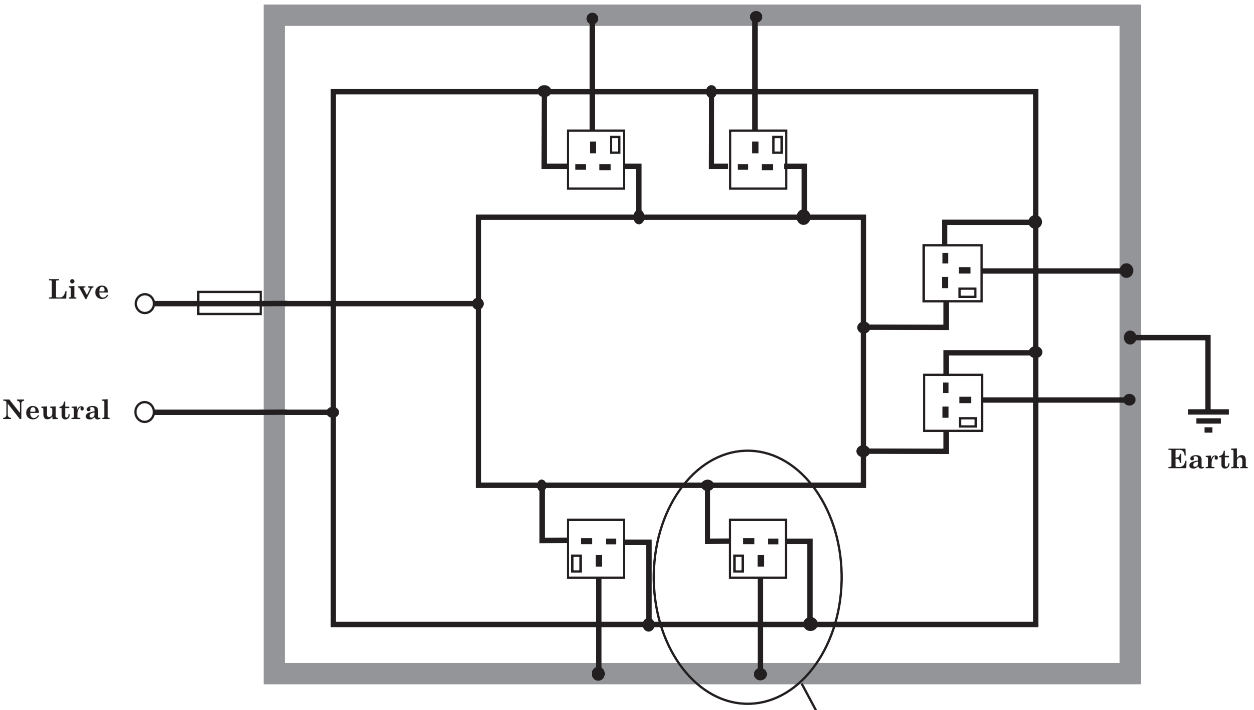


$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

PARALLEL

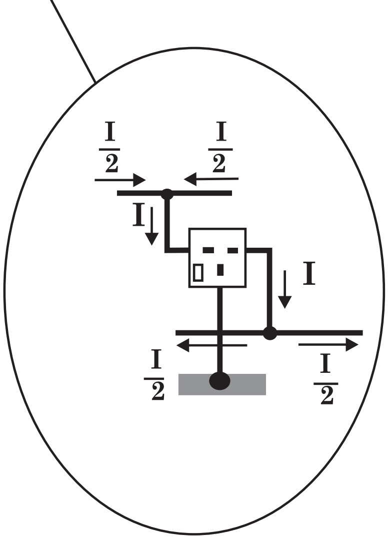
Section 5: BEHIND THE WALL

The Ring Circuit



RING MAINS

3-pin mains sockets are wired up in special ring mains circuits. This provides two paths for current to reach the socket and doubles the current carrying capacity of the cables used in the circuit.
When wired up with 20 amp cable, a ring circuit has the capacity to carry 40 amps. Electricians can use thinner and easier fitted cable to wire up a ring mains.
Ring mains carry an Earth connection. The Earth circuit is part of the house; usually connected to a copper water pipe.



Lighting circuits are parallel circuits with no Earth. Lighting circuits carry less current than a ring mains (5A) and so are wired up with thinner cable. Appliances like cookers and water heaters, which use high currents, usually have their own individual circuit with a separate fuse.

Section 5: BEHIND THE WALL

Fuses and Circuit Breakers

The mains wiring in a house is protected by the fuses or circuit breakers in the mains fuse box (the consumer unit). Circuit breakers perform the same job as a fuse. They switch off the current when it exceeds the circuit breaker's rated value. They are more expensive than fuses but can be reset and do not need to be replaced once they have tripped.

All fuses, circuit breakers and switches are fitted to the live side of the mains wiring so that appliances can be safely turned off (isolated).

The kilowatt hour

Domestic electricity is paid for according to how much electrical energy has been used.

The unit used is the kilowatt hour (kWh). This is the energy consumed when a heater, rated at 1 kilowatt is run for 1 hour.

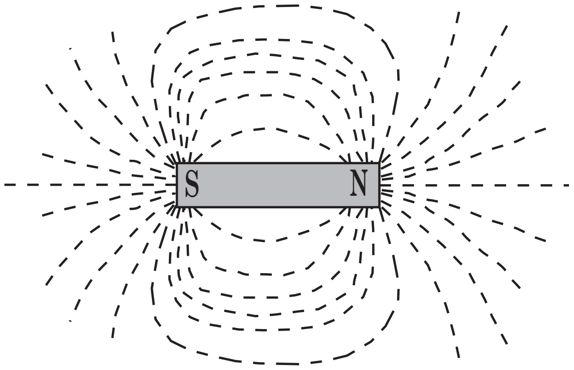
1 kWh = 3,600,000 joules

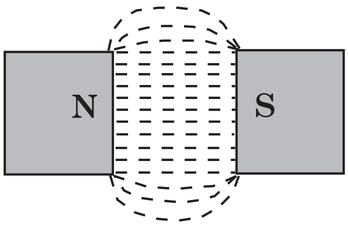
Example. How much does it cost to run a TV (700W) for 1 week if it is turned on for 6 hours per day? Electrical energy costs 7p per unit.

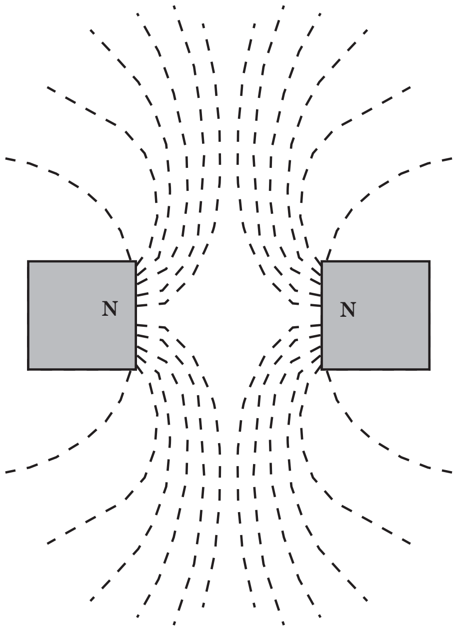
$$\begin{aligned}\text{Number of units} &= \text{Power rating (kW)} \times \text{time (hours)}\\ &= 0.7 \times 6 \times 7\\ &= 29.4\ \text{kWh}\\ \text{Cost} &= 29.4 \times 7\\ &= 205.8\text{p}\end{aligned}$$

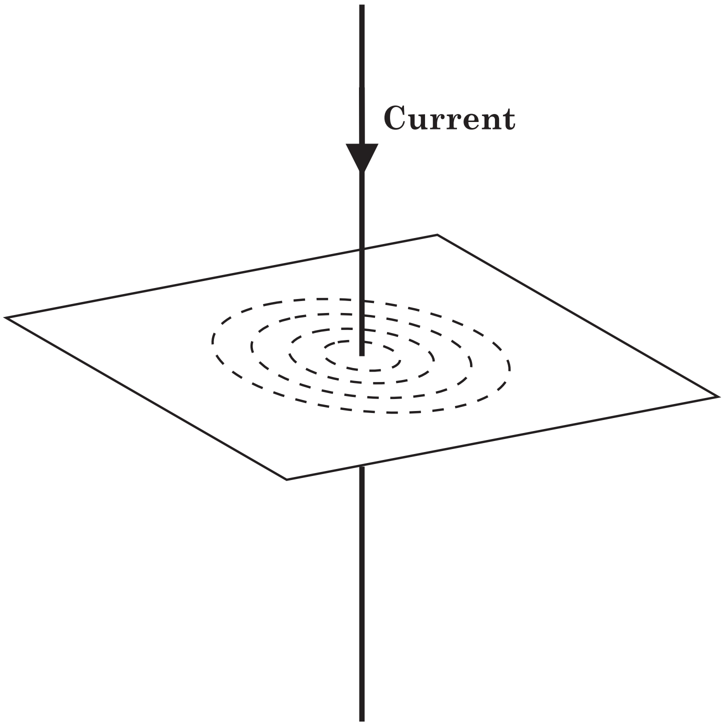
<u>Cost is £2.06</u>

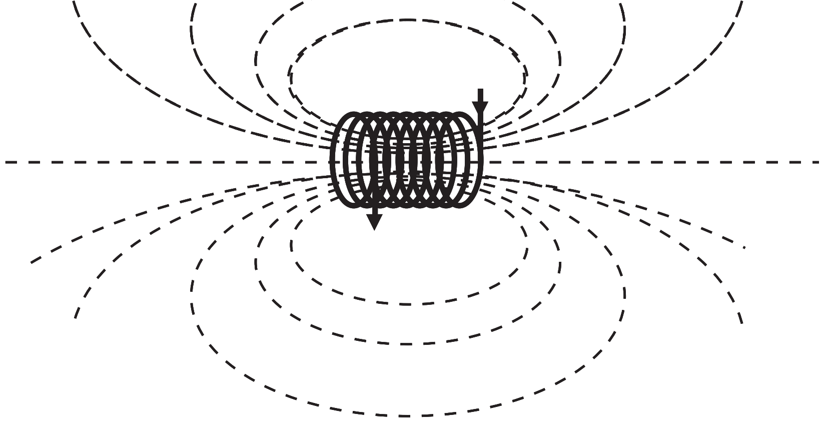
Section 6: MOVEMENT FROM ELECTRICITY











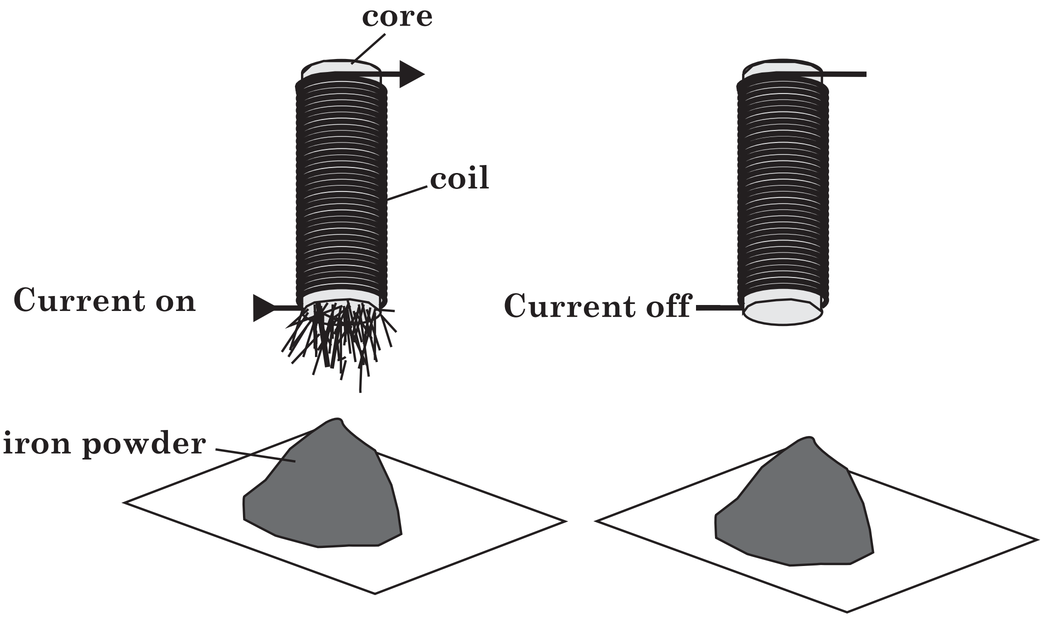
The diagrams on this page show the magnetic field patterns revealed when iron powder is sprinkled around magnets and current carrying wire.

Section 4: MOVEMENT FROM ELECTRICITY

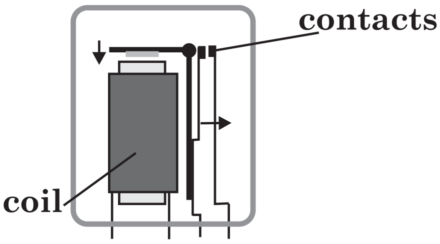
Magnetic Fields.

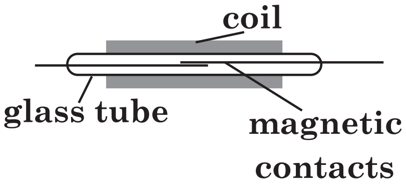
A magnetic field is the volume of space around a magnet where another magnet or magnetic material experiences a force.
We can show the patterns of a magnetic field by sprinkling iron powder round a magnet. The same effects can be discovered if we sprinkle iron powder round current carrying wire.
When current flows along a wire, a magnetic field is generated around it. If we wrap the wire into a coil, we can create a magnet. If we wrap the coil round a soft iron core, we create a stronger magnet. This arrangement is called an electromagnet.

Electromagnets are magnets which can be turned on and off.
They can be made more powerful than normal magnets



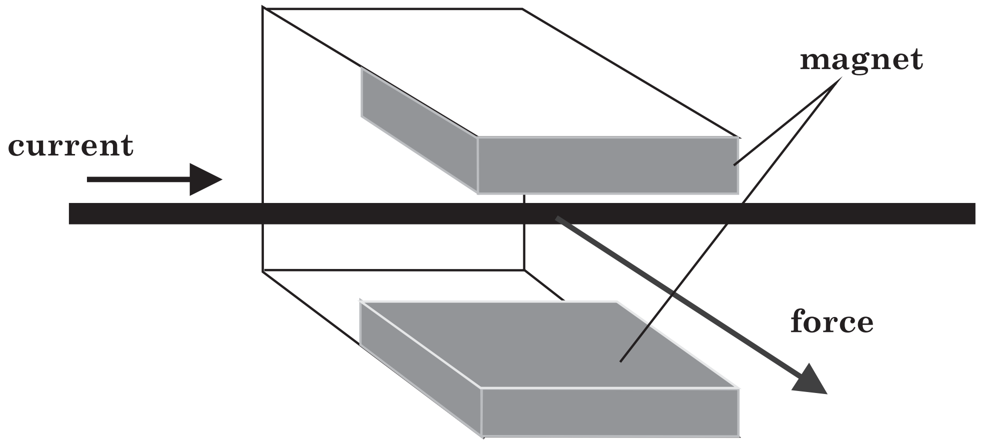
Electromagnets are used in relays, which are magnetically operated switches. The small current used to operate a relay can control very large currents.



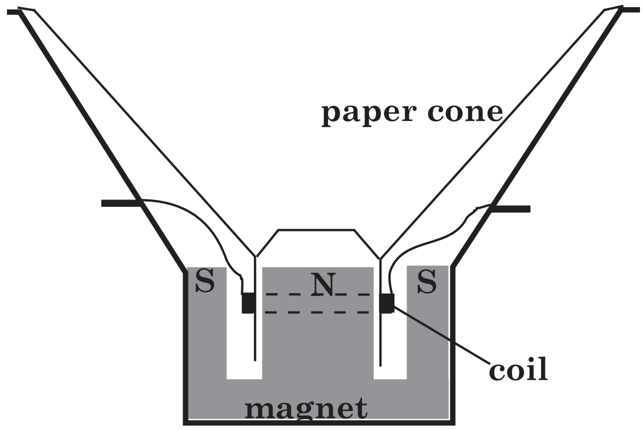


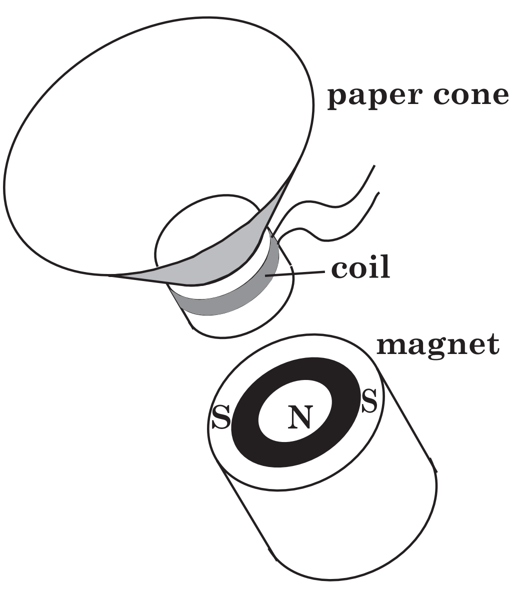
Reed Relay
When current flows through coil, contacts are magnetised and stick together.

Section 4: MOVEMENT FROM ELECTRICITY



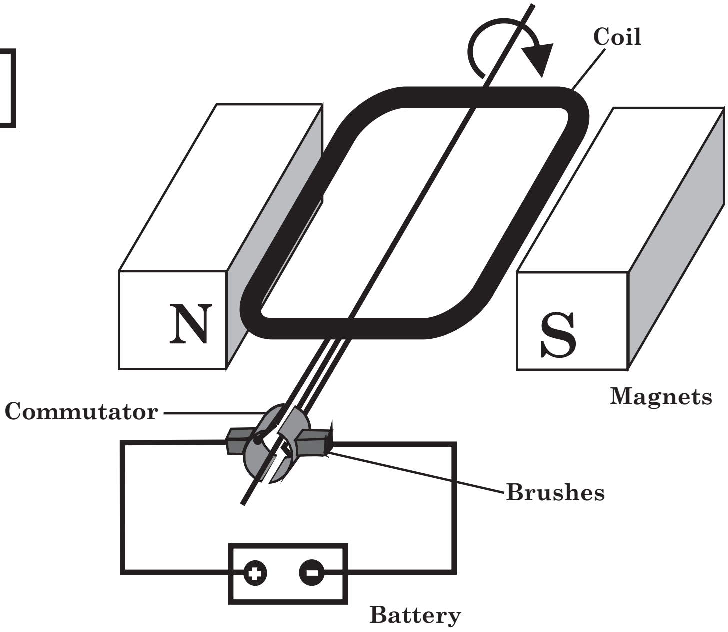
A wire, carrying a current, generates a magnetic field around it. When this wire is placed in a magnetic field it experiences a force.
This is put to use in electric motors and loudspeakers.





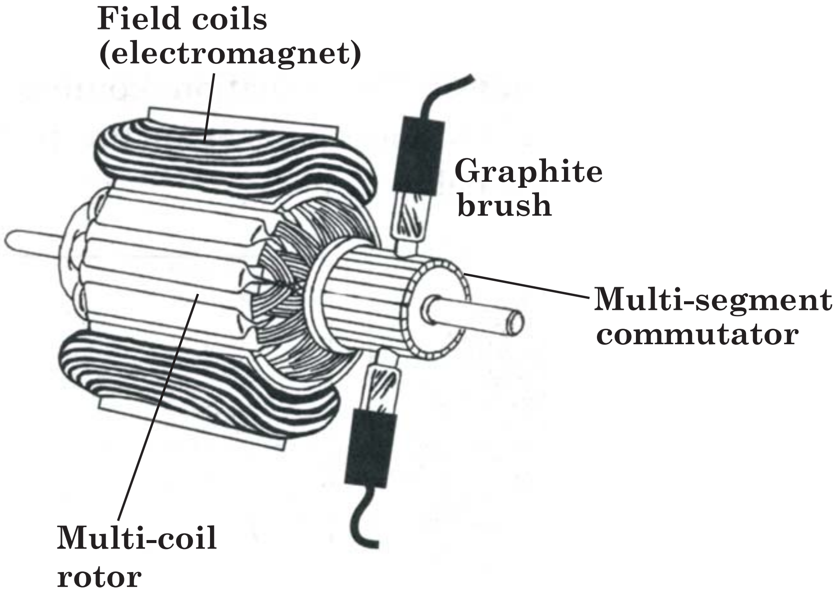
Loudspeaker.
A loudspeaker converts electrical energy into sound energy. The electrical signal is fed to a coil enclosed in a magnetic field. The coil is forced up and down causing the attached paper cone to vibrate and emit sound waves.

The Electric Motor



Simple Electric Motor

A simple electric motor consists of a single coil of wire rotating in the field between two permanent magnets. The split-ring commutator changes the direction of the current as the coil passes the vertical. This keeps the coil rotating, otherwise it would stop when it reached the vertical position.



Commercial DC motor

The simple motor cannot maintain a constant turning force because it has only one coil.
The commercial DC motor has many coils to overcome this problem. The coils are wrapped round a soft iron core. This increases the effectiveness of the coils.
As each coil has two segments on the commutator, the commutator is more complex, with many segments.
The brushes are made of graphite, which has lubricating properties to cut friction.
The magnets are replaced with more powerful electromagnets.

TRANSPORT

Summary Notes

Section	Content
1. Describing Motion	Average and instantaneous speed Acceleration Speed - Time graphs
2. Forces	Recognising and Measuring forces Weight and friction Balanced forces and seat belts Unbalanced force and acceleration
3. Movement and Energy	Energy transformation in vehicles Work done Potential and Kinetic Energy Power Conservation of energy

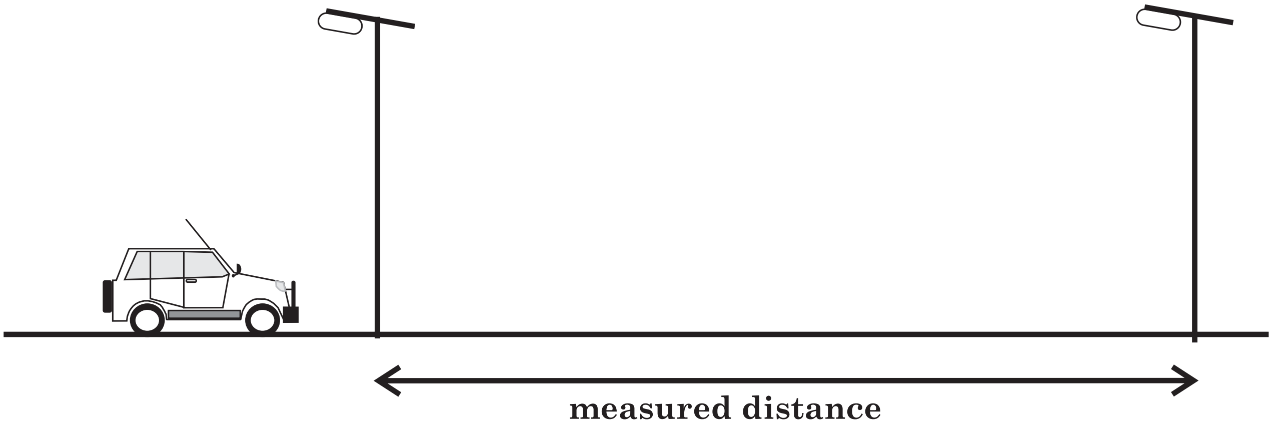
KINEMATICS

Describing Motion: Average Speed

The average speed (v) of a moving object is the distance covered during a journey divided by the time taken.

Average speed is measured in miles per hour (mph), kilometres per hour (kph) or metres per second (m/s)

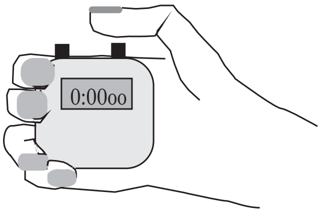
Average speed is measured by timing how long it takes an object to cover a measured distance.



