STANDARD HIGH SCHOOL ZZANA

LIGHT

Light is a form of energy that enables us to see

Sources of light

a) Luminous source of energy
Is that which produces its own light e.g. star, sun, bulb, candle etc.

b) Non luminous source of light is that which doesn't produce its own light but can reflect from luminous object e.g. mirrors, moon, car reflectors etc.

Transparent objects

These are objects which can allow light to pass through them. E.g. driving windscreen of a car, ordinary glass, pure water etc

Translucent objects

These are objects which allow little light to pass through them e.g. bathroom glass, tinted glass, tracing paper e.t.c

Opaque objects

These are objects which don't allow light to pass through them e.g. wood, concrete etc.

PROPERTIES OF LIGHT

- It undergoes reflection
- It undergoes refraction
- It undergoes diffraction.
- It undergoes interference.
- Can be plane polarized
- Travels in a straight line
- It has a velocity of 3.0×10^8 ms^{-1} in vacuum
- Can travel through a vacuum

RAYS AND BEAMS

A ray

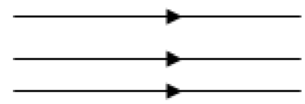
This is a path taken by light from an object (Source) to another. A ray is represented by a thin line with an arrow to indicate the direction of light

Beams of light

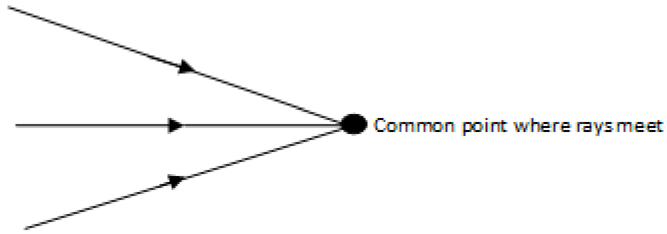
A beam is a collection of light rays moving in the same direction.

TYPES OF BEAMS

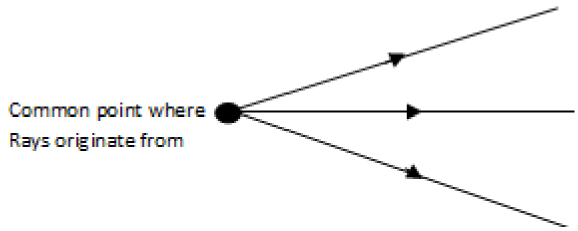
i) Parallel beam



ii) Convergent beam.



iii) Divergent beam



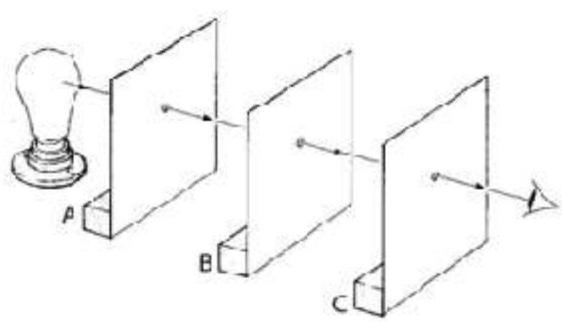
RECTLINEAR PROPAGATION OF LIGHT

This is the phenomenon where by light travels in a straight line

EFFECTS OF RECTLINEAR PROPAGATION

i) Formation of shadows
ii) Occurrence of eclipses

EXPERIMENT TO SHOW THAT LIGHT TRAVELS IN A STRAIGHT LINE



PROCEDURE

Three (3) identical cardboards A, B and C each with a hole in its centre are arranged with the holes in a straight line as shown above

A source of light is placed behind cardboard A and an observer in front of C.

The observer is able to see the light from the source because light travels in a straight line

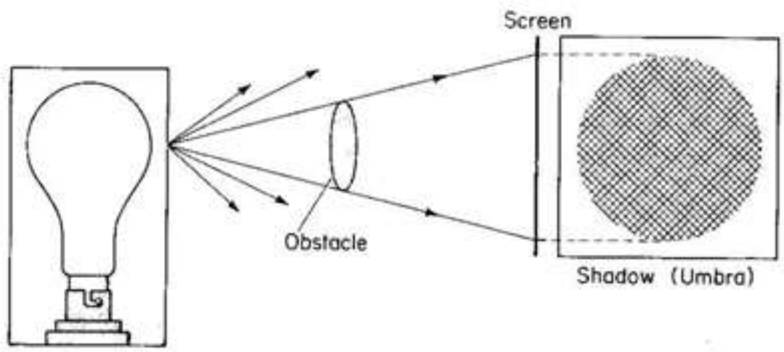
If one of the cardboards is displaced such that the holes are not in the straight line, no light will be seen by the observer

This shows that light travels in a straight line

SHADOWS

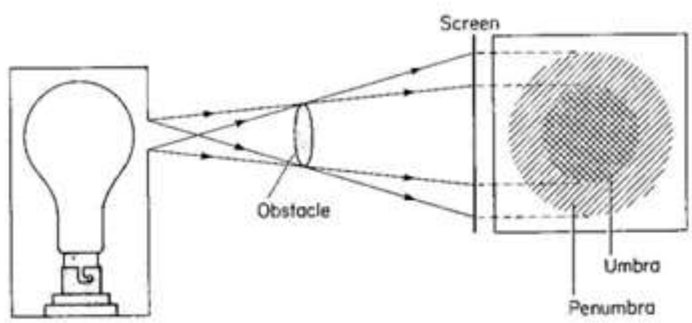
Shadows are formed when light rays are obstructed by an opaque object

FORMATION OF A SHADOW BY LIGHT FROM A POINT SOURCE



The shadow formed is completely dark with sharp edges and is called umbra

Formation of a shadow by light from an extended source



The shadow has two parts

(i) **umbra**
It is the central part of the shadow. It is dark and receives no light.

