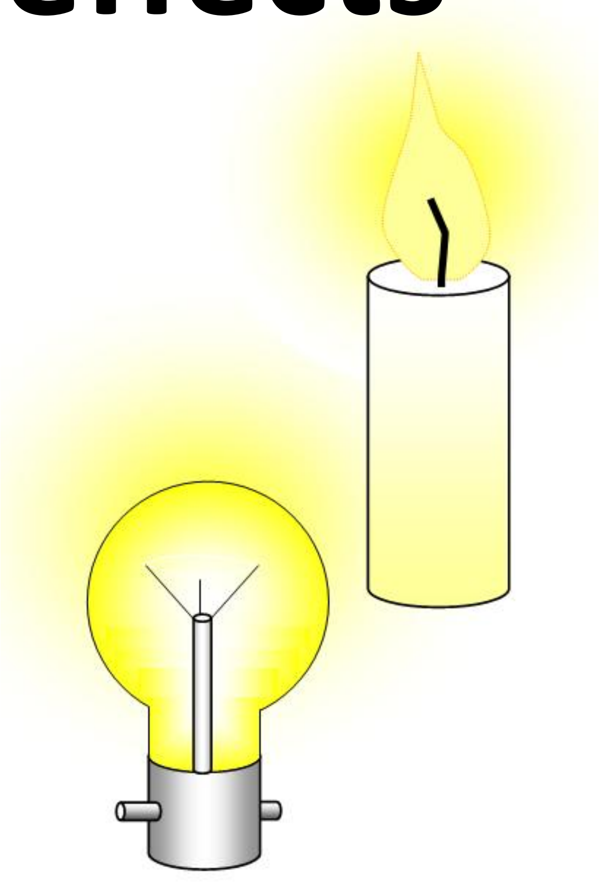
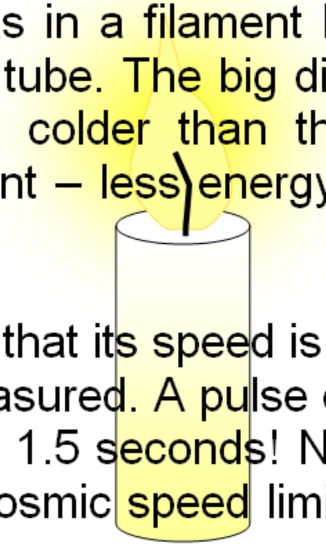
Light and its effects



Light and the speed of light

Life as we know it would be totally different without light.

The earliest form of artificial light was fire - produced by burning wood, oil or candles. Today light is normally produced by electricity, either by heating metals as in a filament lamp or by making gases glow as in a gas filled tube. The big difference is that the gas filled tubes are much colder than the filament lamps, and so are much more efficient – less energy is wasted as heat.

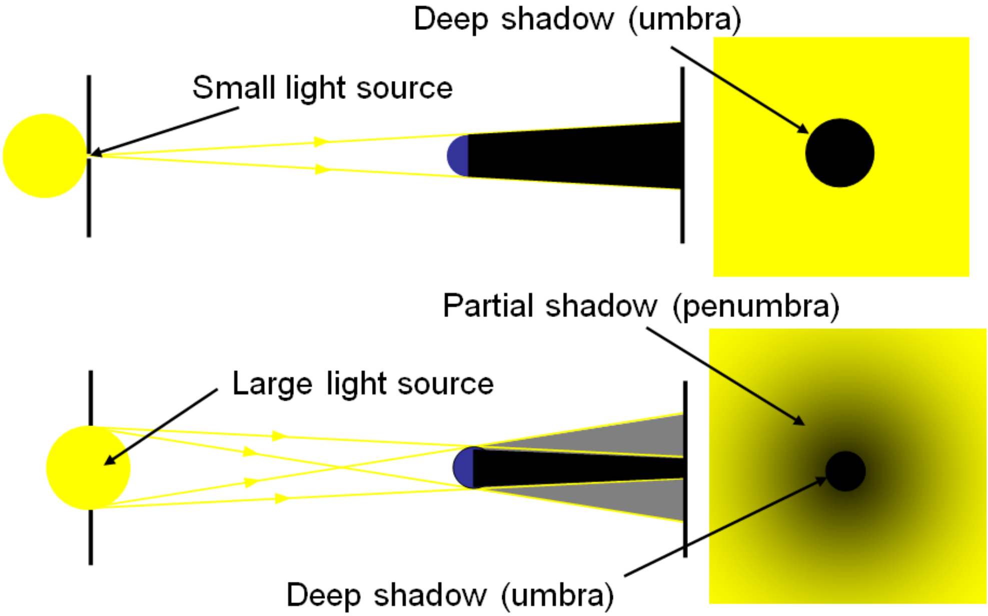


Light travels very fast, to us it seems that its speed is infinite but the speed of light can actually be measured. A pulse of light can travel the 450 000 km to the Moon in 1.5 seconds! Nothing can travel faster than light; it is a kind of cosmic speed limit.

Speed of light in space = 300 000 km/s = 300 000 000 m/s

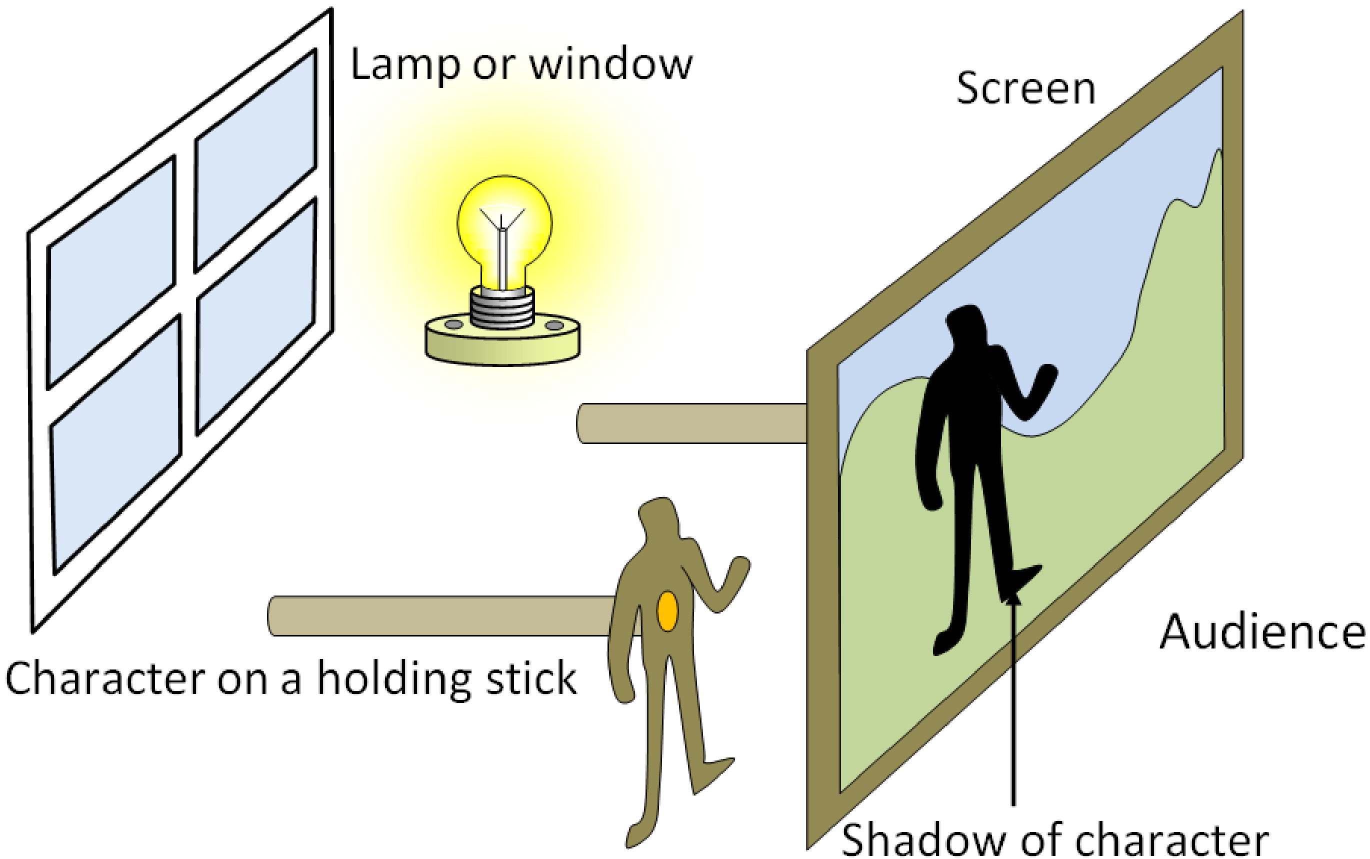
Shadows

There are two types of shadow; a crisp edged one formed by a point source of light and a rather fuzzier one that is formed by a larger source.

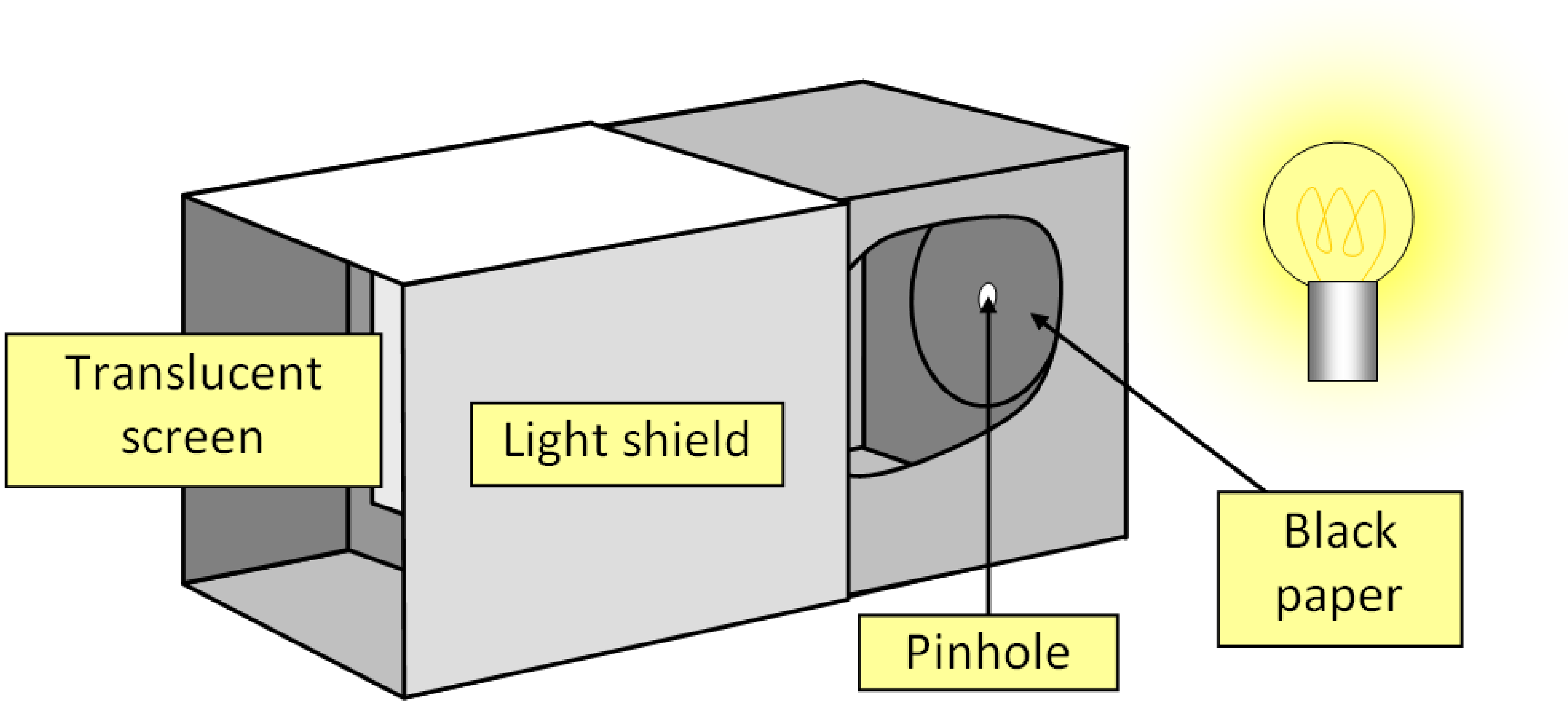


The region of deep, total shadow is called the **UMBRA** and the region of partial shadow is called the **PENUMBRA**. The umbra is a region where no light can get to while the penumbra is a region where some light can reach.

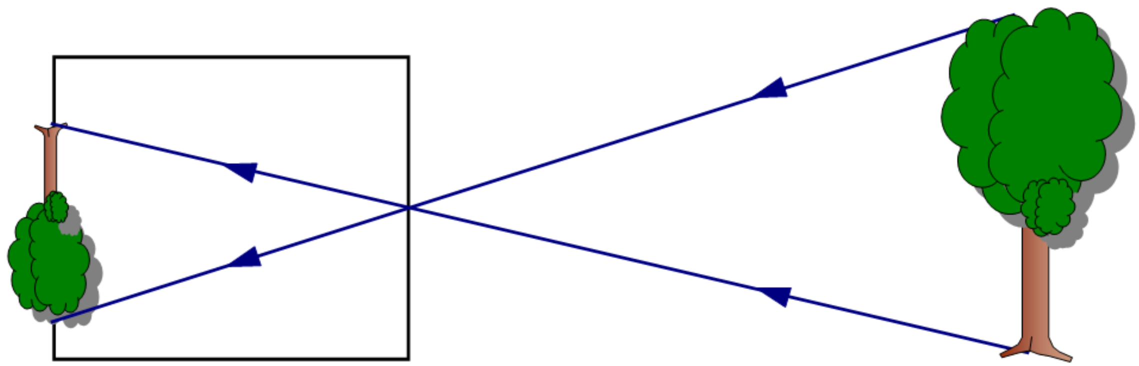
Shadow films



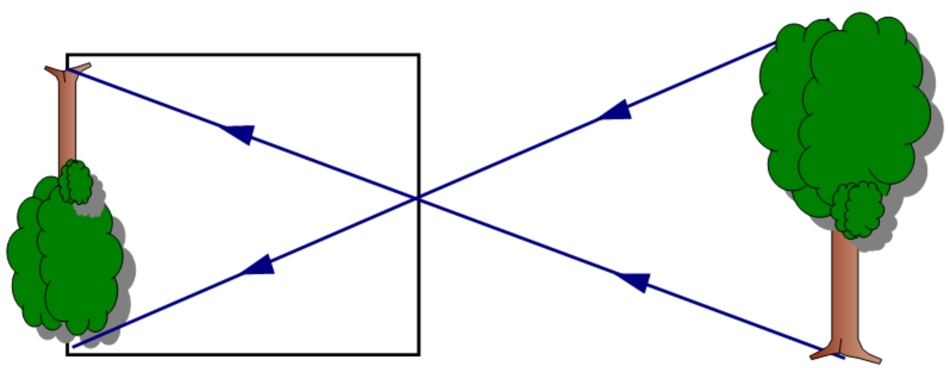
Pinhole camera (1)



Pinhole camera (2)