$\bar{v}$ *Bar over a symbol means average value*

$$\text{Average speed} = \frac{\text{measured distance}}{\text{time taken}}$$

$$\bar{v} = \frac{s}{t}$$

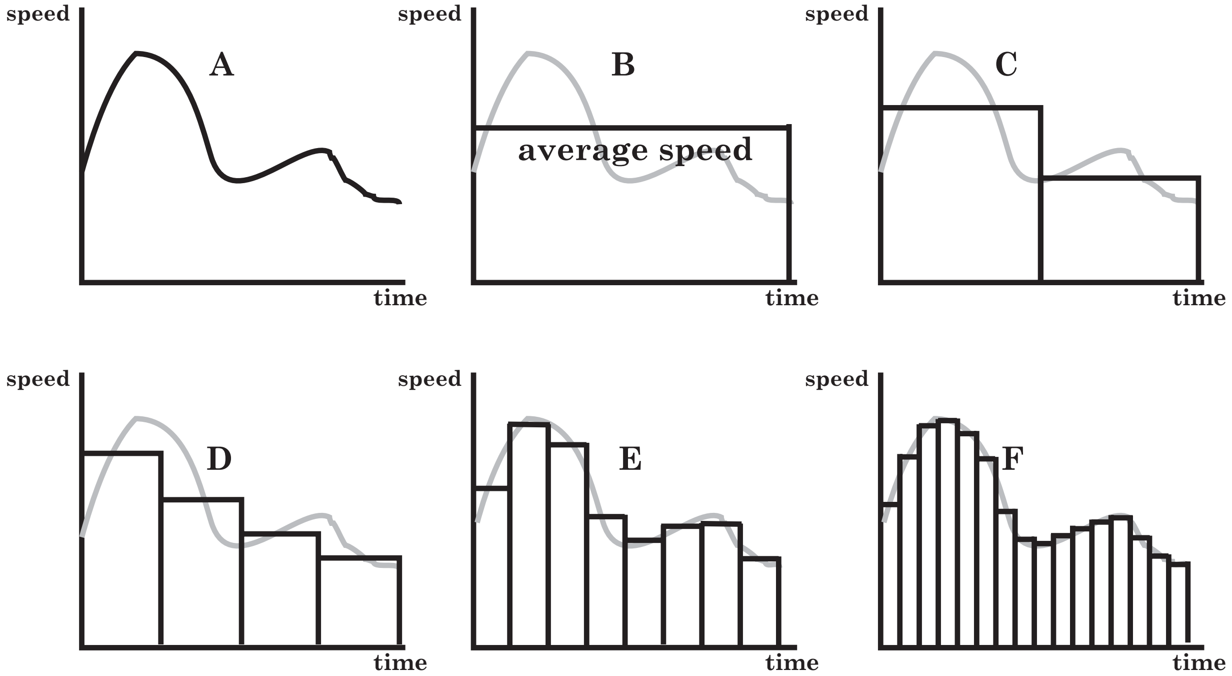


Average speed is a poor description of speed during a journey. We would like to know what speed the object was travelling at any time during its journey.

The speed of an object at any point during a journey is termed the instantaneous speed, or simply the speed, at that point.

The instantaneous speed changes during a journey. The instantaneous speed is only the same as the average speed where it remains constant during the journey.

Describing Motion : Instantaneous Speed



Graph A shows the instantaneous speed during a journey. The horizontal line in graph B shows the average speed over the whole journey.

Graph C shows the average speeds in both halves of the journey. D, E and F shows the average speeds as we break the journey down into smaller and smaller divisions.

We can see that the average speed graph in F is beginning to look like the graph of the instantaneous speed.

If we keep dividing the journey into smaller divisions, the graph of average speed will end up looking the same as that of the instantaneous speed.

We can measure the instantaneous speed of a moving object by measuring the average speed over a small time interval in the journey.
The smaller the time interval, the closer the measurement.

KINEMATICS

Describing Motion : Instantaneous Speed

Measurement of instantaneous speed.

We measure average speed over time intervals.

Hand operated stopclocks cannot be used for measuring small time intervals. We need to use automatic timing.

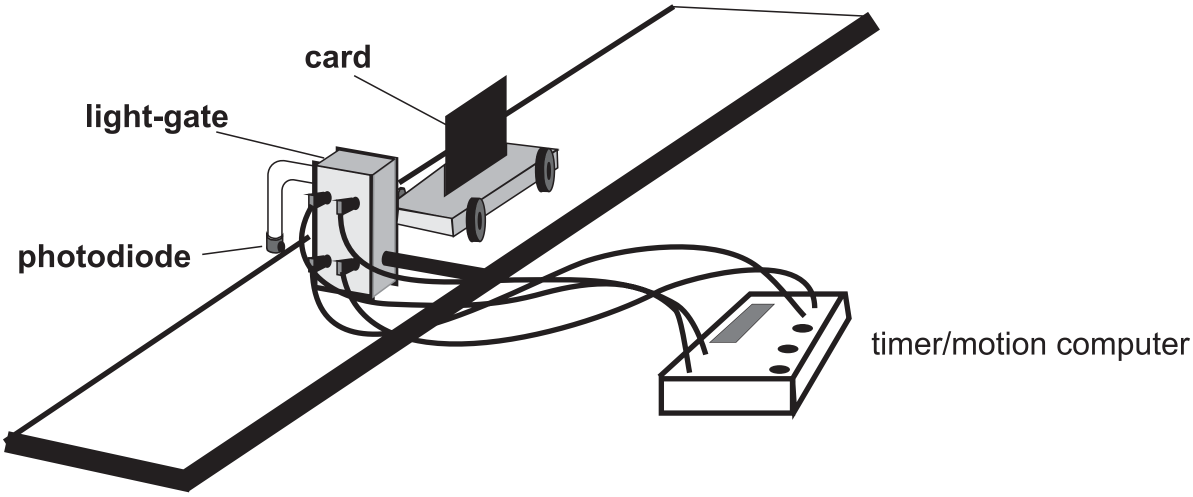
One of the easiest methods is to use a light operated switch (light-gate) to turn a timer on and off.

A beam of light shines on a photodiode. A card attached to the moving object is arranged to cut the light beam. When the card enters the light beam, the photodiode turns the timer on. When the card leaves the beam, the photodiode turns the timer off. The timer records the time taken for the card to pass the light beam

The object has moved the length of the card in the recorded time, so its instantaneous speed is given by:

$$\text{Instantaneous speed} = \frac{\text{length of card}}{\text{time taken to cross light beam}}$$

The arrangement can be connected to a computer which will do the calculation automatically.



KINEMATICS

Describing Motion : Acceleration

The acceleration (a) of an object is the change in instantaneous speed per second.

$$\boxed{\text{acceleration} = \frac{\text{change in speed}}{\text{time taken to change}}}$$

Acceleration is measured in miles per hour per second (mph/s), kilometres per hour per second (kph/s) or metres per second per second (m/s^2)

If we know the final speed 'v' and the initial speed 'u', we can write:

$$\text{acceleration} = \frac{\text{final speed - Initial speed}}{\text{time}}$$

$$\boxed{a = \frac{v - u}{t}}$$

If the object is slowing down, *v* will be less than *u,* and the acceleration will have a negative value.
In this situation we say that the object is decelerating.

Example. A car accelerates from 20mph to 60mph in 5 seconds. Find its acceleration.

$$a = \frac{v - u}{t}$$

$$= \frac{60 - 20}{5}$$

$$= \frac{40}{5}$$

$$= 8\text{mph/s}$$

v = 60mph

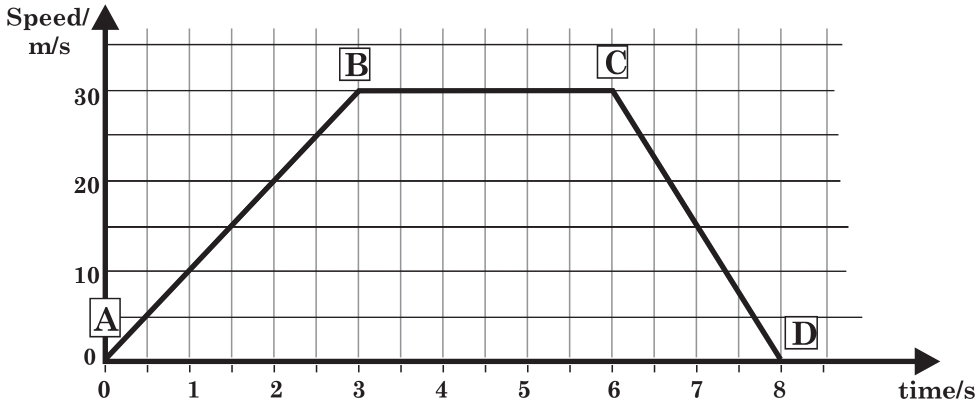
u = 20mph

t = 5 seconds

<u>Acceleration of car = 8mph/s</u>

KINEMATICS

Describing Motion : Speed - Time Graphs



Speed - Time Graphs

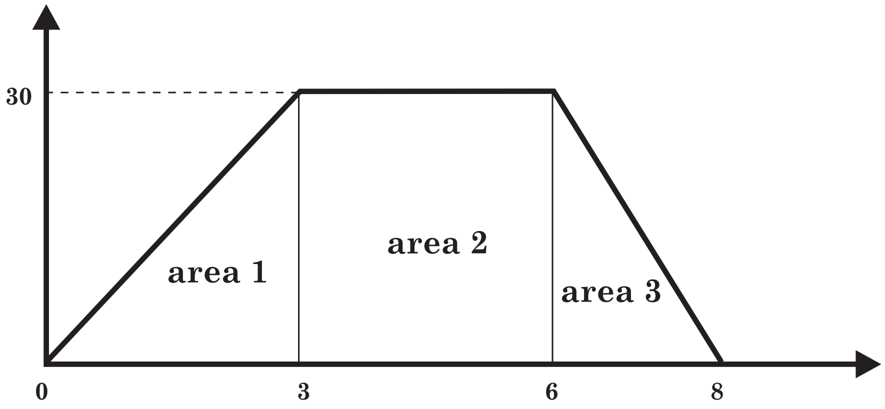
We can describe the movement of any object using a speed - time graph. The graph shows the instantaneous speed at any time during a journey.

From information in the graph, we can work out the instantaneous speed, acceleration and distance travelled.

For the graph above:

Section AB shows *uniform acceleration* from 0 to 30 m/s in 3s
Section BC shows a *constant speed* of 30 m/s for 3s (3 to 6s)
Section CD shows a *uniform deceleration* from 30 m/s to 0 in 2s

The *distance travelled* is calculated from the *area* under the graph.



Distance travelled = area 1 + area 2 + area 3

$= \frac{1}{2} \times 3 \times 30 + 3 \times 30 + \frac{1}{2} \times 2 \times 30$

$= 45 + 90 + 30$

$= 165$ metres

Distance travelled = 165 metres.

Dynamics

Forces : What is a Force?

Forces are created when objects collide or interact with each other. We can only describe or measure forces through their effect on objects.

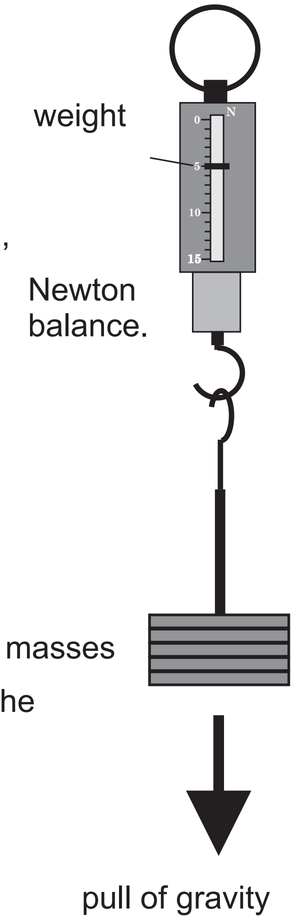
Forces will change the shape of an object: stretching, squashing, bending, twisting. A force will cause a moving object to speed up or slow down. It may also change direction.

Dynamics is the study of the effect of forces on the movement of objects.

Forces : Measurement

Force is measured in newtons (N).
We can measure force using a specially calibrated spring balance, a newton balance.

The newton balance can be used to apply force to an object so that the effect can be measured.



Common Forces

1. Weight

The *weight* of an object is the pull of gravity on the object. Weight is a force measured in newtons and should not be confused with the *mass* of an object which is measured in kilograms.

On the surface of the Earth, the weight of an object is given by:

Weight = 10 x mass

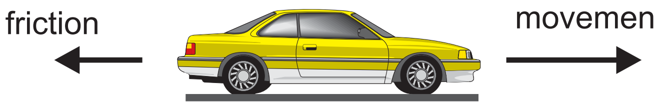
The mass has to be measured in kilograms so an object with a mass of 400 g, will have a weight of 10 x 0.4 = 4 newtons.

The Gravitational Field Strength at a point is the force of gravity on an object with a mass of 1 kg placed at that point.
The gravitational field strength at the surface of the Earth is 10 Newtons per kilogram.

2. Friction

Friction is caused by moving surfaces rubbing together.

Friction affects moving objects. Force has to be used to overcome friction to keep an object moving. The force of friction acts in the opposite direction to the movement of the object.



Friction can be useful. We could not walk without the friction between the soles of our shoes and the floor. Friction in brakes allows cars and cycles to slow down safely.

Overcoming friction uses up costly energy. Engines contain oil to lubricate moving parts. Roller bearings are fitted to rotating shafts so that they turn easily. Skiers wax the bottom of their skis so that they slide easily over snow.

3. Air Resistance.

Every object moving through air is affected by air resistance. Air resistance acts in the same way as friction. Air resistance is also known as ‘drag’ because air is dragged along by the effect.

30 mph

70 mph

Air resistance increases with speed so that a car travelling at 70 mph has much more air resistance than one travelling at 30 mph. Extra force is needed to keep a car moving at 70 mph, so petrol is used at a faster rate.

1920

1990

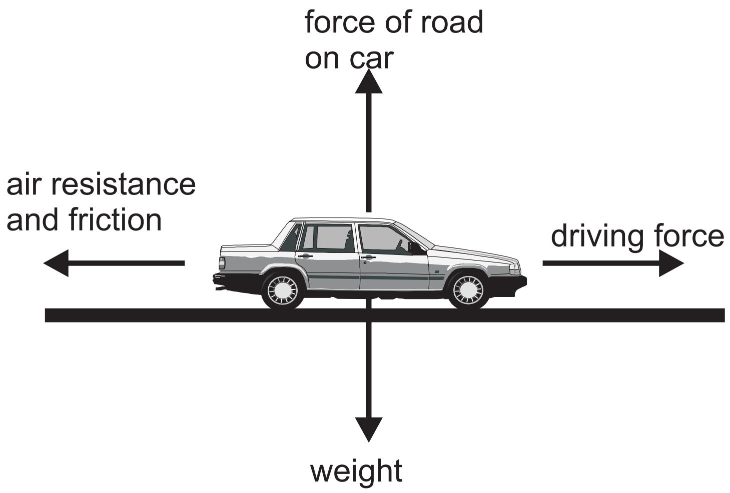
Air resistance is affected by the shape of the moving object. Streamlined shapes which allow the air to flow round them easily have less air resistance.

Dynamics

Newtons' First Law. *An object will remain at rest or continue travelling in a straight line at a steady speed unless acted on by a force.*

Balanced Forces

Moving objects are usually affected by more than one force. If the object is at rest, or the object is moving at a steady speed in a straight line, then the forces acting on the object are said to be balanced, and equivalent to a situation where no forces are acting.

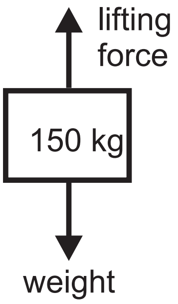


Car travelling at a steady speed along a straight, level road means the forces on the car are balanced. So:

driving force = air resistance + friction

weight = force of road on car

Example : Calculate the force required to lift an object with a mass of 150 kg at steady speed.



Two forces are acting on the object; the force needed to lift the object and its weight.
As the object is moving at a steady speed, the forces acting on the object are balanced so:

lifting force = weight

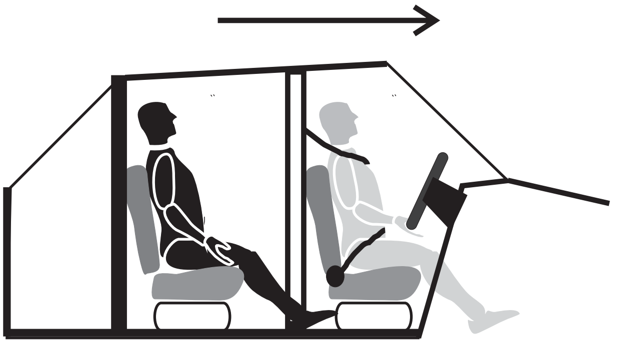
= 10 x mass

= 10 x 150

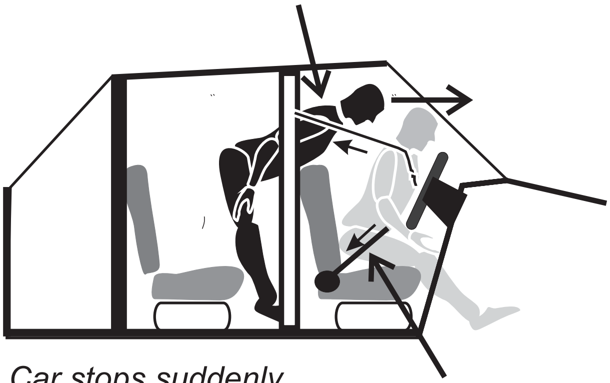
force = <u>1500 newtons</u>

Dynamics

Seatbelts



without a force to prevent him, the passenger continues to move forward when the car stops



Car stops suddenly as it collides with obstacle.

The force provided by the seatbelt restrains the movement of the driver

Cars involved in collisions come to a stop in a short time. Passengers in the car are stopped with the car if they are wearing a seatbelt. Otherwise they will continue to move forward when the car stops as there is no force to stop them. This can involve a passenger leaving the safety of the car via a windscreen.

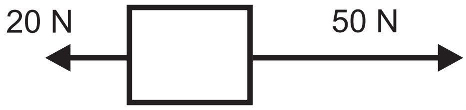
Modern cars are designed to reduce the forces in a collision by crumbling. Passengers are kept in a padded safety cage by their seatbelt. Seatbelts are designed to stretch by tearing and keep the restraining force on the wearer at a safe level.

Dynamics

Unbalanced Forces

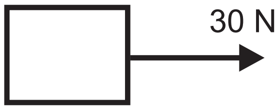
When the forces acting on an object are not balanced, the object will speed up or slow down. The object may also change direction.

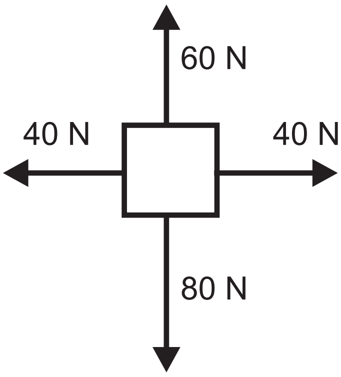
unbalanced forces



same as

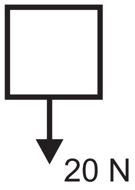
unbalanced force = 30 N





same as

unbalanced force = 20 N



A moving object will accelerate in the direction of the unbalanced force.

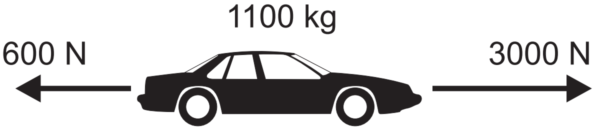
The acceleration depends on the size of the unbalanced force and the mass of the object. The larger the mass, the less the acceleration for a given force. The larger the force the larger the acceleration.

Newtons' Second Law: *The size of the unbalanced force acting on an object is give by :*

Force = mass x acceleration

$$\boxed{F = m a}$$

Force in newtons (N)
mass in kilograms(kg)
acceleration in metres per second per second (m/s^2)



Example : Find the acceleration of the car.

$$F = m a$$
$$2400 = 1100 \times a$$
$$a = \frac{2400}{1100}$$
$$\underline{a = 2.2\, m/s^2}$$

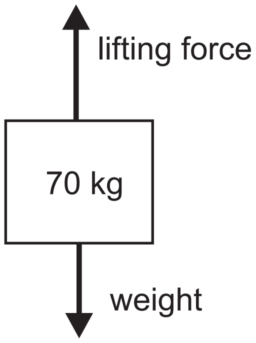
$$F = 3000 - 600$$
$$= 2400\ N$$

$$m = 1100\ kg$$

Dynamics

Example: Calculate the lifting force required to lift an object, mass 70 kg, with an upward acceleration of 4 m/s^2.

Step 1. Draw a diagram showing the forces involved.



Step 2 Find the unbalanced force F

$F = m a$

$= 70 \times 4$

$= 280$ N

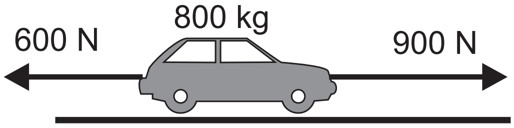
Step 3 Find the lifting force

Unbalanced force = lifting force - weight

280 = lifting force - 700 (weight = 10 x mass)

lifting force = 280 + 700

$\underline{= 980 \text{ N}}$



Example: Calculate the acceleration of the car.

$F = m a$

$300 = 800 \times a$

$a = \frac{300}{800}$

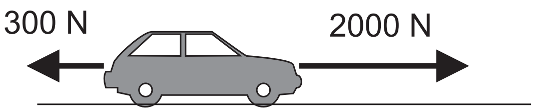
$\underline{a = 0.38 \ m/s^2}$

$F = 900 - 600$
$= 300$ N

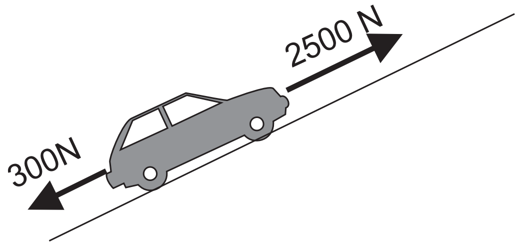
$m = 800$ kg

Movement and energy

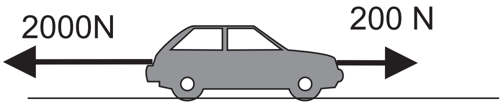
Energy conversion in cars.



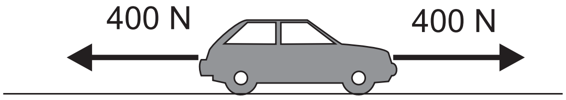
An accelerating car is gaining kinetic energy.



A car moving at constant speed up a slope is gaining potential energy.



When a car brakes, its kinetic energy is converted to heat energy by the friction in the brakes.



A car travelling at constant speed is still burning fuel. The energy is being used to overcome friction: air resistance and in the engine.

Cars obtain their energy by burning fuel. The energy released is used to turn the wheels and move the car. When the car is moving, some energy is required to overcome air resistance and friction in the moving parts of the engine.
Air resistance increases quite sharply with speed, so a car travelling at a constant 70 mph along the motorway must burn fuel at a much higher rate than a car travelling at 30 mph.
Putting the foot down on the accelerator increases the flow of fuel to the engine and generates energy at a higher rate. This allows the car to speed up or climb hills.
Only about 25% of the energy from the burning fuel is used by the car, the rest passes out the exhaust or as heat from the radiator!

Movement and energy

Work Done

When a force is used to move an object in the direction of the force, the object will gain energy. If the object speeds up it will gain kinetic energy. If it is raised it will gain potential energy and if it moves at a constant speed it will gain heat energy from friction.
When a force is used to move an object we say that WORK has been done on the object. The energy gained by the object is equal to the work done on the object:

Work Done = Applied Force x Distance Moved (in the force's direction)

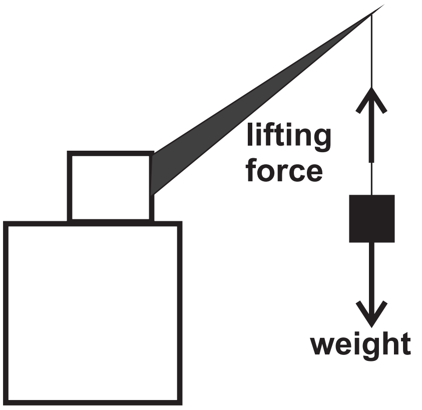
$$E_w = F \times s$$

Work Done is measured in newton metres (Nm)

Work done is a measure of energy transferred. The energy transferred when one newton metre of work is done on an object is equal to one joule, the unit of energy.

