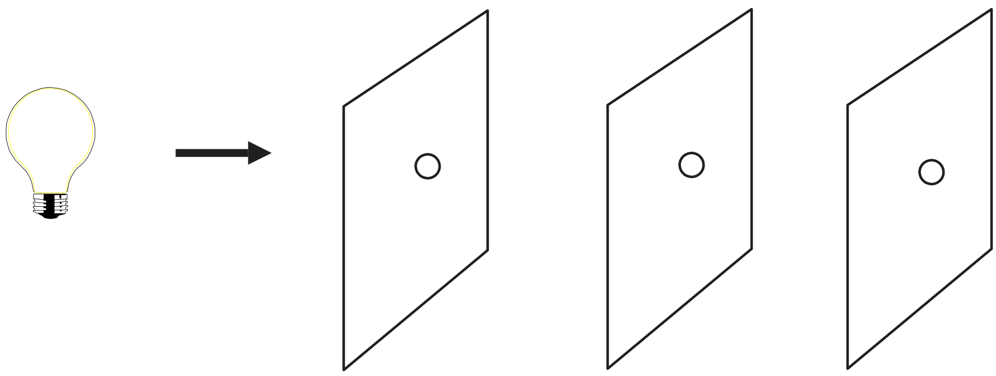
CONTENTS

PHYSICS
LIGHT

By Harry Jivenmukta

LIGHT - INTRODUCTION

Light travels in straight lines. This can be seen by looking at shadows. When a shadow falls across a straight lined object the shadow is always as straight as the shape which obstructs the light. Another way to realise this fact is to try an experiment.



Shining a light, place pieces of cardboard with a small hole cut out, at intervals. Make sure that the small holes in the cardboard pieces are in the same place and lined up. Thread a piece of string through the holes to line them up. When you look through the holes you can see the light. If you move the cardboard pieces out of line, the light will be blocked and will not show.

There were two historical viewpoints about what light is and how it travels. Sir Issac Newton thought that light was a stream of tiny particles which travelled in a straight line. The Dutch physicist, Huygens, thought that light was made up of waves. Traditionally, scientists believed that Huygens theory was correct but there is some proof today that light is made up of tiny packets of energy called Photons which travel along in a wave like way.

Questions...

1. What is light and how important is it to humans?
2. What proof can you give to show that light travels in straight lines?
3. Find out what the following words mean and give examples:

Self Luminous,

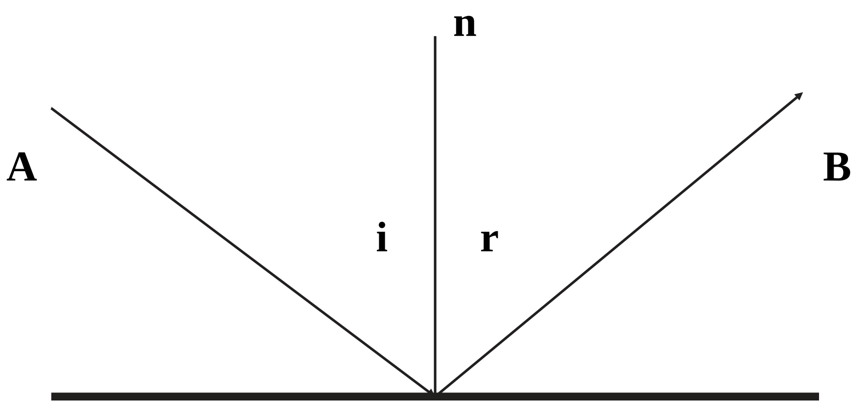
Shadow,

Refraction,

Dispersion.

REFLECTION

Physicists call the light which falls on a reflective surface **the incident ray** and the reflection is called **the reflected ray**. The point at which the ray falls on the reflective surface is called **the point of incidence**.



Reflective Surface

In the example shown above, the incident ray is the one marked 'A', and the reflected ray is the one marked 'B'. Sometimes you may be asked what the **angle of incidence** is or the **angle of reflection**. These are the angles which are formed between the normal, expressed as 'n', and the surface. Angles of the rays of incidence and reflection are marked above by 'i' and 'r'.

The laws of reflection are:

The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

The angle of incidence is equal to the angle of reflection.

Questions...

1. Define reflection.
2. Draw a picture to illustrate reflection.
3. Make a list of reflective surfaces and list them in order of greatest reflection.
4. What do the following words mean:

incident,

ray, (in physics terms),

experiment.

MIRRORS - INTRODUCTION

The typical mirror is a sheet of glass that is coated on its back with aluminium or silver that produces images by reflection.

The mirrors used in ancient times and in the Middle Ages were simply disks of metal, either bronze, tin, or silver, that reflected light off their polished surfaces. A method of backing a plate of flat glass with a thin sheet of reflecting metal came into production in Venice in the 16th century; a mixture of tin and mercury was the metal used. The chemical process of coating a glass surface with metallic silver was discovered in 1835, and this advance started the modern techniques of mirror making. Present-day mirrors are made by spreading a thin layer of molten aluminium or silver onto the back of a plate of glass in a vacuum.

When light falls on a body three things happen to the light:

- some of the light may be reflected,
- some absorbed,
- some transmitted through the body of the reflecting object.

In order for a smooth surface to act as a mirror, it must reflect as much of the light as possible and must transmit and absorb as little as possible. In order to reflect light rays without scattering or diffusing them, a mirror's surface must be perfectly smooth or its irregularities must be smaller than the wavelength of the light being reflected. Mirrors may have plane or curved surfaces. A curved mirror is **concave** or **convex** depending on whether the reflecting surface faces toward the centre of curvature or away from it. Curved mirrors can include:

Spherical mirrors which produce images that are magnified or reduced; e.g. mirrors for applying make-up and rear view mirrors for cars.

Cylindrical mirrors focus a parallel beam of light to a line focus.

A **paraboloidal** mirror may be used to focus parallel rays to a real focus, as in a telescope mirror, or to produce a parallel beam as in a searchlight.

An **ellipsoidal** mirror will reflect light from one of its two focal points to the other.

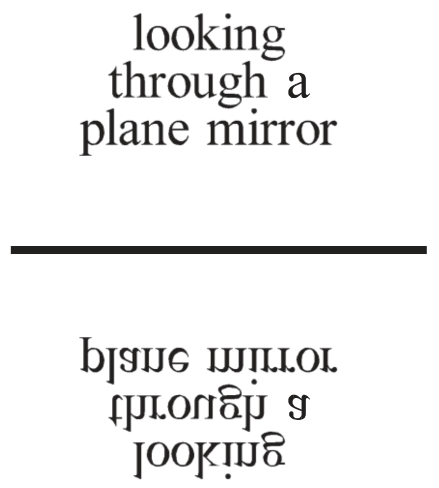
Questions...