Clear upside down (inverted) image with a small pinhole



Camera closer to the object – a larger image

Reflection of light

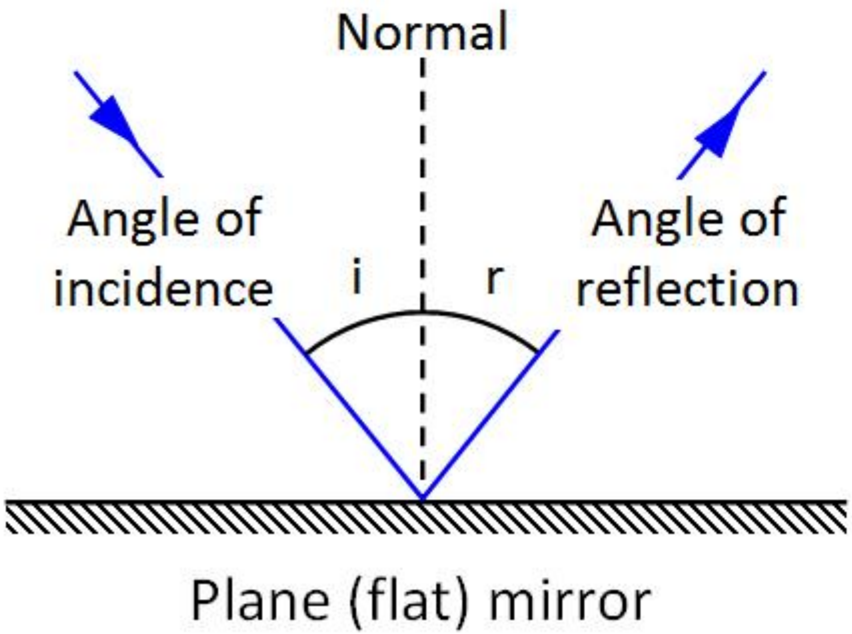
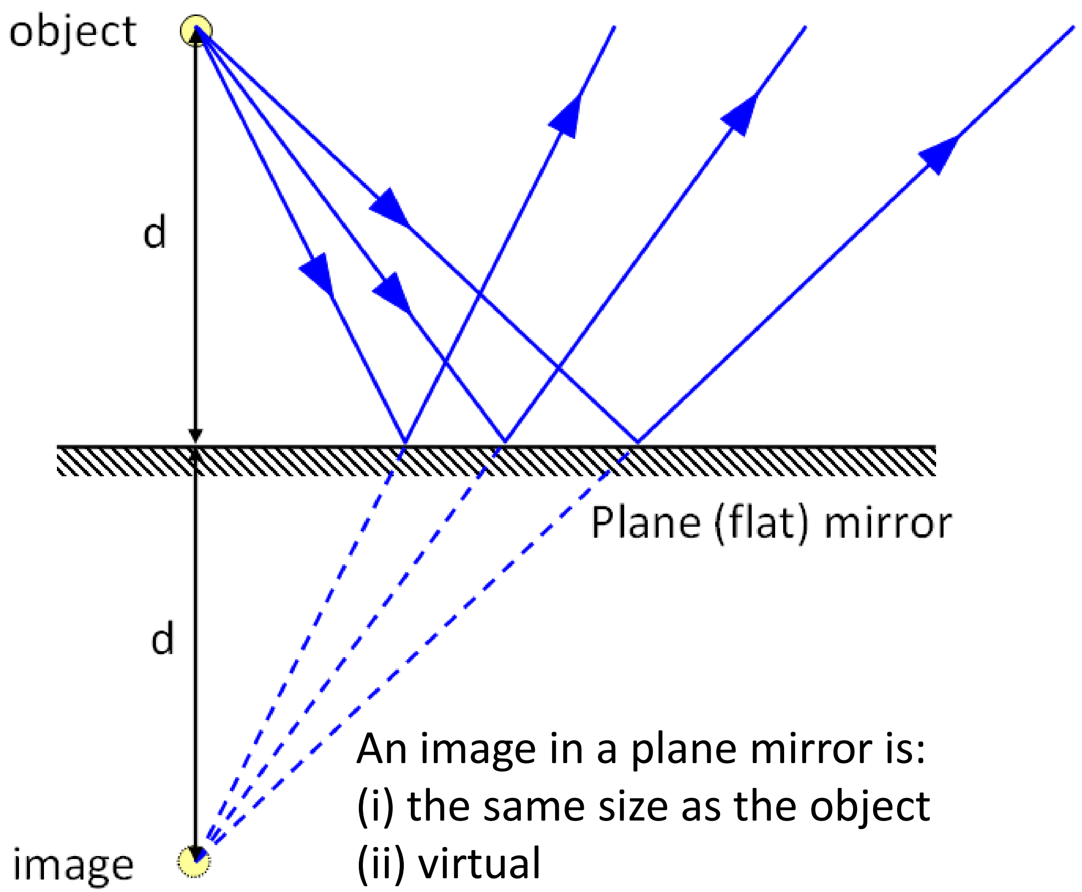


Image in a plane mirror



An image in a plane mirror is:

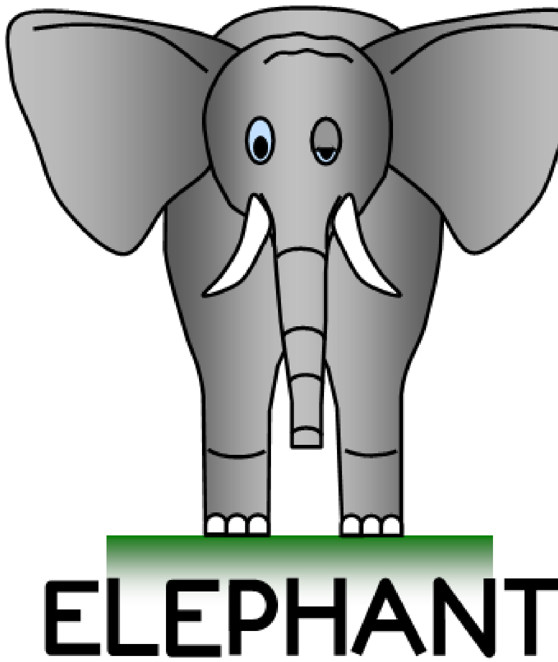
(i) the same size as the object

(ii) virtual

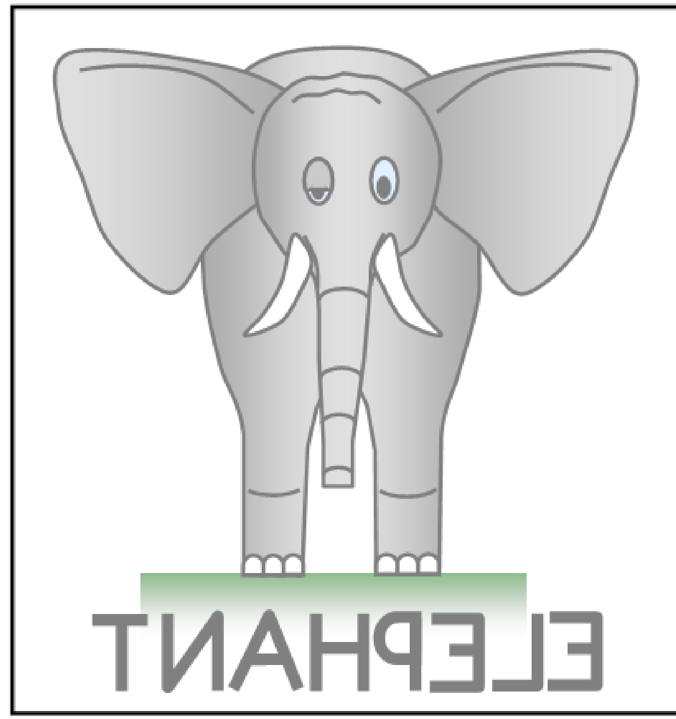
(iii)laterally inverted

(iv) the same distance behind the mirror as the object is in front

Reflected object

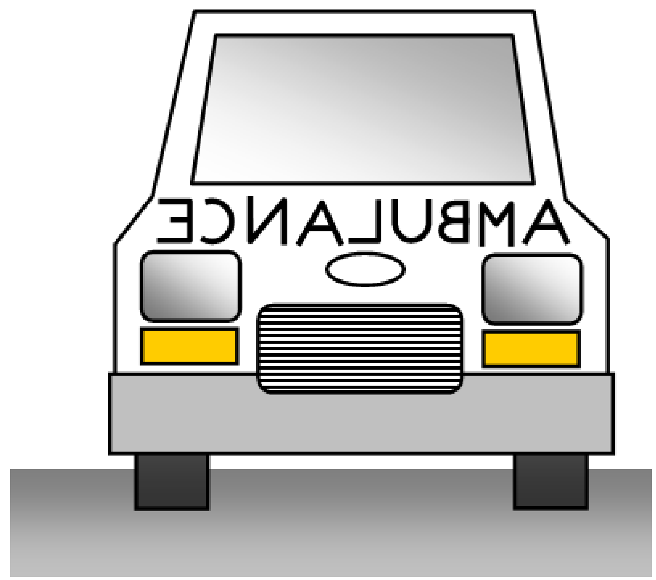


Real view



Reflection in a flat mirror

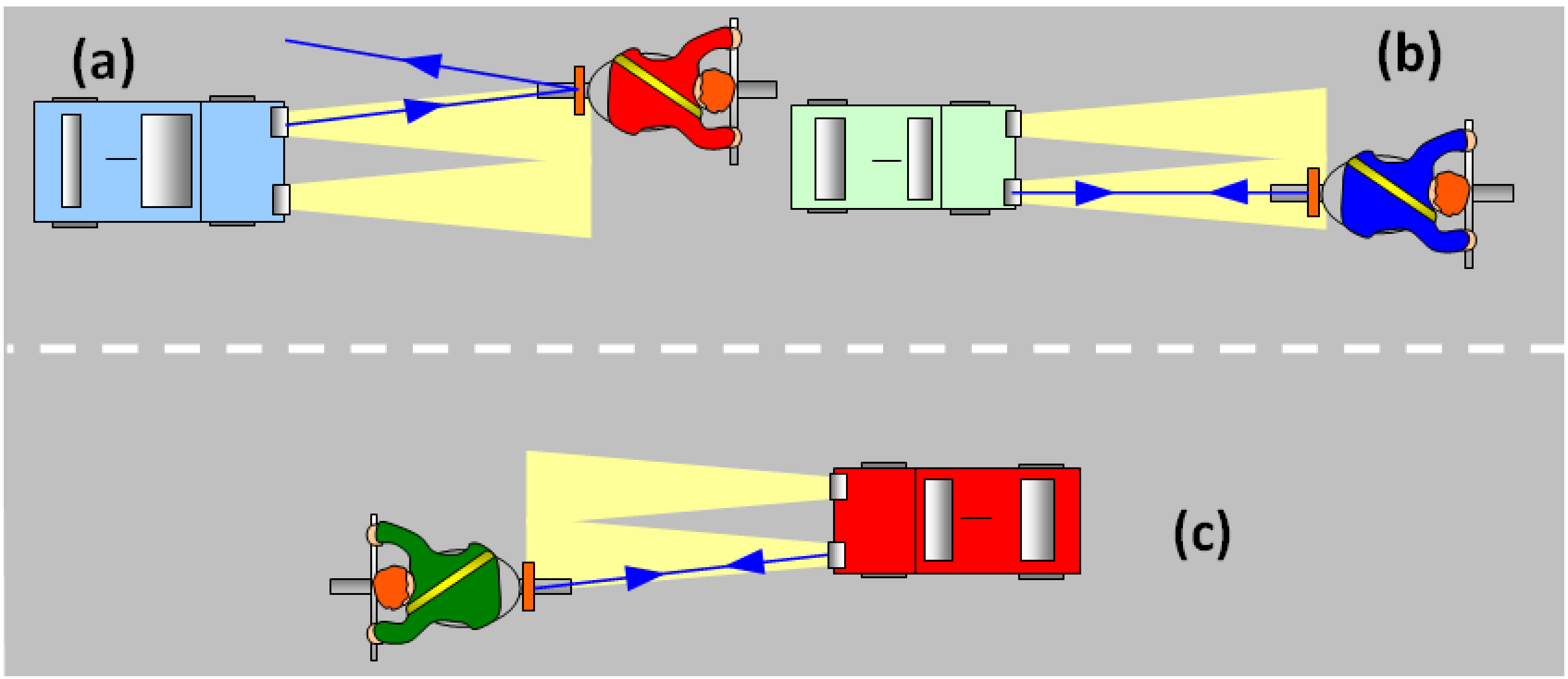
Reflection of an ambulance



Ambulances often have their name on the front written backwards.

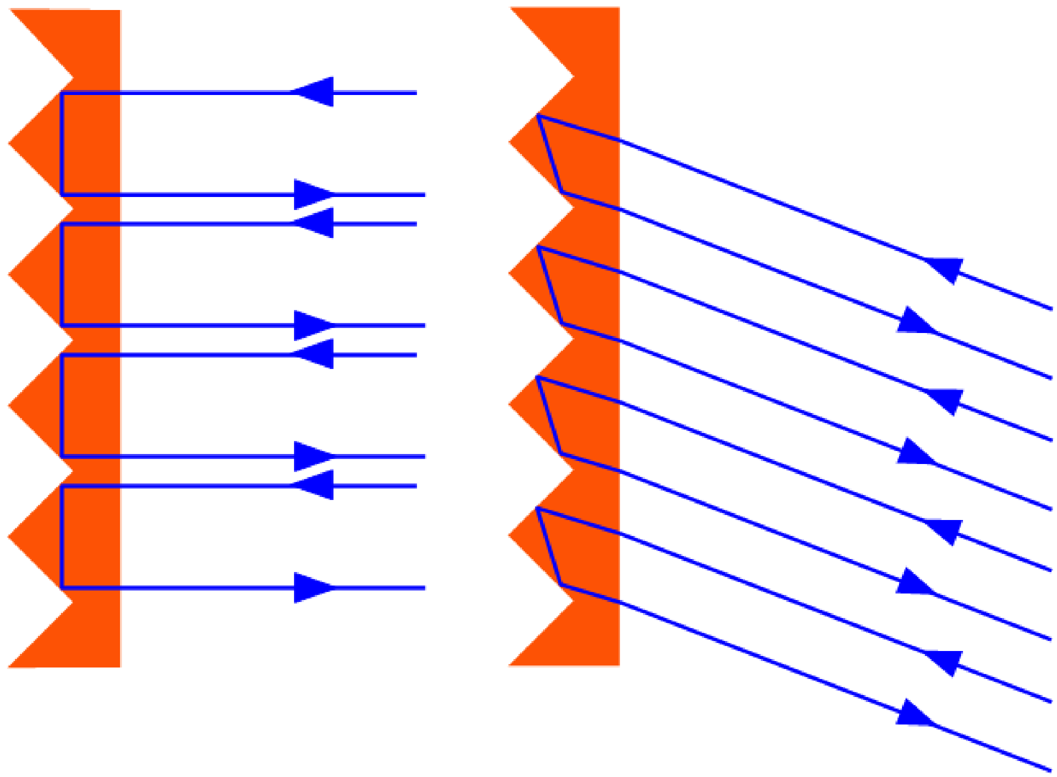
Why do you think this is?

Bicycle reflector (1)

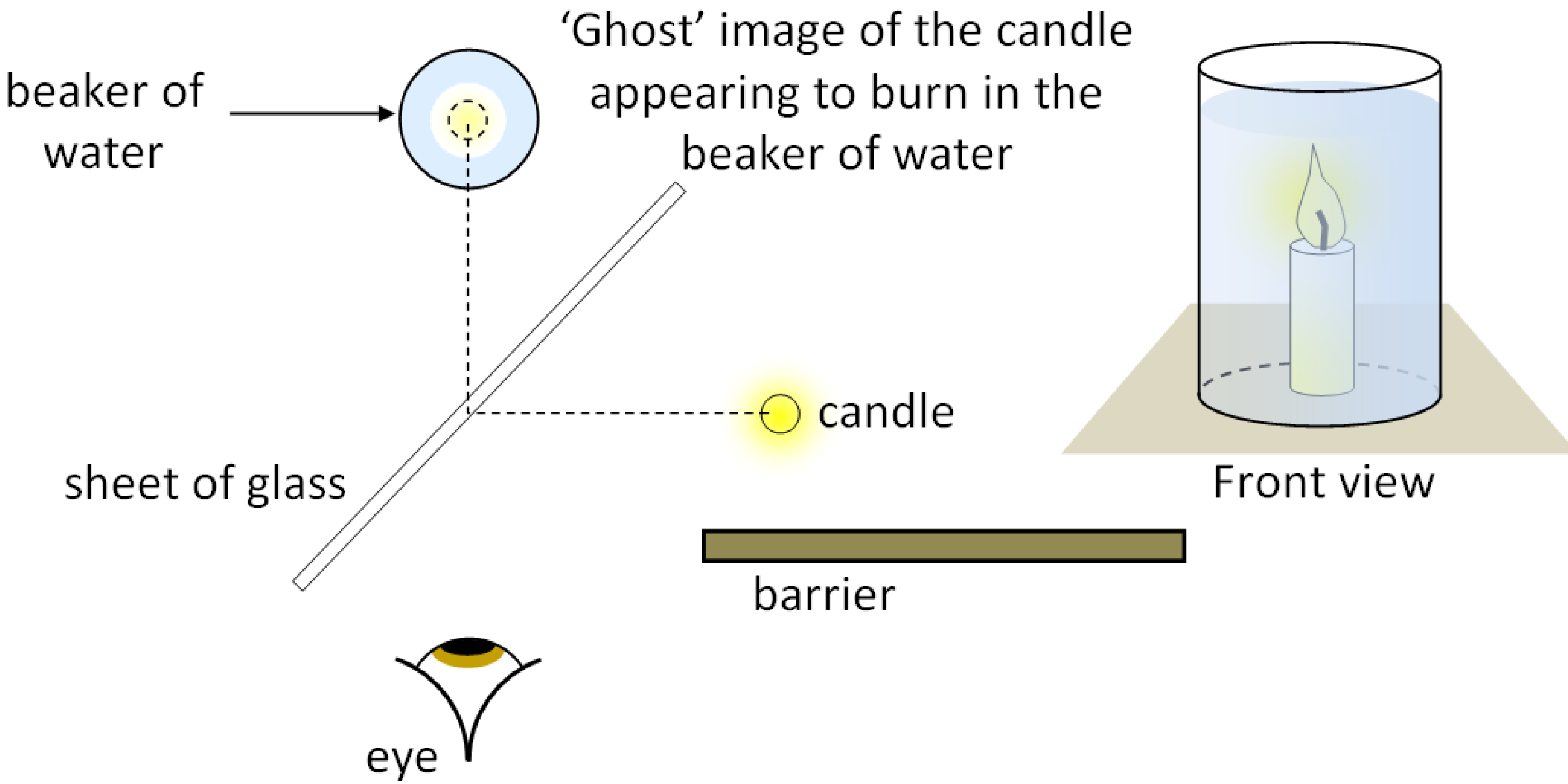


Bicycle reflector (2)