1 joule = 1 newton metre

Work Done is usually expressed in joules rather than newton metres.



A crane lifts a package, mass 500kg, from the ground to a height of 20m.

a. Calculate the work done by the crane on the package.

b. Find the energy gained by the package.

Work Done = Applied force x distance moved

= lifting force x height

= 5000 x 20

Work Done = 100000 joules

lifting force = weight

= m.g

= 500 x 10

= 5000N

b. Energy gained by package = Work Done on package

Energy gained = 100000 joules

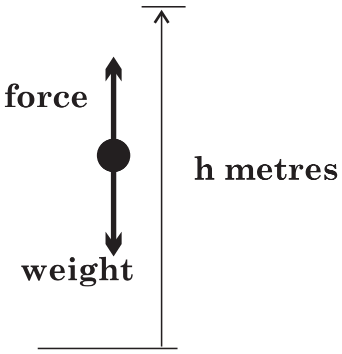
Movement and energy

Potential and Kinetic Energy

Gravitational Potential Energy

The potential energy gained by an object raised to a height above the ground is equal to the Work Done in raising it.

The force required to raise the object is equal to its weight. Work done in raising object to a height of h metres



Work Done = Force used x height

$E = m.g \times h$

Potential energy gained E_p

$$\boxed{E_p = m.g.h}$$

Kinetic Energy

The kinetic energy of a moving object depends on its mass and speed. Kinetic energy increases with the speed of the object.

Kinetic Energy = $\frac{1}{2}$mass x speed^2

$$\boxed{E_k = \frac{1}{2} m.v^2}$$

All energy is measured in joules (J)

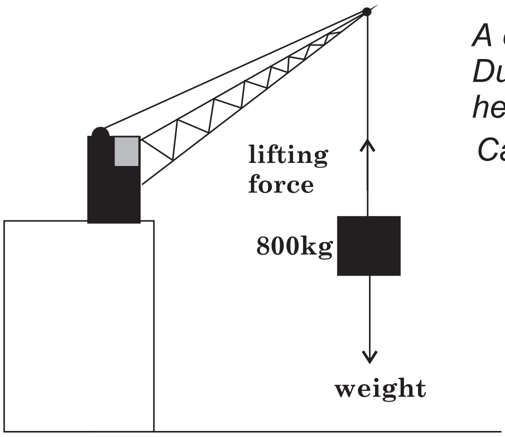
Movement and Energy : Power

Power.

A machine is any device used to convert energy from one form to another. Humans, car engines, light bulbs, batteries, are all machines. One of the important factors we have to know about a machine is how fast it can convert energy.
The rate at which a machine converts energy is called its power.
Power (P) is the rate at which energy is transformed from one form to another. For a mechanical device, this is the rate at which it does work.
Power is measured in watts (W). One watt is equal to a rate of transformation of one joule per second.
If E Joules of energy is transformed in t seconds, Then the Power P, is given by

$$\textit{Power} = \frac{\textit{Energy transformed (work done)}}{\textit{time taken (seconds)}}$$

$$\boxed{P = \frac{E}{t}}$$



A crane is used to lift cargo from a ship's hold. During one lift it raised a load of 800kg to a height of 15 metres in 2 minutes.

Calculate the power output of the crane.

$$\text{Power output} = \frac{\text{work done on load}}{\text{time taken}}$$

work done on load = lifting force x distance moved

E = F.s
= 8000 x 15
= 120000 J

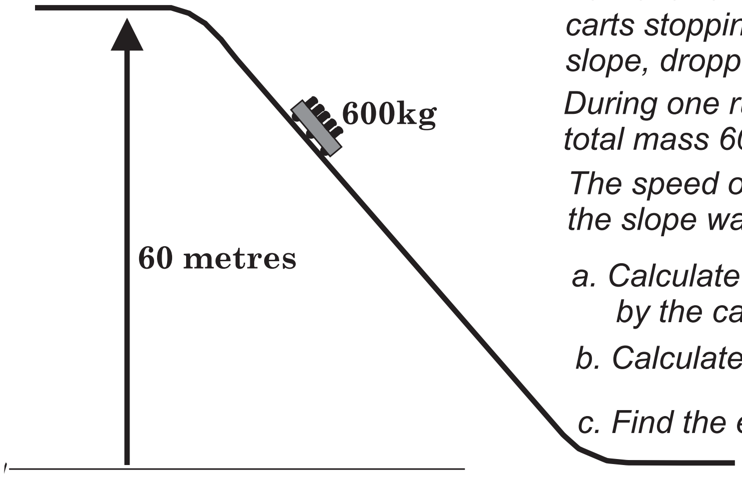
F = lifting force
= weight
= m.g
= 800x10
= 8000 N
s = 15 m

$$\text{Power output } P = \frac{\text{work done}}{\text{time (s)}}$$

$$= \frac{120000}{120}$$

$$P = \underline{1000 \text{ watts}}$$

Conservation of Energy: energy cannot be created or destroyed. It can only be converted from one form to another.



Part of a roller-coaster ride involves the carts stopping, then rolling down a long slope, dropping 60 metres in height.

During one run, a cart and passengers, total mass 600 kg , rolled down the slope.

The speed of the cart at the bottom of the slope was 20 m/s.

a. Calculate the potential energy lost by the cart.

b. Calculate the kinetic energy gained.

c. Find the energy lost to friction.

a.

E_p = m.g.h

= 600 x 10 x 60

= 360000 J

m = 600kg
g = 10 N/kg
h = 60 m

Potential energy lost by cart = 360000 joules

b.

$E_K = \frac{1}{2}m.v^2$

$= \frac{1}{2} \times 600 \times 20 \times 20$

= 120000 J

m = 600kg
v = 20 m/s

Kinetic energy gained by cart = 120000 joules

c.

The conservation of energy applies to this situation

Potential energy lost by cart = Kinetic energy gained by cart + Work done overcoming friction.

360000 = 120000 + Work Done

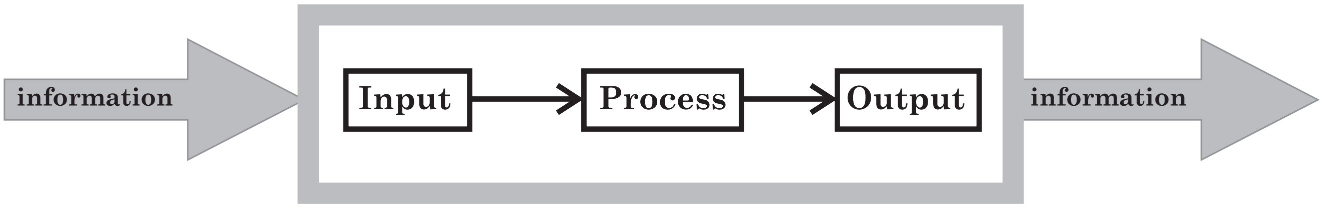
Work done overcoming friction = energy lost to friction = 240000 joules

ELECTRONICS

Summary Notes

Section	Content
1. Overview	Practical systems. Input ⟶ Process ⟶ Output. Analogue/digital output.
2. Output devices	Output devices producing light, sound, movement. Light emitting diode. 7-Segment display.
3. Input devices	Microphone, thermocouple, solar cell, thermistor, light dependent resistor, switch, voltage divider, capacitor.
4. Digital processes	Transistor as switch. Simple switching systems: fire alarm, burglar alarm, automatic parking light, time delay. Digital logic gates. Applications of combined logic. Clock signals. Counter.
5. Analogue processes	Devices containing an amplifier. Amplifier gain.

Section 1: OVERVIEW



Electronic System

Electronic systems are designed to use information carried in electric current. An electronic system consists of three stages as described above:

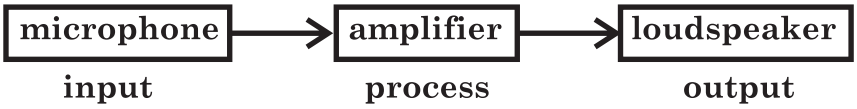
Input stage: converts information carried in sound, light etc. into equivalent
electrical signals.

Process stage: changes, or uses the signal in some way, to carry out a function.

Output stage: converts the processed signal from electrical energy into some
other form which we can use or sense.

Humans are not equipped to read electrical signals so all information must be converted to a form we can sense.

Public address system



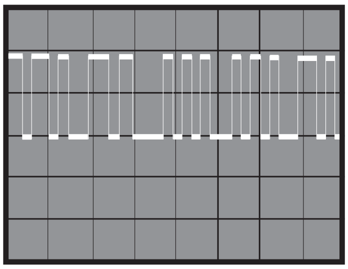
Microphone converts sound energy to electrical energy

Amplifier boosts the electrical energy, using the energy from a power supply

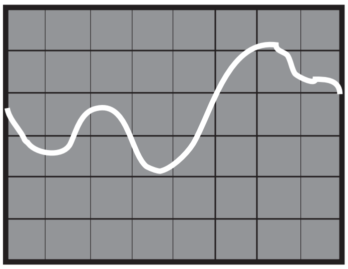
Loudspeaker converts the boosted electrical energy back into loud sound

Section 1: OVERVIEW

Analogue or Digital ?



Digital Signal

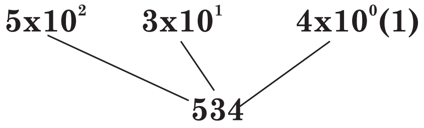


Analogue Signal

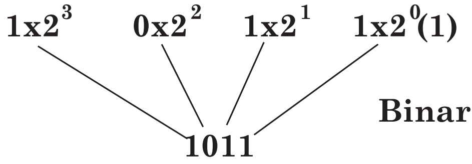
There are two kinds of electronic circuit. Both kinds can do the same job. The difference between them is in the type of signal they are designed to process.
Digital signals can either be high or low; on or off. The circuit information is carried in binary code; numbers. A digital signal appears as shown above.
Analogue signals show variation in levels. Information is carried in the level of current or voltage.

Binary numbers

Binary numbers are the same as decimal numbers except they are based on 'two' rather than 'ten'. As in a decimal number, the further to the left it is placed, the higher the value it has.



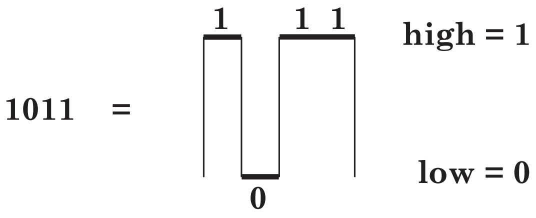
Decimal Numbers



Binary Numbers

Binary	Decimal
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

Binary numbers are simply a series of '1's and '0's. This can be represented electronically as 'on' or 'off', or 'high' or 'low'.

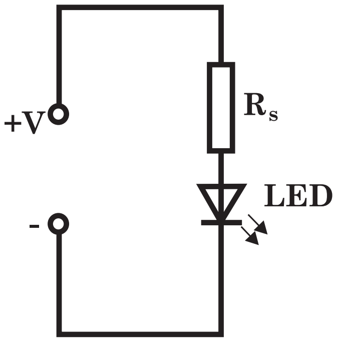


Section 2: OUTPUT DEVICES

Output devices convert information carried in electric currents into forms which we can understand or use.
Most output devices are energy converters.

Output Device	Energy Conversion
Loudspeaker	**Electrical energy → Sound energy**
Buzzer	**Electrical energy → Sound energy**
Light Emitting Diode (LED)	**Electrical energy → Light energy**
Electric Motor	**Electrical energy → Kinetic energy (movement)**

Other output devices are designed to operate other devices indirectly. A **relay**, for example, is a current controlled switch which is used in automatic controls to turn large currents on and off. Electronic circuits carry small currents. Relays allow them to control much larger currents than they could safely carry.



LED

An LED is a special diode which is designed to emit light. Over 95% of the electrical energy is converted to light compared with the 10% converted by a filament lamp.

Like all diodes, current can only flow in the one direction through an LED.

LEDs are always operated with a series resistor to limit the current flowing through the LED.

LEDs come in a variety of colours, including red, orange, yellow, green and blue.

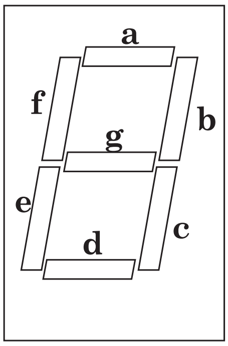
LEDs are used as indicators and are built into special displays like 7-segment displays.

Finding the right series resistor.
A red LED is to be powered from a 6.0 volt supply. When operating, the LED carries a current of 20mA, and has a voltage across it of 1.8volts.
Find the value of a suitable series resistor.

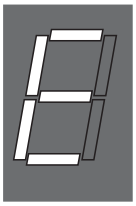
Voltage across the resistor = (6 - 1.8) Volts - Series circuit
= 4.2 volts
Current through resistor = 20 mA = 0.02 A

$$\text{Resistance } R = \frac{V}{I} = \frac{4.2}{0.02} = \underline{210 \text{ ohms}}$$

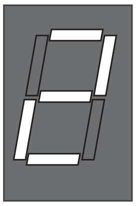
Section 2: OUTPUT DEVICES



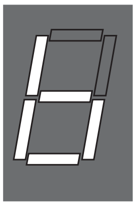
7-segment display



Segments a, d, e, f, g lit = E



Segments a, b, d, e, g lit = 2



Segments c, d, e, f, g lit = 6

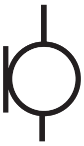
A 7-segment display is a means of converting digital output into letters and numbers. It consists of 7 LEDs in a block. The numbers and letters are generated by turning on the appropriate LEDS. A 7-segment LED is usually operated with a special integrated circuit which decodes the digital signal into numbers or letters.

Section 3: INPUT DEVICES

There are two kinds of input device we shall look at. One type are energy converters which generate an electric current. The other type are variable resistors

Current generators

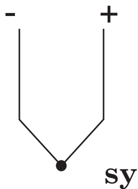
1. Microphone



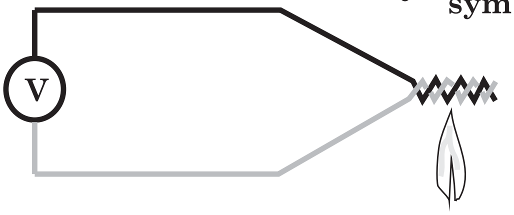
Sound energy → Electrical energy

There are several different types of microphone. The dynamic microphone is a simple electromagnetic generator. The crystal microphone generates by bending a special crystal. Microphones do not generate enough electrical energy to move a loudspeaker. The signal needs amplification.

2. Thermocouple



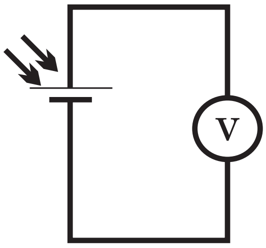
symbol



Heat energy → Electrical energy

A thermocouple is made by twisting together the ends of two wires made from different metals to form a junction.
When the junction is heated, a small voltage is generated across the ends of the wire. The size of the voltage is proportional to the temperature.

3. Solar Cell



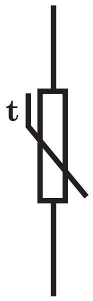
Light energy → Electrical energy

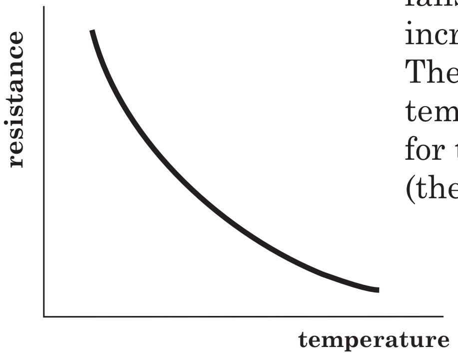
Solar cells are designed to generate electric current using light energy. They provide useful power in remote locations and in space.
They can be used to detect the presence of light. A more suitable device for this is the photodiode.

Section 3: INPUT DEVICES

Variable resistors

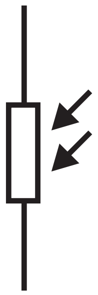
1. Thermistor

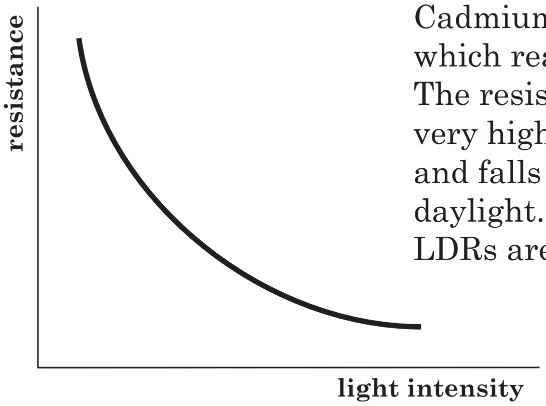




The resistance of a thermistor falls as the temperature increases.
Thermistors are used in temperature detection inputs for temperature control circuits (thermostats).

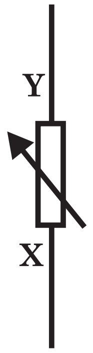
2. Light Dependent Resistor (LDR)

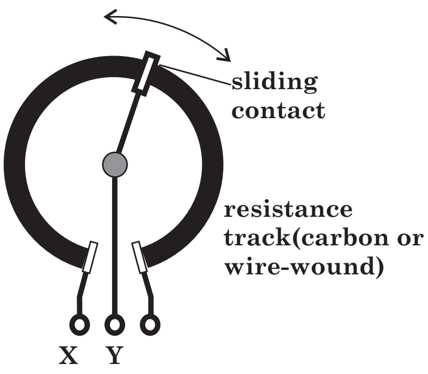




An LDR is a resistor made from Cadmium Sulphide, a substance which reacts strongly to light.
The resistance of an LDR is very high (50kohms) in the dark, and falls to around 100 ohms in daylight.
LDRs are used in light detection

3. Variable Resistor

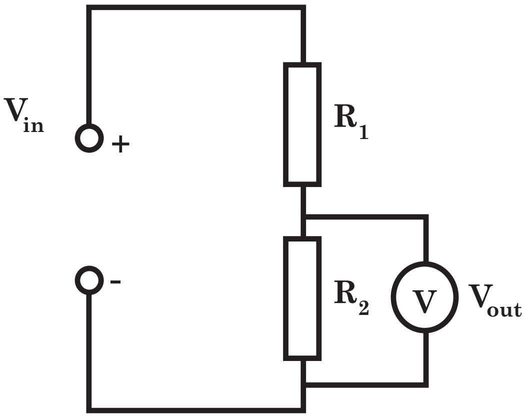




Variable resistors are adjustable resistors. The adjustment is usually made by turning a shaft. This moves a sliding contact across a resistance track made from carbon or wire. This changes the resistance between the two terminals (X and Y).
Variable resistors can be used as position sensors.

Section 3: Input devices

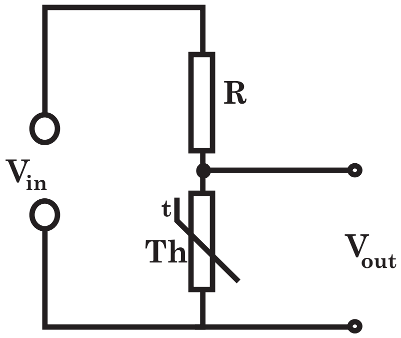
The Potential Divider



Input stages usually need to supply changes in voltage to the process stage.
Variable resistor input sensors are normally fitted into a Potential Divider. This is a circuit consisting of two series resistors. The resistors share the voltage placed across them in proportion to their resistances. The higher resistor has the larger share.
The voltage across a variable resistor in a potential divider will change with the changing resistance.

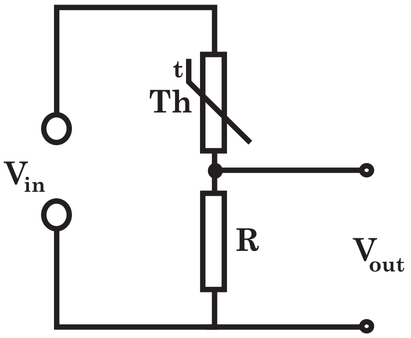
$$\boxed{V_{out} = V_{in} \frac{R_2}{(R_2 + R_1)}}$$

INPUT CIRCUITS



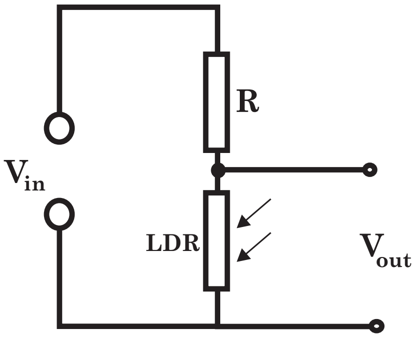
Cold Detector

V_{out} **increases** when the temperature falls and resistance of thermistor increases



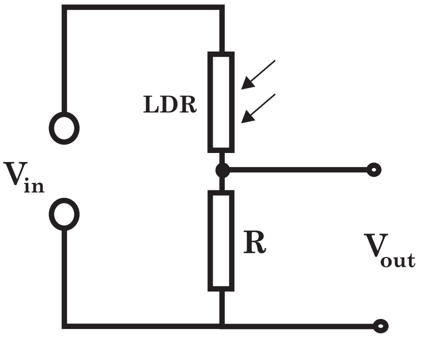
Heat Detector

V_{out} **increases** when the temperature **increases** and resistance of thermistor falls



Dark Detector

V_{out} **increases** when it gets **darker,** and the resistance of the LDR increases.

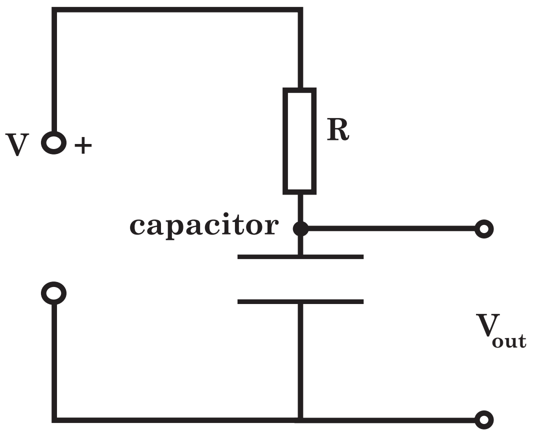


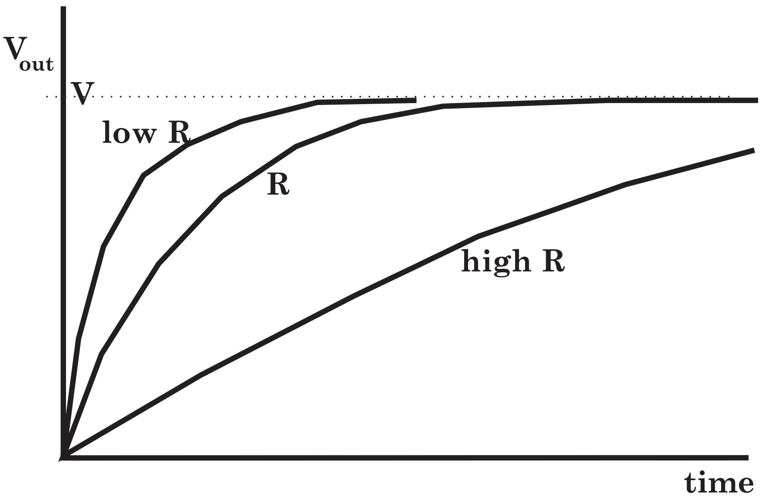
Light Detector

V_{out} **increases** when it gets **lighter,** and the resistance of the LDR decreases.