(ii) **Penumbra**
It is the outer part of the shadow. It is fairly dark. It receives some light from the source

ECLIPSE

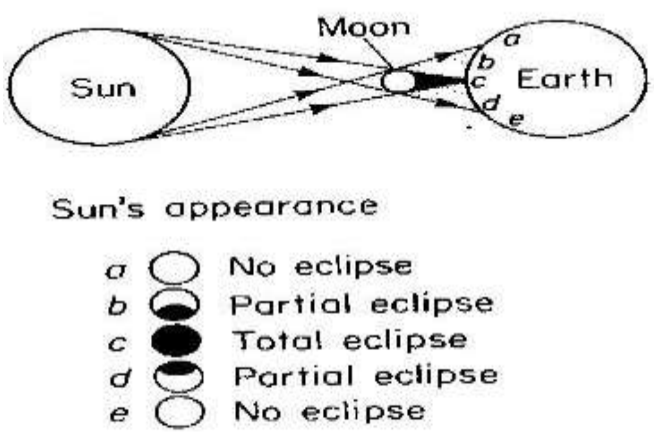
An eclipse occurs when the sun, moon and earth are in a straight line. It is a natural effect of the rectilinear propagation of light

TYPES OF ECLIPSE

1. SOLAR ECLIPSE

It occurs when the moon is between the sun and the earth. It is also called eclipse of the sun. In this eclipse there is total eclipse i.e. total darkness on the earth and partial eclipse where there is little light on earth

ILLUSTRATION



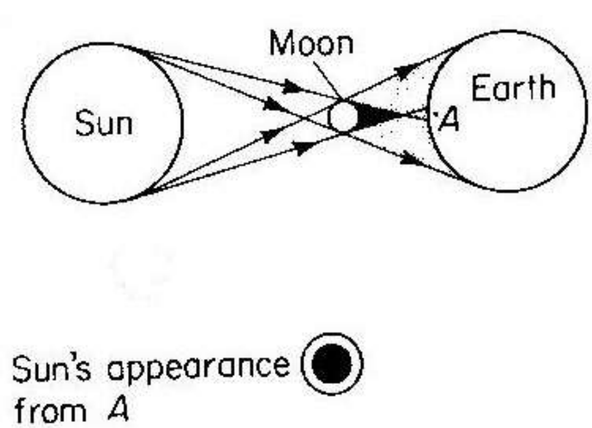
Region **c** represent total eclipse i.e. no light from the sun reaches the earth and the sun is not visible.

Regions **b** and **d** represent partial eclipse i.e. some light reaches the earth and part of the sun is visible There is partial darkness

In Regions **a** and **e** no eclipse occurs

A NNULAR ECLIPSE

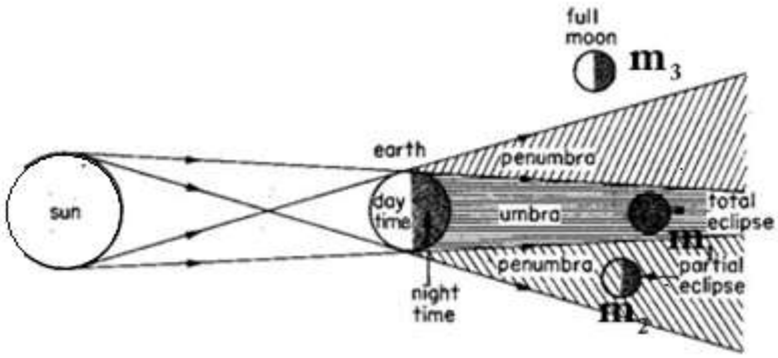
This is a solar eclipse when the shadow of the moon fails to reach the earth. The sun appears as an annulus.



LUNAR ECLIPSE (ECLIPSE OF THE MOON)

This occurs when the earth is between the sun and the moon. It takes place at night, as the moon revolves about the earth, along its orbit. If m_1, m_2 and m_3 are different positions of the moon, then during lunar eclipse, no eclipse occurs in position m_3, i.e moon is fully visible. In position m_2 partial eclipse occurs. i.e. only part of the moon is visible.

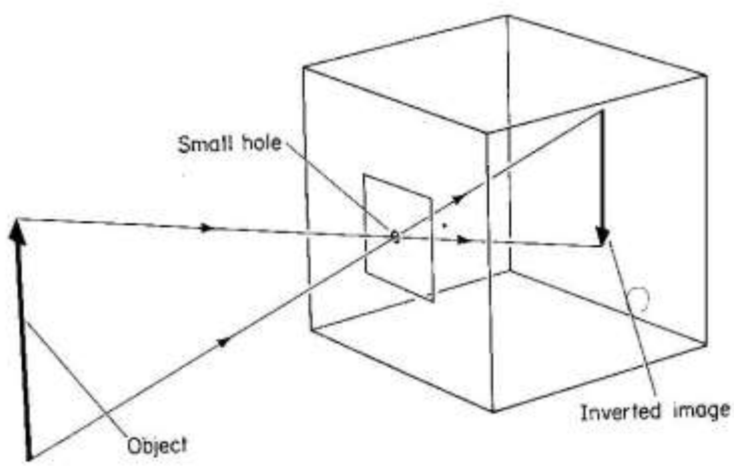
But the moon is visible with a copper like colour due to some light refracted by the earth at position m_1



THE PIN – HOLE CAMERA

This is a box or tin with a black and roughened internal surface and a screen opposite the face with a small hole. It works on the principle of rectilinear propagation of light.

N.B: the internal surface is made black by painting it and roughened so as to prevent reflection of stray light in box.



Light from object enters the pinhole camera through a small hole forming an inverted image.

Nature of the image formed in the pin-hole camera

1. It is real
2. It is inverted

FACTORS AFFECTING THE SIZE OF THE IMAGE

i) Distance between the object and the hole or camera
The image size increases as the distance from the pinhole decreases

ii) Distance between the hole and screen
The image size increases i.e. magnified as the distance increases or the image size diminishes as the distance decreases.