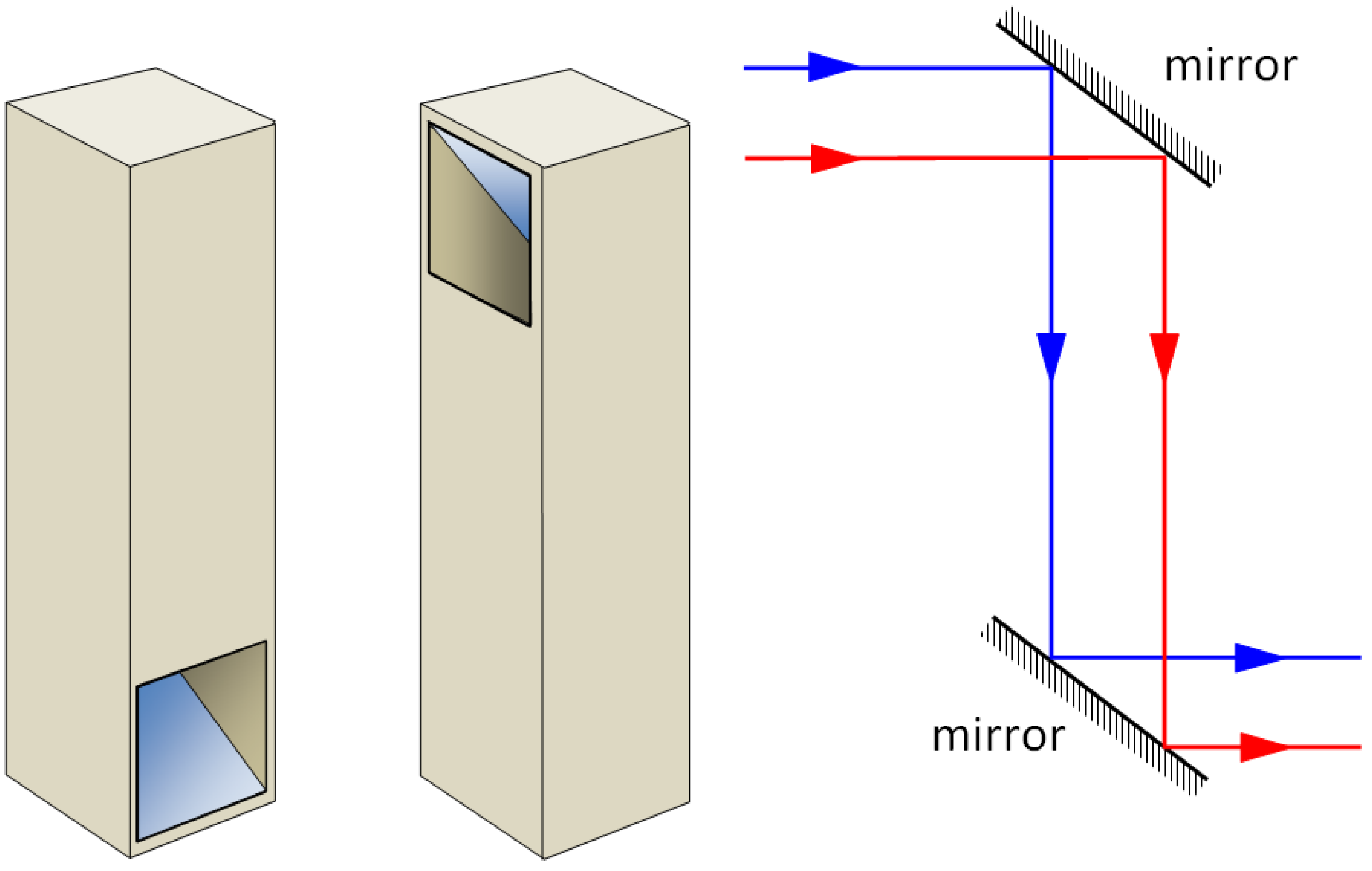
Light hitting a 2D bicycle reflector at two different angles



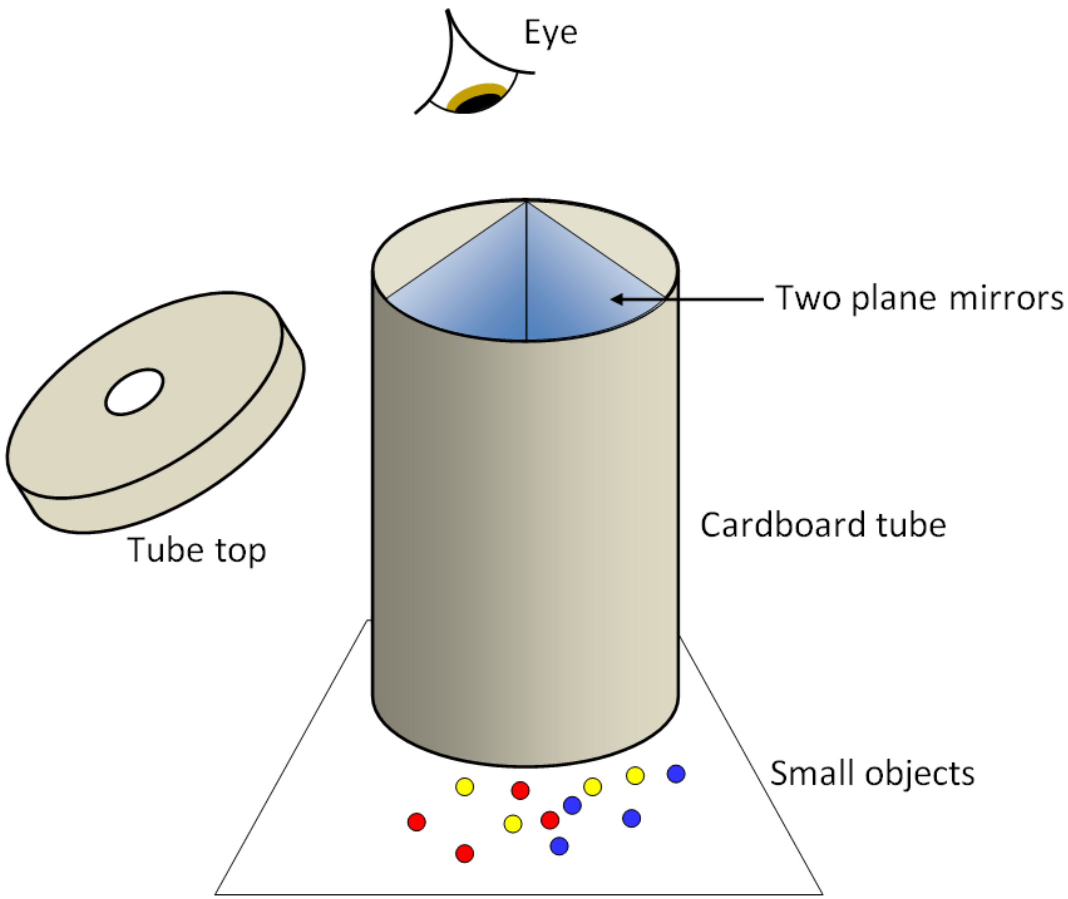
Pepper’s ghost



Periscope



Kaleidoscope



Curved mirrors

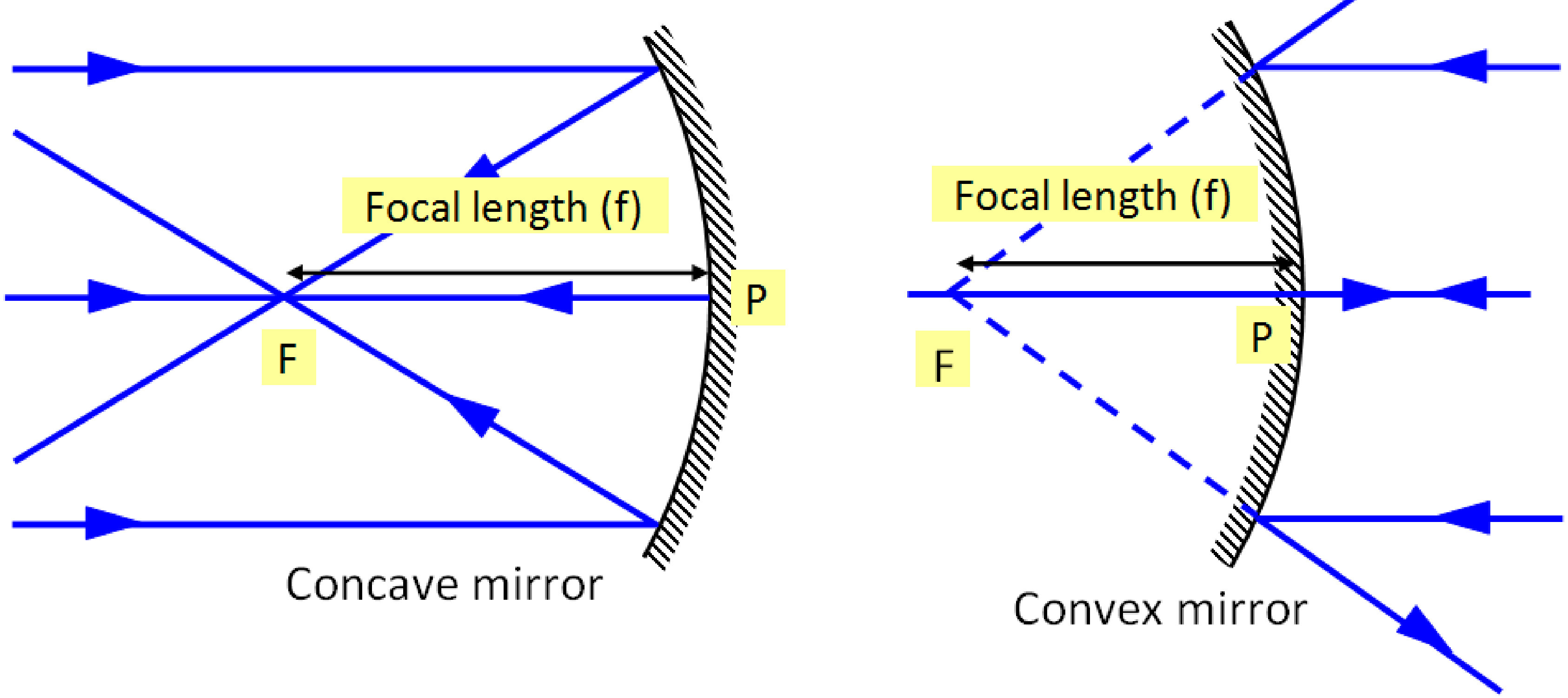
A concave mirror will converge a beam of light and it gives a real image.
A convex mirror will diverge a beam of light and it gives a virtual image.

Uses of concave mirrors

Shaving mirrors, make-up mirrors, dentists' mirrors, microscopes, fun mirrors, lamp reflectors, reflecting telescope

Uses of convex mirrors

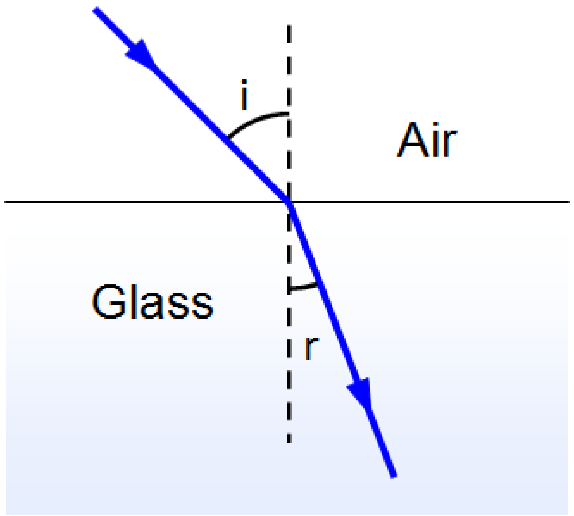
Wide angle car wing mirrors, buses' mirrors, security mirrors in shops, fun mirrors.



Refraction

When light passes from air into a transparent and denser material such as glass, water or plastic at an angle it bends – this bending is called **refraction**.

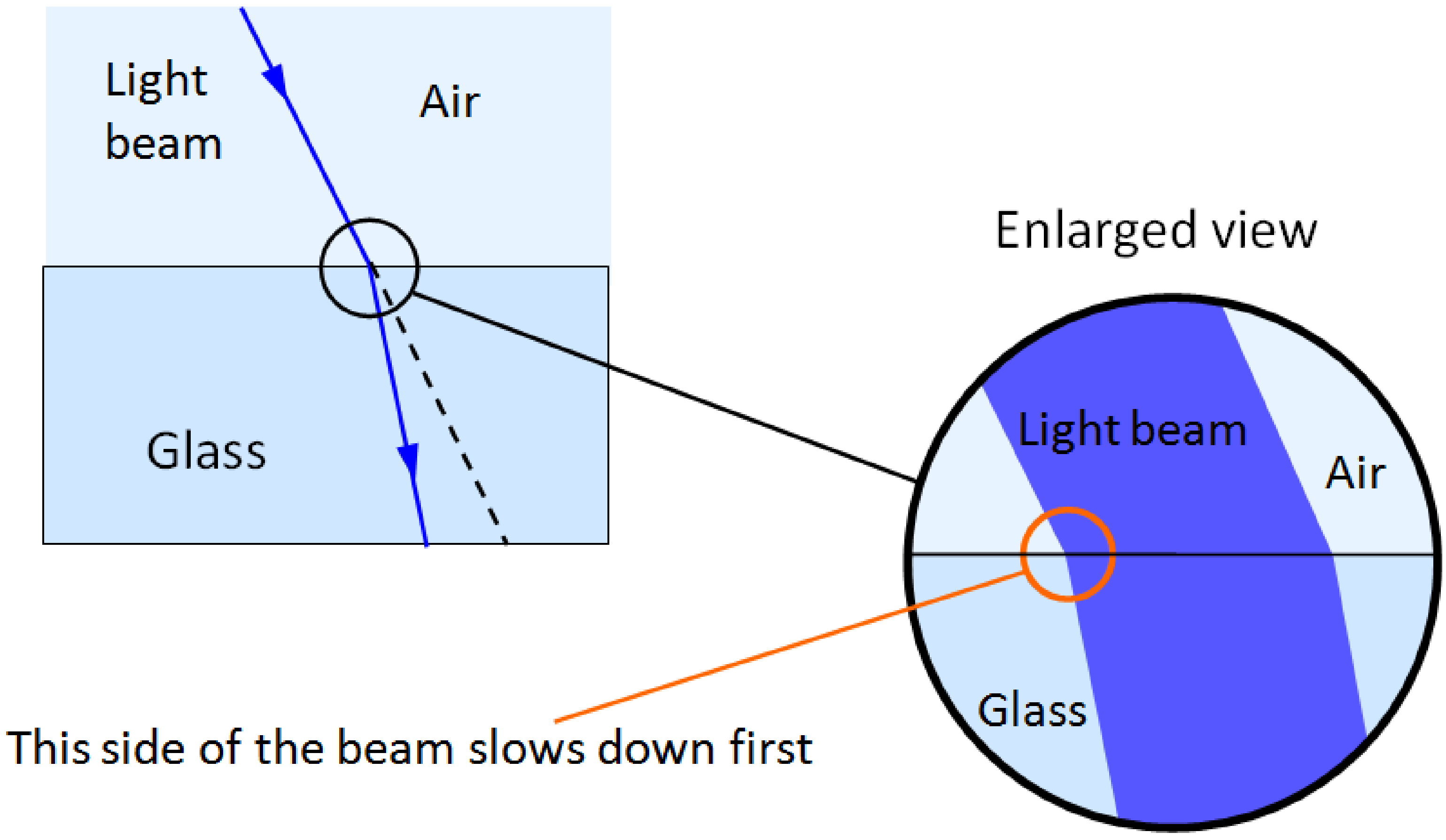
The light bends towards the normal line so that the angle of refraction (r) is less than the angle of incidence (i). The amount of bending for a given angle of incidence depends on the material. It is greater for diamond than for glass and greater for glass than it is for water.