1. Write in a short paragraph how mirrors are made.
2. List some of the more important uses of mirrors.
3. Find out more about the types and uses of curved mirrors.

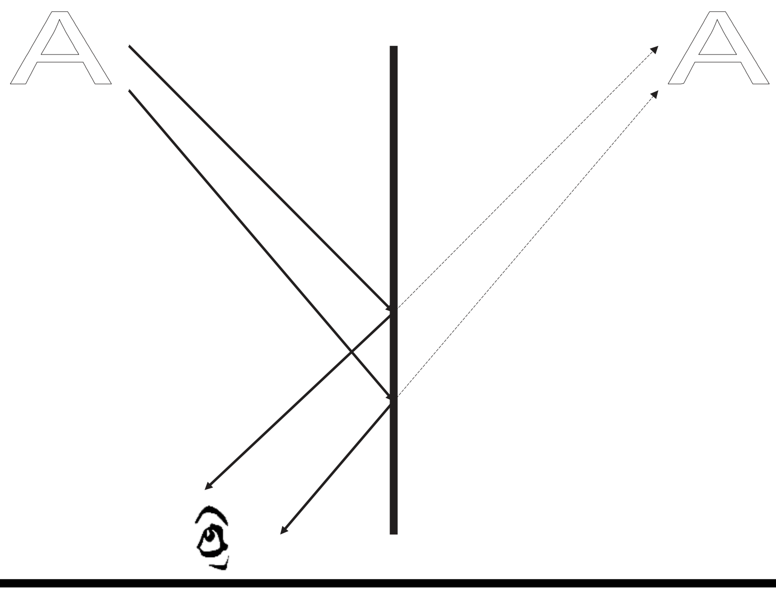
MIRRORS - REFLECTION

The image formed in a plane mirror is an exact copy but inverted. The example shows a picture with writing which has been reflected in a mirror below the original. If it were on one side then the words would be upright but the wrong way round. When you reflect something in a plane mirror the image:

- is the same size as the object,
- is the same distance behind the mirror as the object is in front of it,
- inverted.



The illustration below shows how the eye sees a reflection in a plane mirror and how the object is reflected. Can you work out how the eye would see the image(s) if there were two mirrors at right angles to each other?



Questions...

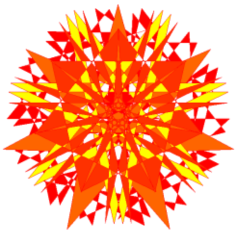
1. Decipher the words opposite without using a mirror.

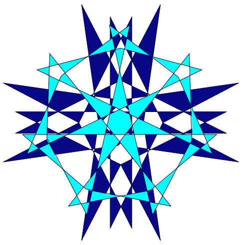
2. Think of times when signs are deliberately written so that they appear correct when read through a mirror

MIRRORS - REFLECTION

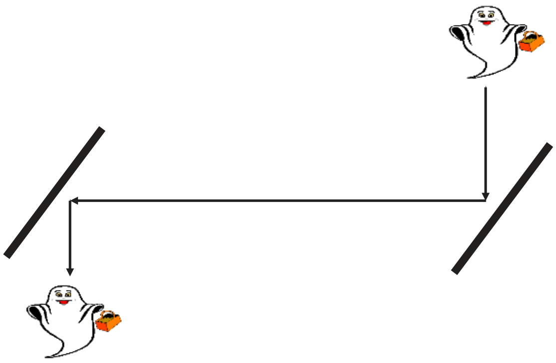
If you place two mirrors parallel to each other with an object in the middle the number of images formed are seemingly infinite because the mirrors reflect each others images on and on. Get two mirrors and try it. However, some light energy is absorbed by even the most perfect mirror and the images do in fact become less bright the more times they are reflected.

Using mirrors to see things in unusual ways can be seen in the use of a kaleidoscope. Two mirrors facing each other are placed at about 60^0 to each other in a tube. Bits of coloured glass or other shiny fragments are dropped in the tube between the mirrors. They reflect each fragment six times to form a hexagon and hence a pattern. They would reflect in different ways if the angles of the mirrors to each other were different.





In drama and plays, mirrors can be very effective in creating haunting or UFO type scenes. A large mirror can be placed in the middle of the stage at 45^0 pointing out into the audience. Another mirror can be placed at 45^0 at one end of the stage pointing behind the stage. The 'ghost' or apparition can then be acted out behind the scenes and look as if it is real to the audience.



Questions...

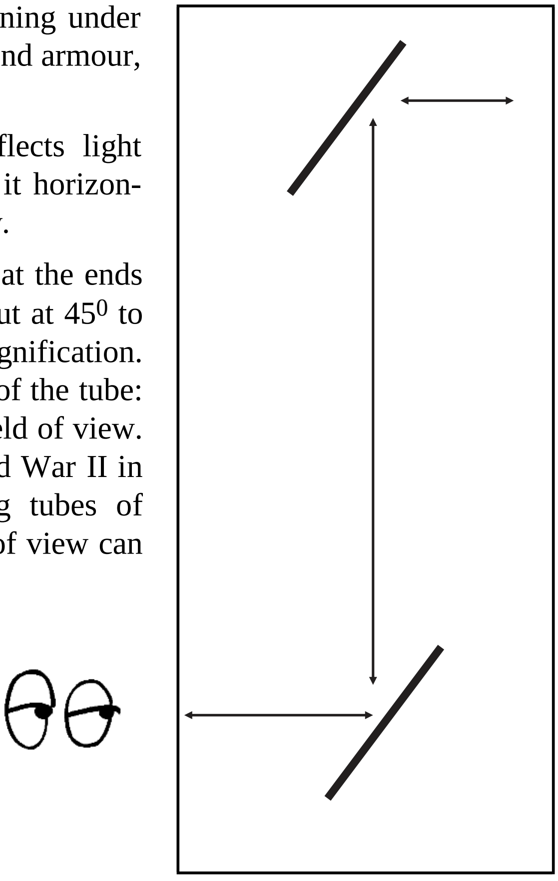
1. There are other ways in which mirrors can be used to make special effects. Find out about these.
2. Draw a picture of a kaleidoscope and outline what qualities a good kaleidoscope should have.
3. Explain why the images created by two parallel mirrors would not be reflected infinitely.