EFFECTS OF SEVERAL HOLES OR ENLARGING THE PINHOLE

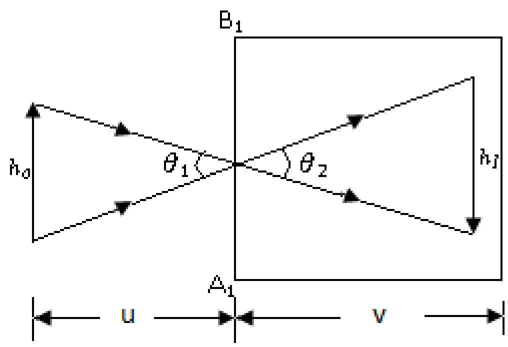
The image becomes blurred (not sharp) and brighter because more light is admitted into the pinhole camera. It has no effect on the size of the image

MAGINIFICATION

This is the ratio of image size to object size

M = =

Note



For $_1$ = $_2$ (vertically opposite)

By Proportionality

= = m

Where V – Image distance from pinhole to screen

Object distance from pinhole to object

Example

An object 2cm high forms an image on a screen of the pinhole camera. If the distance between the object and screen is 24cm and the distance between the object and the pinhole is 6cm find

i) The magnification of the image
ii) The size of the image.

i) h_I = 2cm , u = 6cm v = 24cm
Magnification M = = = 4
ii) M = = 4 = = h_1 = (4 x2) = 8 cm

REFLECTION OF LIGHT

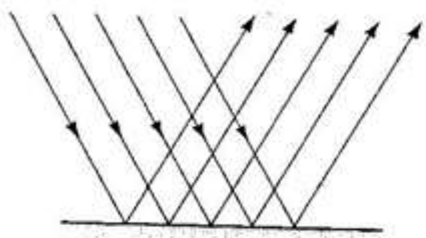
It is the bouncing of light from a shiny surface

TYPES OF REFLECTION

There are two types of reflection

i) Regular reflection
ii) Diffuse / irregular reflection

Regular reflection



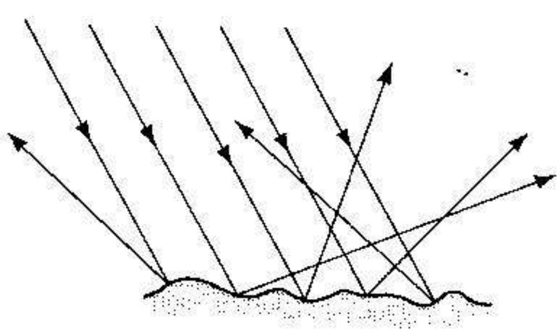
Regular reflection

Regular reflection is the type of reflection in which a parallel beam of light is incident on a smooth surface is reflected as a parallel beam

The angles of incidence are equal to the angles of reflection

Diffuse reflection

This is a type of reflection in which a parallel beam of light incident on a rough surface is reflected as a scattered beam. Angles of incidence and reflection keep varying with the points of incidence

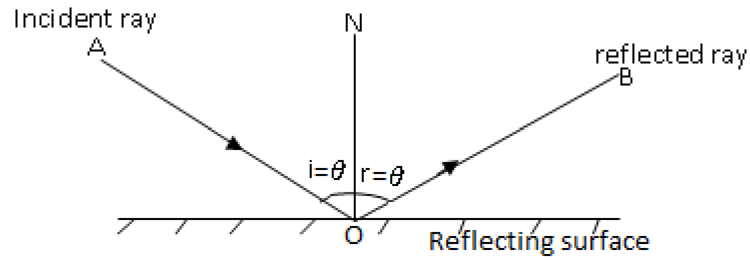


Diffuse reflection

Application of diffuse reflection

- Ability to see many objects at the same time
- Ability to read a book

TERMS USED IN REFLCTION OF LIGHT



i) Point O (point of incidence)
This is the point on the reflecting surface where the incident ray is directed

ii) Normal (ON)
This is a line drawn from point O and perpendicular to the reflecting surface

iii) Incident ray (AO)
This is the path along which light is directed on to the reflecting surface

iv) Angle of incidence (i)
This is the angle that the incident ray makes with the normal at the point of incidence

v) Reflected ray (OB)
Is the path along which light incident on a surface is reflected

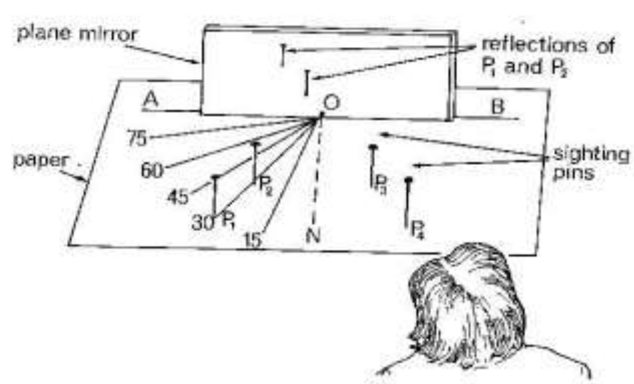
vi) Angle of reflection Ө
This is an angle between the reflected ray and the normal at the point of incidence

LAW OF REFLECTION OF LIGHT

There are two laws

1. The incident ray, the normal and reflected ray at the point of incidence all lie in the plane.
2. The angle of incidence is equal to the angle of reflection

EXPERIMENT TO VERIFY LAWS OF REFLECTION



Draw lines AB and ON perpendicular to each other on white sheet of paper

Measure angle I = 30^0 and draw line IO

Put the white piece of paper on the soft board. Fix pins p_1 and p_2 vertically

Insert a plain mirror along AB with the reflecting surface facing you.

Looking through the plain mirror in the opposite side, fix pins p_3 and p_4 such that they appear to be in line with images of p_1 and p_2.