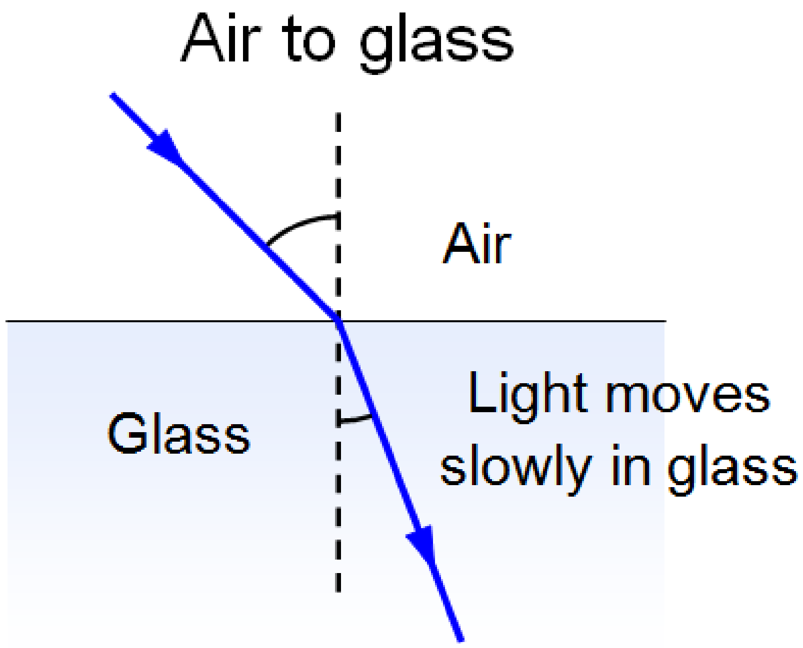
The list shows the angles of refraction in various materials for an angle of incidence in air of 40^o:

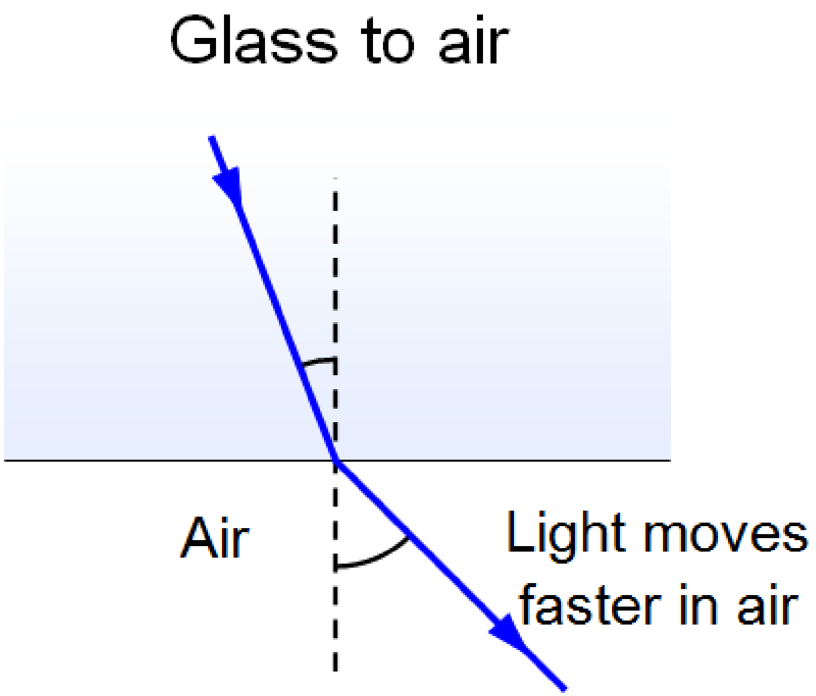
Water	29^o	a change of direction of 11^o
Glass	25^o	a change of direction of 15^o
Diamond	16^o	a change of direction of 24^o

Refraction at a surface



Refraction and speed

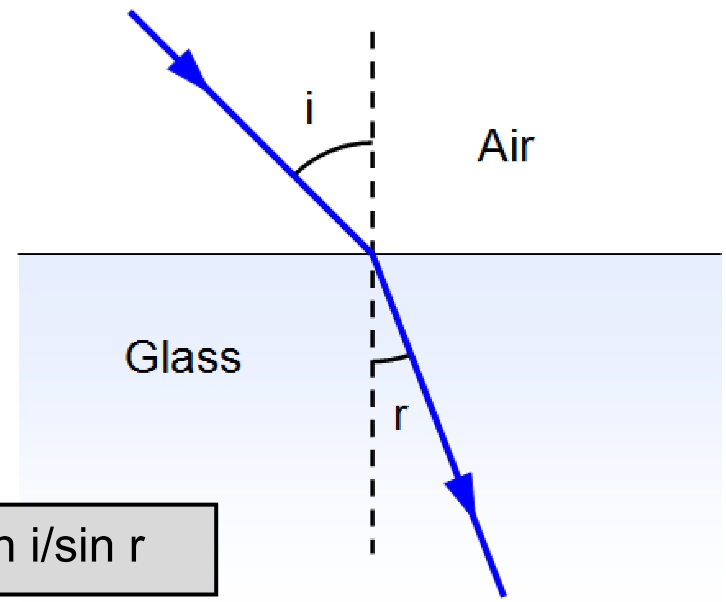




Snell’s Law

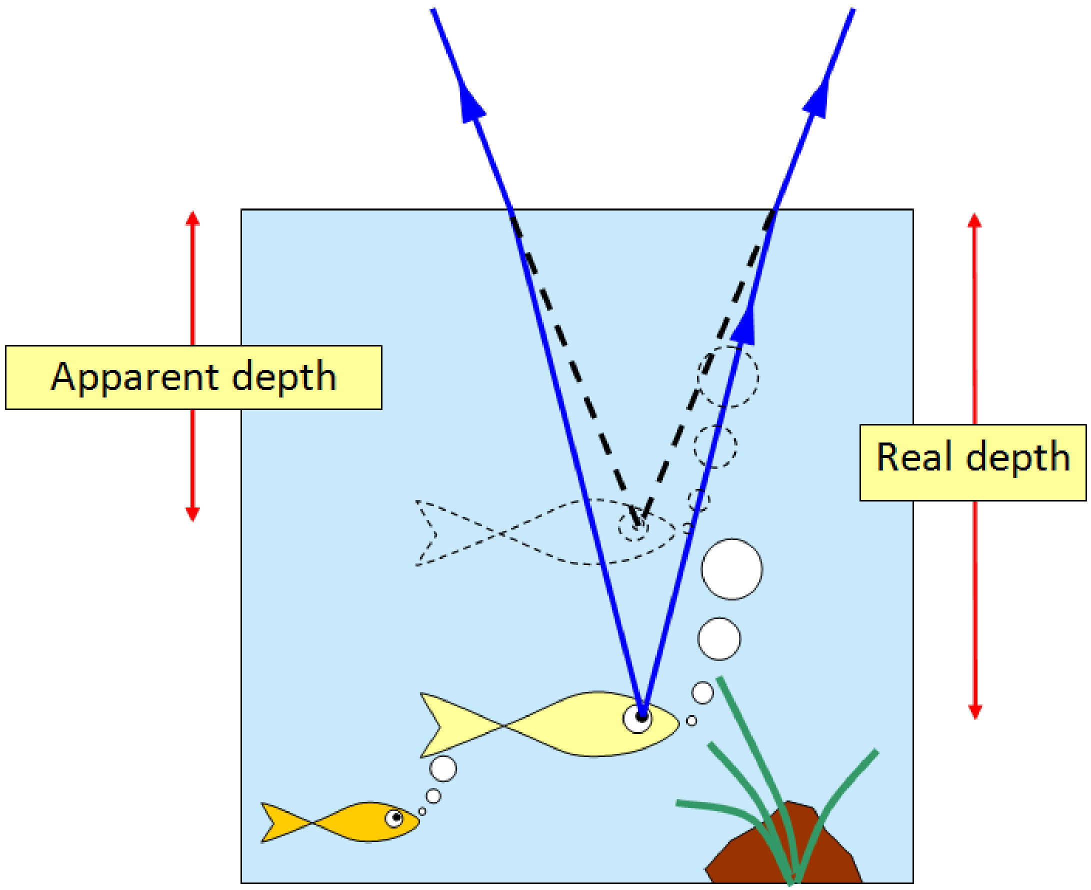
When light travels from air to glass (or air to water) it bends towards the normal line so that the angle of refraction (r) is less than the angle of incidence (i). The amount of bending for a given angle of incidence depends on the material. It is greater for diamond than for glass and greater for glass than it is for water.

The amount of bending (refraction) depends on a property of the material known as its **REFRACTIVE INDEX**. This property connects the angle of incidence (i) with the angle of refraction (r). The law is known as Snell’s Law.



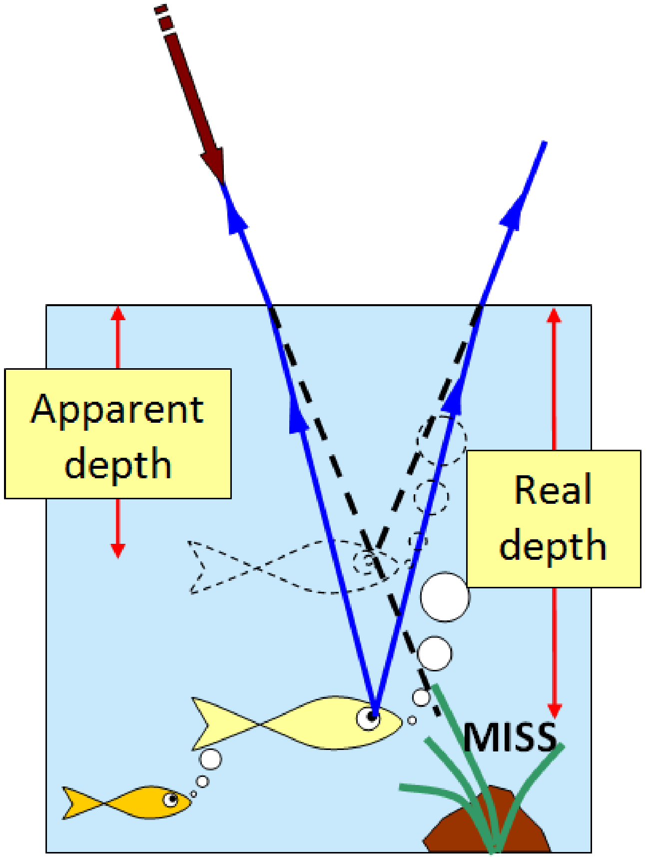
Snell’s Law: Refractive index = sin i/sin r

Real and apparent depth

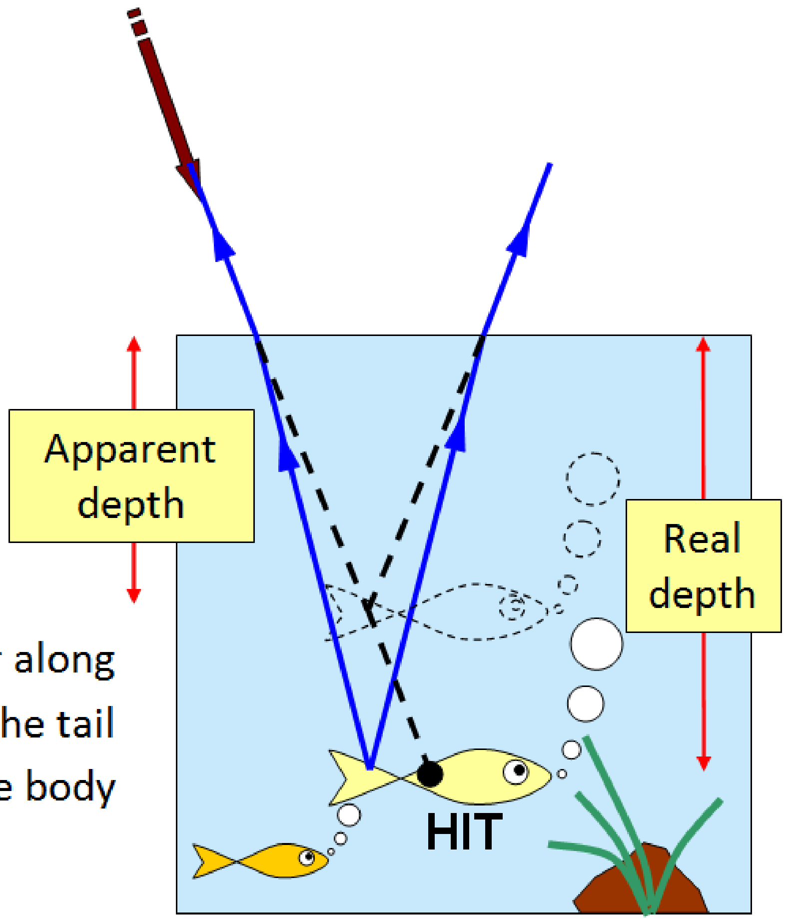


Refraction and fishermen (1)

Fisherman aims their spear along the line where they think the head of the fish is and so misses the body of the fish (dotted line).

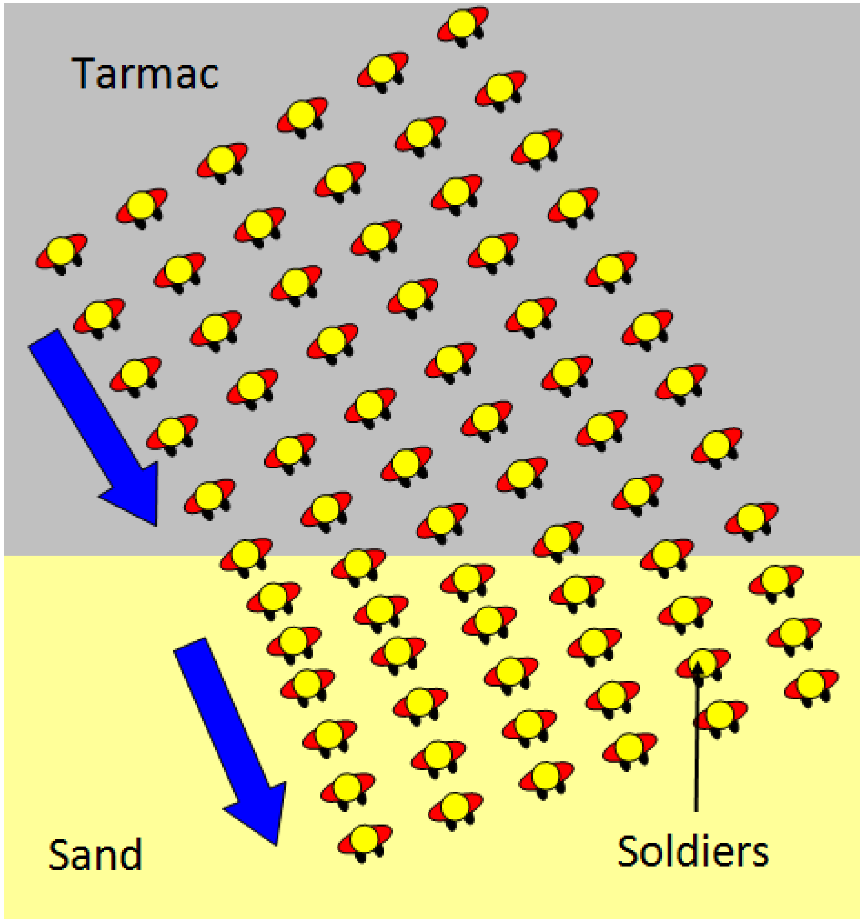


Refraction and fishermen (2)



Fisherman aims their spear along the line where they think the tail of the fish is and so hits the body of the fish (dotted line).

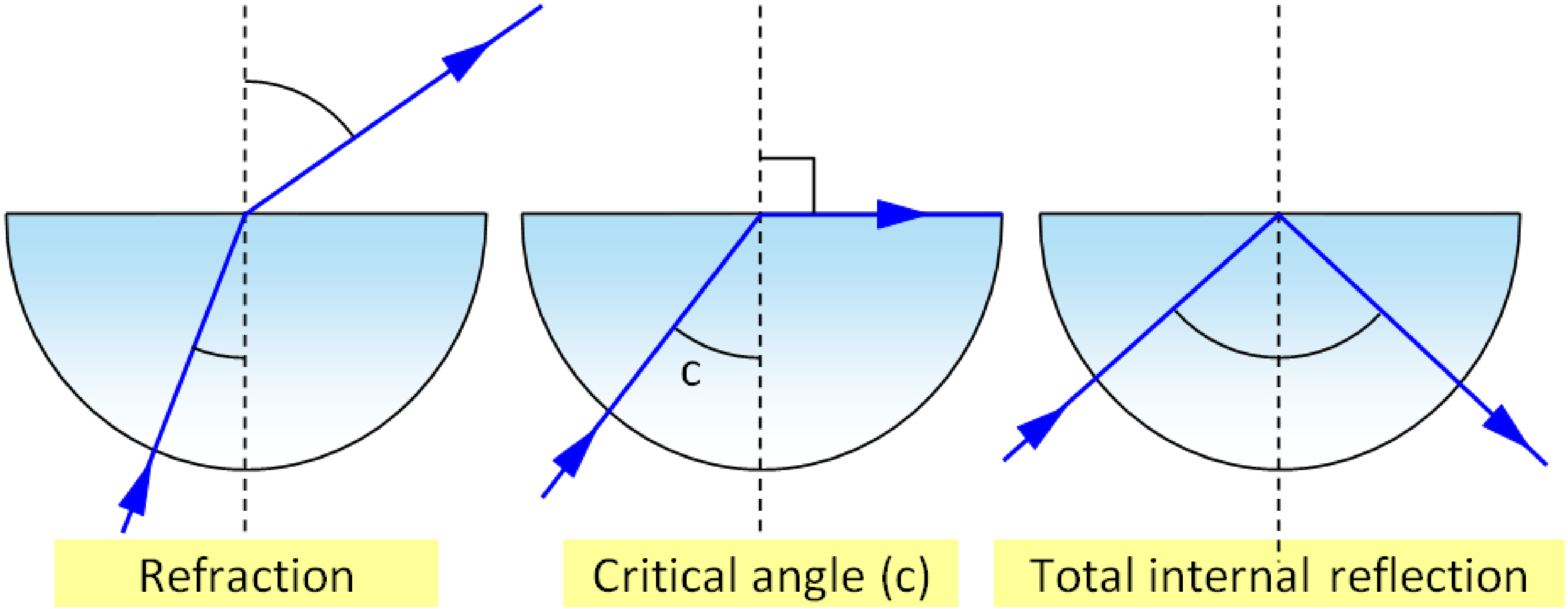
Refraction and soldiers



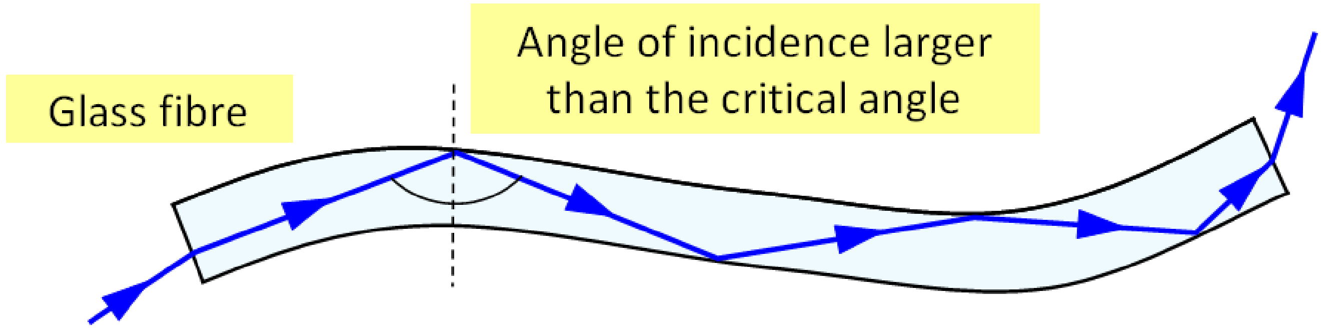
Total internal reflection

When light hits the boundary between glass and air it is usually refracted out. As the angle of incidence is increased the angle of refraction also increases until the light emerges along the boundary between the block and the air.