Section 3: INPUT DEVICES

The Capacitor

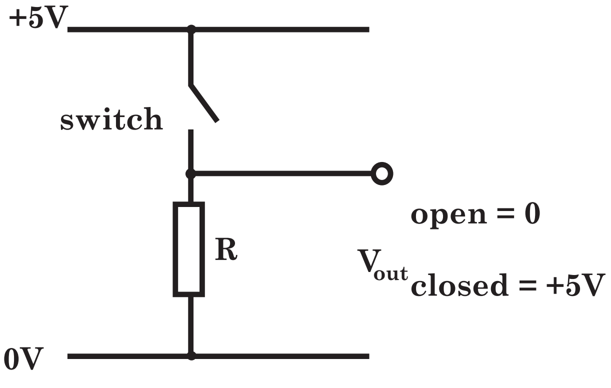


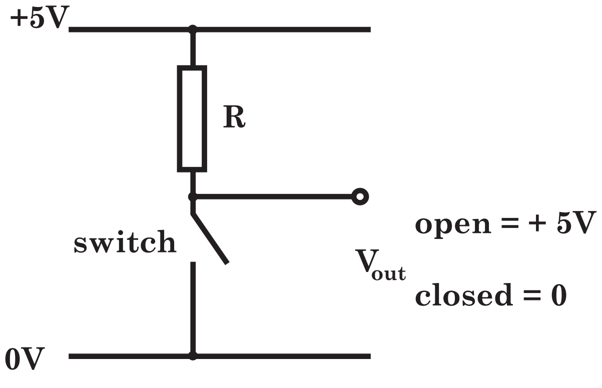


A capacitor is a component which stores electric charge. The voltage across a capacitor increases with the stored charge. The flow of charge into the capacitor is controlled by the resistor, R. The higher the resistance, the smaller the current, and the slower the charge and voltage increases.

Large capacitors store more charge for the same voltage. Increasing the size of the capacitor slows down the rate of voltage increase.

Capacitors are used where a time input is required.

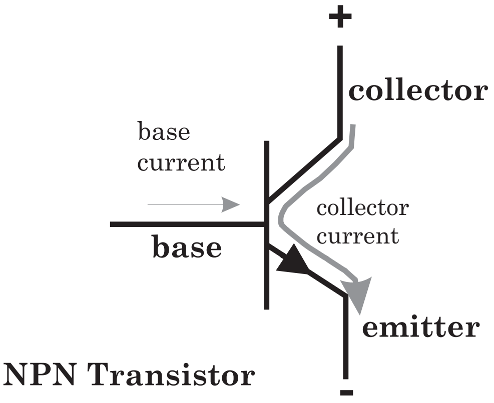




When switch is **open,** no current flows through R. The voltage across R is 0. **V_{out}** must therefor be 0. When the switch is **closed, V_{out}** is connected to the +5 volt line.

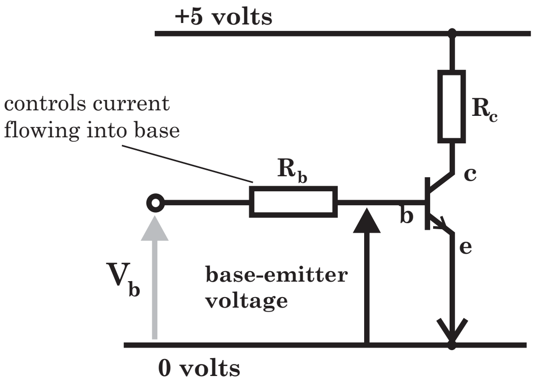
When switch is **open,** no current flows through R. The voltage across R is 0. **V_{out}** must therefor be +5 volts. When the switch is **closed, V_{out}** is connected to the 0 volt line.

The Transistor as a Switch



NPN Transistor

A transistor is a three pin semiconductor device. The pins are called the **collector, emitter** and the **base.**
The main current; the collector current, flows between the collector pin and the emitter pin. This current is controlled by the smaller current flowing between the base pin and the emitter pin; the base current.
The collector current can only flow if there is a base current: no base current, no collector current.
Once flowing, the change in collector current varies directly with the change in base current.



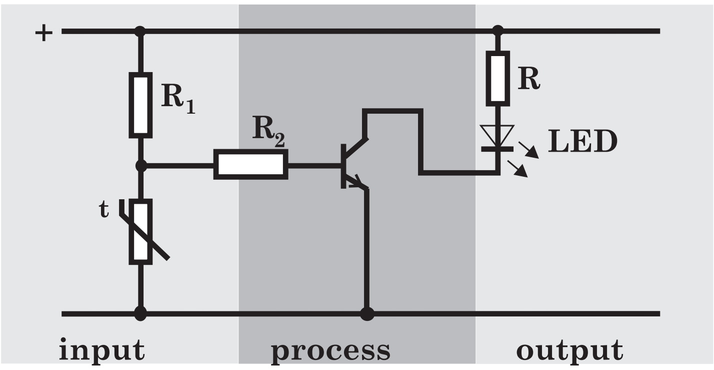
Transistor Switch

The base current will not flow until the voltage between the base and the emitter is greater than approximately 0.7 volts.

By applying a voltage $\mathbf{V_b}$, as shown, we can switch the collector current on or off.

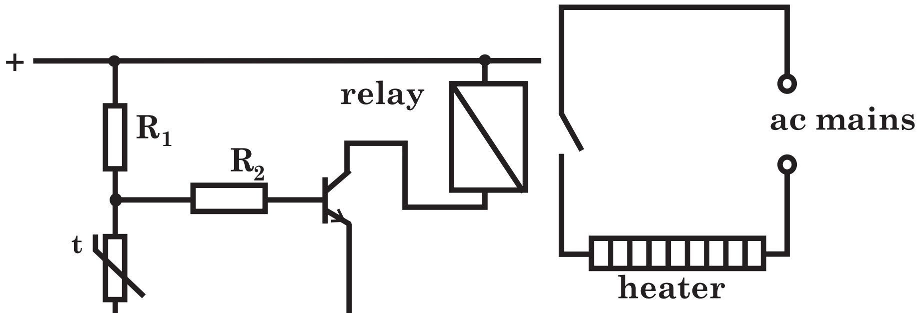
The collector current is ON when the base - emitter voltage is over 0.7 volts. The current is OFF when the base - emitter voltage falls below 0.7 volts.

In effect, the transistor is a voltage operated switch.

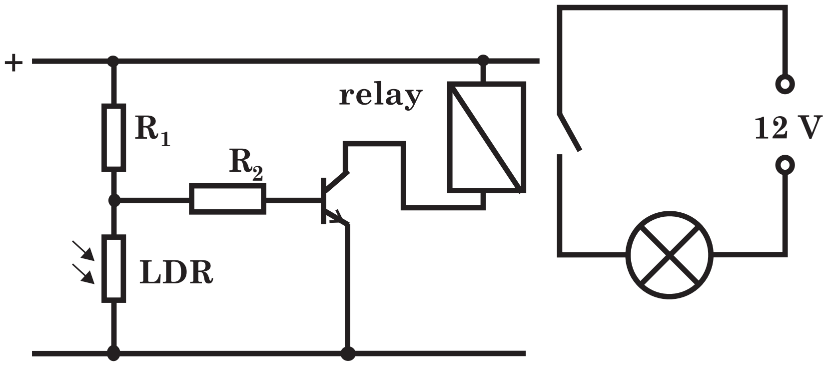


Frost detection circuit

The resistance of the thermistor increases as it gets colder and the voltage across it increases. Around freezing point the voltage across the thermistor is high enough to turn on the base current. This turns the collector current on and lights the warning LED.

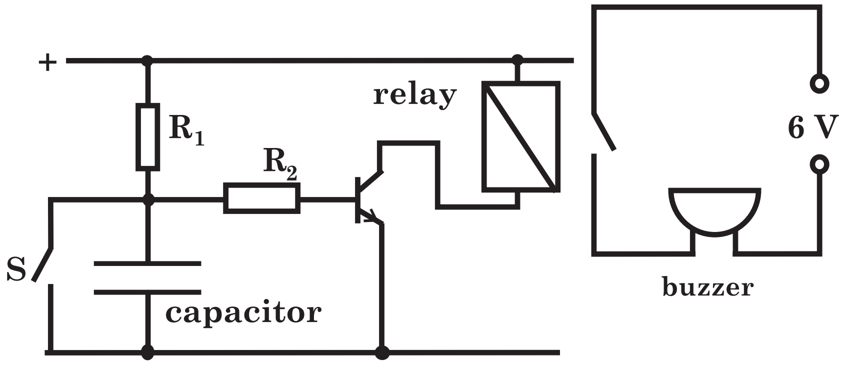


The same circuit as for the frost detector, except this time, it uses a relay to turn on a mains heater.
This circuit could be used to keep water pipes from freezing.



Automatic lamp

Lamp turns on automatically when it gets dark.
The resistance of the LDR increases as it gets darker. The voltage across it increases until it turns on the base current. The collector current turns on and operates the relay, lighting the lamp.



Egg timer

When switch S is opened, the capacitor starts to charge up and the voltage across it starts to increase. After a time it turns on the transistor base current. This turns on the collector current and operates the relay. This turns the buzzer on.

The transistor switch is a simple, versatile circuit which can be used for many control applications. Transistors cannot carry heavy current. This would damage them. The range of current a transistor can switch on and off can be extended by using the transistor current to operate a relay.
Transistors are not used in modern circuits. Instead integrated circuits, containing, sometimes, thousands of transistors are used.
Within these integrated circuits, however, the transistor switch is alive and well. This is specially true of logic gates and their associated circuits.

Section 4: DIGITAL PROCESSES

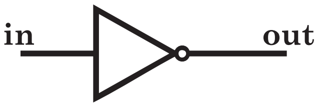
Logic Gates

Digital circuits operate with binary signals. The signal voltage can be high, representing binary '1', or low, representing binary '0'.

Boole, a nineteenth century Oxford mathematician, developed a system of algebra to deal with logical problems. Boolean algebra converts complex logical problems into simple steps where the only input and output are 'true' or 'false'. If we substitute '1' for 'true', and '0' for 'false' then we can use the functions developed by Boole to solve logic problems in digital circuits.

Logic gates are electronic circuits designed to mimic a Boolean function.

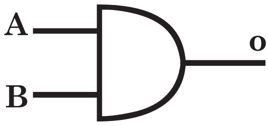
To understand what these circuits do, we have to create their 'Truth Table'. This shows the output ('0' or '1') for every combination of inputs. As each input is either '1' or '0', this is not a difficult task.



NOT gate or Inverter

in	out
0	1
1	0

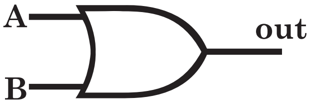
Input is NOT the output



AND gate

A	B	out
0	0	0
0	1	0
1	0	0
1	1	1

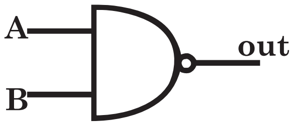
Output is '1' if A AND B are '1'



OR gate

A	B	out
0	0	0
0	1	1
1	0	1
1	1	1

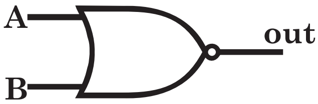
Output is '1' if A OR B is '1'



NAND (NOT AND) gate

A	B	out
0	0	1
0	1	1
1	0	1
1	1	0

Output is '1' for inputs which are NOT (A AND B)



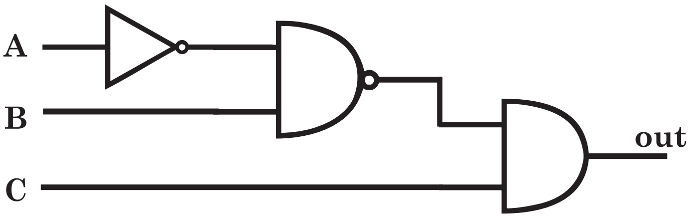
NOR (NOT OR) gate

A	B	out
0	0	1
0	1	0
1	0	0
1	1	0

Output is '1' for input which is NOT (A OR B)

Section 4: DIGITAL PROCESSES

Combinational Logic

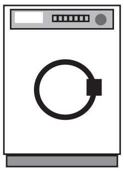


A	B	C	out
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

Truth Table

Combinational Logic

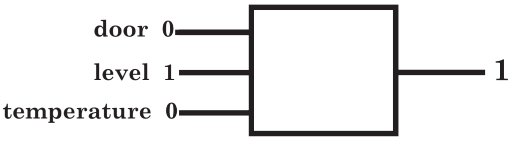
Logic gates can be combined to give more complex functions. Again the truth table is used to define the combined function.



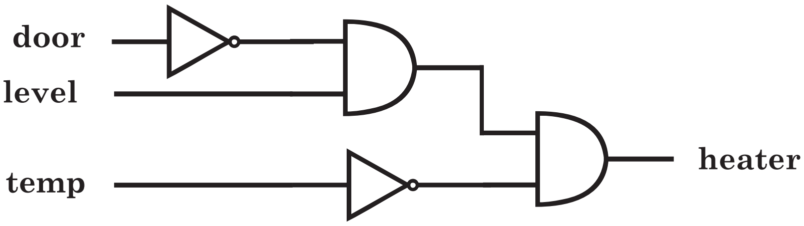
A washing machine uses logic circuits to control the water heater. The heater is turned on when a '1' is generated by the control circuit.

The control circuit generates a '1' when the door is closed, the water level is full and the water temperature is below 50°C. The different sensors have the following outputs.

Door	**open**	**1**
	closed	**0**
Water level	**full**	**1**
	not full	**0**
Temperature	**50°C or above**	**1**
	Below 50°C	**0**



When dealing with an output which can only be '1' for a single input situation then we usually use AND gates.



door	level	temp.	heater
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

Truth Table

Combinational logic problems are either to construct a truth table for a given set of gates, or to solve a simple control problem. Either way, it is important that you know the truth tables for the basic logic gates and you can construct a truth table for three or four inputs.

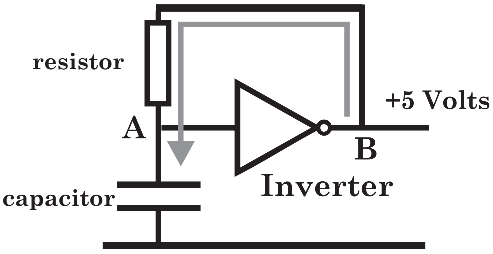
Section 4: DIGITAL PROCESSES

Clocks and Counters

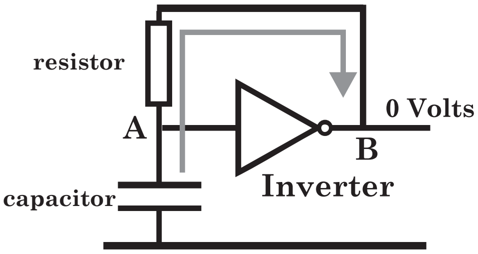
Every digital computer and most digital circuits contain clocks. The clock is a special circuit which generates regular voltage pulses.
The clock circuit provides the rhythm which the rest of the digital circuit follows (rather like the drummer who set the rhythm for the rowers in ancient galleys). The clock allows the digital circuit to operate one step at a time. Modern computers have clocks running at >1 GHz.

A simple clock circuit

We can make a simple clock circuit from an special Inverter (NOT gate). This is an inverter designed to change instantly from one state to the other, once the input changes.



When circuit is turned on, there is no charge in the capacitor so point A is at 0 volts. B is therefore at +5volts, so current flows through resistor into capacitor



When the capacitor has accumulated enough charge, the potential at A is high enough to generate a '1', so B changes to '0', 0 volts. As the voltage across the capacitor is high it starts to discharge through the resistor. After a time, the potential at A has fallen enough to change to a '0', and the whole cycle starts again.

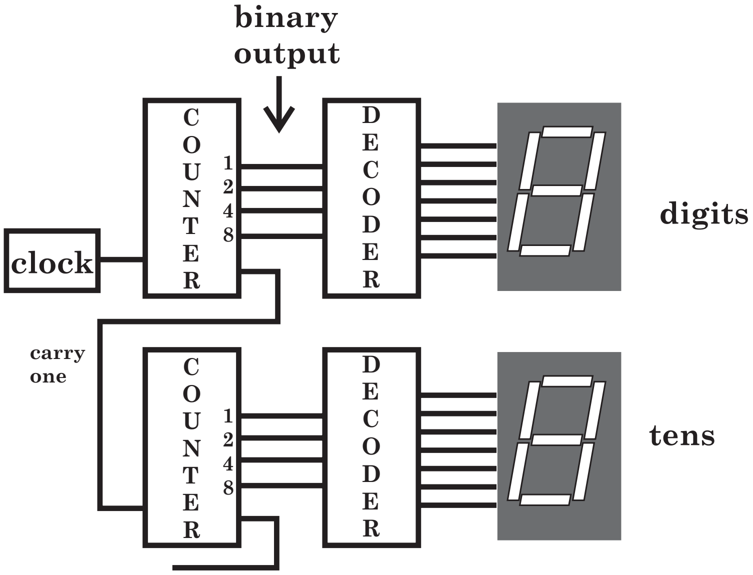
We can change the frequency of the clock by changing the size of the capacitor or the resistor.
Increasing the value of the resistor decreases the frequency of the clock. Increasing the value of the capacitor has the same effect. Decreasing the values has the opposite effect ... a smaller capacitor or resistor increases the clock's frequency.

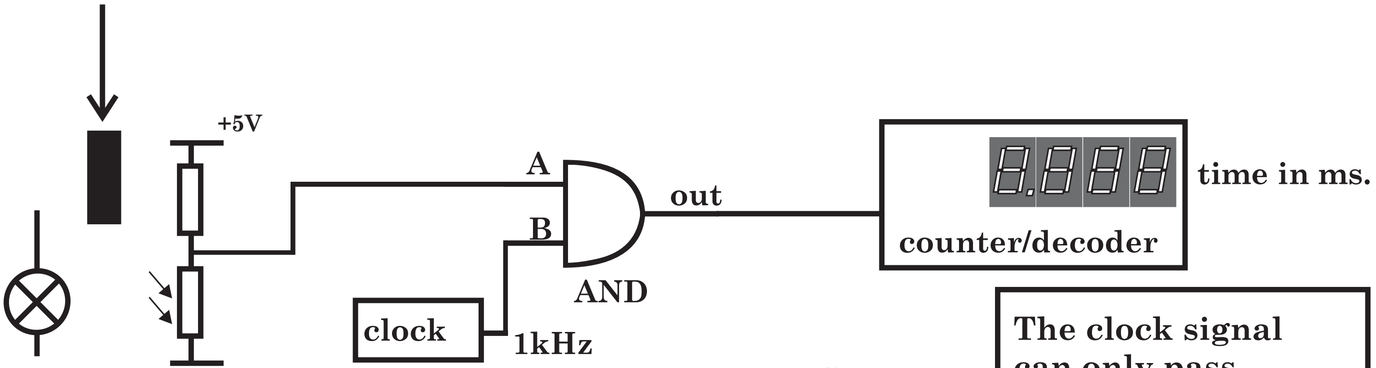
Section 4: DIGITAL PROCESSES

Clocks and Counters

A 4-bit Binary Counter counts the pulses from the clock.
It can be set to count from 1 to 10, resetting to 0 on 10 and sending a pulse to the next counter.

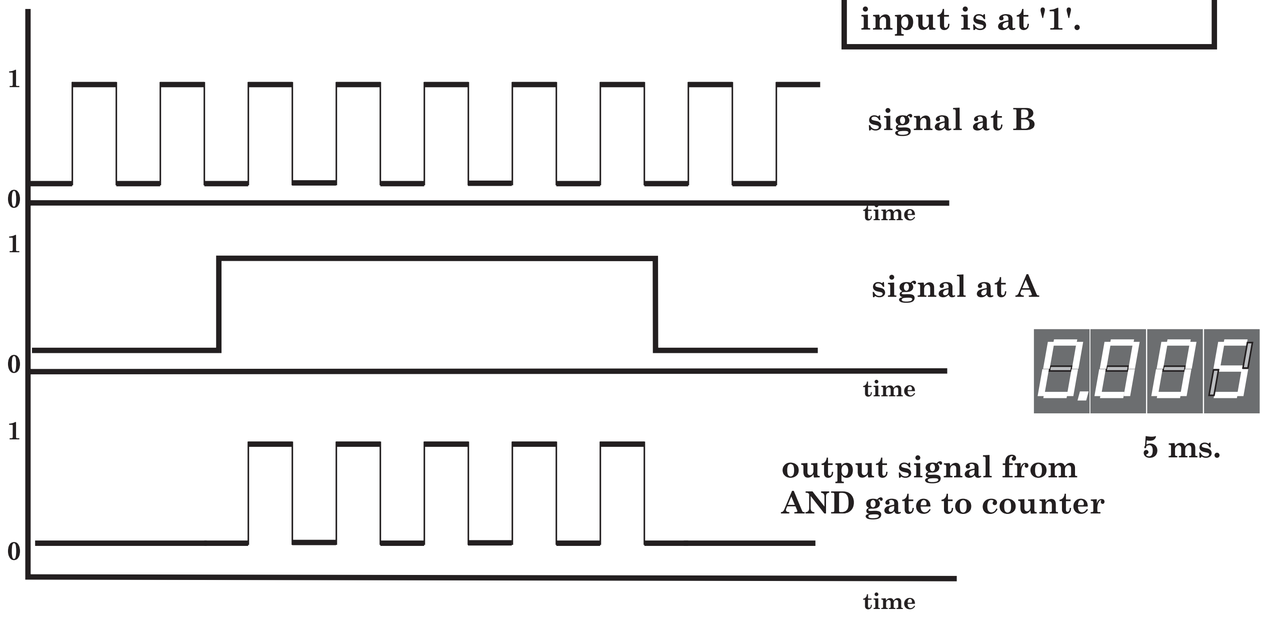
The decoder converts the binary input into a 7-segment read-out. By combining readouts it is possible to produce multi digit numbers





Timing Circuit

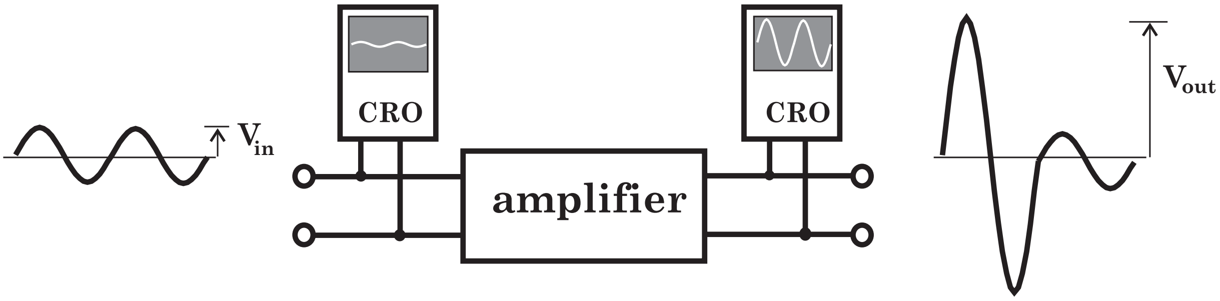
The clock signal can only pass through the AND gate when the other input is at '1'.