Measure angle i and r using a protractor

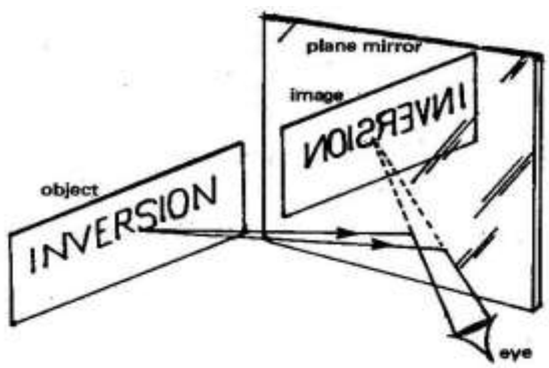
The procedure above are repeated for angle of incidence 45^0 and 40^0

It is observed that angle of incidence i is equal to angle of reflection and since IO, ON and OR are drawn on the same sheet of paper

The laws of reflection

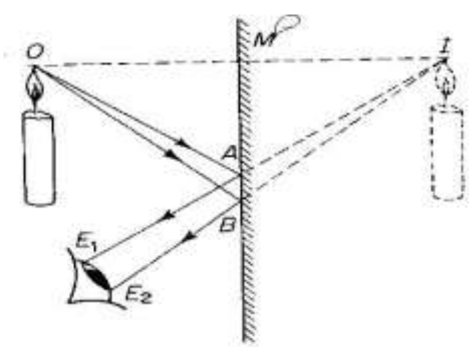
NATURE OF IMAGE FORMED BY A PLANE MIRROR

- The image formed is of the same size as the object
- The image distance from the mirror is equal to the object distance from the mirror
- The image is laterally inverted



- It is virtual i.e. can't be formed on the screen

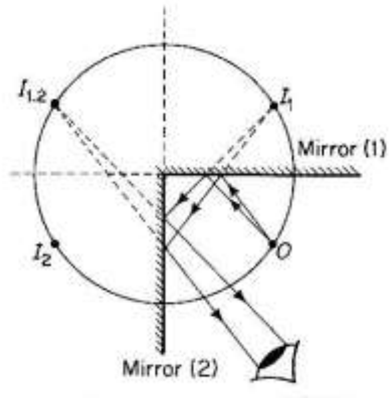
IMAGE FORMATION IN A PLANE MIRROR



Note: the line joining any point on the object to its corresponding point on the image cuts the mirror at 90^0

Distance OM = distance MI

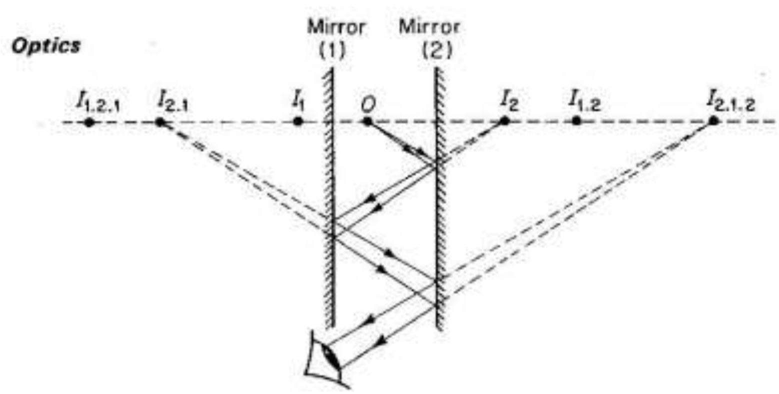
Images formed in two plane mirrors inclined at 90^0



When two mirrors are inclined at 90^0 to each other, images are formed by a single reflection in addition to two extra images formed by 2 reflections

Image formed in parallel mirrors

An infinite number of image is formed when an object placed between two parallel mirrors. Each image seen in one mirror will act as virtual object to the next mirror



The object O gives rise to image I_1 in mirror m_1 and I_2 on m_2 .I_1 acts as virtual object to give an image $I_{(1,2)}$ in mirror m_2 just as I_2 gives an image $I_{(2,1)}$ in mirror m_2. $I_{(1,2)}$ in mirror m_2 gives $I_{(1,2,1)}$ after reflection in m_1 while I $_{(2,1,2)}$ after reflecting in Mirror m_2.

Image formed by an inclined mirror at an angle θ

The table below summarizes how one can obtain the number of image formed by 2 mirrors inclined at an angle

Angle between mirrors θ (°C)		**n = 1**
90	4	3
60	6	6
45	8	7
30	12	11
15	24	23

Where n = number of images formed

When two mirrors are parallel, the angle θ between them is zero and the number of images formed between them is

n = (1) = (1)= ∞ (infinite)

This shows infinite number of images when two plane mirrors are parallel. The image lies in a straight line through the object and perpendicular to the mirrors

Questions

1. Two plane mirrors are inclined at an angle 50^0 to one another. Find the number of images formed by these mirrors
2. Two plane mirrors are inclined at an angle θ to each other. If the number of image formed between them is 79, find the angle of inclination θ.

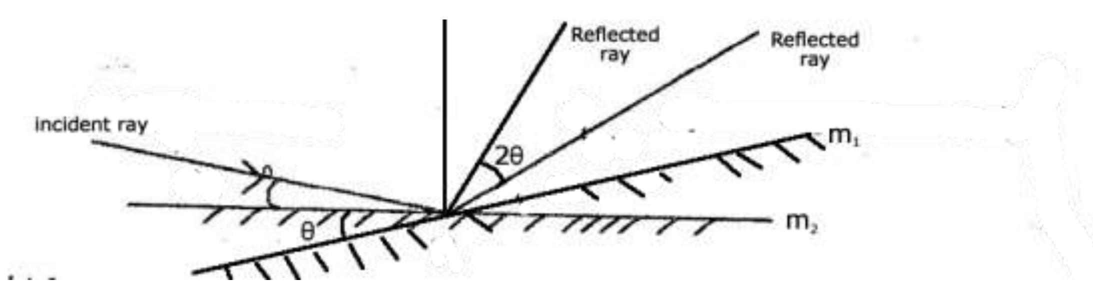
1. n = (1)

   n = ( ) = 7.2 -1= 6.2 images.