The angle of incidence in the transparent material when this happens is called the CRITICAL ANGLE. For angles of incidence greater than the critical angle ALL the light is reflected back - this is known as TOTAL INTERNAL REFLECTION. Total internal reflection only happens when the light is travelling from the more dense material to the less dense i.e. glass to air, glass to water or water to air.



Fibre optics



Uses of Fibre Optics

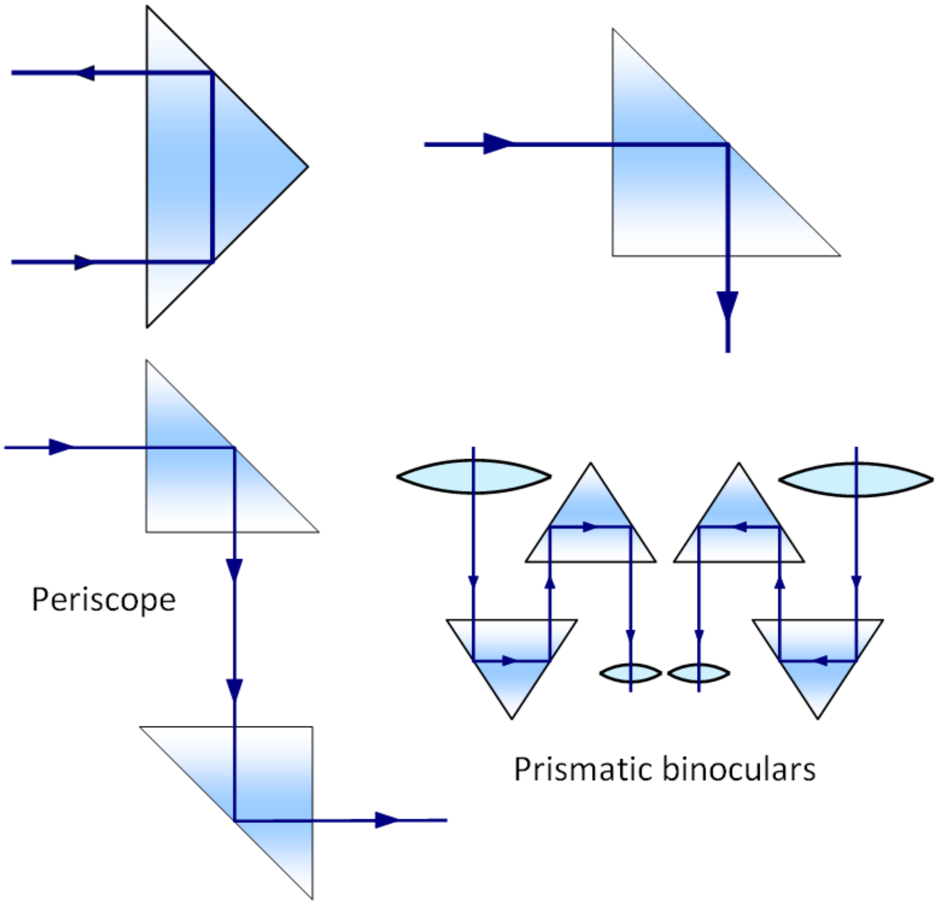
In many of the following uses each fibre has an outer cladding of glass and a bundle of the fibres can be enclosed by a plastic cover.

1. Communications – sending information along a light beam. This is useful for telephone, television, radio, computer networks, stereo links and control in aircraft.
2. Endoscopy - seeing down inside a patient's body
3. Illuminating models or road signs using only one bulb
4. Security fencing – very difficult to bypass.

Prisms

The first two diagrams show right angled prisms. Since the critical angle for a glass-air boundary is 42° any light which hits the boundary at 45° will be totally internally reflected.

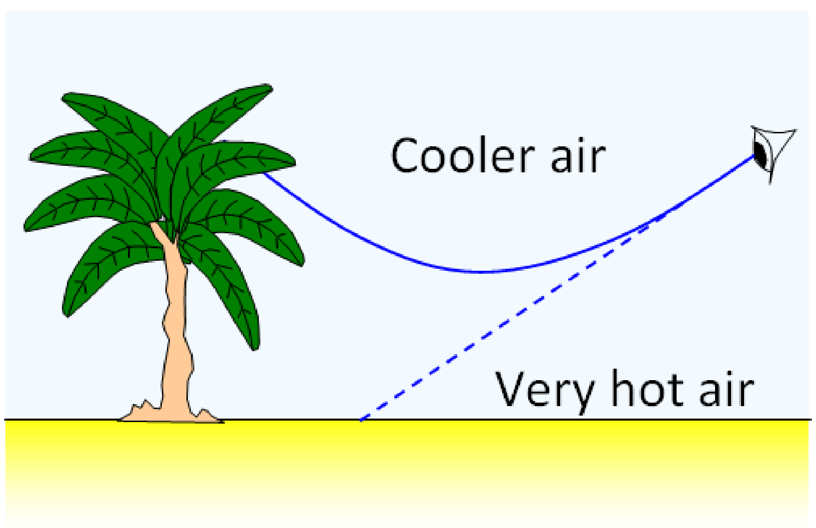
The last two diagrams show how right-angled prisms are used in
(a) a periscope
(b) in prismatic binoculars

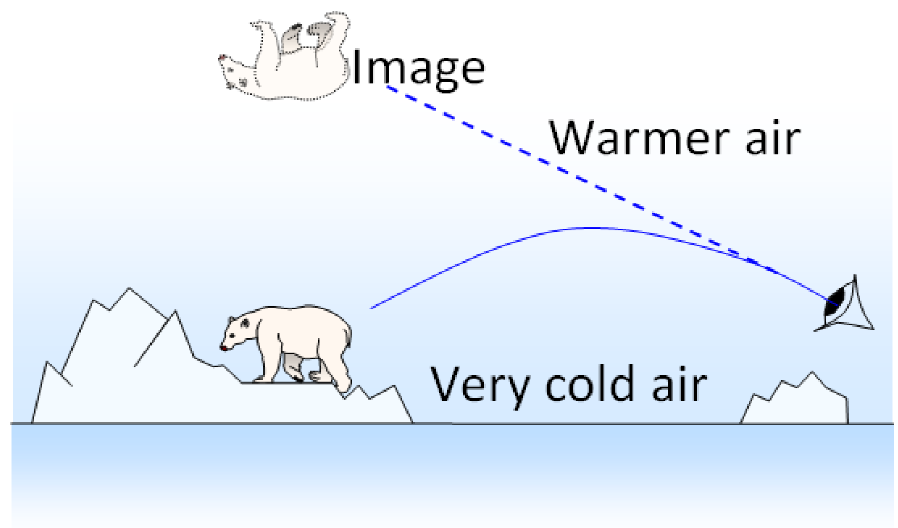


Mirages

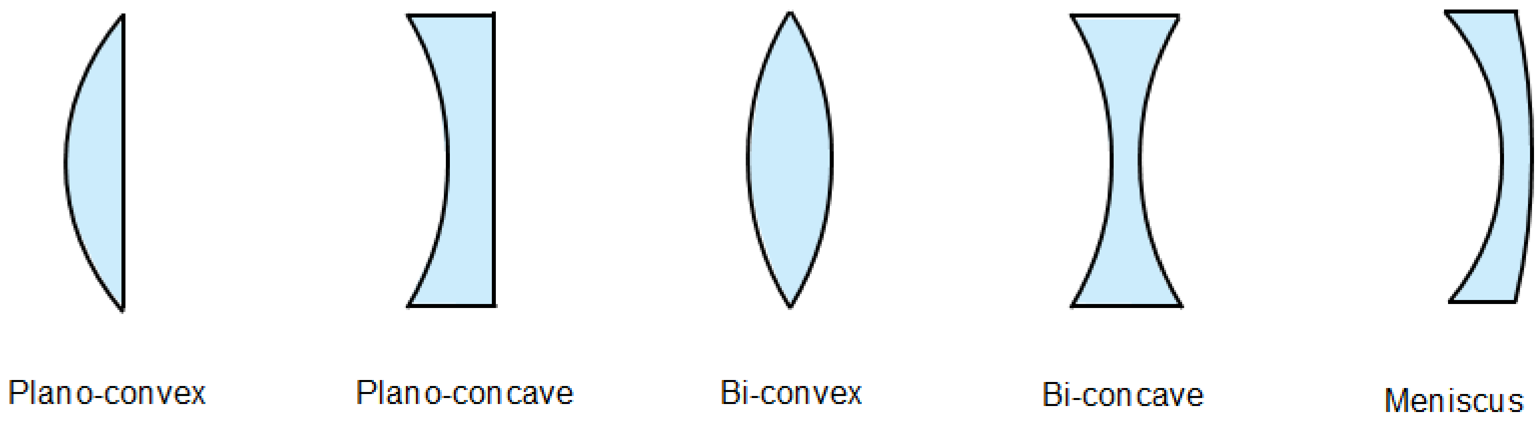
A mirage occurs on very hot days when a layer of hot, low density air lies on the ground. Light from the sky will be totally internally reflected at this layer and so you see what looks like a pool of water - it's actually a reflection of the sky.

Mirages also occur in very cold countries. See if you can explain why. In the right hand diagram the mirage appears in the sky and the polar bear seems to be flying upside down!

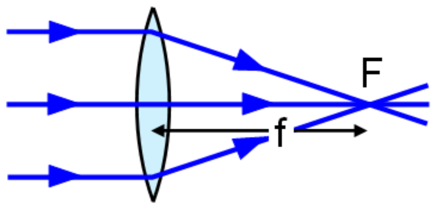




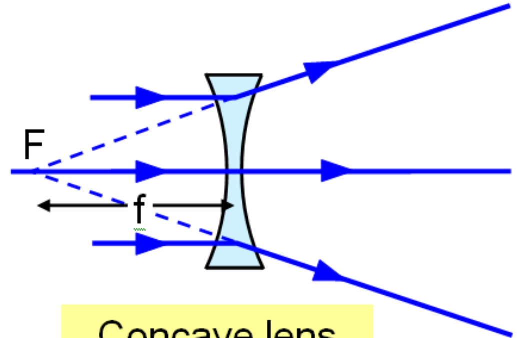
Types of lens



Lenses – focal length

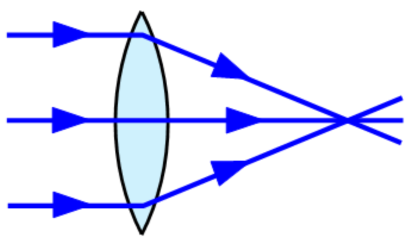


Convex lens

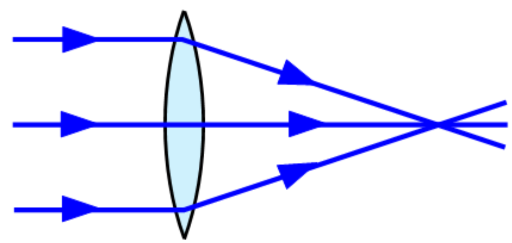


Concave lens

The point where parallel light is brought to a focus is called the PRINCIPAL FOCUS (F) of the lens and the distance of this point from the lens is called the FOCAL LENGTH (f) of the lens.



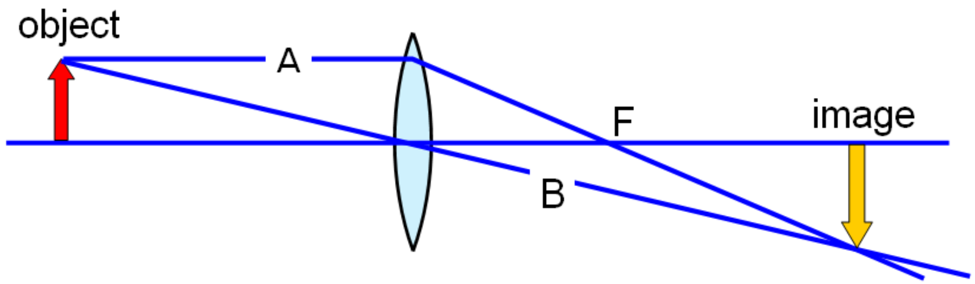
Sharply curved sides - short focal length



Gently curved sides – long focal length

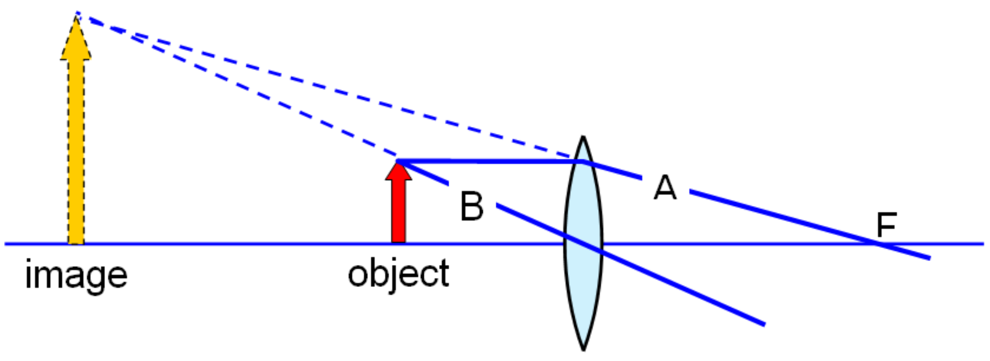
Lenses – image by drawing

Convex lens



After passing through the lens ray A will go through the principal focus (F).

Concave lens

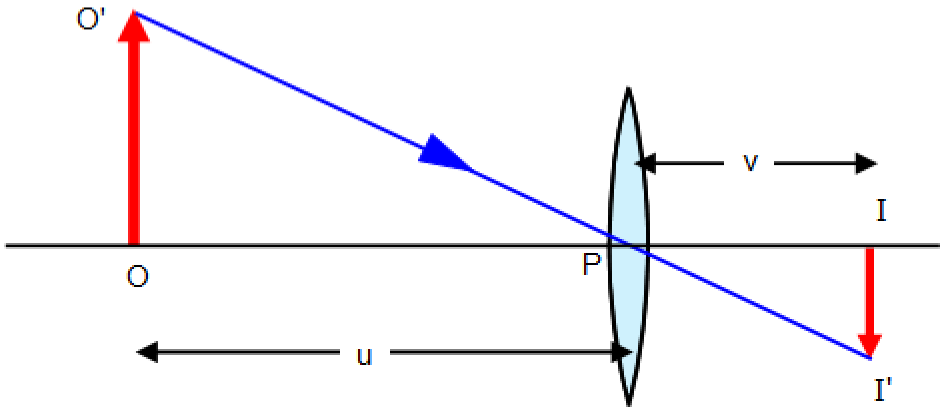


Magnification produced by a lens

Lenses give an image of the object. The size of the image compared with the object depends on the magnification of the lens.