A PERISCOPE

A periscope is an optical instrument used to enable an observer to see his or her surroundings while remaining under cover; in wars it would be for remaining behind armour, or submerged.

A periscope includes two mirrors. the first deflects light down through a vertical tube, the second diverts it horizontally so that the scene can be viewed conveniently.

The simplest type of periscope consists of a tube at the ends of which are two mirrors, parallel to each other but at 45^0 to the axis of the tube. This device produces no magnification. The arc of vision is limited by the size and shape of the tube: the longer or narrower the tube, the smaller the field of view. Periscopes of this type were widely used in World War II in tanks and other armoured vehicles. By making tubes of rectangular cross section, wide, horizontal fields of view can be obtained.

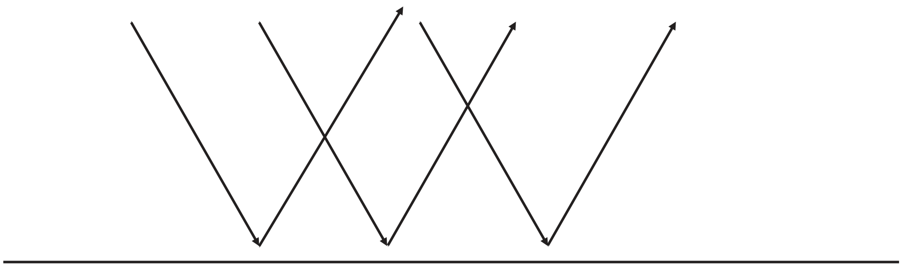


Questions...

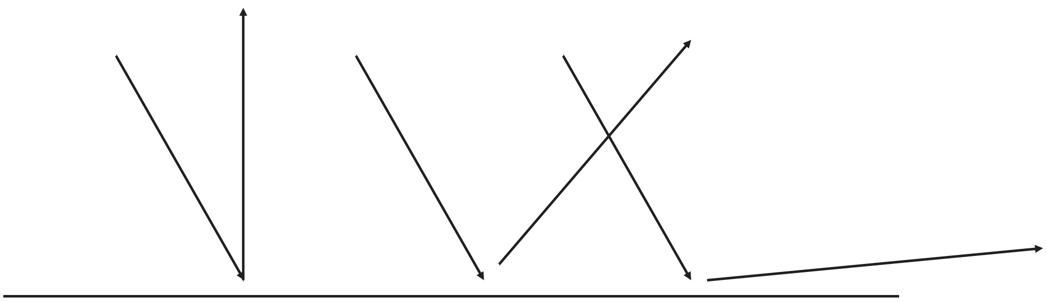
1. What is a periscope?
2. How might a periscope be useful? Make a list.
3. What does magnification mean? How could a periscope be made which could magnify the image?
4. Make a simple periscope. Write an instruction page on how the periscope is made and the materials required so that someone who did not know what a periscope was could make it.

REFLECTION - SURFACES

Mirrors can reflect in different ways depending on their shape and quality of manufacture. In physics there are two basic types of reflection which you need to understand; **regular reflection** and **diffuse reflection**. With regular reflection the image is reflected very crisply and clearly back and the image is a 'true' reflection of the object.



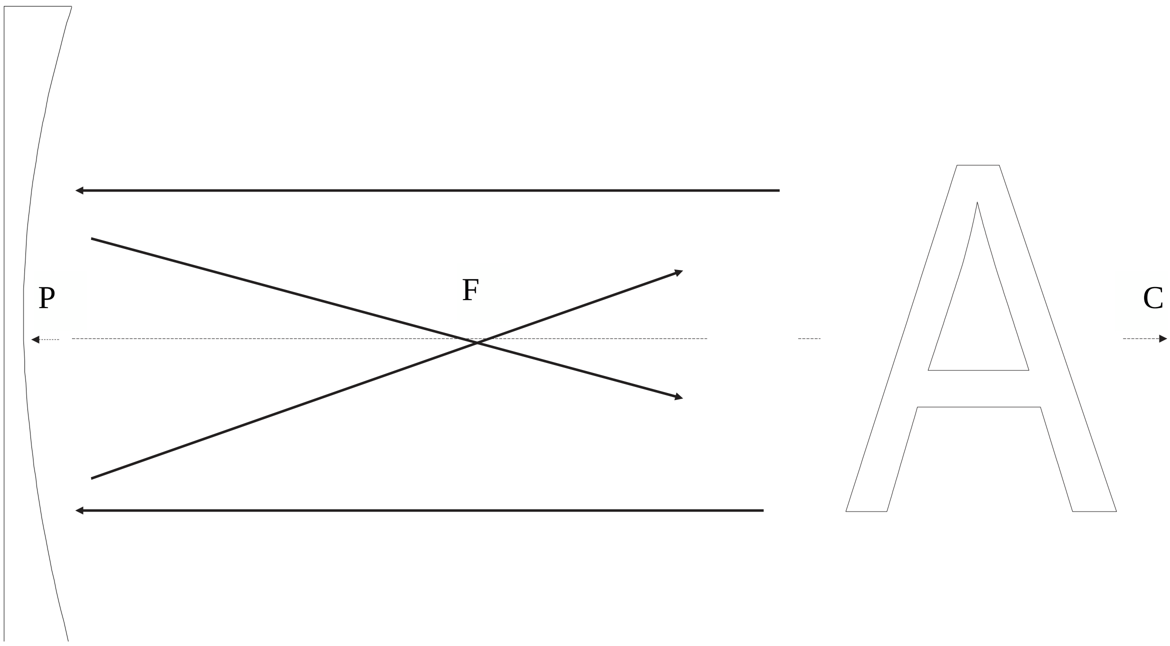
With a diffuse reflection the surface of the reflecting material is such that it has tiny irregularities on its surface so that when the ray hits the surface it is not properly reflected. In some cases the rays are very diffused indeed. Try an experiment where you shine light on different surfaces. See how some surfaces reflect quite well whilst others, like paper, do not reflect but diffuse the light.



Questions...

1. Think of examples where very good quality plane mirrors are useful.
2. When might diffusing reflecting surfaces be used?
3. Make a list of surfaces which diffuse light.
4. Which surfaces diffuse light the most?
5. Which surfaces absorb all or almost all the light shined on them?