2. n =

   79 =
   θ = 4.5°

ROTATION OF REFLECTED RAY



When a mirror is rotated through any angle, the reflected ray will rotate through an angle 2θ provided the direction of the incident ray remains the same

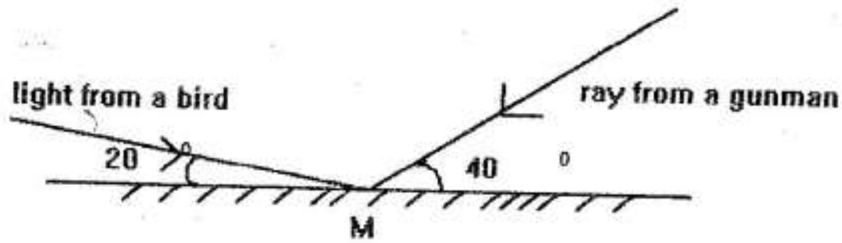
Example

The angle between the incident ray of light and a mirror is 25^0, if the mirror rotates through 20^o. Find by how many degrees do a reflected ray rotates.

Required angle = $2\theta = 2 \times 20 = 40^0$

N.B. the angle through which the reflected ray is rotated does not depend on the angle of incidence but depends on the angle of rotation of the reflecting surface.

Questions



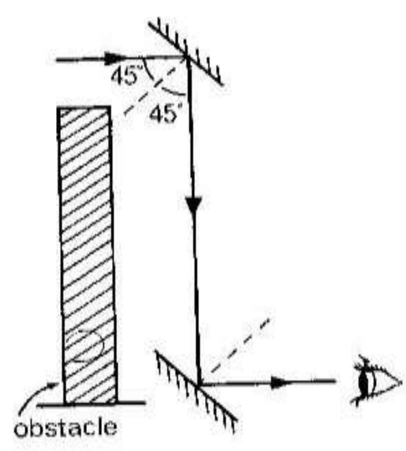
An incident ray makes an angle of 20^0 with the plane mirror in position m_1 as shown in the diagram

a) What will the angle of reflection be if the mirror is rotated through 6^0 to position m_2 while direction of incident ray remains the same?
b) An object is placed 6cm from a plane mirror. If the object is moved further, find the distance between the object and its image

Application of reflections

- Periscope

This is the instrument used for looking over top obstacles. It is made of 2 plane mirrors inclined at each other at 45^0. It is mainly used in submarines.



- Used in pointers to prevent errors due to parallax.
- Used in optical lever instruments to magnify angle of rotation.
- Used in kaleidoscope
- Used in small shops and supermarkets, takeaway and saloons to give a false magnification as a result of multiple reflections

REFLECTION BY CURVED MIRRORS

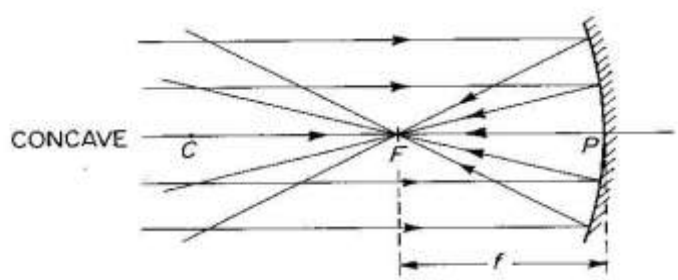
For some purposes, curved mirrors are more useful than plane mirrors. There are two types of curved mirrors

i) Concave / converging mirror (curve inwards)

ii) Convex /diverging mirror (curve outwards)

CONCAVE MIRRORS

A concave mirror converges parallel rays to a point called principal focus



P- Pole of mirror

F- Principal focus

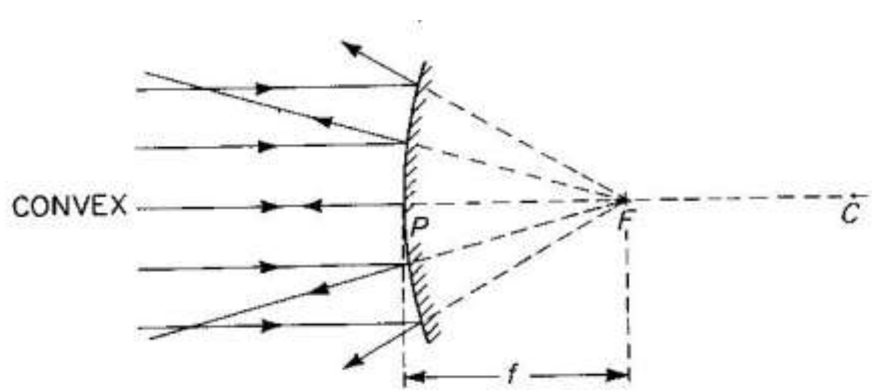
C- Center of curvature

r- Radius of curvature

f- Focal length

CONVEX MIRRORS

A convex mirror diverges (spreads out) parallel rays so that they never meet but appear to come from a point called virtual focal point



Terms used

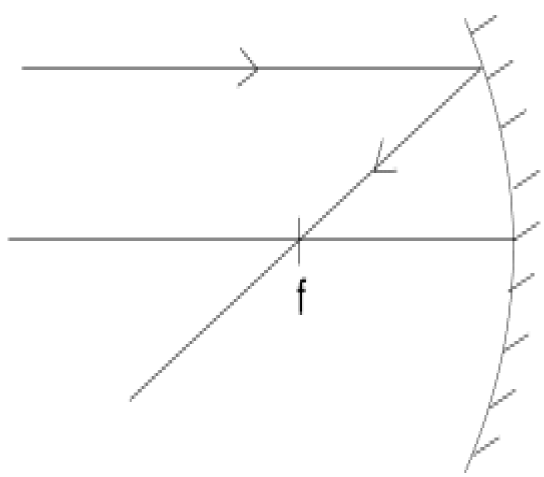
- **The point (P):** the point P is the center of reflecting surface
- **Center of curvature(C):** it is the center of sphere of which the mirror is part
- **Principal axis:** is the line joining the pole of the curved mirror to the center of curvature
- **Radius of curvature:** this is the radius the of sphere of which the mirror is part
  OR: it is the distance between the pole of the mirror and its center curvature
- **Focal length (f):** this is the distance from the pole of the mirror to the principal focus i.e. (r = 2f or f = r/2)
- **Principal focus / focal point(f):**
  a) *For a concave mirror.*
     Focal point is a point on the principal axis through which all rays parallel and close to the principal axis converge after reflection
  b) *For a convex mirror.*
     Principal focus is a point on the principal axis from which all rays parallel and close to the principal axis appear to diverge from after reflection
     Note: F is real for a concave mirror and virtual for a convex mirror. It is mid way between c and p.
- **Aperture:** this is the width of the mirror

a) **Real image:** is one which can be formed on the screen? It is formed by actual intersection of rays
b) **Virtual image**: it is one which cannot be formed on the screen. It is formed by apparent intersection of rays.