The magnification of a lens is defined as:

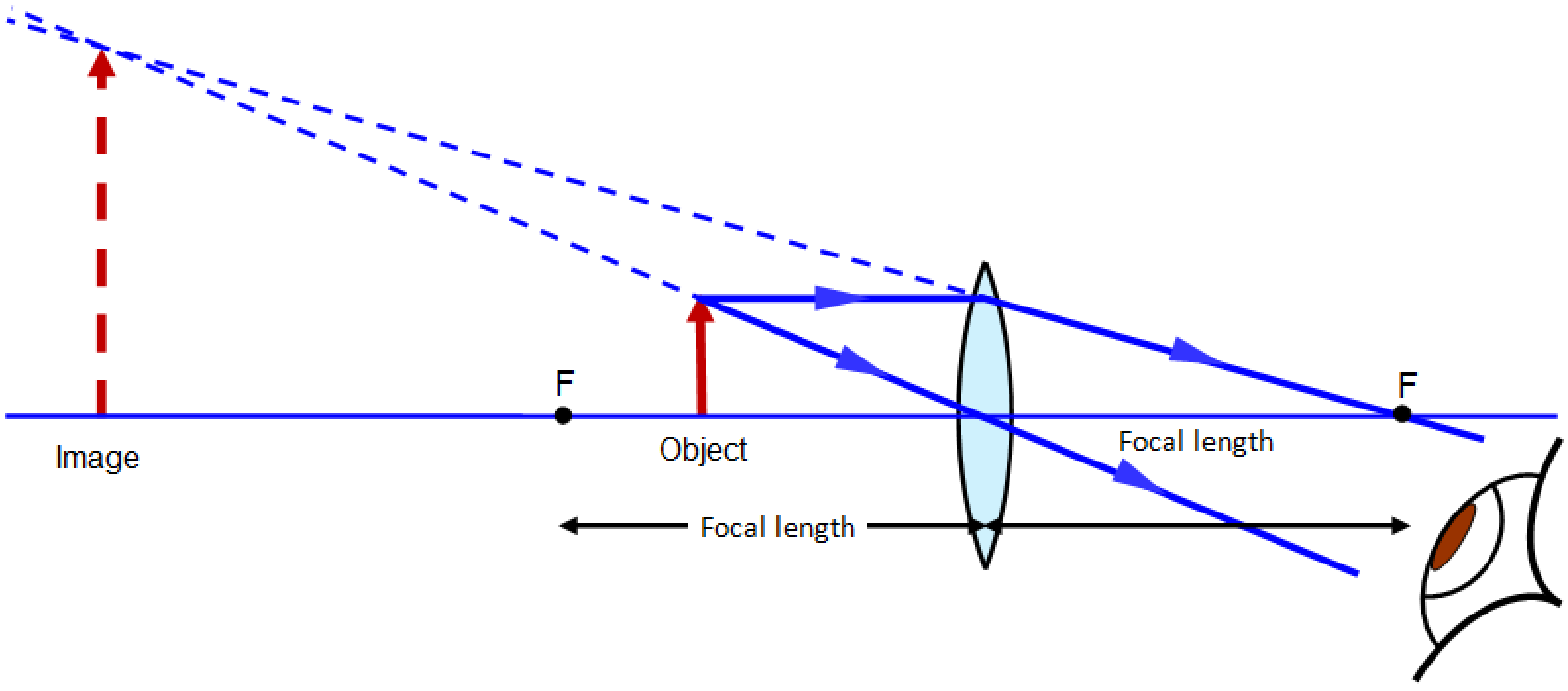
Magnification = image height (II')/object height (OO') = image distance (v)/object distance (u)



In spite of what you might think magnifications don't always have to be bigger than one. For example in a camera and in your eyes the image is smaller than the object.

Magnifying glass

If the object is closer to the lens than the focal length of the lens then the lens behaves as a magnifying glass. The image produced by the lens is virtual, magnified and the right way up.



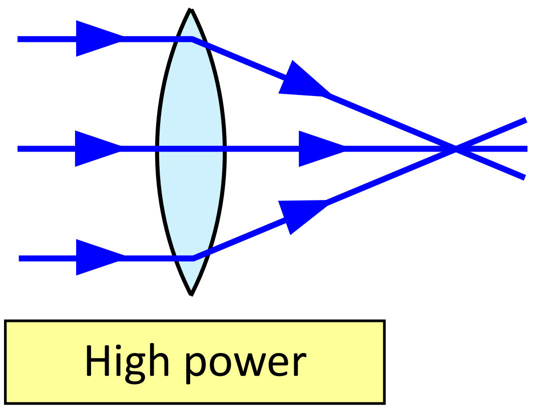
Power of a lens

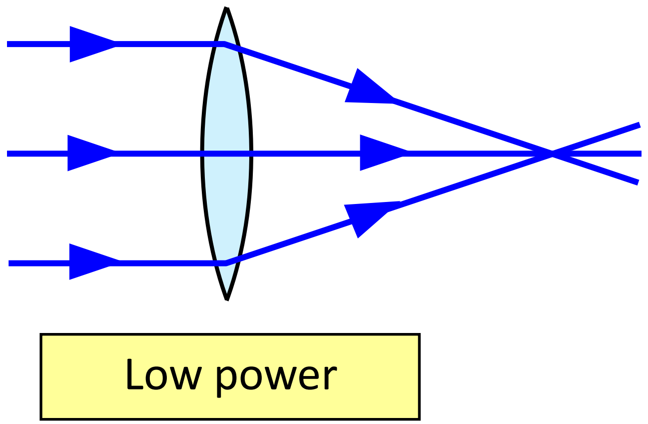
The power of a lens (what opticians use to describe the strength of a lens when you go to have your eyes tested) is defined as:

Power of a lens = 1/[focal length in metres]

Converging lenses have positive powers, diverging lenses have negative powers.

A lens with a power of + 5 D (dioptres) is a convex lens with a focal length of 20 cm. One with a power of -10 D is a concave lens with a focal length of 10 cm.

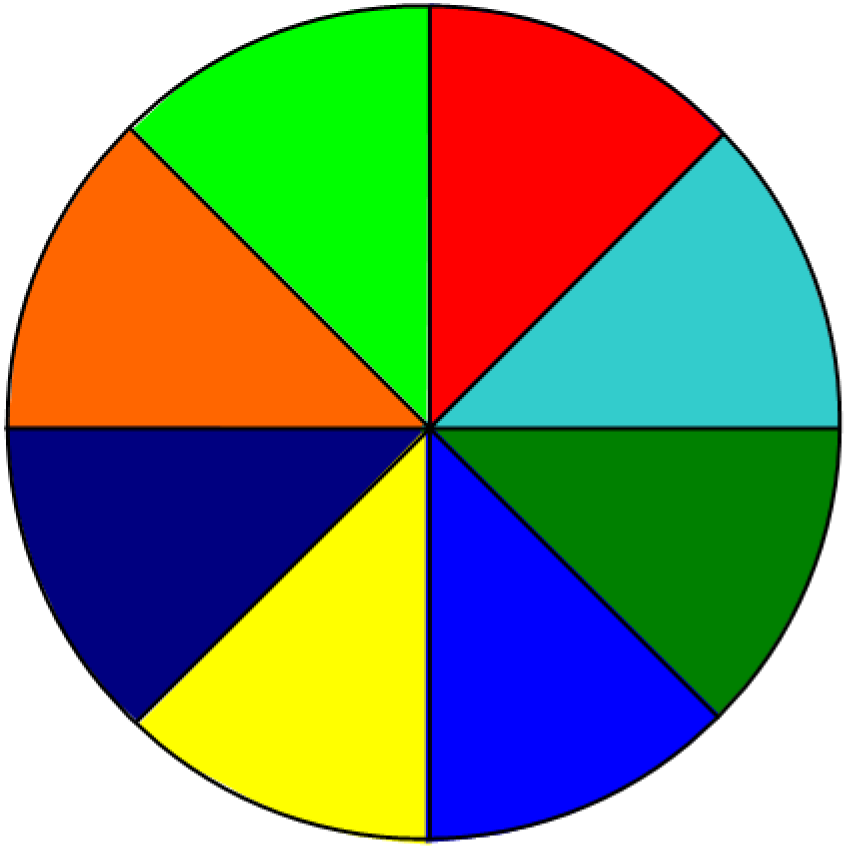




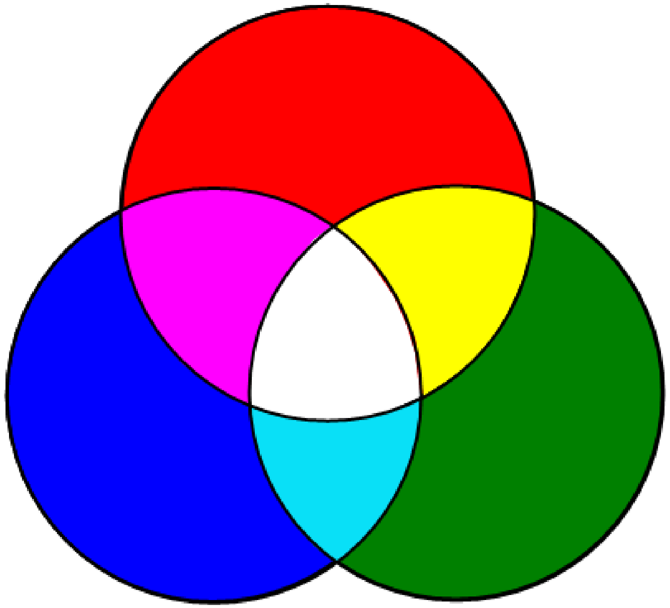
Colour wheel

The simplest of adding colours together way is by spinning a disc on which are painted the colours of the spectrum. The result will be something like white!

A sample disc is shown in the diagram – in reality there are more colours and they are not all the same width, this is because of the different sensitivity of your eyes to different colours.



Colour addition



If you have three lights, one red, one blue and one green you could make any other colour by using different combinations and brightnesses of these three. For this reason red, green and blue are called **PRIMARY COLOURS**.

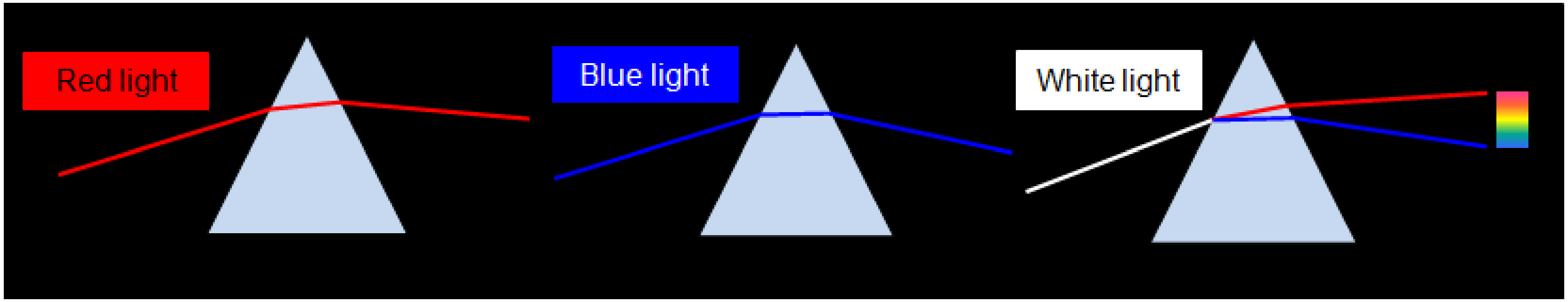
The diagram shows the result of adding different combinations, notice that if you add all three together you see white.

Any two colours that can be added together to make white are called **COMPLEMENTARY COLOURS**.

Prisms and colour (1)

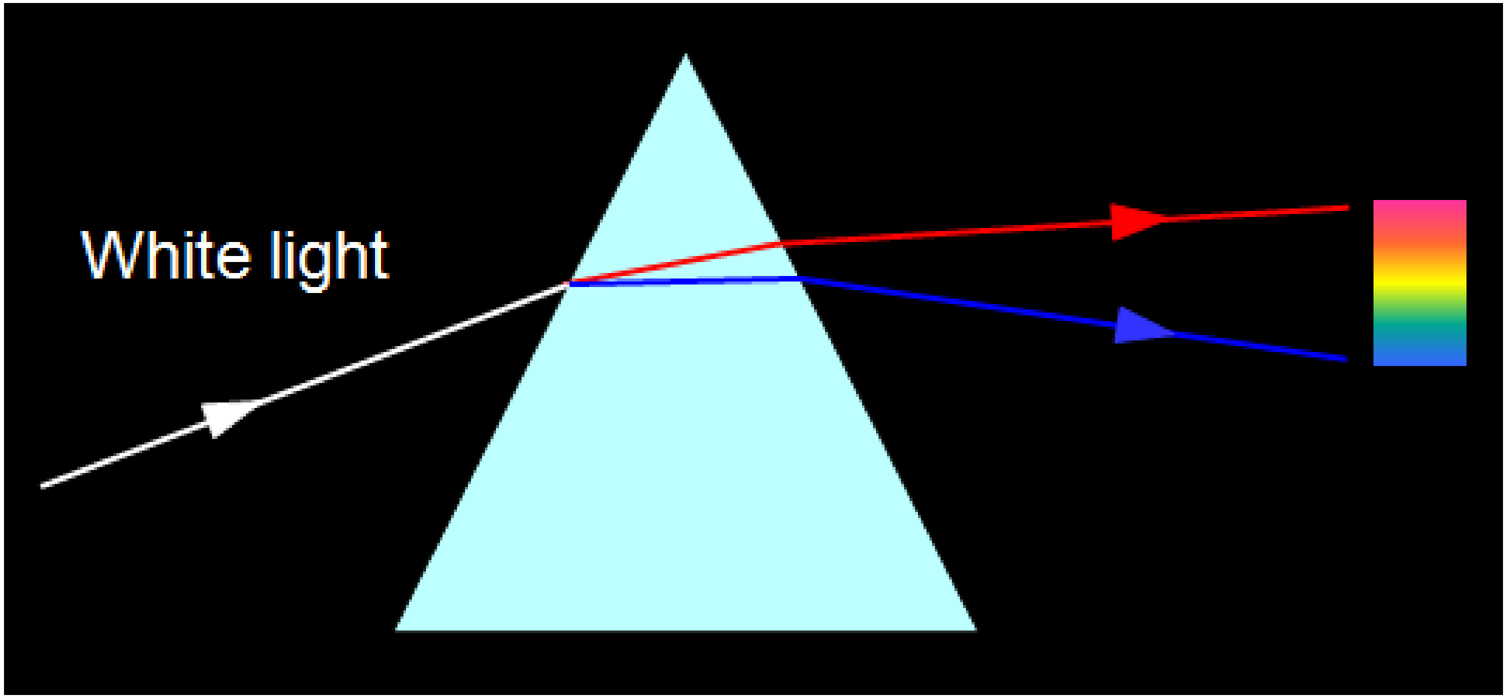
If a beam of light of one colour is shone through a prism, the direction of the beam is changed by the prism. This is because the two faces of the prism through which the light passes are not parallel.

Red light is bent less than blue light. (The glass slows down the blue light more than it does the red and so the direction of the blue is changed more.)



If white light is used the prism splits up the light into a series of colours. This shows that white light is actually made up of many other colours - a fact first shown by Newton in 1666. The spread of colour is called a **SPECTRUM**.

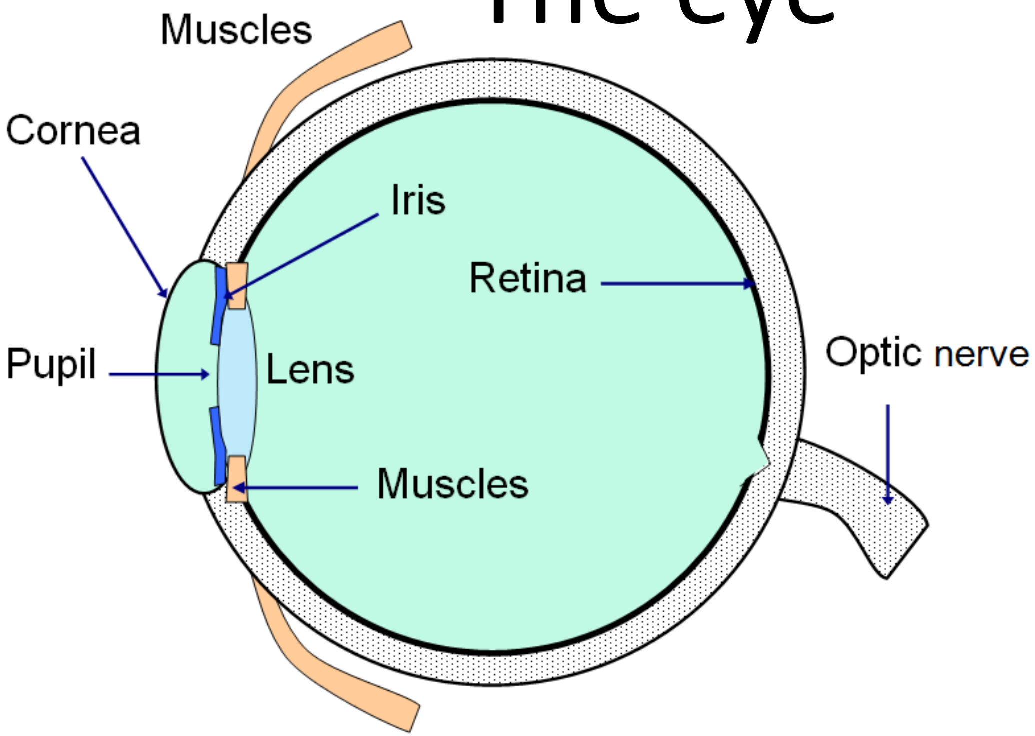
Prisms and colour (2)



Violet light is refracted most by a prism and red light is refracted least.