A CONCAVE MIRROR



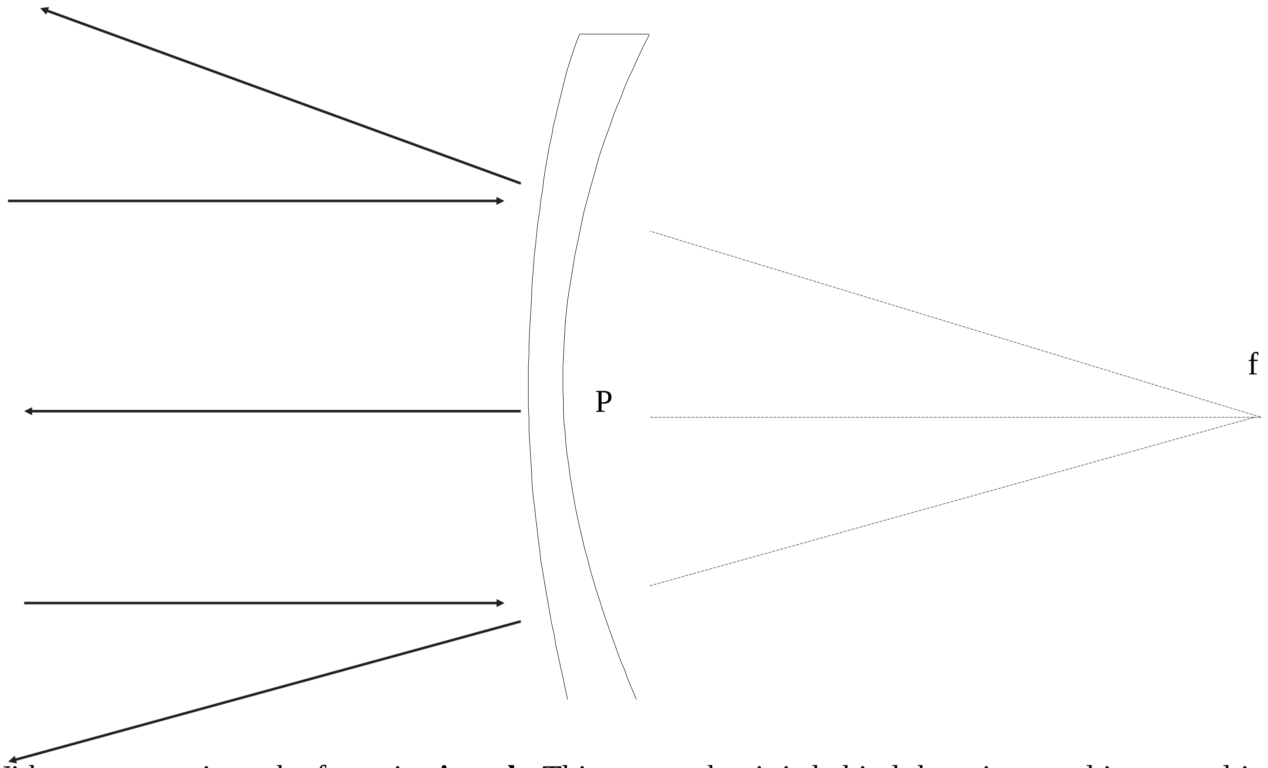
When you look at a concave mirror the image will be inverted, (seen upside down). This is because the rays are reflected as in the example shown above. The top of the image is reflected downwards and the bottom reflected upwards. Where the two reflected rays meet is called the **principal focus**. If you look before the rays meet you will still see the image the right way up, but it will be smaller as the rays are coming together. At the focal point the image crosses over and is seen upside down. The further away you are the bigger the upside image will become.

There is also an invisible line which runs from the centre of the mirror to the centre of curvature. If you imagine the curve of the mirror continued until it became a circle then the centre of that circle is called the **centre of curvature**. If you draw a line from the centre of curvature to the centre of the mirror that line is called the **principal axis**. The distance from the centre 'C' to the middle of the mirror or **pole** 'P' is called the radius of curvature or expressed as the distance 'CP'.'

Questions...

1. What happens to the focal length when the mirror is more concave than the one illustrated?
2. Draw you own illustration showing this.
3. What practical uses do concave mirrors have?

A CONVEX MIRROR



With a convex mirror the focus is **virtual**. This means that it is behind the mirror and is not real in the same way as a focus in front of a mirror is. The rays hit the convex mirror and are reflected off wider. The effect of this is to magnify the image.

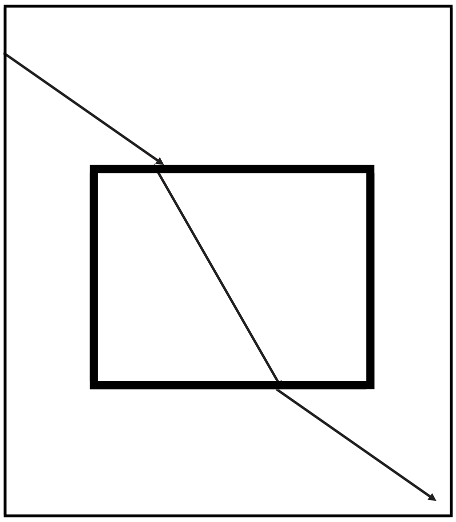
The definition which applies to spherical mirrors can be summarised as follows:

- The principal focus of a spherical mirror is that point on the principal axis to which all rays originally parallel and close to the principal axis converge, or from which they appear to diverge, after reflection from the mirror.
- The focal length 'f' of a spherical mirror is the distance between the pole of the mirror and the principal focus.

Questions...

1. What is the difference between a **real focus** and a **virtual focus**?
2. Will the focus always appear as virtual with a convex mirror? Why?
3. What practical uses do convex mirrors have?

REFRACTION



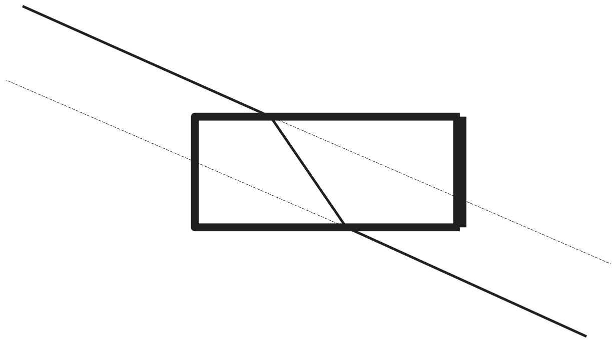
Refraction is the change in direction of a wave passing from one medium to another caused by its change in speed.