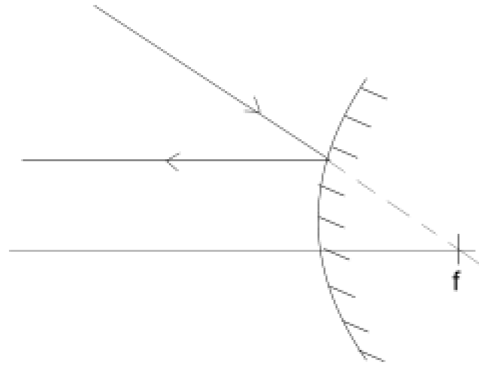
CONSTRUCTION OF RAY DIAGRAMS

Ray diagrams can be used to explain how and where a curved mirror forms images. The rays are drawn using any two of the following 3 principal.

1. A ray parallel to the principal axis is reflected through the principal focus
   a) For a concave mirror

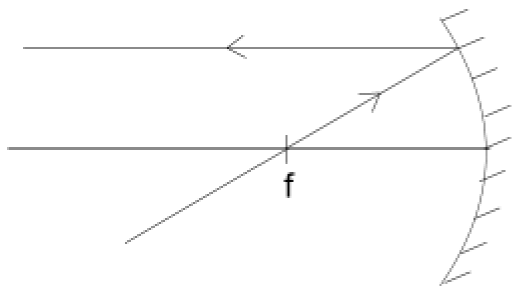


b) For a convex mirror

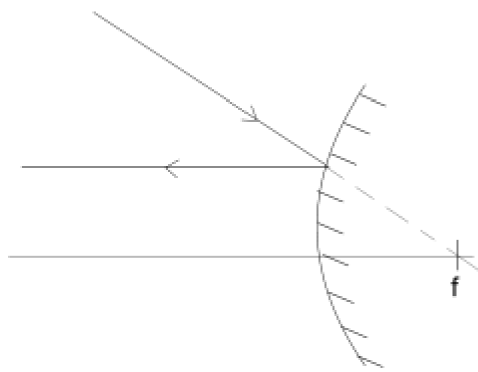


2. A ray through the principal focus is reflected parallel to the principal axis

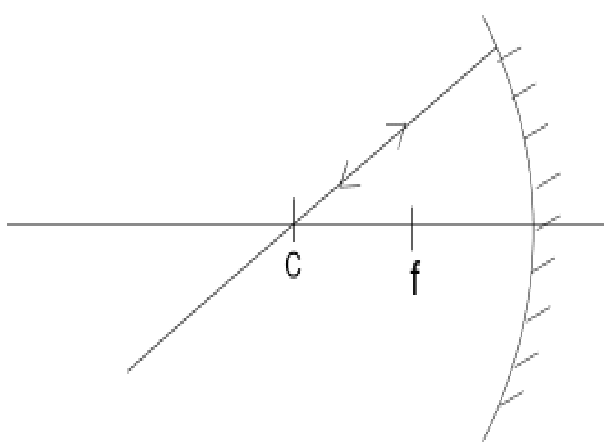
a) For a concave mirror



b) For a convex mirror



3. A ray through the center of curvature is reflected along the same path
   a) For a concave mirror



b) For a convex mirror

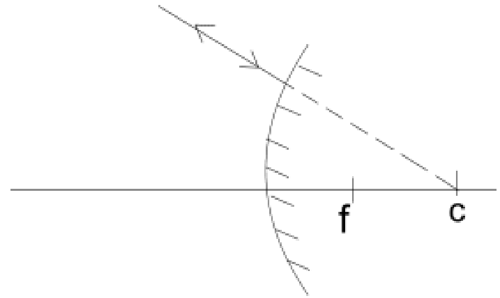
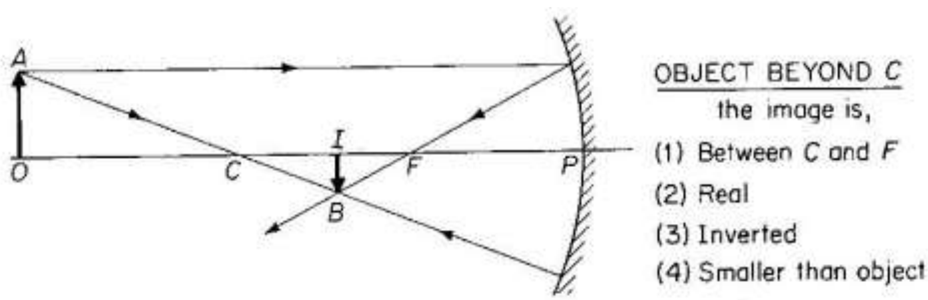


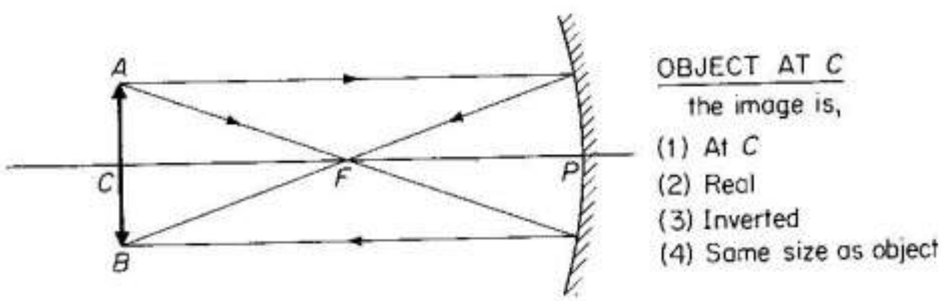
Image formation by concave mirror

The type, size and position of the image formed by a concave mirror depends centrally on the distance of the object from the mirror