Section 5: ANALOGUE PROCESSES

The Amplifier

Amplifiers are found in many different types of equipment. Audio amplifiers: amplifiers designed to operate at signal frequencies between 0 and 20 kHz, are found in Hi-Fi, radios and TV. RF amplifiers: for radio frequencies, are found in radio transmitters, and radio and TV receivers.
Amplifiers change the amplitude of signals. They make weak signals more powerful.



$$\boxed{\text{Voltage Gain} = \frac{V_{out}}{V_{in}}}$$

Power Gain

$$\boxed{\text{Power Gain} = \frac{\text{output power}}{\text{input power}}}$$

Power gain is difficult to measure directly as we are usuually dealing with tiny currents at the input. We usually know the input **impedance** of the amplifier and the impedance of the device at the output of the amplifier. As far as we are concerned impedance is another name for resistance.
We can work out the input and output powers by measuring the input and output voltages and using:

$$\text{Power} = \frac{V^2}{R}$$

$$\text{output power} = \frac{V_{out}^2}{R_{out}}$$

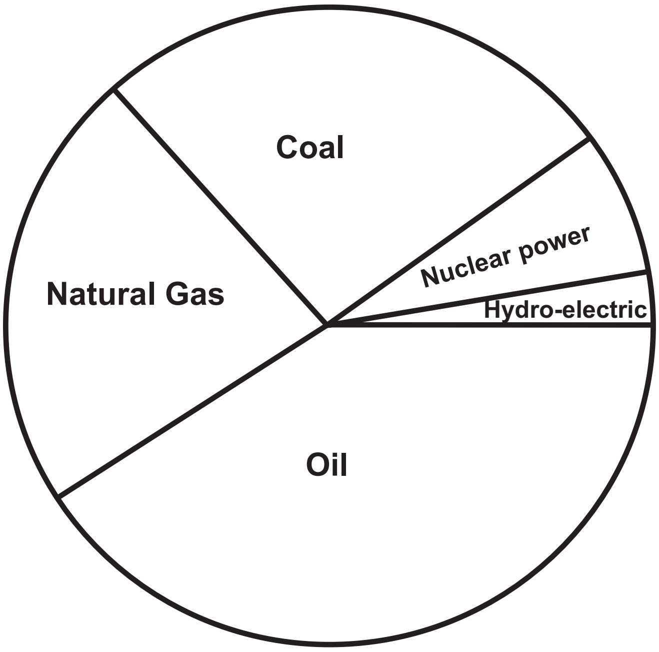
$$\text{input power} = \frac{V_{in}^2}{R_{in}}$$

ENERGY MATTERS

Summary Notes

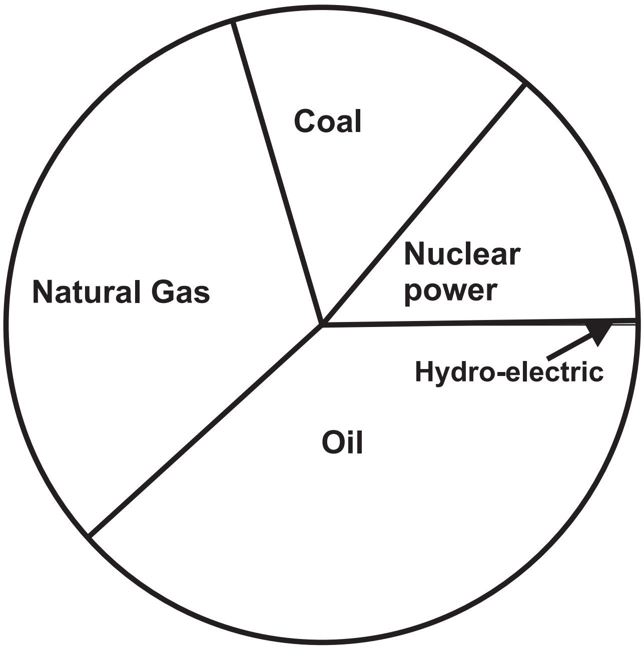
Section	Content
1. Supply and Demand	Main sources, relative demands, conservation issues, alternative sources, environmental issues.
2. Generation of Electricity	Fossil-fuelled power stations, hydro-electric stations, nuclear power stations, energy transformations, efficiency.
3. Source to consumer	Induced voltage, alternating current, transformers, National Grid.
4. Heat in the House	Energy conservation in buildings, specific heat capacity, domestic applications, change of state, refrigerator.

Section 1: SUPPLY and DEMAND



WORLD ENERGY
1997

The Pie-chart opposite shows how the world was supplied with energy in 1997.
The total energy used was equivalent to the energy released by burning 8510 million tonnes of oil!
90% of this was obtained by burning the fossil fuels; coal, oil and natural gas.



UK ENERGY
1997

The UK uses around 2.6% of the world's energy supply (compare this with the 25% used by USA!).
The UK uses a higher proportion of nuclear power, but even so, 88% of our energy is still supplied by fossil fuels.

Figures taken from
BP statistical review of World Energy
(June 1998)

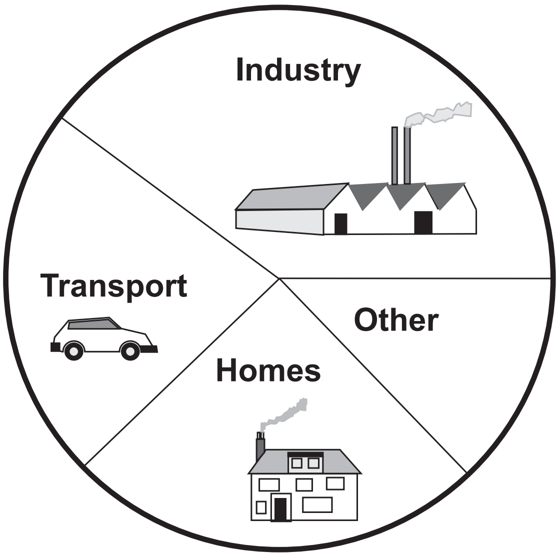
Section 1: SUPPLY and DEMAND

Introduction

The energy we need to run our homes, our industry and our transport is supplied from various sources. The basic supply comes from **Primary fuels** which are traded on the world markets. These are oil,natural gas, coal and uranium for nuclear power. A small portion of the world's energy is supplied by hydro-electric power schemes.

Most of the energy we use (90%) is supplied by the fossil fuels; coal, oil and natural gas. Fossil fuels are recovered from reservoirs in the ground. The amounts left are **finite;** they will run out! Estimates of how much we have left vary according to the degree of optimism in the estimator. If they are used at the current rate, oil will last around 40 years, natural gas 64 years and coal 220 years.

If we want to retain our energy-hungry society in the manner to which it has become accustomed, then we need to find replacement sources of energy. Meantime, we can eke out the remaining supplies by using what we have sparingly.

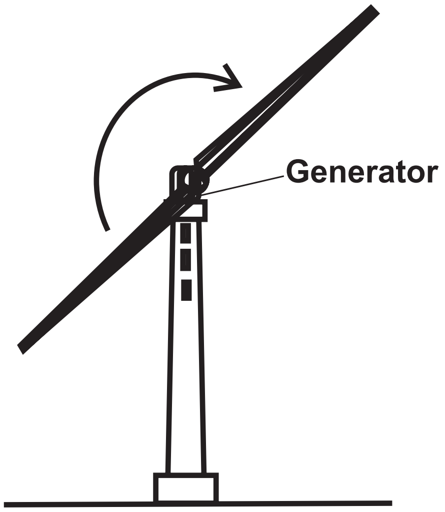


UK Energy Users

As we might expect, industry uses the greatest proportion of the energy supply. However private homes use almost one quarter of the energy supply, closely followed by transport. Most of the energy used by the transport sector is used on the roads.

Private citizens use around 40% of the energy supply, if we take into account the energy used by private cars.

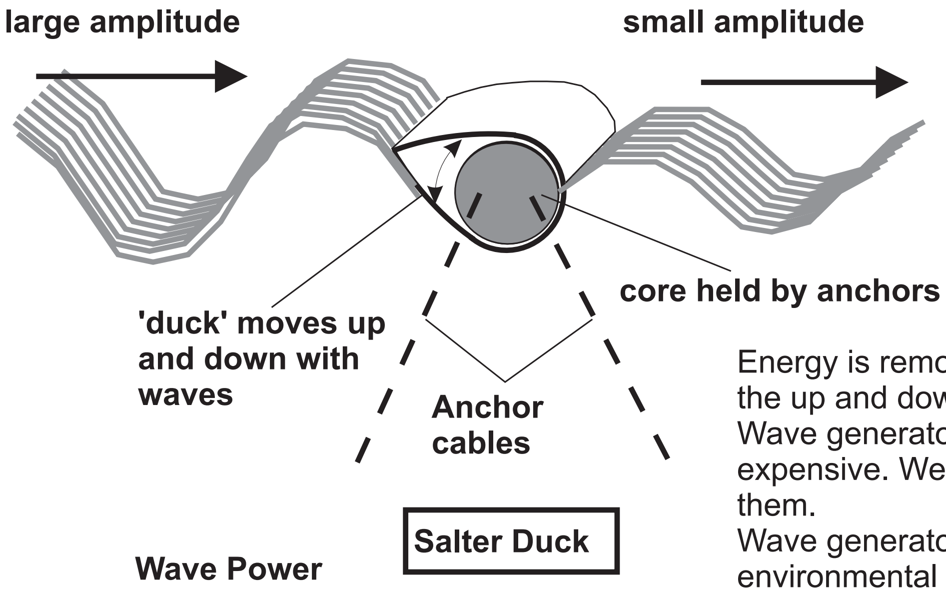
The other users are agriculture and public services (street lights etc.)



Wind Power

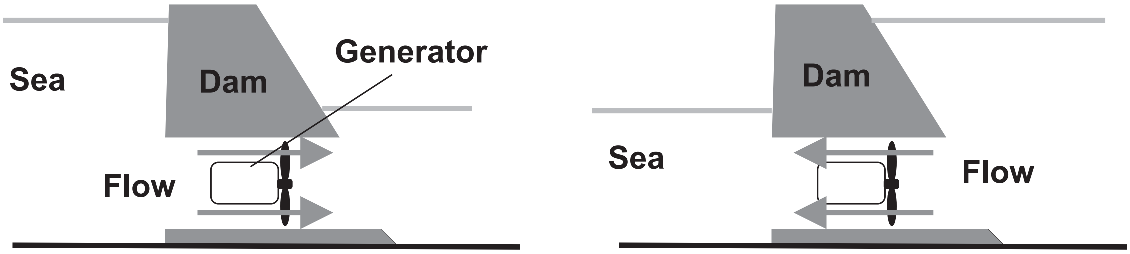
Wind Power

Wind power is a renewable energy source which is already being exploited in many countries.
Kinetic energy in moving air is converted to electrical energy with an efficiency of around 40%.
Wind power is not a constant supply, and the generators are unsightly and noisy.
Offshore sites have been proposed for large UK windfarms.



Wave Power

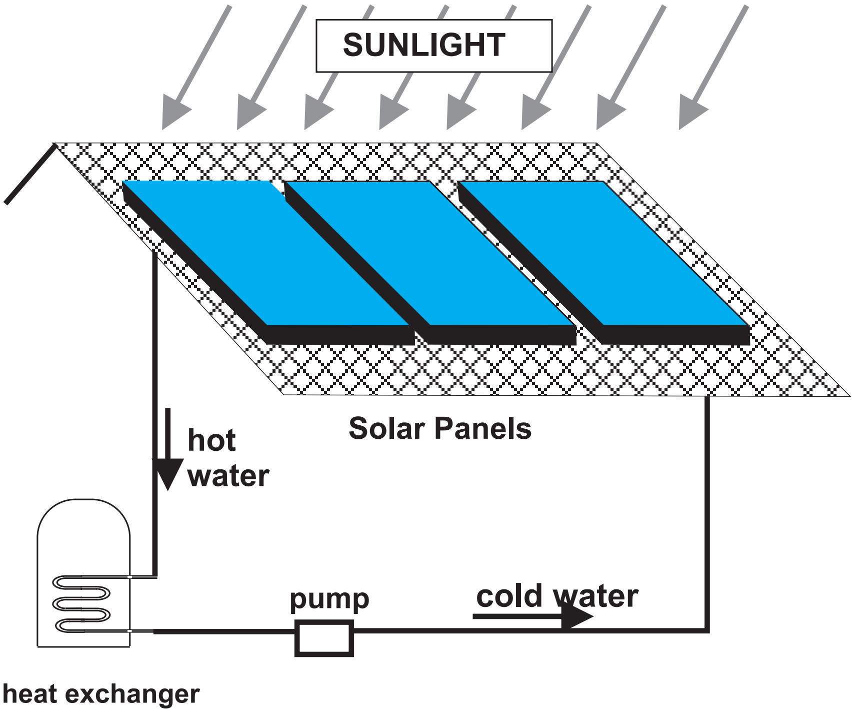
Energy is removed from the waves by the up and down movement of the 'duck'.
Wave generators are very large and expensive. We will need 300 miles of them.
Wave generators may cause environmental problems.



Tide coming in **Tide going out**

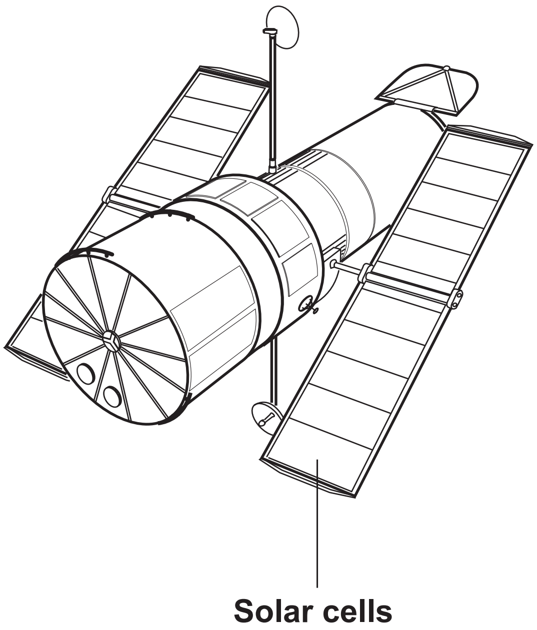
Tidal Power

Tidal power is a reality in France. There are suitable sites in the UK ; the Severn estuary and the Solway. Tidal power stations are expensive and interfere with the environment of estuaries.



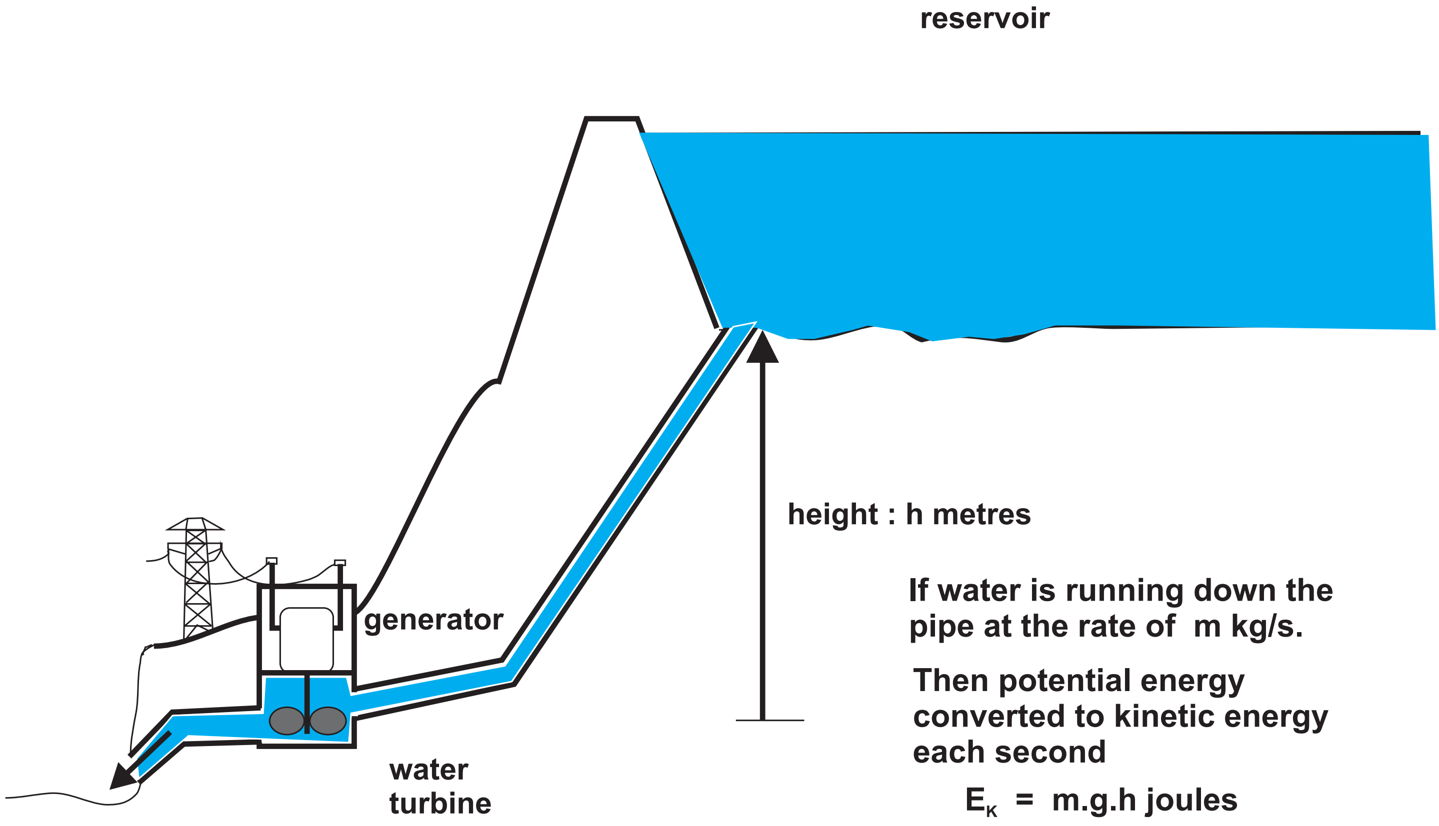
Solar Energy

Solar panels are available to mount on suitable roofs. Sunlight is absorbed by the panels and converted to heat energy. The heat energy is collected by water flowing through the panels and transferred to a heat-store for use in the house.



Satellites in space need electrical power to run their electronics. This can be provided by batteries over the short term. If, however, the satellite is remaining in space for a long time it usually obtains its energy from panels containing hundreds of solar cells.

Solar cells convert light energy directly to electrical energy. They are not very efficient. Only about 10% of the light energy falling on a cell is converted to electrical energy.



If water is running down the pipe at the rate of m kg/s.

Then potential energy converted to kinetic energy each second

$$E_K = m.g.h \text{ joules}$$

max power output = m.g.h watts

Hydro-electric power

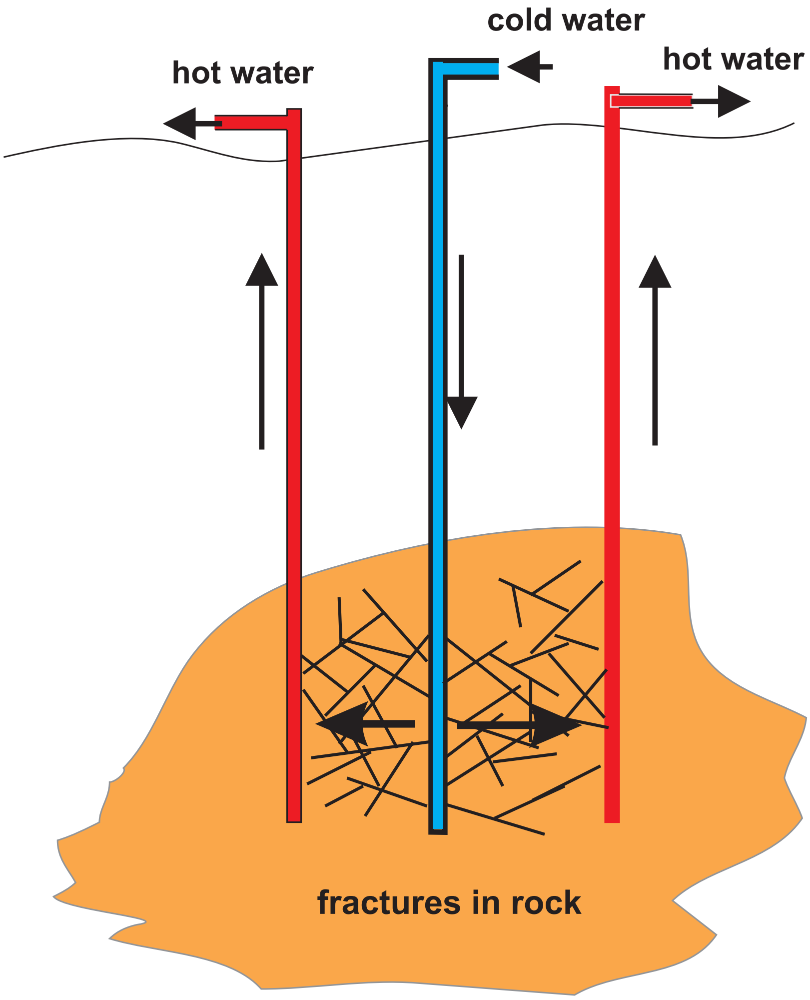
Hydroelectric power.

Hydro- electric power is obtained from the kinetic energy in flowing water. Water is allowed to fall from a high reservoir and turns a water turbine. This is used to generate electricity.

About 80% of the kinetic energy is converted to electrical energy. Some kinetic energy must be left in the water to allow it to flow out of the turbine.

The amount of kinetic energy available is determined by the height of the reservoir and the flow of water into the reservoir. This depends on the local rainfall. These conditions restrict the availability of locations. Those in the UK are mostly used up.

Hydro power has the advantage that it can be turned on and off very quickly. Thermal power stations cannot be turned off and need a day to be heated up to operating temperature!



Geothermal Energy. The temperature of the Earth increases the deeper you go. Usually it rises approximately 1°C for every 30 metres depth increase. After 300 metres the temperature is above 100°C..

Certain areas of the Earth's surface are hotter than others and it is these areas which can be tapped for geothermal energy.

The technology is the same as drilling for oil. A series of wells is drilled. The rock is fractured using explosives, and cold water pumped down one well. The water flows through the rocks and heats up. The hot water is collected by the other wells.

The cold water is pumped under high pressure and the hot water turns to steam when it reaches the surface. This can be used to generate electricity.

Countries like Iceland and New Zealand, where there is lots of volcanic activity, make use of the abundant steam generated by such areas. In the UK, however, there are only a few areas where the rocks are hot enough to justify the cost.

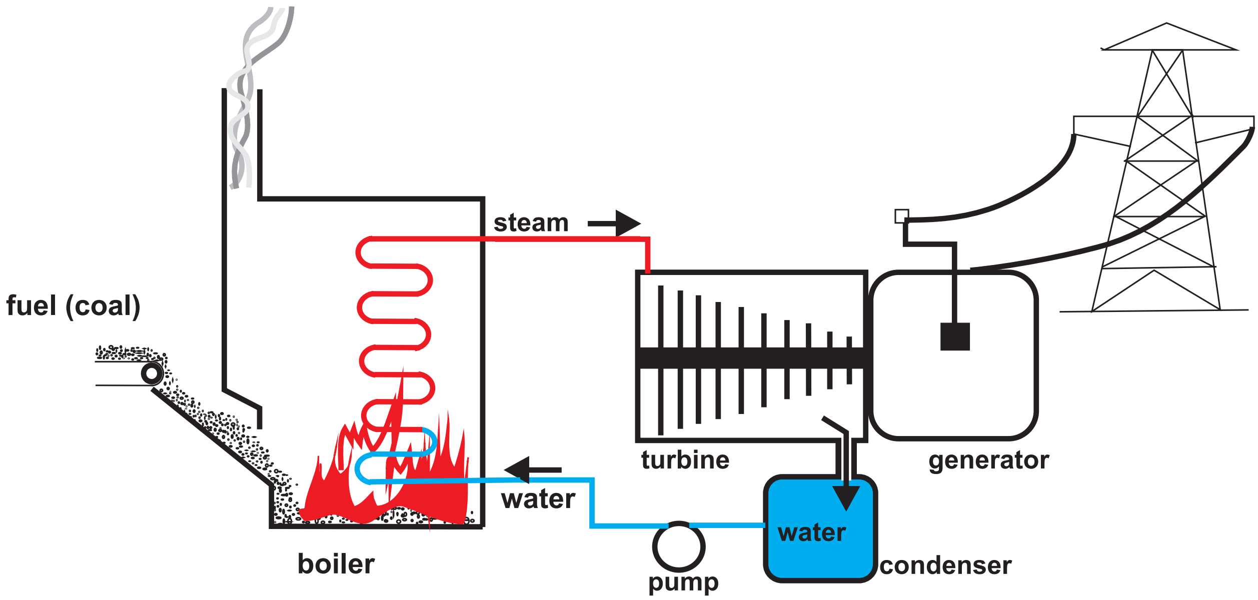
Biomass

Plants are grown to provide fuel. Some tree species grow very quickly and can by harvested for burning.

Brazil uses its excess sugar crop to make alcohol. The alcohol is added to petrol to eke out the supplies.

Plant waste can be composted to provide methane gas, especially if it has gone through a cow first! Some farms already use this source as a major part of their fuel supply.

Section 2: GENERATION of ELECTRICITY



Thermal Power Stations

Thermal power stations use steam to generate electricity. Heat energy is produced by burning coal, gas or oil. The heat energy turns water into steam which is used to turn a steam turbine. The turbine turns a generator which generates AC electricity. Only the energy stored in the steam is used. The energy used to heat the water and turn it into steam is not used but is thrown away. Only 30% of the energy released by burning the fuel ends up as electrical energy.