The light waves are refracted when crossing the boundary from one transparent medium to another because of their change in speed. A straight stick appears bent when partly immersed in water and viewed at an angle to the surface other than 90^0. A ray of light of one wavelength, or colour (different wavelengths appear as different colours to the human eye), in passing from air to glass is refracted, or bent, by an amount that depends on its speed in air and glass, the two speeds depending on the wavelength. A ray of sunlight is composed of many wavelengths that in combination appear to be colourless; upon entering a glass prism, the different refractions of the various wavelengths spread them apart as in a rainbow.

The law governing how light refracts is called **Snell's Law of Refraction**. It states:

- The incident and the refracted ray are on opposite sides of the normal at the point on incidence and all three are on the same plane.
- The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

Remember that the ray coming towards the surface is the incident ray and the refracted ray is the one which passes through the object. The 'normal' mentioned is an imaginary 90^0 vertical line which is drawn and crosses the point at which the incident ray hits the object. The refracted angle will always run parallel to the incident angle but at a different level.



Questions...

1. What is refraction?
2. Do all transparent surfaces refract light in the same way? Why?
3. What happens when sunlight is passed through a glass prism?

A MIRAGE

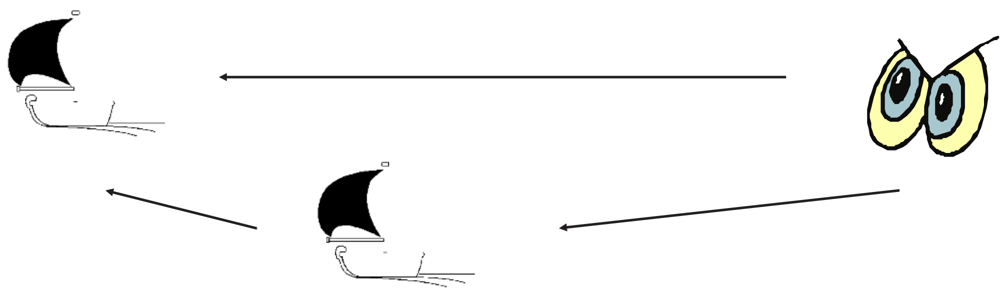
A mirage is when you see something which appears to be real but is not. Often people talk about seeing things in deserts or other hot places and it is usually the heat which causes a mirage to appear.

A mirage is:

- the deceptive appearance of a distant object or objects caused by the bending of light rays (refraction) in layers of air of varying density.

Under certain conditions, such as over a stretch of pavement or desert air heated by intense sunshine, the air rapidly cools with elevation and therefore increases in density and refractive power. Sunlight reflected downward from the upper portion of an object will be directed through the cool air in the normal way; although the light would not be seen ordinarily because of the angle, it curves upward after it enters the hot air near the ground, thus being refracted to the observer's eye as though it originated below the heated surface. An image is seen also because some of the reflected rays enter the eye in a straight line without being refracted. The double image seems to be that of the object and its upside-down reflection in water. When the sky is the object of the mirage, the land is mistaken for a lake or sheet of water.

Sometimes, as over a body of water, a cool, dense layer of air is under a heated layer. An opposite phenomenon will then occur in which light rays will reach the eye that were originally directed above the line of sight. Thus, an object ordinarily out of view, like a boat below the horizon, will be apparently lifted into the sky. This phenomenon is called **looming**.



Questions...

1. Explain, in your own words, what a mirage is.
2. Draw an illustration and explain how someone walking in a desert might see a mirage.
3. Explain the phenomenon of looming.

LENSES

A lens is a piece of glass or other transparent substance that is used to form an image of an object by focusing rays of light from the object. A lens is a piece of transparent material, usually circular in shape, with two polished surfaces, either or both of which is curved and may be either convex (bulging) or concave (depressed). The curves are almost always spherical, i.e., the radius of curvature is constant. A lens has the valuable property of forming images of objects situated in front of it. Single lenses are used in:

- eyeglasses, contact lenses,
- pocket magnifiers,
- projection condensers,
- signal lights,
- viewfinders, and on simple box cameras.

More often a number of lenses made of different materials are combined together as a compound lens in a tube to permit the correction of abnormalities. Compound lenses are used in such instruments as cameras, microscopes, and telescopes.

A lens produces its focusing effect because light travels more slowly in the lens than in the surrounding air, so that refraction, a bending of a light beam occurs both where the beam enters the lens and where it emerges from the lens into the air.

A single lens has two precisely regular opposite sur- faces; either both surfaces are curved, or one is curved and one is plane. Because of the curvature of the lens surfaces, different rays of an incident light beam are refracted through different angles, so that an entire beam of parallel rays can be caused to converge on, or to appear to diverge from, a single point. This point is called the focal point, or principal focus.

Questions...

1. A magnifying glass is one of the most popular type of lens we see in everyday life. What use does it have and how does it work?

2. Think of other types of lenses we see every day. Make a list.

3. What materials are lenses made of? Why are different materials used?

TYPES OF LENSES

There are many types of lenses but all lenses are a combination, variation, or adaptation of these six lenses. Below you can see the names of these six lenses. They are mixed up. Find out and correctly label the lenses:

PLANO-CONCAVE

BI-CONVEX

CONVERGING MENISCUS

BI-CONCAVE

PLANO-CONVEX

DIVERGING MENISCUS

The top and bottom groups of three lenses also have a collective name. Find out which name belongs to which group:

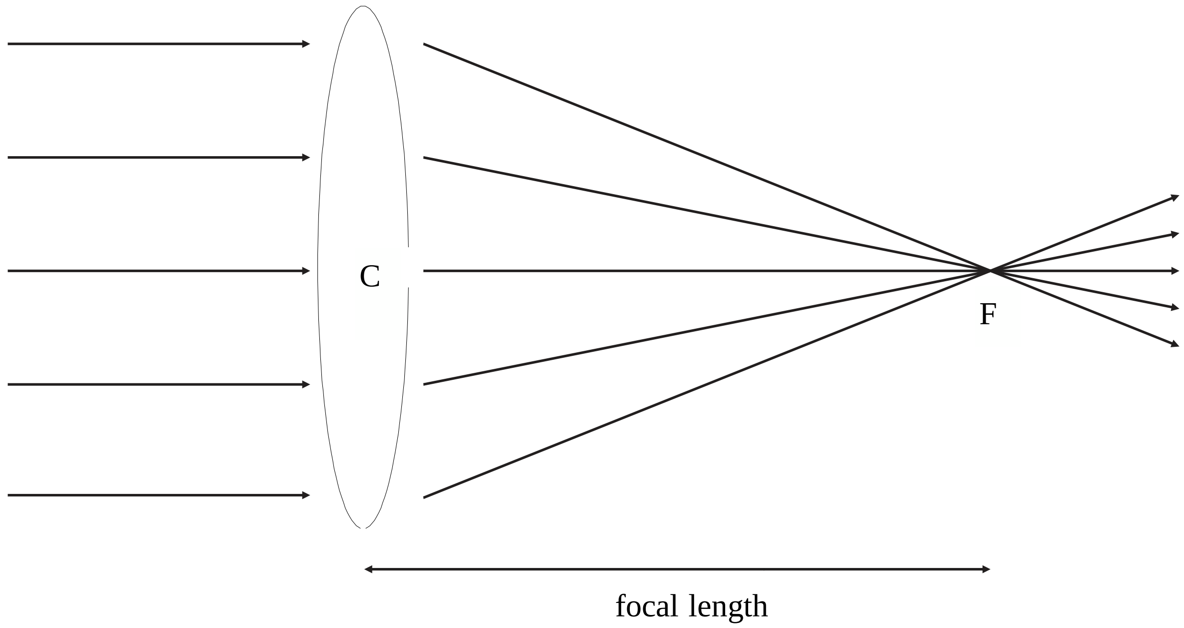
CONVERGING LENSES

DIVERGING LENSES

Questions...

1. Find out and list the types of lenses used in making spectacles.
2. What is the difference between concave and convex lenses and how does their use differ?

CONVERGING LENS



A converging lens is the same as a magnifying glass. The image which it forms is:

- the same way up as the object,
- magnified,
- virtual,
- on the same side of the lens as the object.

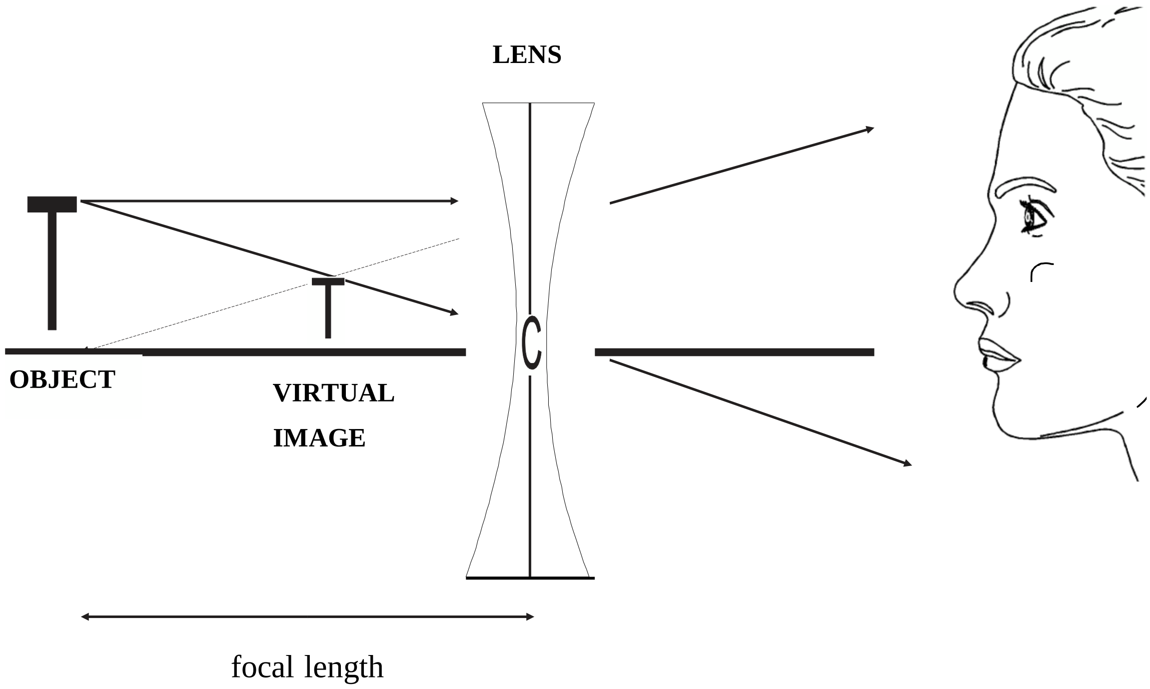
Questions...

1. What does virtual mean?
2. Why is the image on the same side as the object?
3. Think of uses which such lenses have. Make a list.
4. What is the difference between a simple converging lens and;

a microscope,

a telescope?

DIVERGING LENS



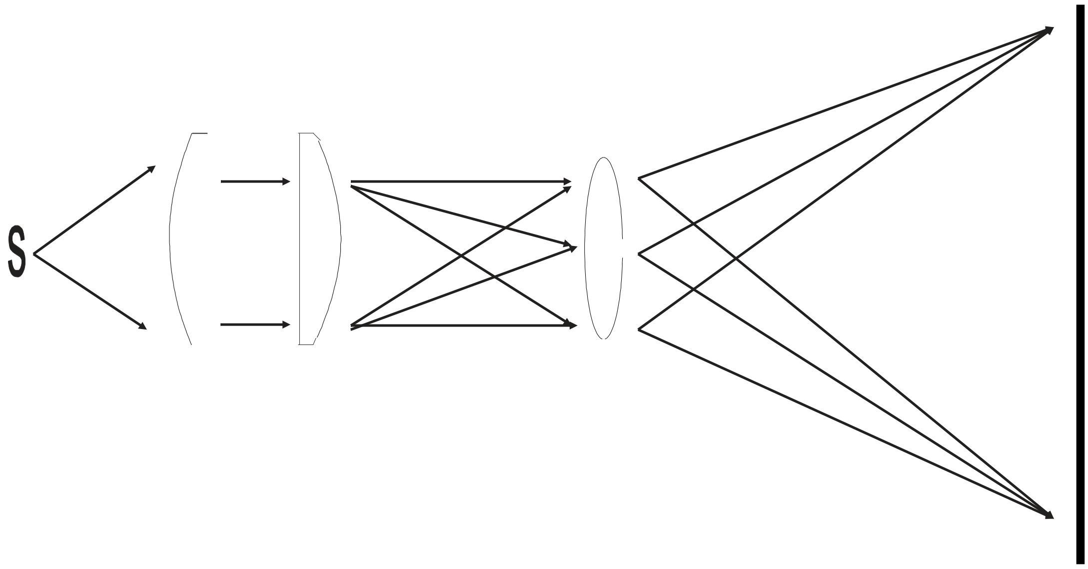
The qualities of the image formed by diverging lenses are:

- the image is virtual,
- the image is upright,
- the image is smaller than the object and situated between the object and the lens.