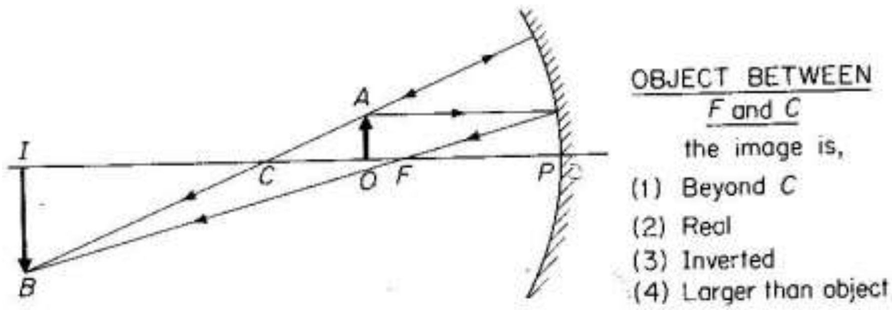
1. Object O beyond C



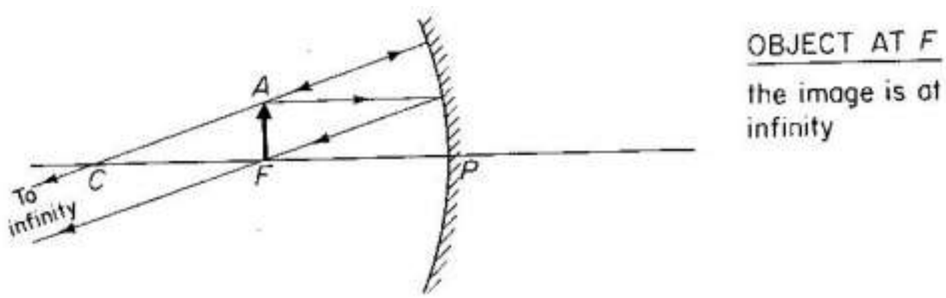
2. Objects O at C



3. Object O between C and F



4. Object O at F



5. Object O between F and P

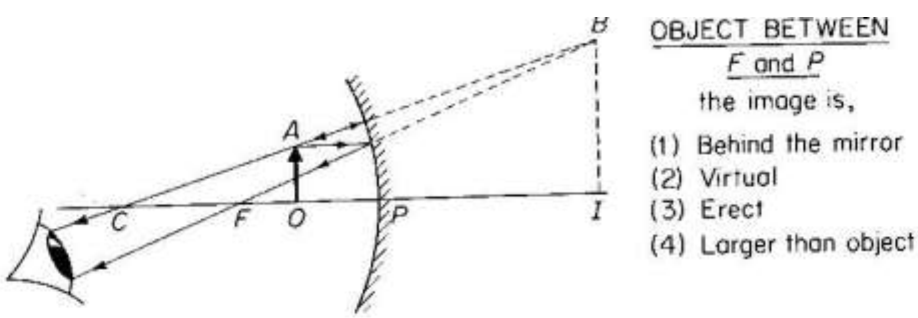


Image formation by convex mirror

No matter the position of the object from the convex mirror, the image formed is always virtual, diminished and upright.

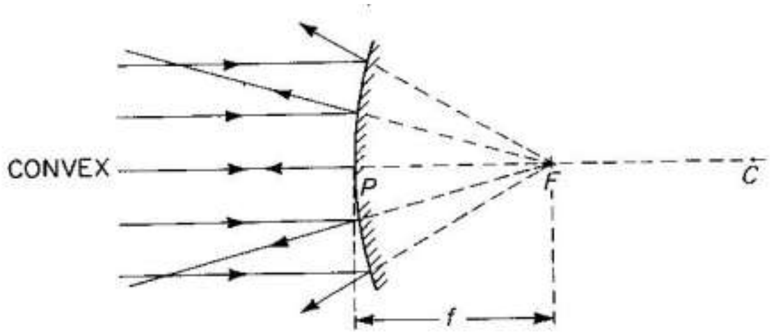


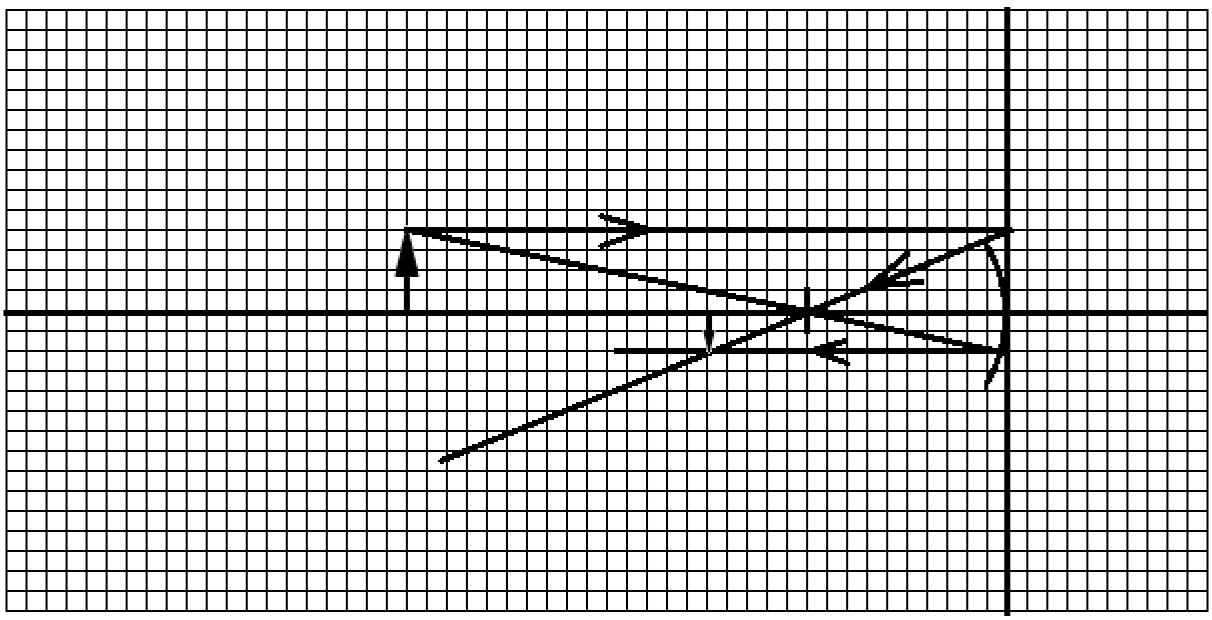
Image formed is virtual, diminished, upright (erect) and formed between F and P