Combined heat and power stations

Thermal power stations generate lots of hot water which is usually thrown away. It is possible to sell this hot water to heat homes. This reduces the wastage and increases the efficiency of the power station to 60%.
This change would mean the building of smaller community power stations rather than the enormous stations built today. This system is a reality in countries like Sweden

Thermal power stations generate most of the electricity we use. They operate 24 hours a day, every day of the year.

Demand for electricity varies throughout the day and is lowest at night. Power stations generate more electricity than is needed during the night and, if it is not used, it is wasted.

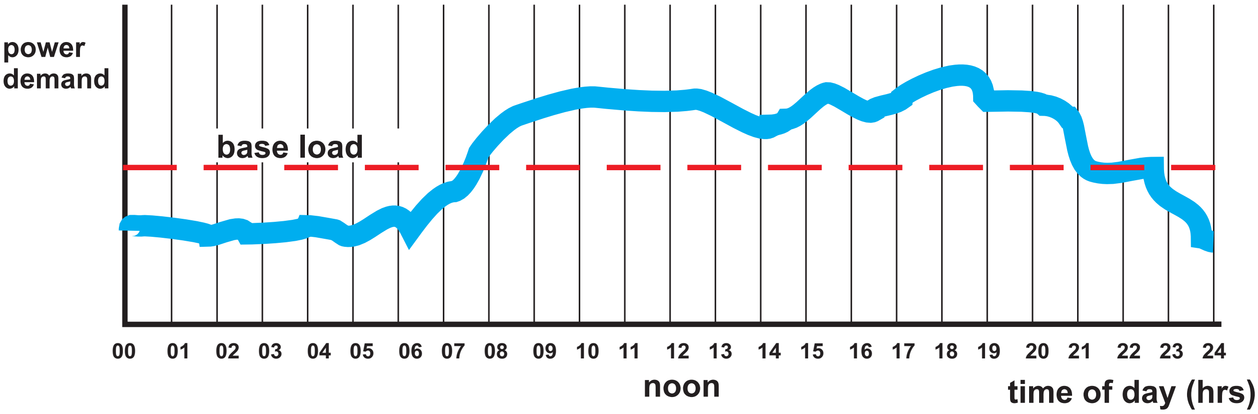
Electricity suppliers offer special low rates to anyone using electricity at night (white meter) to stop wastage.

Some of the excess power is used to pump water up into reservoirs where it can be used to generate hydro electricity when required.

Section 2: GENERATION of ELECTRICITY

Introduction.

The generation of electricity is a national industry in the UK. There are several companies running power stations, but the electrical energy they produce is distributed through the **National Grid.** The National Grid is an electric circuit connecting every power station to every user.

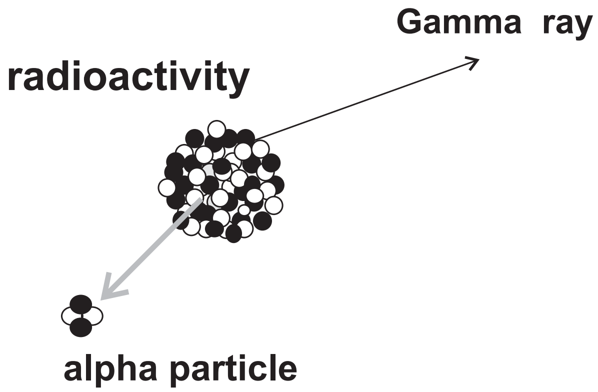


The demand for electrical energy varies through the day. It is higher during the daylight hours and lower during the night.
Most of the electrical power (the Base Load) is supplied by coal fired and nuclear power stations. These must be run 24 hours a day as they are difficult to close down and start up. This means that during the night there is an excess of electrical power in the grid. During the day there is not enough to meet the demand.
When required gas-fired power stations and hydro-power stations can be turned on during the day to provide extra power. These types of power stations can be turned on and off quickly.

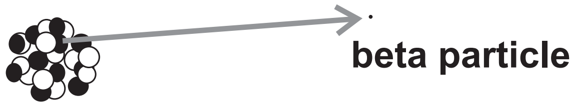
The operators of the National Grid keep watch on the current flowing in the grid. This gives them an indication of the level of demand. They alert the power stations when the demand starts rising. Sometimes the demand rises too quickly for the system to adjust and there are power cuts

Section 2: GENERATION of ELECTRICITY

radioactivity

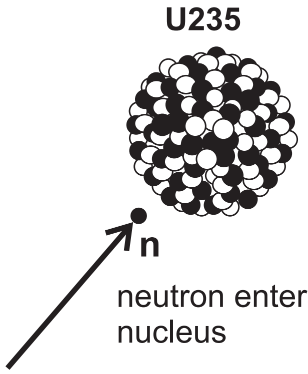


Radioactive sources become warm, because radioactive particles transfer some of their energy to the atoms inside the source.
Radioactive sources are used in special batteries in satellites (why only there??), where they last for a few years.
Radioactivity cannot be controlled, it is a spontaneous event which will not be influenced by any man made process.

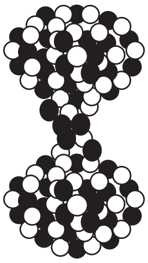


Nuclear Fission

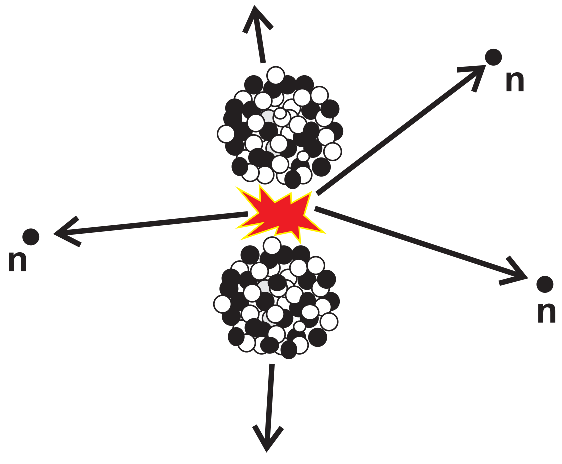
The nucleus of an atoms contains protons and neutrons, held together by a strong nuclear force. Without this force, the positively charged protons would fly apart. As the size of the nucleus increases, the effect of this strong force reduces. Eventually we reach a situation where it is impossible to hold the protons in a nucleus. This process sets a limit to the size of a nucleus.
Large nuclei can by so unstable that they split apart: they undergo **nuclear fission**. The process is the same as radioactivity but involves much more energy.
Unlike radioactivity, nuclear fission can be controlled. If we bombard a nucleus of an isotope of uranium : uranium- 235, with neutrons, and a neutron enters the nucleus, the nucleus will immediately split into two. When this happens, two or three extra neutrons are usually emitted. If we collect enough uranium - 235 together, the neutrons emitted by one nucleus splitting will cause a **chain reaction** spreading through the rest of the atoms very quickly. Enormous quantities of energy are released. This sort of chain reaction is termed an **atom bomb!!**



neutron enters nucleus

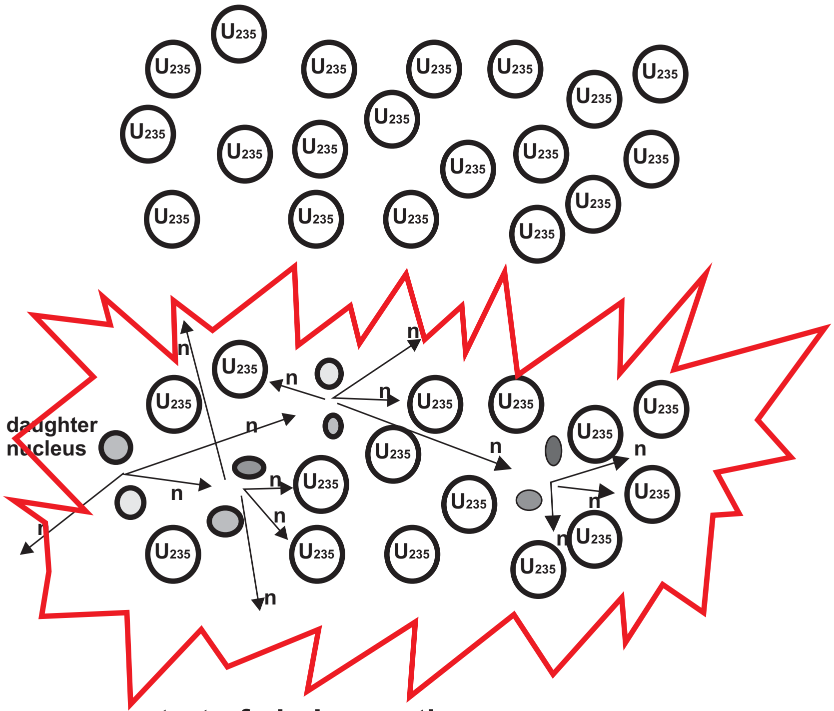


nucleus becomes unstable



nuclear fission

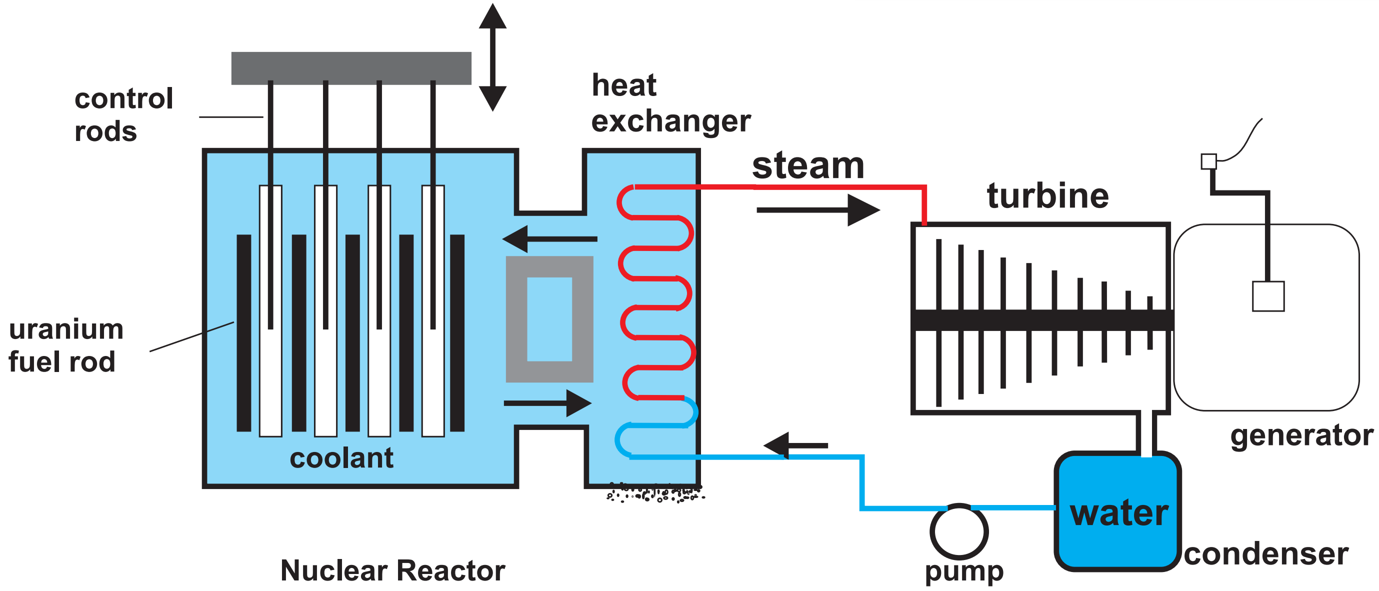
Section 2: GENERATION of ELECTRICITY



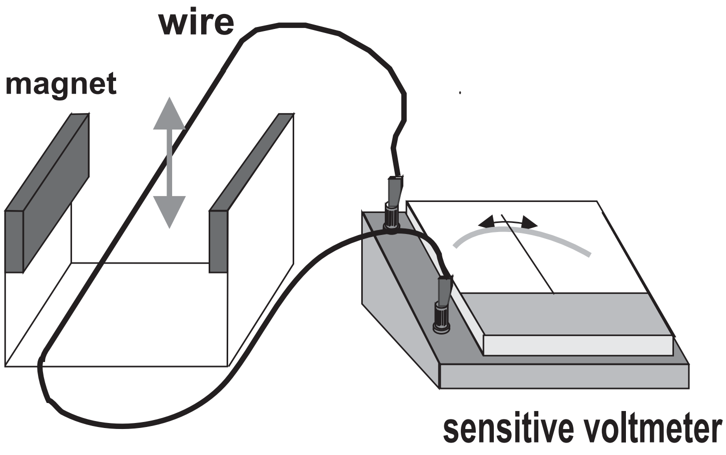
start of chain reaction

Chain reactions are controlled by controlling the number of neutrons flying around inside the uranium- 235.
This is achieved, in a nuclear reactor, by lowering rods, made from material which absorbs neutrons, into the uranium.
Reducing the number of neutrons slows down the fission chain reaction.

If all the atoms in 1kg of uranium- 235 were to undergo nuclear fission, the energy released would be equivalent to that released by burning 290,000,000 kg of coal!!



Nuclear power stations have the same efficiency as a coal fired station: around 30%.
Nuclear power plants are 'clean'. They do not produce waste gases to pollute the atmosphere. However, nuclear fission creates many new atoms which are highly radioactive. The waste products need to be safely stored for a long time until they are safe.
One of the products of Uranium fission reactors is the substance plutonium- 239.
Plutonium-239 can also be used in reactors and weapons but is regarded as too hazardous for civilian power stations and is used in naval reactors.



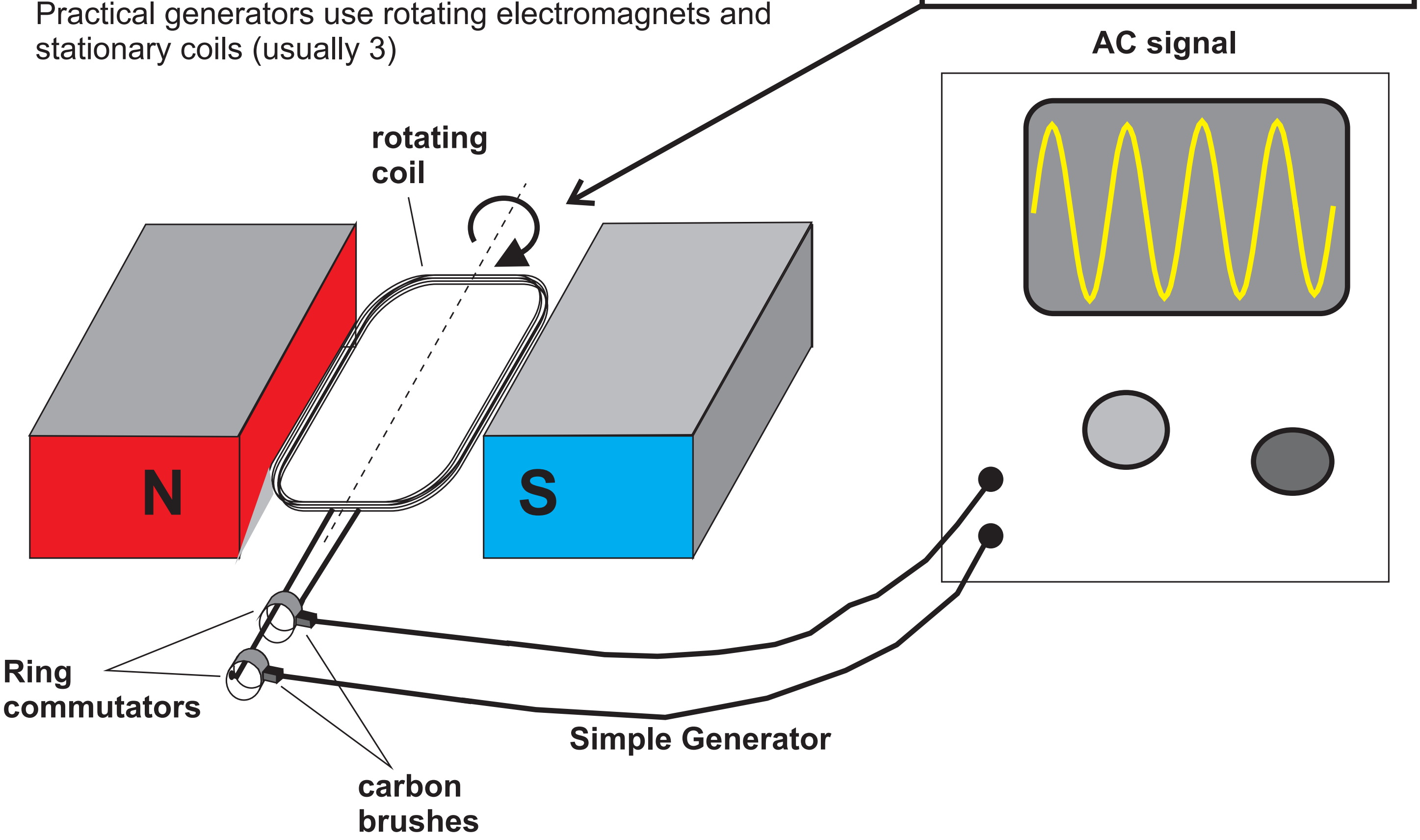
Moving a length of wire up and down, cutting a magnetic field, generates a small voltage across the ends of the wire.

The size of the voltage depends on the strength of the magnets, the length of the wire and the speed of the wire.

The Generator

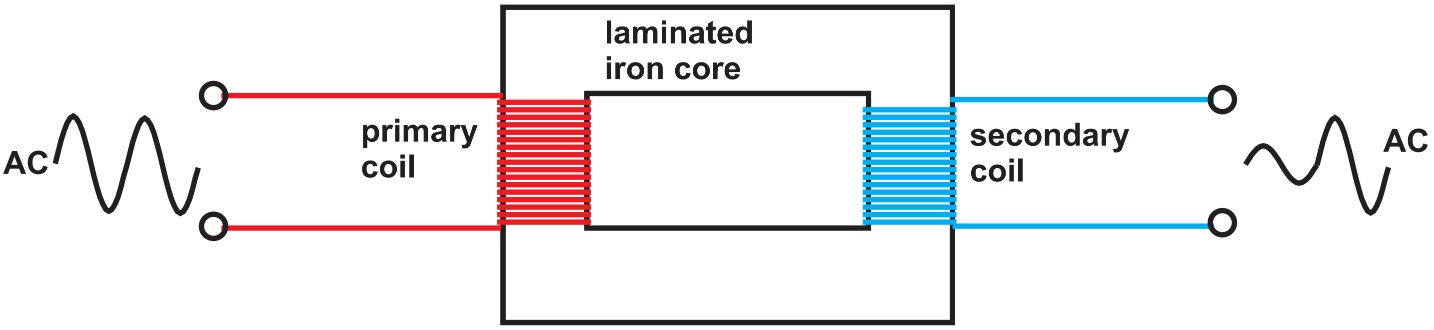
A generator, at its simplest, consists of a coil rotating in between magnets. The arrangement is similar to an electric motor (electric motors can be used as generators) except that the commutator is a complete ring.
Generators produce AC electricity, one half of the rotation produces a current in one direction, the other half reverses the direction.
Practical generators use rotating electromagnets and stationary coils (usually 3)

AC voltage depends on:
1. number of turns in coil
2. strength of magnetic field
3. speed of rotation.

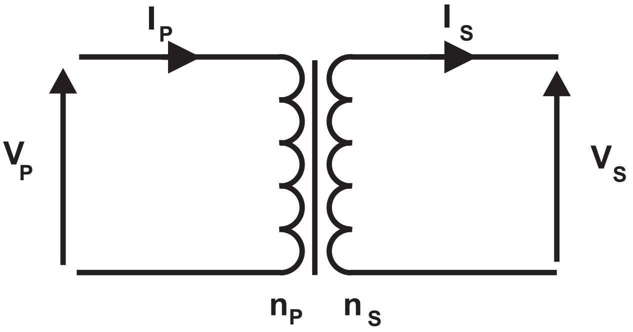


Simple Generator

Section 3: SOURCE to CONSUMER



When a changing magnetic field is passed through a coil of wire, a voltage is induced across the ends of the coil.
A transformer consists of two coils wrapped round a magnetic core. When a current is passed through one coil, the magnetic field it creates is passed to the other through the the core. The core ensures that all the magnetic field is passed over.
If an AC voltage is applied to one coil (the primary), the changing magnetic field it generates induces an AC voltage across the other coil (the secondary).



The symbol for a transformer is shown opposite.
V_P, V_S are AC voltages.
n_P, n_S are the number of turns of wire in the primary and secondary coils.

$$\boxed{\frac{V_P}{V_S} = \frac{n_P}{ns}}$$

If the tranformer is 100% efficient at transferring power from the primary coil to the secondary coil, then:

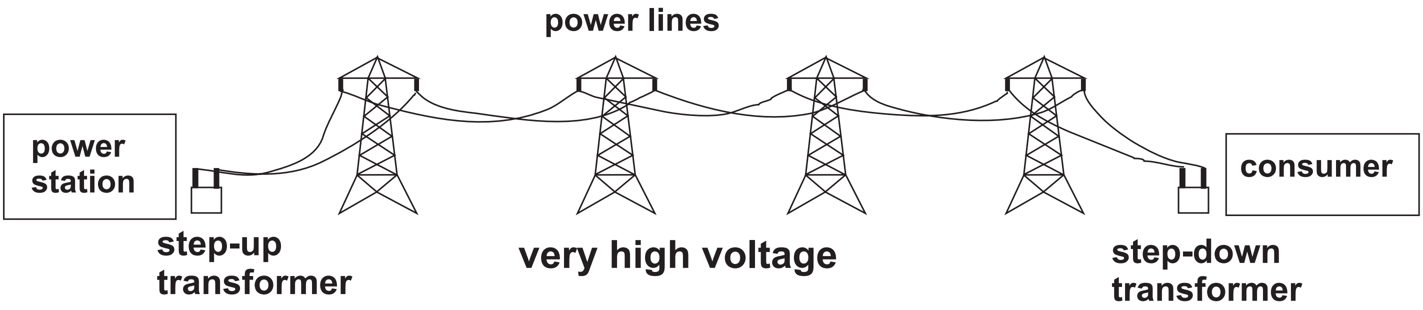
$$\boxed{V_P I_P = V_S I_S}$$

Transformers are not 100% efficient.

1. **Some electrical energy is converted to heat energy in the coils.**
2. **Some of the magnetic field escapes the coil and is not transferred to the secondary coil.**
3. **Energy is required to magnetise the core.**
4. **Energy is lost to eddy currents in the core material.**

With proper design, transformers can be up to 98% efficient.

Section 3: SOURCE to CONSUMER

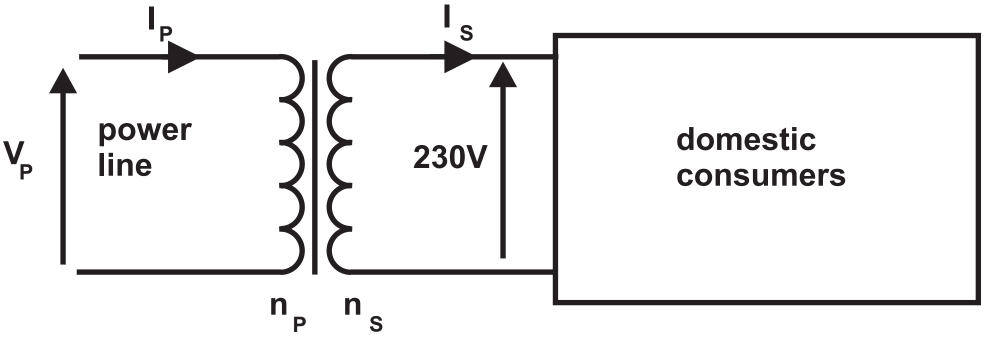


Transmission of electrical power.

Electrical energy is sent from the power station to the consumer through power lines. The wires in the power lines have a resistance so, when current flows through them some electrical energy is converted to heat energy and lost. The rate of loss of electrical power is given by:

$$\boxed{P = I^2R}$$

To minimise the losses, we need to minimise the current flowing in the power lines. We can do this using transformers.



The current to the domestic consumer, I_S, is supplied from a power line carrying current I_P.

Assuming the transformer is 100% efficient;

$$V_P\, I_P = 230 \times I_S$$

$$I_P = \frac{230}{V_P} \times I_S$$

For I_P to be small then the ratio of $\frac{230}{V_P}$ must be small.