Questions...

1. What are the features of the image created by a diverging lens?
2. What practical applications do these lenses have?
3. What would happen to the focal length if the curve of the lens was less than shown?
4. Draw illustrations to show your findings.

A PROJECTOR



The principle of the projector shown above is very similar to the projector you would find at your local cinema or multiplex. The light source 's' shines through the film and onto a plano-convex lens. The light is collected together in this way. The ordered light is then passed through another plano-convex lens positioned the opposite way round. The light is directed onto the projection lens which is usually on a sliding construction. This allows it to be magnified to a greater or lesser extent depending on the size of picture required. The projection lens then magnifies the picture onto the screen. This example is only a simple construction and the real projector would have other features including complex focusing equipment.

Questions...

1. List the types of lenses needed for a projector.
2. Why is it necessary to collect the light rays from the original source of light rather than immediately passing it through the projection lens?
3. Find out and draw an illustration of how a camera works?
4. How does the camera differ from the projector?

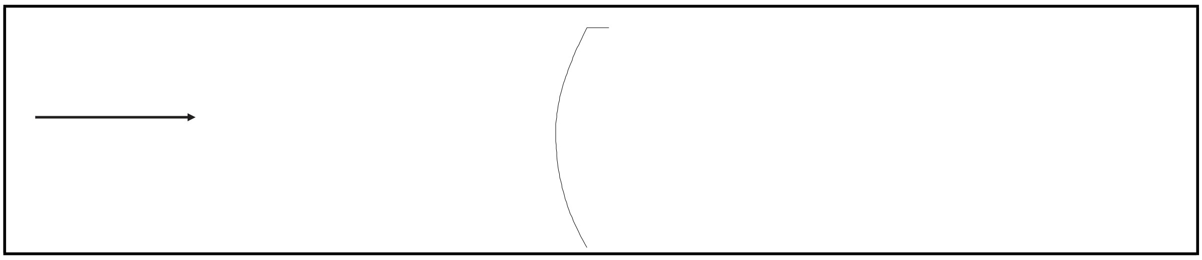
LENSES EXERCISE

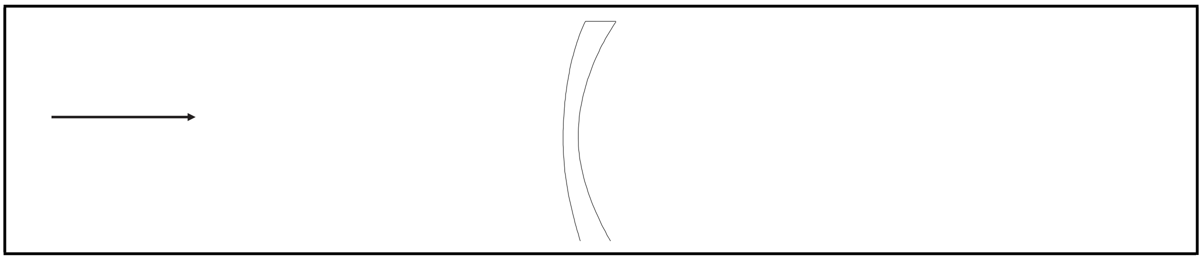
Questions...

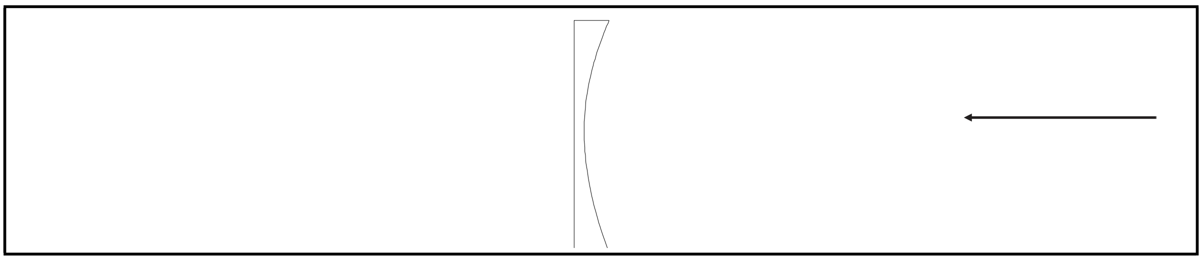
1. Using the diagrams shown in previous examples and by your own research, find out how light rays would be affected if they were passed through the lenses shown below. Draw the rays and indicate where the point of focus is, (if applicable), and the focal length.

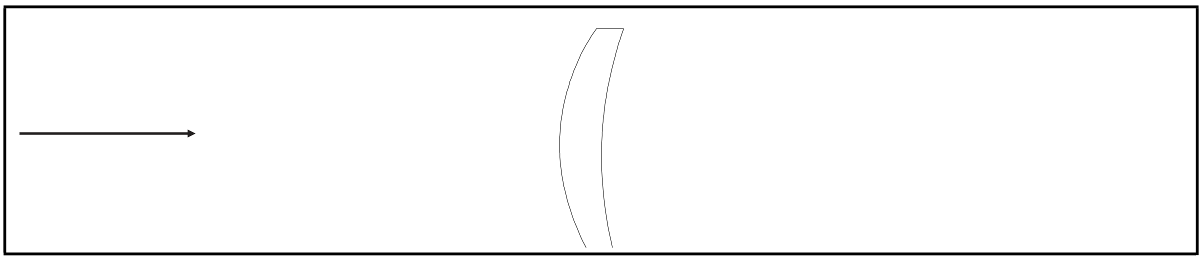
2. Give written examples of where lenses like these might be used.

3. Choose two of the lenses and draw an illustration showing what would happen if the light rays were passed through both lenses.