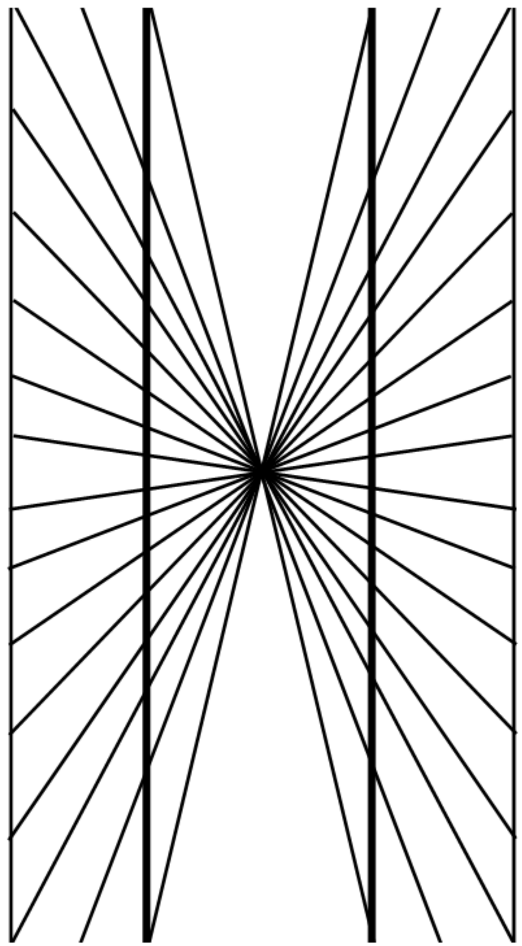
Red	Orange	Yellow	Green	Blue	Indigo	Violet

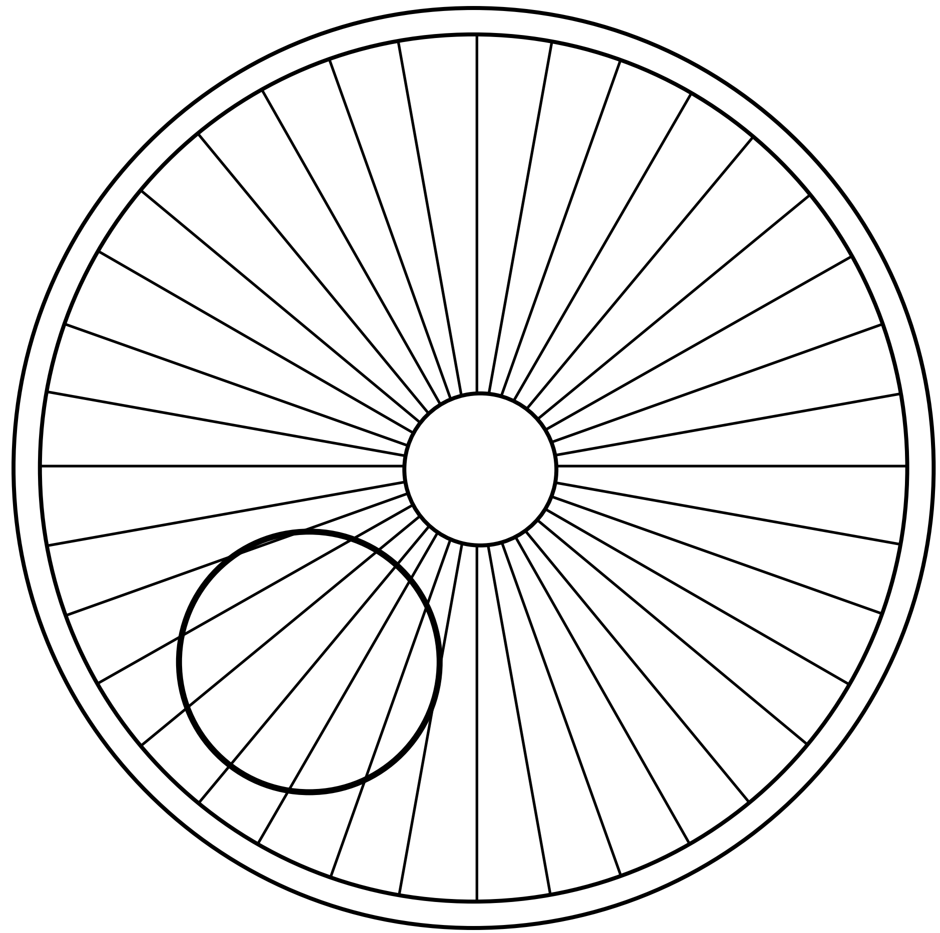
The eye



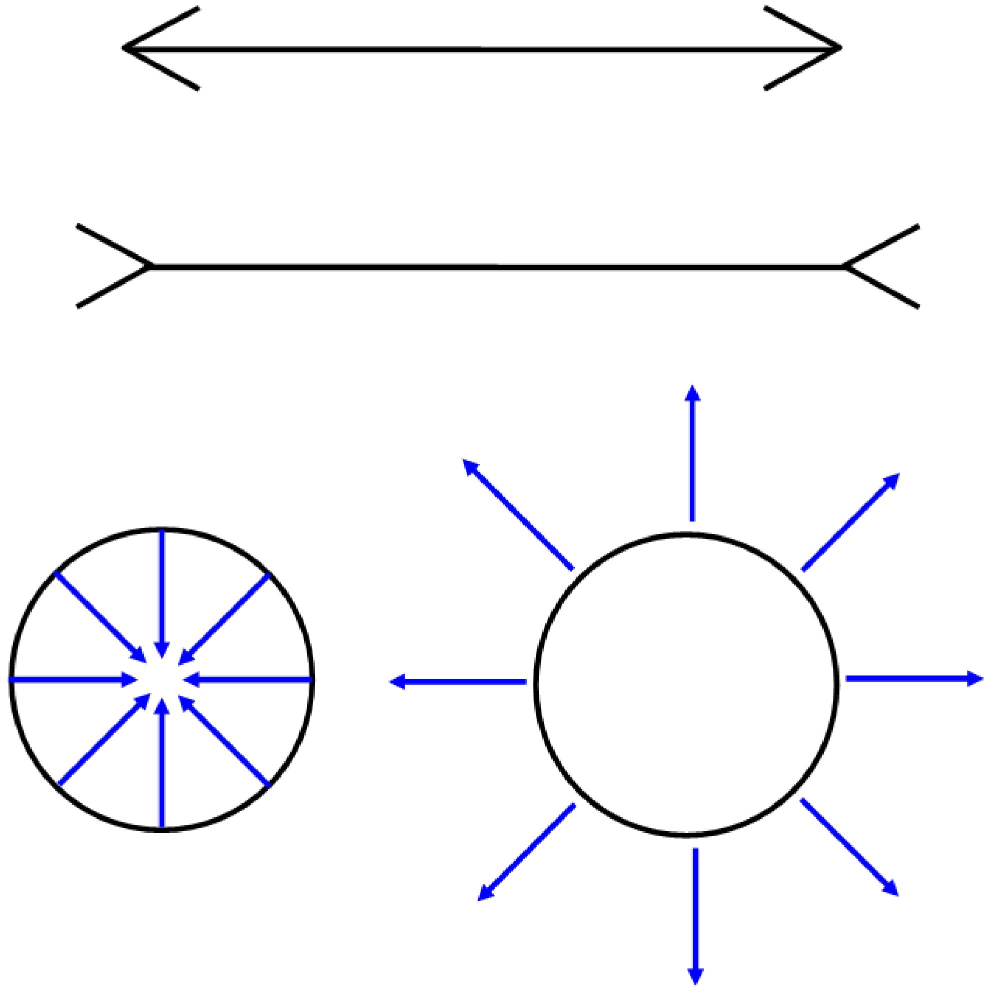
(a) lens - this makes fine adjustments to the focus of the view that we see
(b) cornea – the transparent part at the front of our eye. This helps to focus the view on our retina.
(c) retina – the part of the eye that is sensitive to light.
(d) optic nerve - this takes the signals from out retina to our brain so that we can see
(e) muscles – there are two different sets of muscles in your eyes.
  (i) One set goes round the lens. These are used in fine focusing of the eye.
  (ii)The ones at the top and bottom and on the sides of the eye swivel your eye in its socket.
(f) iris – this is the coloured part of your eye

Optical illusions (1)

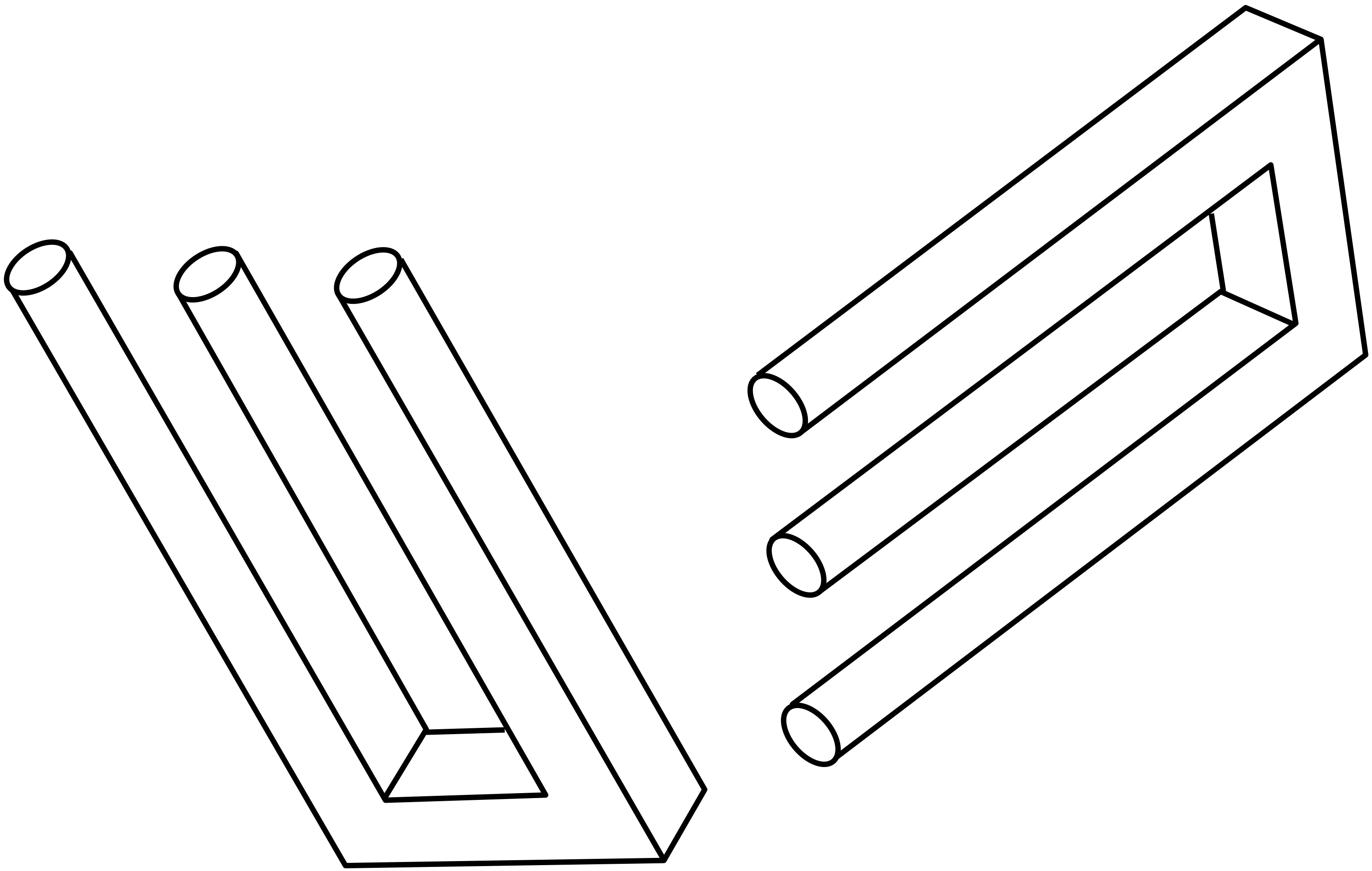




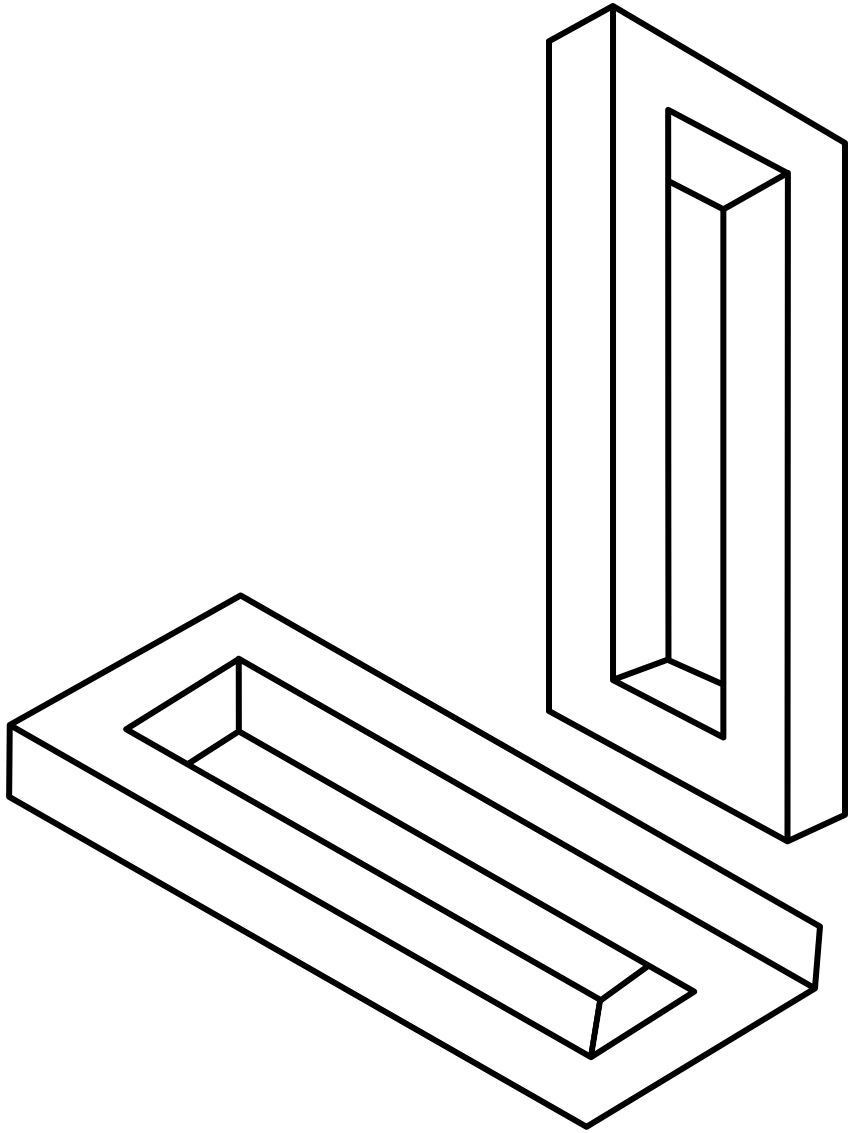
Optical illusions (2)

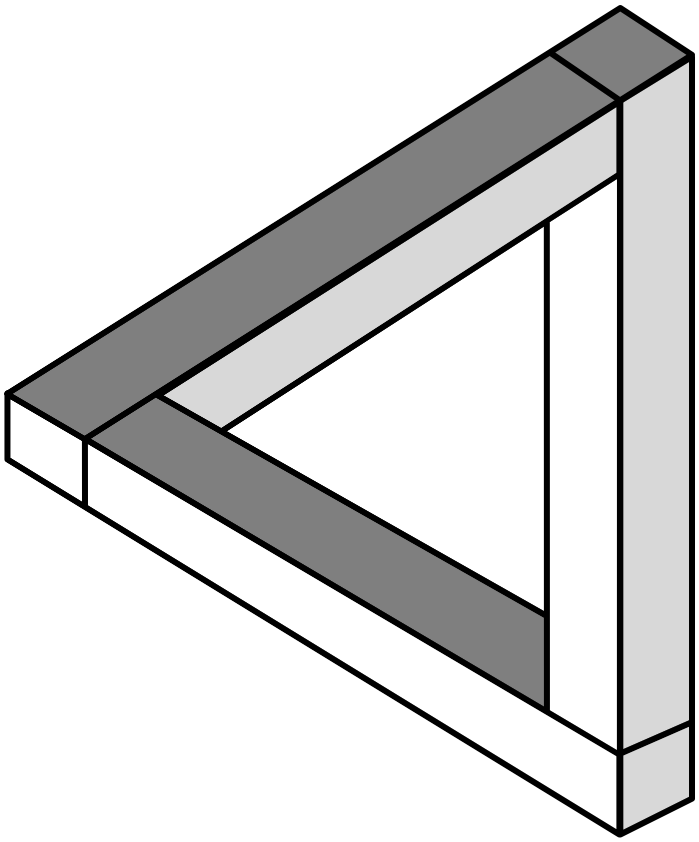


Optical illusions (3)