This means that V_P must be as large as possible

In order to minimise the the amount of power converted to heat in the power lines, power is transmitted at very high voltages. **This minimises the current flowing in the power lines.**

This is achieved by using transformers: a step-up transformer at the power station to boost the voltage and a step-down transformer at the consumer to reduce the voltage.

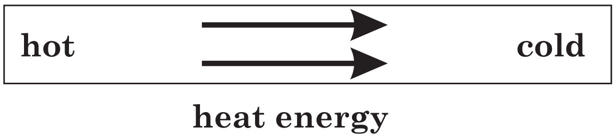
Section 4: HEAT in the HOME

Introduction.

Most of the energy used in the home is used to provide heating: heating water, cooking, heating the house. More than 75% of the energy we buy is spent directly on running heaters of one form or another. If we are serious about reducing energy consumption, then we must consider our use of heat.

Heat and Temperature.

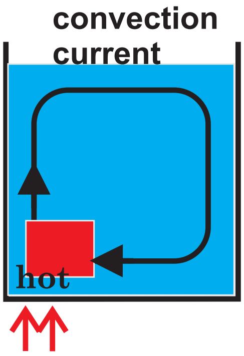
Heat is a form of energy and is measured in joules. Temperature is a scale of hotness and is measured in degrees Celsius (°C). Do not confuse the two!!
Heat energy travels naturally from a hot place to a colder place. If there is a temperature difference in a material, the heat energy will pass from the high to the low temperature.
Three processes can be identified in heat transfer. They are called conduction, convection and radiation.



Conduction

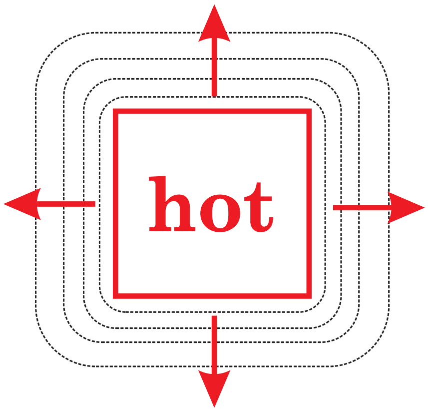
Conduction

Heat energy passes from atom to atom through a substance. It is a similar process to the conduction of electricity.
Conduction is the only way heat energy can pass through solids.
Metals, particularly copper and aluminium, are good conductors. Non metals are poor conductors; insulators.



Convection.

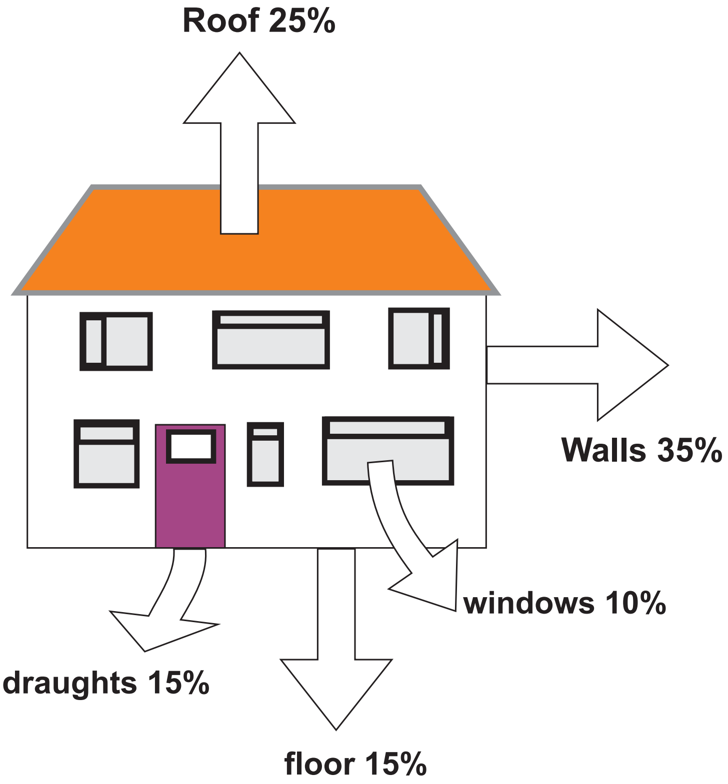
Gases and liquids are poor conductors (except for mercury). Instead, heat passes through gases and liquids in convection currents. Hot liquid or gas becomes less dense and rises. Colder liquid or gas flows in to replace it. A current is quickly set up, carrying heat to the rest of the substance.



Radiation

All hot objects emit infrared radiation. We can use it to take photographs of them (thermogram.)
When infrared radiation strikes a surface, it is absorbed and converted to heat energy. In this way heat energy is transferred from one object to another.
Black surfaces are the best emitters and absorbers of radiation.
Silvered surfaces are the poorest emitters and absorbers of radiation.
Infrared radiation is a form of light and can pass through a vacuum. Conduction and convection both require a material to carry heat energy.

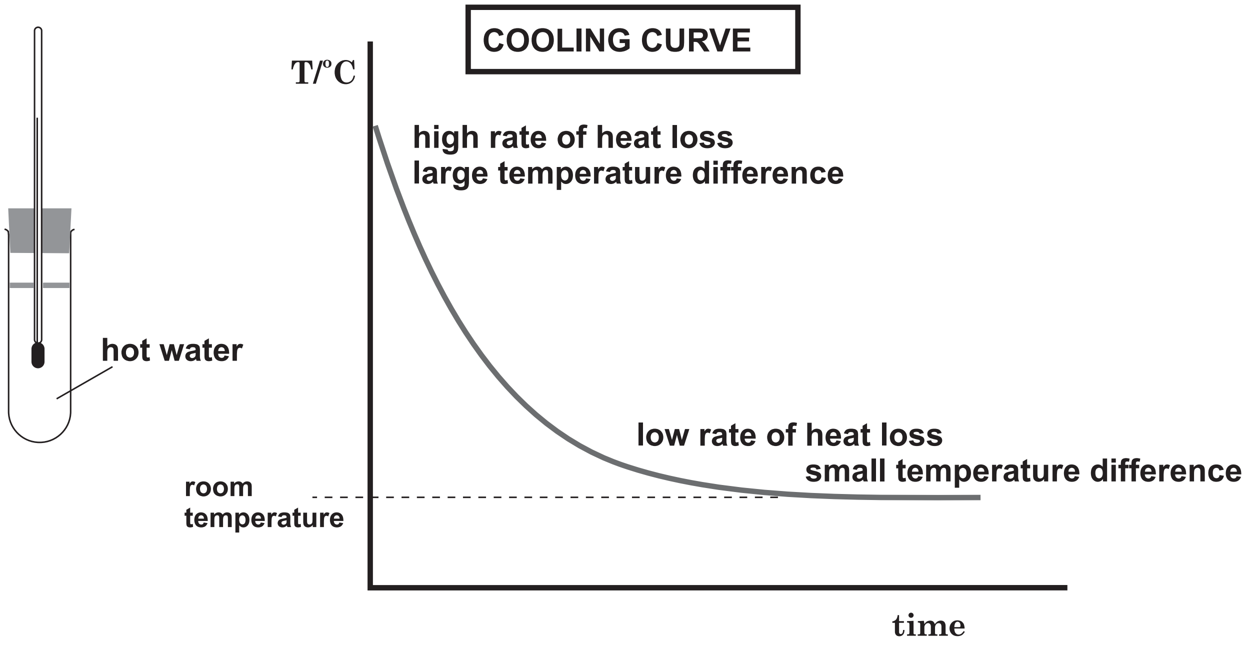
Section 4: HEAT in the HOME

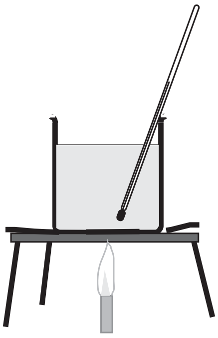


The quantity of heat lost in a given time depends on temperature difference. In winter, a house will lose heat quickly because of the temperature difference between the inside and outside. The temperature difference in the summer is small so the rate of loss of heat is low. If we need to keep a house warm, the heat energy lost to the outside has to be replaced by heaters. The faster it is lost the more often the heaters have to be turned on and the higher the cost.

Insulation reduces the rate at which heat is lost. It does not stop heat being lost. We can insulate a home by fitting **draught excluders** to doors and windows; laying **loft insulation** in the roof space; injecting **foam insulation** into the cavity between the walls; fitting **double glazing**; laying **carpets** and **lagging** our hot water tank. All these things cost money, and we need to consider whether the savings in energy cost are worth the outlay in money.

COOLING CURVE





Specific Heat Capacity.

When heat energy is added to a substance, its temperature rises. The temperature rise depends on the **quantity of energy** added, the **mass of the substance** and the **type of substance.**

The relationship between these factors can be expressed as;

$$\boxed{E_h = c.m.\Delta T}$$

Where; E_h = Quantity of heat energy added to the substance in joules.

m = mass of substance in kilograms

deltaT = change in temperature of the substance in °C

c = Specific Heat Capacity of the substance in Joules per kilogram.degree Celsius (J/kg.C)

Substance	Specific heat capacity in J/kgC
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Glycerol	2400
Ice	2100
Lead	128
Silica	1033
Water	4180

How much heat energy is required to change the temperature of 120 kg of water from 20°C to 80°C?

E_h = c.m.DT

= 4180 x 120 x 60

= 30096000 Joules

= 30.1 MJ

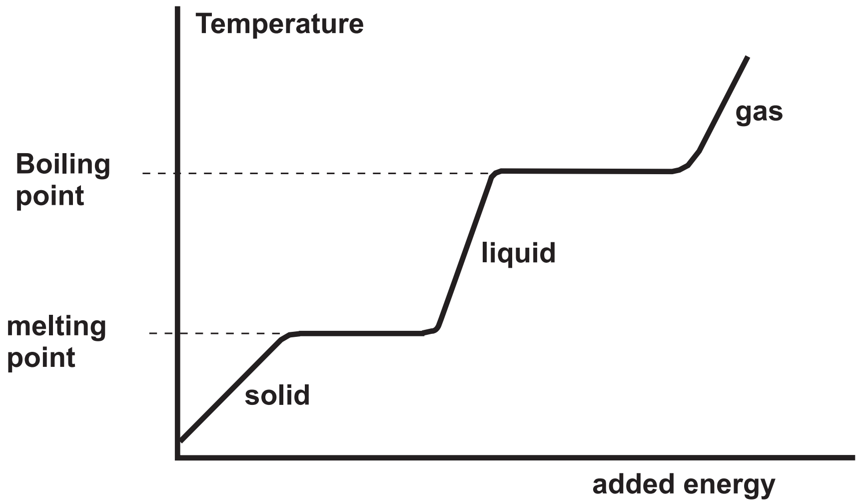
c = 4180 J/kg °C

m = 120 kg

DT = 80 -20

= 60°C

Normally, much more heat would be required as heat energy would be lost to cooler surroundings.



When a substance changes state: from a solid to a liquid or from a liquid to a gas, the temperature remains constant. Energy is required to change the state of a substance but this energy does not show up on the thermometer. This energy is called Latent Heat. Latent means hidden.

The quantity of heat energy gained or lost when one kilogram of a substance changes state is called the Specific Latent Heat. Most substances have two:

Specific Latent Heat of Fusion, L_F

Specific Latent Heat of Vaporisation, L_V

To find the quantity of energy gained or lost when changing state:

Energy = Specific Latent Heat x mass

$$\boxed{E_h = m.L}$$

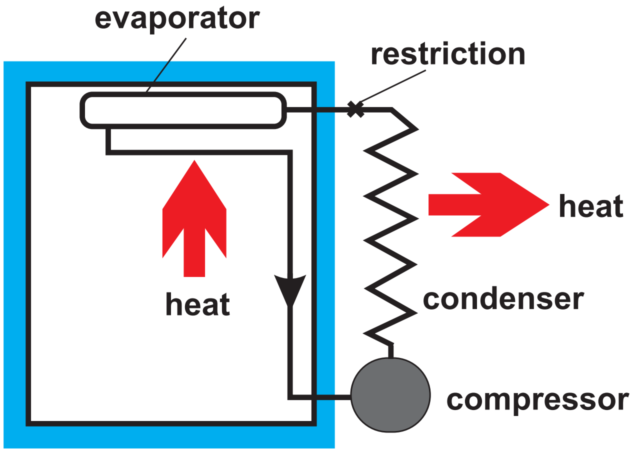
How much energy is required to melt 100 g of ice?

L_F for water = 3.34×10^5 J/kg

m = 100g
= 0.1 kg

$$E_h = L_F.m$$
$$= 3.34 \times 10^5 \times 0.1$$
$$= 3.34 \times 10^4$$
$$= \underline{33.4\ \text{kJ}}$$

Section 4: HEAT in the HOME



refrigerator

Refrigerator

The compressor pumps gas into the condenser.

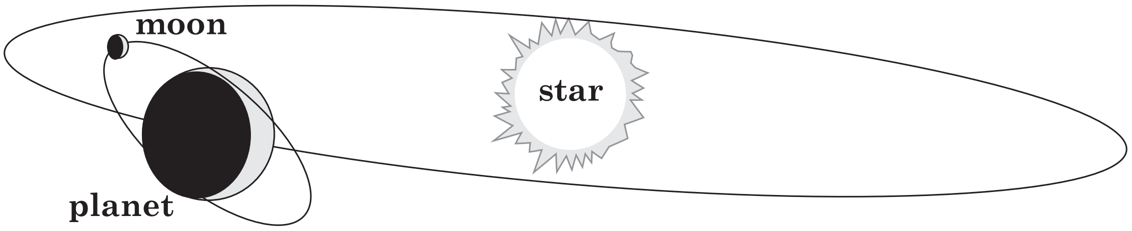
Some of the gas condenses into a liquid, releasing heat to the air. Once the liquid and gas pass the restriction, the pressure is reduced and the liquid evaporates in the evaporator, taking the required latent heat from inside the refrigerator Heat energy is thus moved from inside the refrigerator to the outside air.

Latent heat is often used to keep things cool. Plastic ice packs keep picnic boxes cool. We sweat when we are warm. The evaporation of the sweat from our bodies cools us down. The latent heat required to turn the sweat into water vapour is taken from our bodies.
Steam is used to make espresso coffee. The coffee is stored cold and heated using steam. The large amount of heat released by condensing steam means that only a small amount of extra water volume is created.

Space Physics

Summary Notes

Section	Content
1. Signals from space	Astronomical terms
	Refracting telescope
	Spectroscopy, invisible signals (the electromagnetic spectrum)
2. Space travel	Rockets
	Interplanetary flight
	Gravity and weightlessness
	Artificial satellites and projectiles
	Re-entry

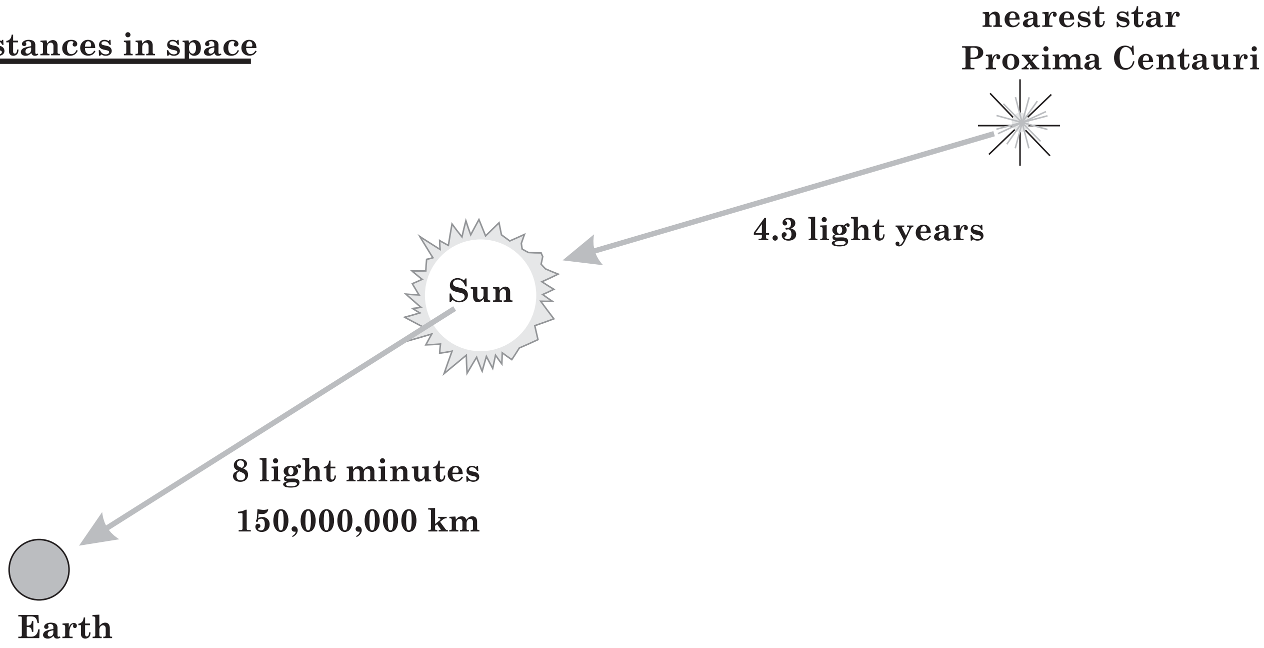


A star is a massive ball of gas. It is extremely hot due to the nuclear reactions taking place inside it. Stars radiate large amounts of energy in the form of electromagnetic radiation and radioactive particles.
A planet is a body which orbits a star. Moons orbit planets

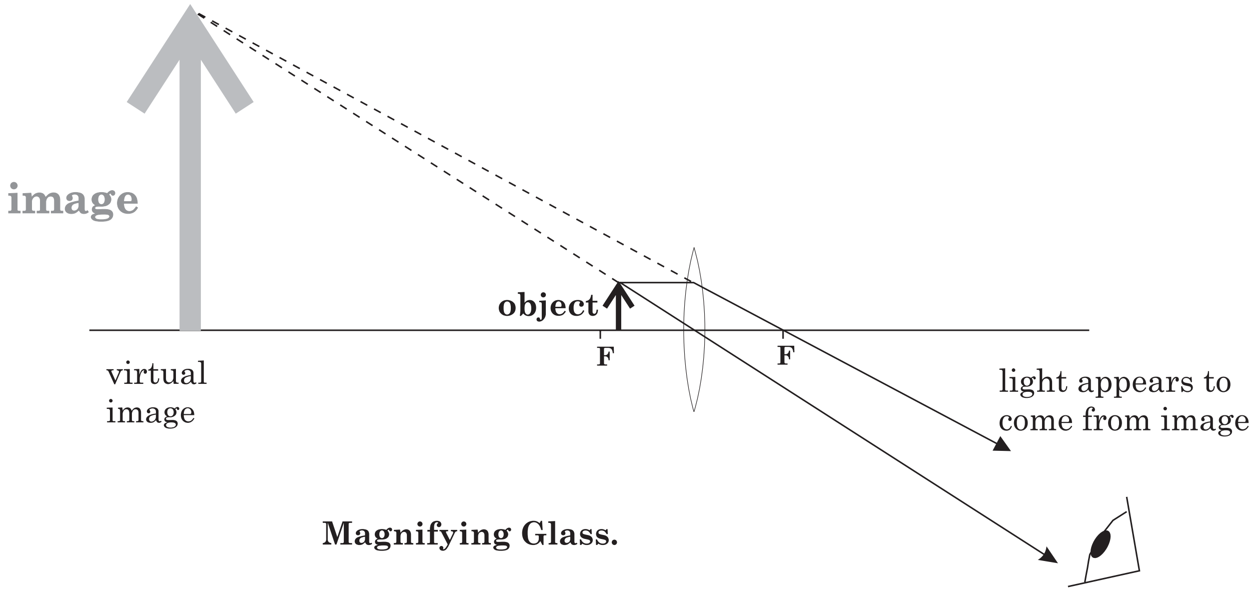
The Solar System

The Solar System consists of the Sun and all the bodies which orbit around it. There are nine major planets including Earth, and millions of minor planets (asteroids). Most of the planets have moons.
The Sun is our local star which is part of the Galaxy we call the Milky Way. The Sun lies at the outside edge of the Galaxy. There are millions of stars in the Galaxy and millions of other galaxies in the Universe.

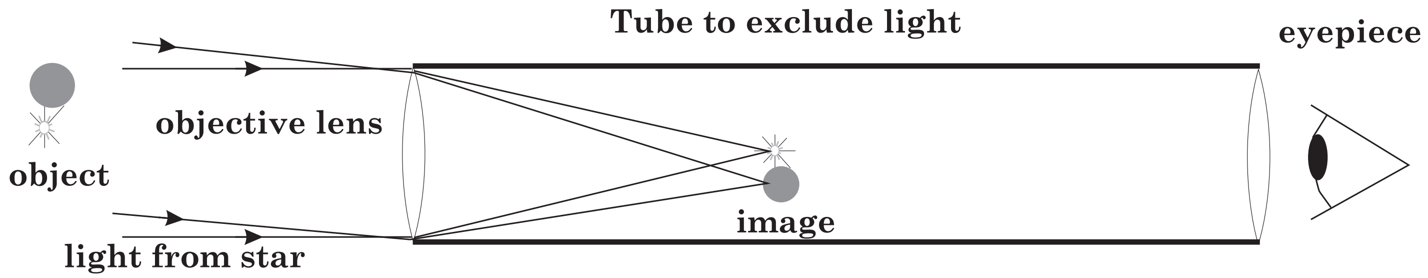
Distances in space



The distance between stars are enormous. We cannot measure them in Earth units as the results would be meaningless. Instead we use the time taken by light to travel the distance.
We measure distance in **light years (ly),** The distance covered by light in a year.
The Galaxy is 100,000 light years across. The Universe is maybe 20 million light years across.
This means that what we see in the night sky is history, events which happened millions of years ago; sometimes from before Earth existed.



Magnifying Glass.