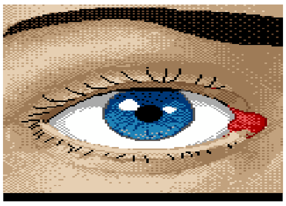




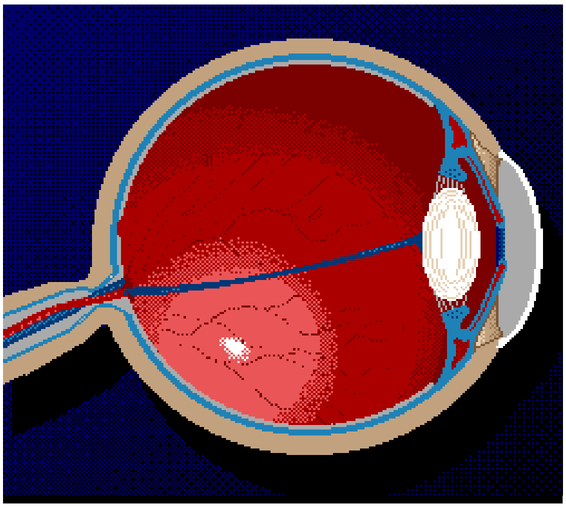




THE EYE



The human eye is similar to a camera. It can adjust itself to admit more or less light. The eye is round with a bulge at the front where the light comes in. The outer layer of the front part of the eye is called the cornea. The light is focused back to the retina which is like the film in a camera. This is where the image is formed. The cells of the retina turn the light into electrical signals which are then sent to the brain. The brain processes the electrical signals sent from each eye and makes one image.



At the front of the eye there is the iris and pupil. The pupil lets the light into the eye and the iris controls the amount of light which is let in. When it is bright, the iris contracts and lets less light in but when it is dark or dull the iris lets more light in. Just behind the iris and the pupil is the lens. It curves outwards like the lens of a magnifying glass. But it is much more delicate. It must also adjust itself to see things very near or far away.

People who wear glasses have a defect which means that they are either short-sighted or long-sighted. Short-sighted people see everything blurred because they eye ball is too long from back to front or because the lens is too weak and cannot bend the light enough. The image they see would focus before it reached the retina. Long-sighted people on the other hand focus the image behind the retina. This is because the eyeball is too short or because the lens is too strong. When people wear glasses the lens helps to focus the image so that it falls exactly where it should, on the

Questions...

1. In your own words explain what the main features of the human eye are.
2. Draw an illustration to show how images are processed by the eye.
3. What is short-sightedness, and long-sightedness?

A PRISM

Newton tried an experiment in which he closed the window shutters of his room and made a small hole to let some light in. He then placed a triangular piece of glass, (prism), near the wall where the light was shining and noticed that the white light split into a spectrum of colours. He noted the colours in order of appearance as:

RED

ORANGE

YELLOW

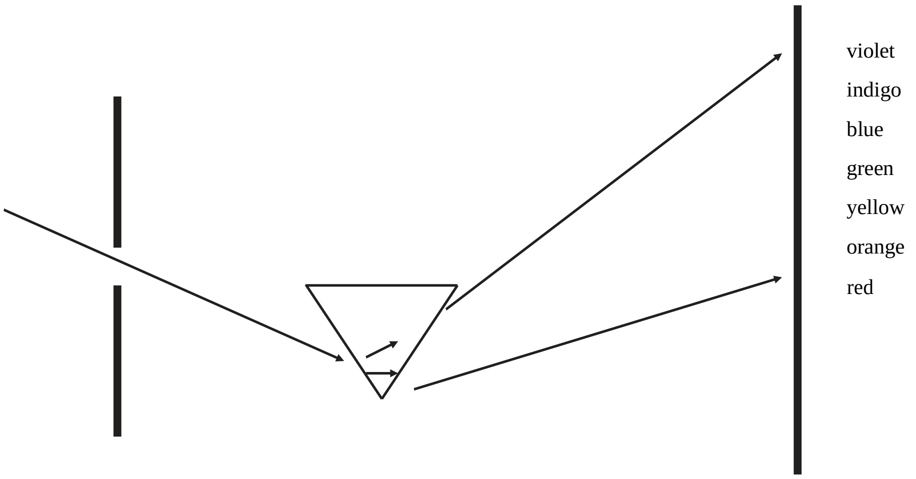
GREEN

BLUE

INDIGO

VIOLET

Newton reasoned that what was happening was that white light was made up of a mixture of different colours. When the light was refracted through the glass the different colours separated because their refractive index was different. This difference in the speed and way the different colours refracted, meant they separated. In later years Newton's theory was improved. In his experiment the light approaching the prism was not parallel but diverging because sunlight was spreading into the room from the hole where it entered. By using lenses it is possible to ensure that the light becomes more parallel before it enters the prism.



Questions...

1. What is a spectrum of light?
2. How does light separate into the colours of the spectrum?
3. Draw an illustration which shows how you can use lenses to make the spectrum more pure.

FIBRE OPTICS

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This is the science of transmitting data, voice, and images by passing light through thin, transparent fibres. In telecommunications, fibre optic technology has virtually replaced copper wire in long-distance telephone lines, and it is used to link computers within local area networks. Fibre optics is also the basis of the fibrescopes used in examining internal parts of the body (endoscopy).

The basic medium of fibre optics is a hair-thin fibre that is sometimes made of plastic but most often of glass. A typical glass optical fibre has a diameter of 125 micrometres, or 0.125 mm (0.005 inch). This is actually the diameter of the outer reflecting layer; the core, or inner transmitting cylinder, may have a diameter as small as 10 micrometres. Through a process known as total internal reflection, light rays beamed into the fibre can travel within the core for great distances with remarkably little reduction in intensity. The degree of weakening over distance varies according to the wavelength of the light and to the composition of the fibre. When glass fibres of core/cladding design were introduced in the early 1950s, the presence of impurities restricted their employment to the short lengths sufficient for endoscopy. In 1966, electrical engineers working in England, suggested using fibres for telecommunication, and within two decades silica glass fibres were being produced with sufficient purity that infrared light signals could travel through them for 100 km (60 miles) or more without having to be boosted by repeaters. Plastic fibres are cheaper to produce and more flexible than glass fibres, but less efficient.

Fibrescope inspection in endoscopy or industry is conducted in the visible wavelengths, one bundle of fibres being used to illuminate the examined area with light and another bundle serving as an elongated lens for transmitting the image to the human eye or a video camera.

Questions...

1. What is fibre optics technology?
2. Make a list of industries in which fibre optics technology is important.
3. How are fibre optics better than wires?