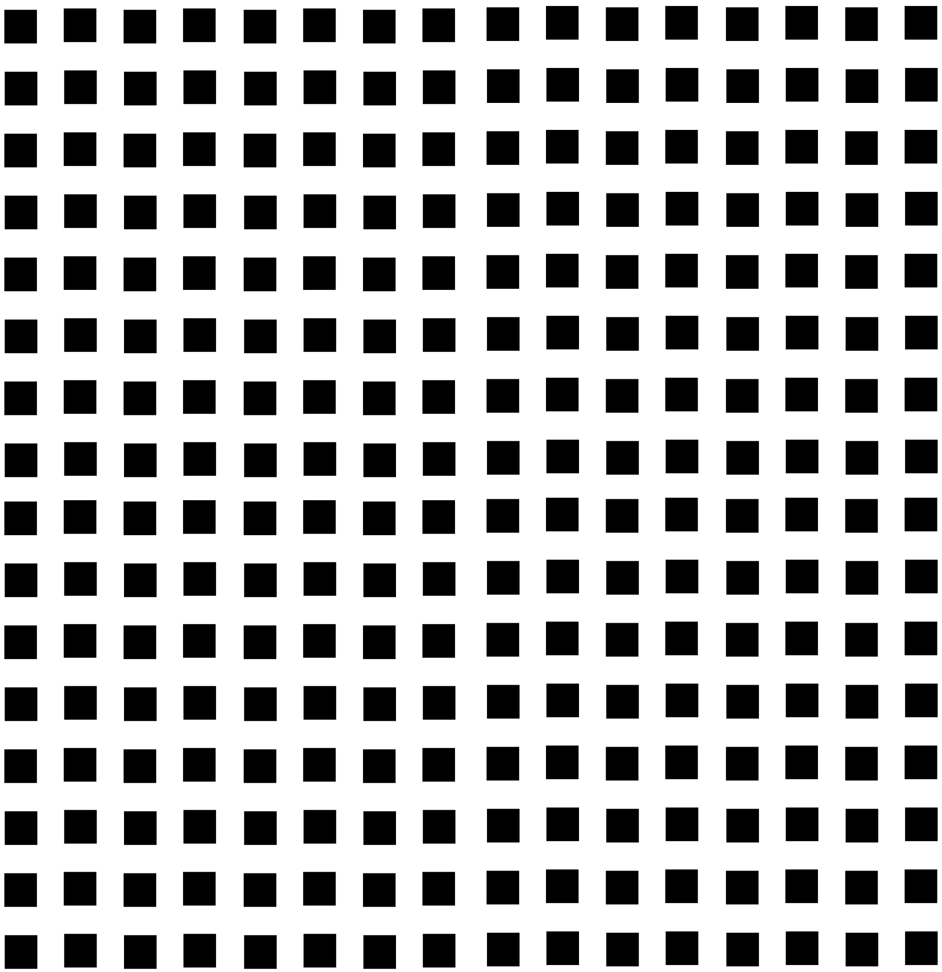


Optical illusions (4)

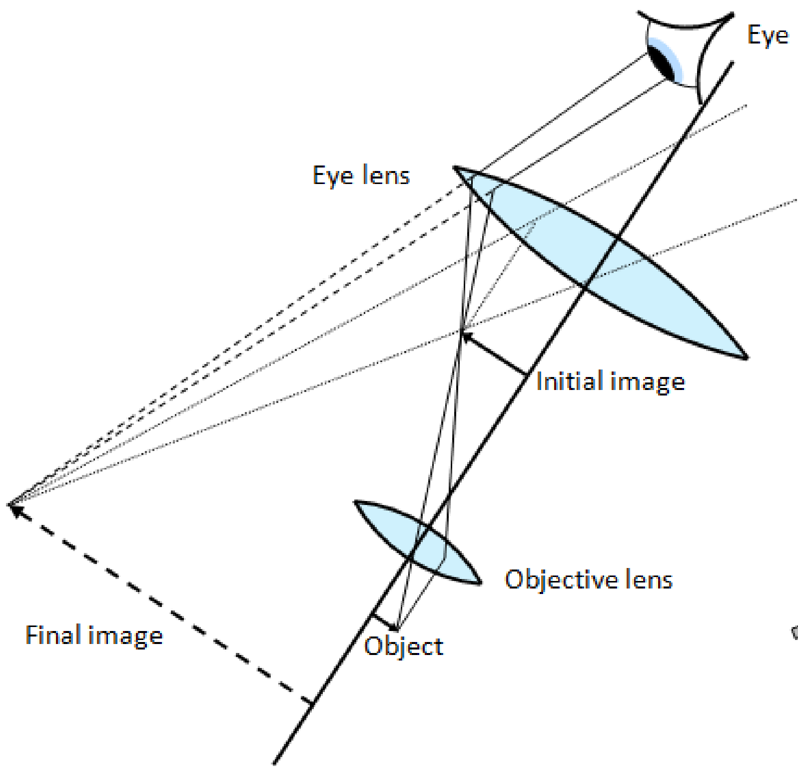


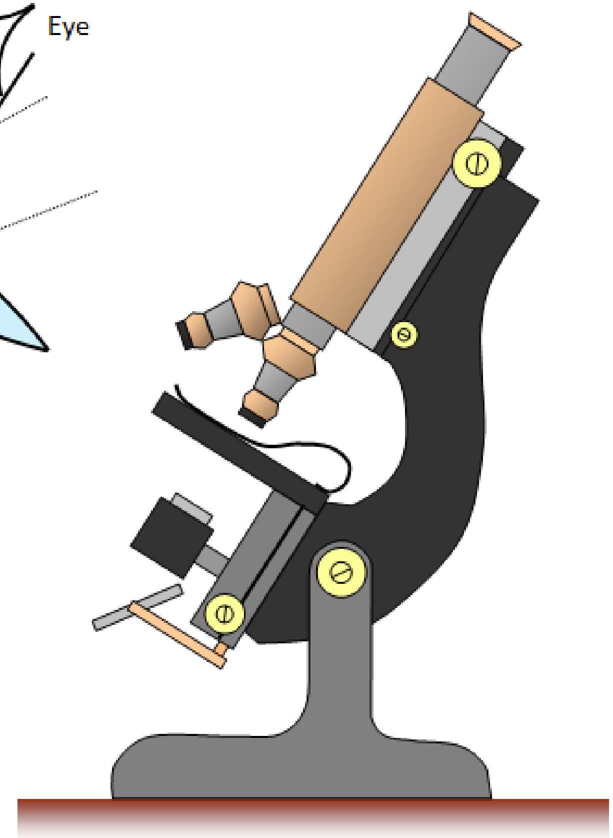


Optical illusions (5)

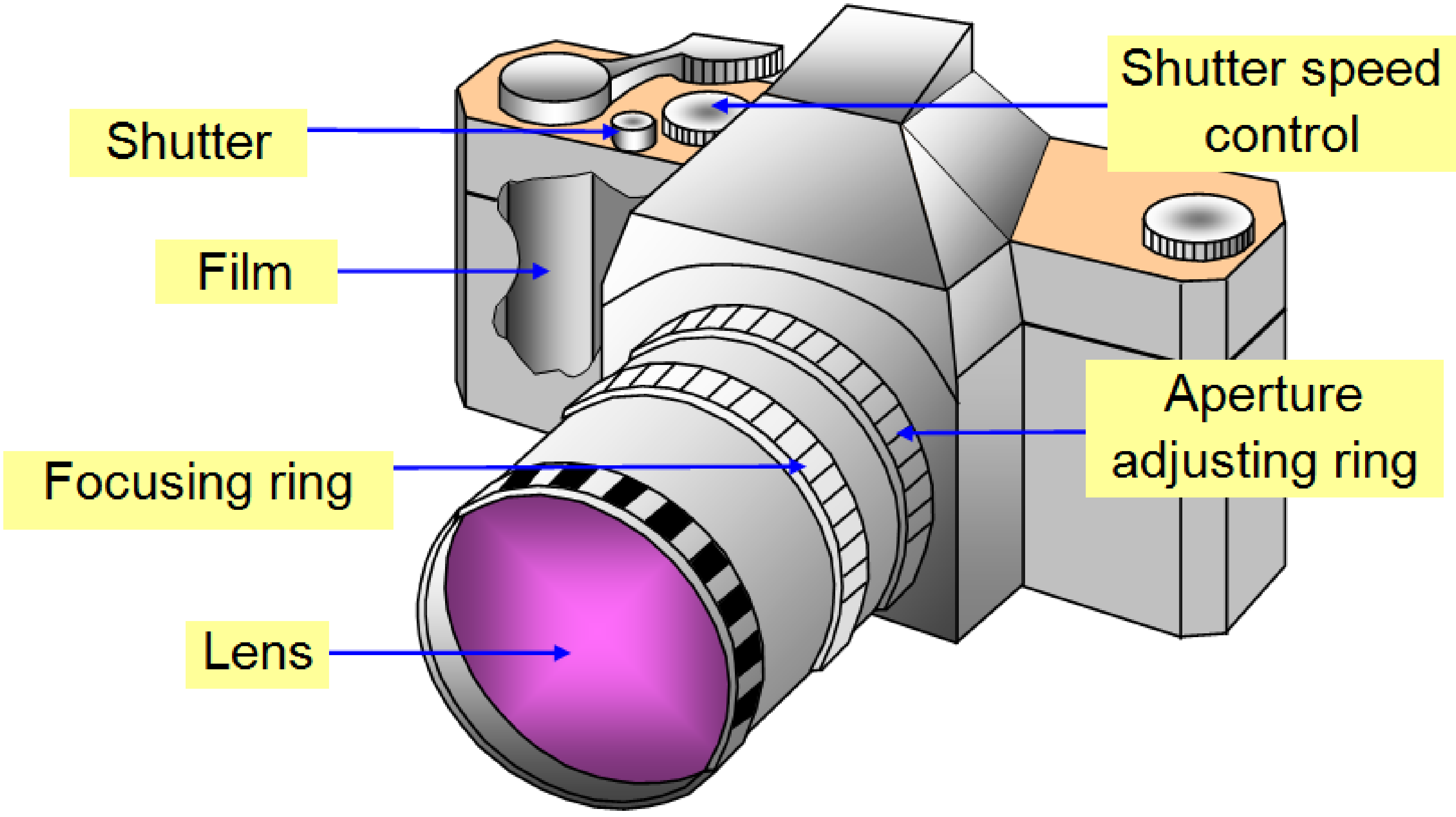


The compound microscope





Camera



Shutter speed control
Shutter
Film
Aperture adjusting ring
Focusing ring
Lens

Telescopes

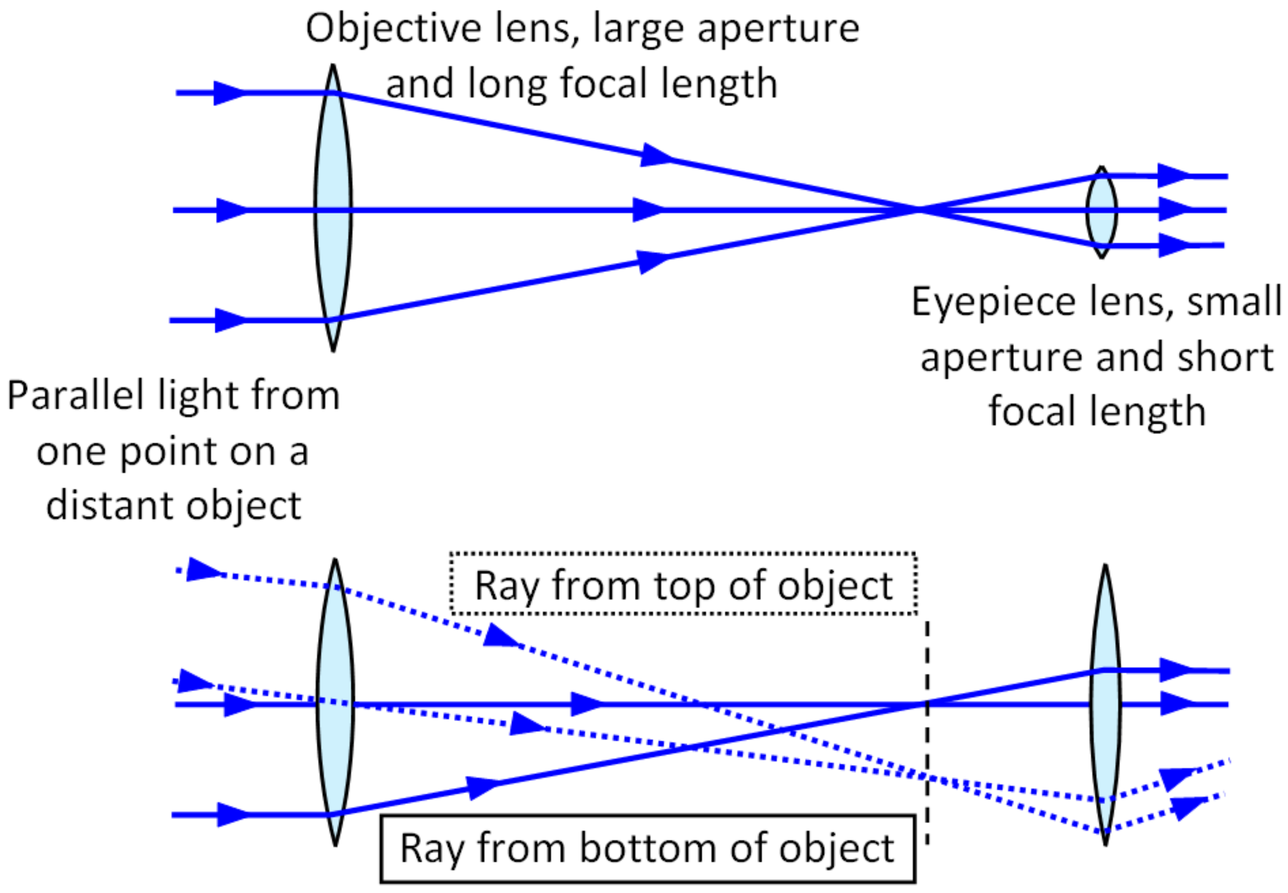
The main purposes of a telescope used for astronomy are:

(a) to gather as much light as possible – this is done by using a large aperture lens or mirror. The amount of light gathered depends on the AREA of the lens – so a lens with an aperture of 300 mm diameter gathers four times a much light as one with an aperture of 150 mm diameter.

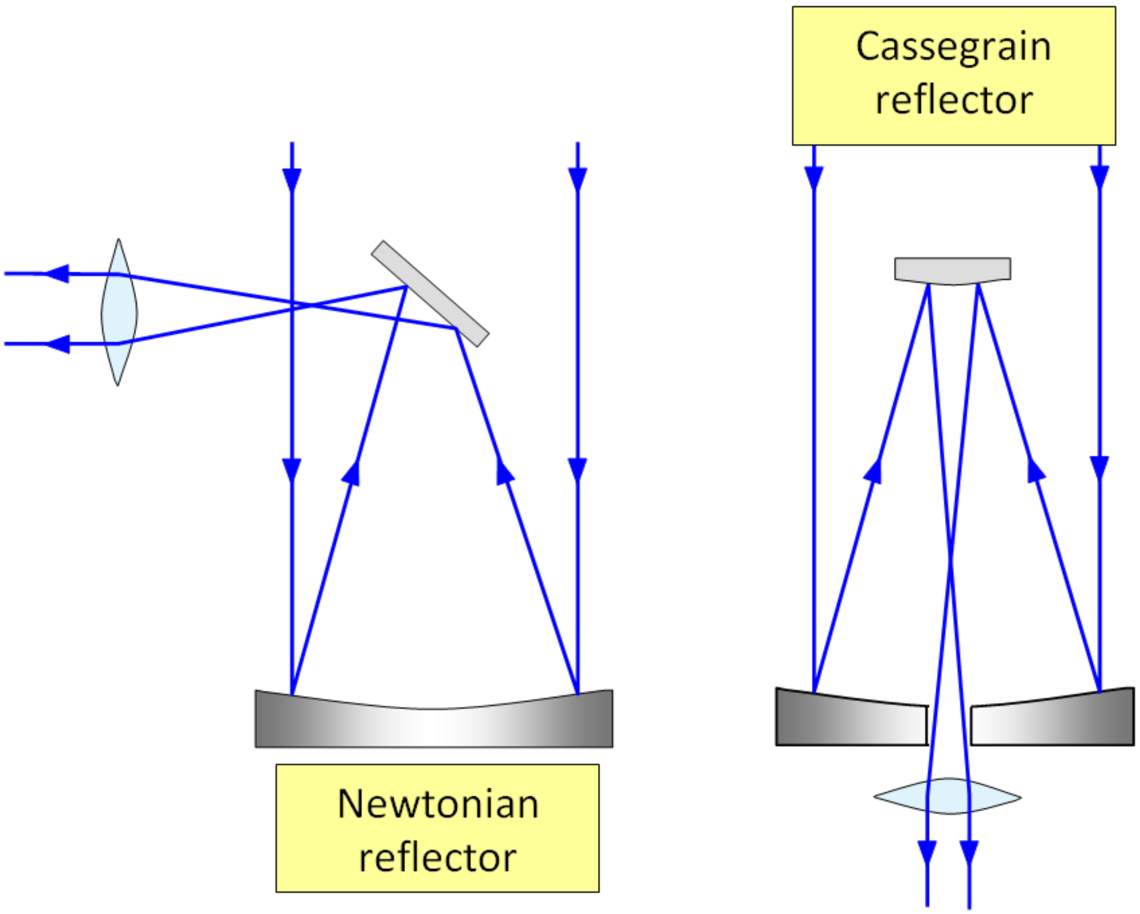
(b) to resolve fine detail – this is also done by using a large aperture lens or mirror. The larger the aperture the finer the detail that can be seen. (Usually called the resolving power of the telescope.)

(c) to magnify the image of a distant object – this is done by using a lens or mirror with a long focal length.

Refracting telescopes



Reflecting telescopes



Sextant

The angle between mirror 2 and the telescope is 60°. One half of this mirror is silvered and the other half is clear glass. Mirror M_1 is completely silvered and can be rotated on the arm M_1V . When the arm is in position O the two mirrors are parallel to each other.

Light coming from one object (B) makes an angle of $\theta°$ with light coming from another object (C). Direction B could be the horizon and direction C the Sun or a star.