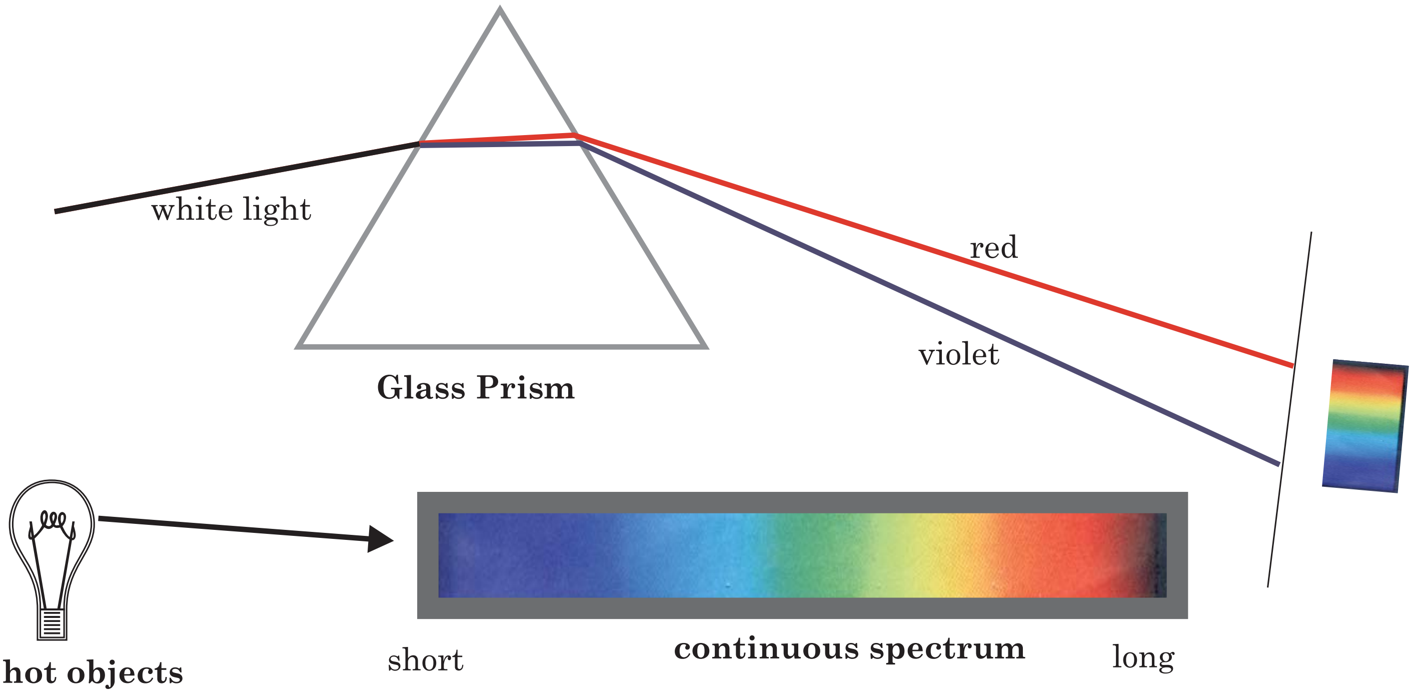
Astronomical Telescope

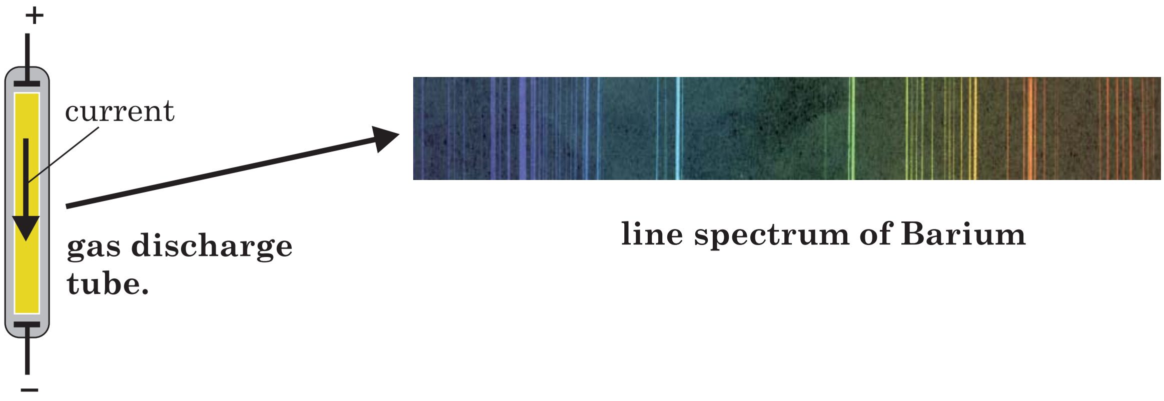
The Astronomical telescope consists of two convex lenses called the objective lens and the eyepiece.

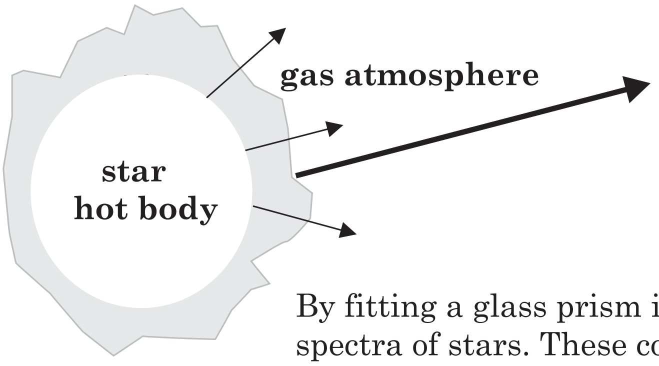
The objective lens forms an image of the object being viewed. The eyepiece acts as a magnifying glass and magnifies the image.

The objective lens projects an inverted image, so the observer sees a magnified inverted image. This is no real problem for astronomers but poses problems for use as a terrestrial telescope.

The brightness of the image depends on the diameter of the objective lens: the amount of light collected. The amount of light collected by the eye is limited to the size of the pupil. A telescope collects much more light than the pupil so it allows the observer to see objects which would otherwise be too faint to detect. The larger the diameter of the objective, the more easy it is to see faint objects.

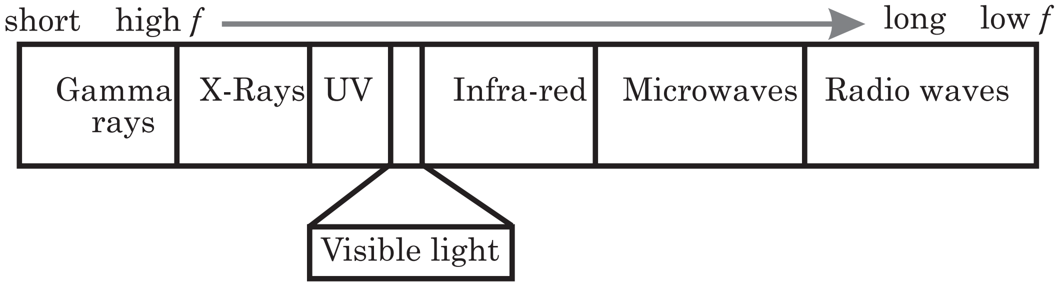






By fitting a glass prism in front of their telescopes, astronomers can record the spectra of stars. These consist of continuous spectra with hundreds of dark lines which are the absorption spectra of the gases in the star's atmosphere. Hot gases both emit and absorb light as line spectra. The absorbed lines show up where the bright line should be. From these lines, astronomers can work out what elements are present in the star's atmosphere.

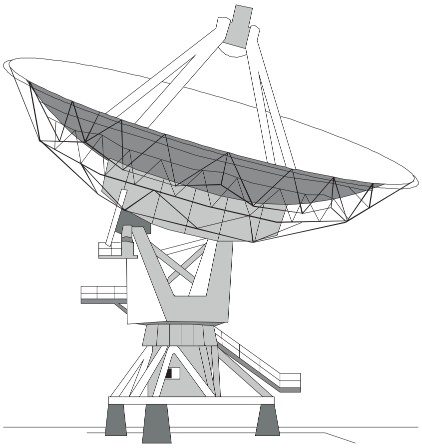
The electromagnetic spectrum



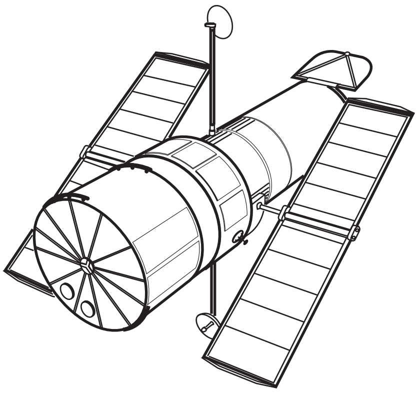
Radiation	Detector
Gamma rays	Film, Geiger counter, Scintillation counter.
X-Rays	Film
Ultra Violet	Film, Fluorescence.
Visible Light	Film, Photo-diode
Infra-red	Film, Photo-diode, Thermopile
Microwaves	Aerial
Radio waves	Aerial

All electromagnetic waves travel at 300,000,000 m/s ... the speed of light!

The whole spectrum of electromagnetic radiation exists in space. Only part of it, however, makes it through our atmosphere to ground level.
In addition to visible light, only microwaves can pass through the atmosphere.
Microwaves are observed using **Radio Telescopes.** These are commonly large dish aerials similar to satellite receivers or, more commonly now, arrays of smaller dish aerials.
Dust clouds in space hide 95% of the visible stars! Radio telescopes can see through these dust clouds



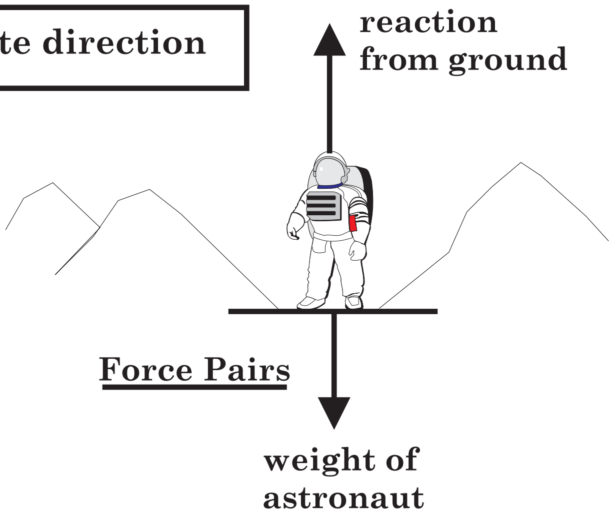
Radio telescopes observe microwave radiation.



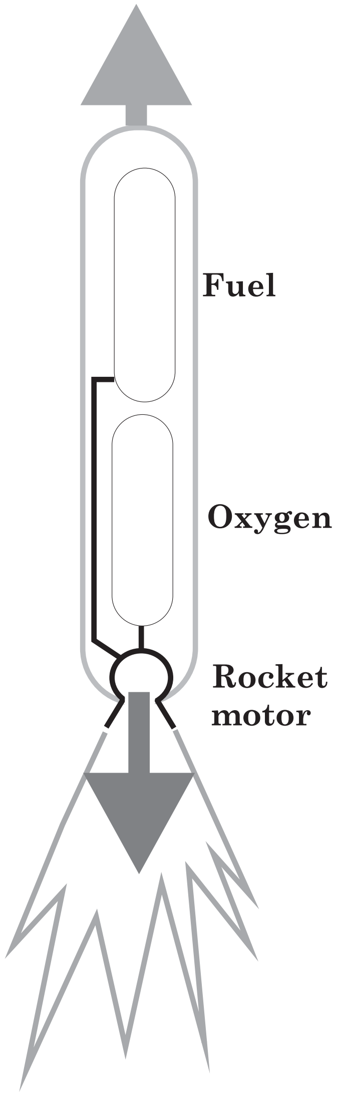
The Hubble space telescope can observe infra-red and X-rays which cannot be seen on Earth.
X-rays give a very detailed picture of the Universe.

Newton’s Third Law

$F_b = F_a$ **but acts in the opposite direction**

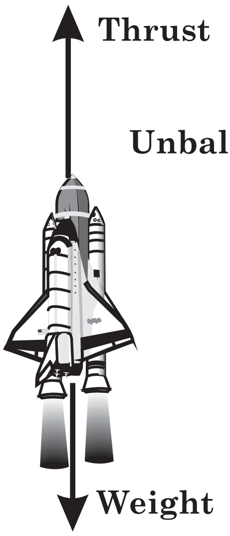


Newton’s Third Law states that forces are created in pairs by the interaction between two bodies. The forces are such that the force exerted by body A on body B is equal to, and opposite in direction to, the force exerted by body B on body A.
‘To every action there is an equal and opposite reaction’.



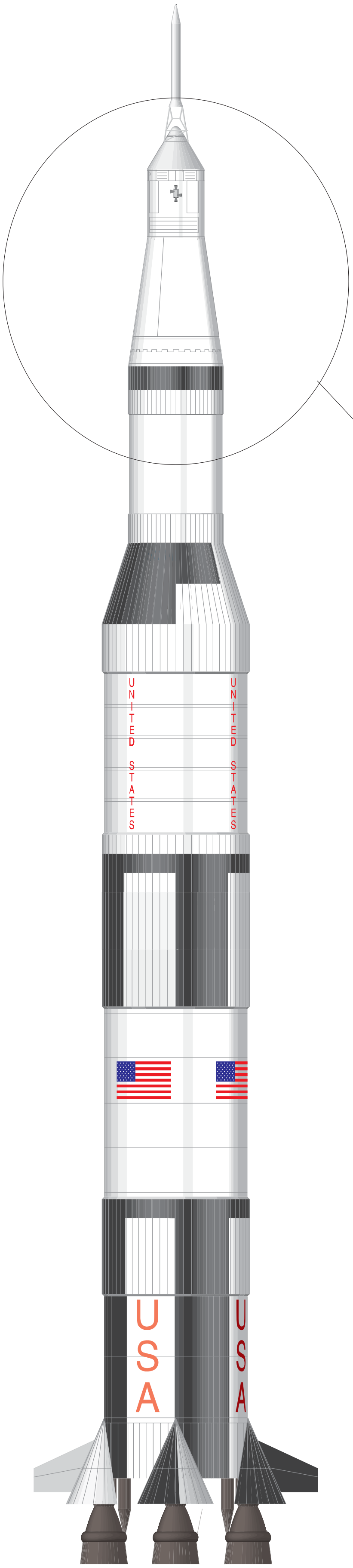
The Rocket

A rocket contains both fuel and the oxygen needed to burn it.
The fuel and oxygen are brought together in the rocket motor and ignited causing a continuous explosion.
The force exerted by the motor to push the exhaust gases out the tail creates an equal force pushing the rocket in the opposite direction.
As the rocket carries its own oxygen supply, it can operate in the vacuum of space.
During a rocket flight, both fuel and oxygen are quickly used up. The force exerted by the motor remains the same but acts on a rocket with reducing mass and weight. This means the acceleration of a rocket increases with time and is not constant.



Unbalanced Force = Thrust -Weight

$$F = T - W$$

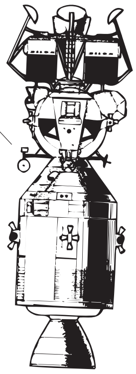


SATURN V

Space Flight.

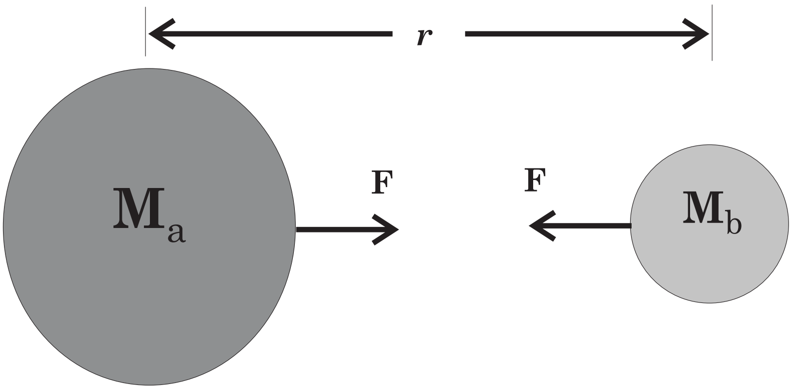
The Moon is the only other world visited by man. The journey covered a distance of approximately 300,000 kilometres . A massive Saturn V rocket was used to lift the lunar vehicle (Apollo) into Earth orbit. The bulk of the rocket was jettisoned, leaving a smaller rocket to take the lunar vehicle to the Moon. This involved turning the rocket motors on for a short time to speed the vehicle out of orbit and towards the Moon. Once on its way, the rockets were turned off and the vehicle coasted at a constant speed. There is no air resistance in the vacuum of space to slow the lunar vehicle down.

Once in orbit round the Moon, the lunar vehicle split in two and part of it landed on the Moon.



Lunar Vehicle

A space vehicle needs a large amount of kinetic energy to escape Earth’s gravity. This requires large amounts of rocket fuel. Once free of Earth’s gravity, a space vehicle can coast for ever at high speed without using any fuel at all.



$$F = \frac{G\,M_a M_b}{r^2}$$

Gravity is a force of attraction between masses. It depends on the masses involved and the distance between them. The force decreases as the distance apart increases.
The force of gravity decreases the further we travel from Earth.
On the surface it is 10 N/kg; 6500 km above the Earth it is only 2.5 N/kg.

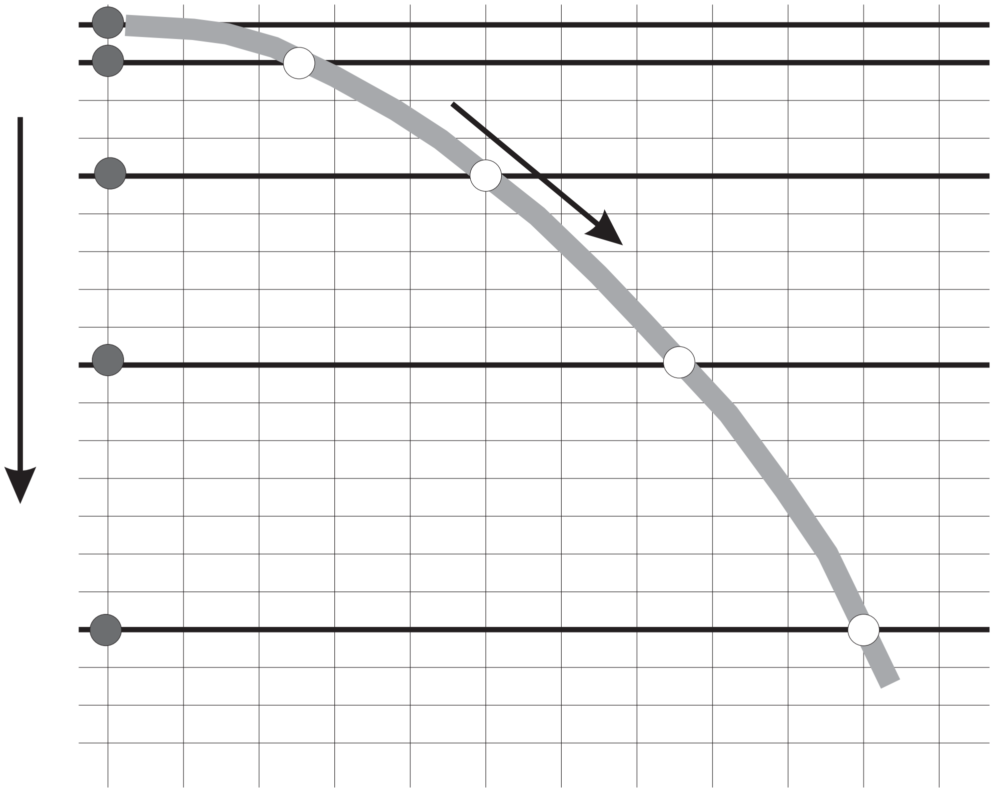
Planet	**Gravitational Field Strength N/Kg**
Earth	**10**
Jupiter	**26**
Mars	**3.7**
Mercury	**3.7**
Moon	**1.6**
Neptune	**12**
Saturn	**11**
Venus	**9**

The planets in the solar system have different masses and diameters. The gravitational field strengths on their surfaces are different. The table opposite shows the approximate values.
The weight of an object changes as it moves from planet to planet. Its mass remains the same.

The gravitational field strength and the acceleration due to gravity are the same, so they are both designated by '*g*' .

F = *ma* : 1 newton = 1 kg x 1 metre per second squared

force/mass = acceleration



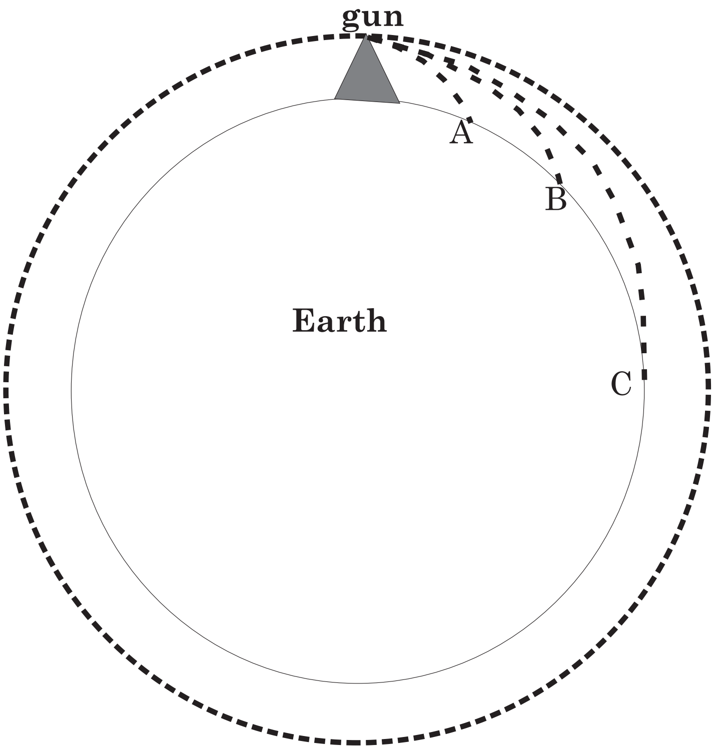
Projectile motion is the motion of an object under the influence of gravity. It describes the motion of objects, like stones or rocks, dropped or thrown into the air.
Once projected, the only force acting on the object is gravity and air resistance. We usually ignore air resistance.
All projectiles are accelerated vertically towards Earth with an acceleration of 10 m/s^2.
As shown above, an object projected horizontally falls vertically at the same time as it is moving horizontally. It falls in a curve called a parabola.
The motion in the vertical direction is the same as if it had simply been dropped.

To work on projectile motion, we consider the HORIZONTAL movement and the VERTICAL movement separately.

In the absence of air resistance, the horizontal speed stays constant.

The vertical speed is affected by gravity and increases at the rate of 10 m/s every second.

At any point in the object's journey, its speed is found by combining both horizontal and vertical speeds. (Note: this is 'Higher' work)

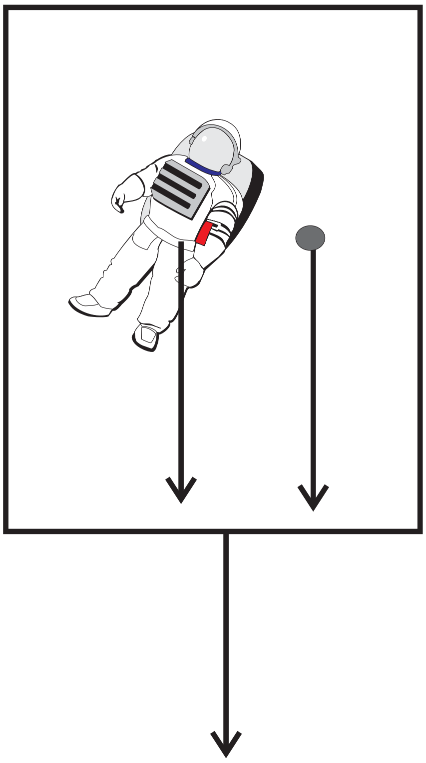


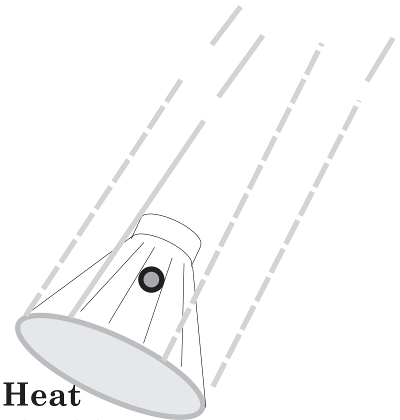
Newton's thought experiment.

Imagine a powerful gun mounted on a high mountain just above the atmosphere.
When the gun is fired, the shell lands at A. More powder is used and the shell given a greater speed, landing at B. More speed and it lands at C. Eventually, with enough speed it will fall right round the Earth. It will be in orbit, a satellite.

Satellites are **FALLING** round the Earth. Moving with high speeds which allow them to fall round the Earth and miss it each time. With no air resistance in space, there is nothing to slow them down.
To come back to Earth, the satellite slows down. If it wants to move further out, it speeds up.

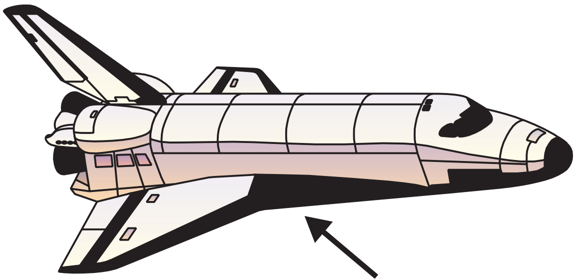
Astronauts in satellites are still affected by gravity, but as they are falling with the satellite, they lose the sensation of Weight. If they let go of an object, it does not fall to the floor as it is already falling like the astronaut and the satellite. The object will appear to float in space with the astronaut.
Weightlessness is an effect of free fall.
The astronauts are not without weight but they have lost the sensation of weight.





Re-Entry

Capsules re-entering the atmosphere are travelling at very high speeds. To slow down to a low enough speed to use parachutes, they have to lose an enormous amount of kinetic energy. They do this through friction with the atmosphere. Friction generates heat. To protect the capsule against overheating it is fitted with a special heat shield which absorbs the heat energy by melting.



The Space Shuttle has the same re-entry problem as the older capsules. However it does not use the same type of heat shield, Instead, the underside of the shuttle is lined with special silicon tiles which heat up on re-entry but are such poor conductors that little heat is transferred to the shuttle.