Construction of ray diagrams to scale.

Example

An object 4cm high is placed 30cm from a concave mirror of focal length 10cm. by construction, find the position, nature and size of the image (scale, 1:5)

Graph



Questions

1. An object 4cm high is placed 2.4cm from concave mirror of focal length 8cm. draw a ray diagram to find the position size and nature of image. Scale 1cm = 2cm
2. An object of height 10cm is placed at a distance 60cm from a convex mirror of focal length 20cm. By scale find the image position, height, nature and magnification (scale 1cm: 5cm)

MAGNIFICATION

This is the ratio of image height to the object height

M = where h_I – image height, h_o – object height

OR

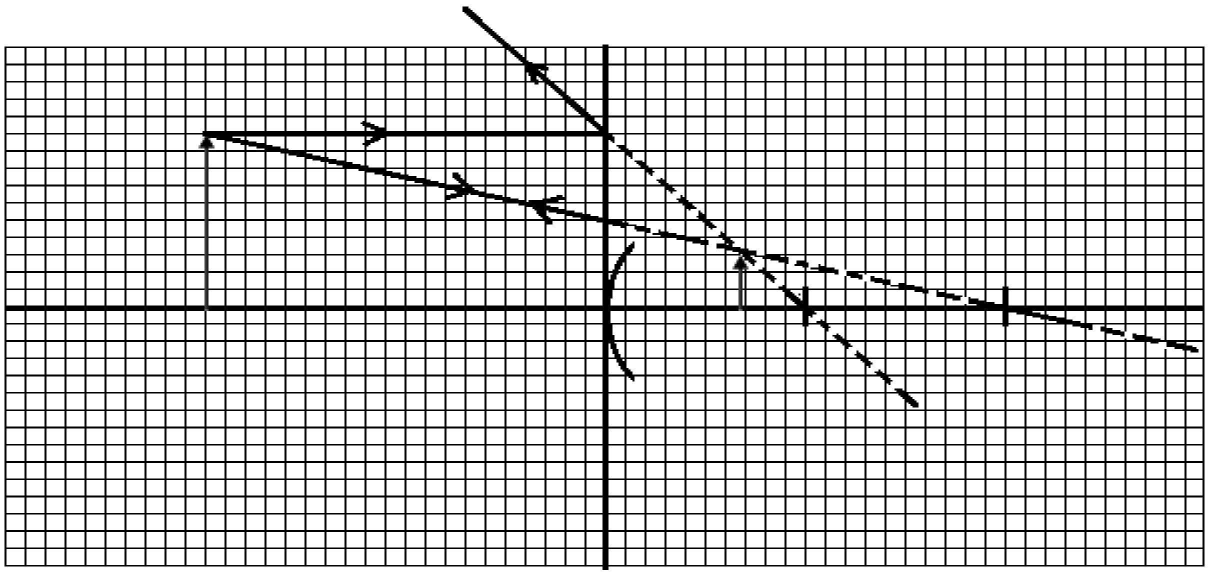
This is the ratio of image distance from distance from the mirror to the object distance from the mirror

M= where v – image distance, u – object distance

Example 1

An object 10cm high is placed at distance of 20cm from a convex mirror of focal length 10cm

i) Draw a ray diagram, locate the position of the image
ii) Calculate the magnification (1cm :5cm)



M = =

USES OF CURVED MIRRORS

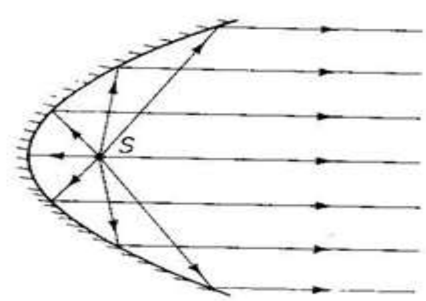
a) Convex mirrors
They are used as driving mirrors because
i) They give a wide field of view
ii) They give upright images of the object

Disadvantages

- It gives a false impression of the distance of an object
- The object is diminished.

b) Concave mirror

- Used in head lamps , torches , parabolic mirrors



- It can be used as shaving mirror
- Used by dentists for magnification

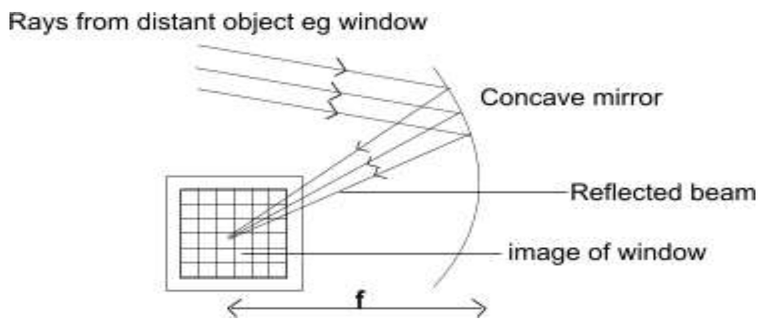
- Can be used in astronomical telescope (reflecting type)
- Can be used as solar concentrators

MEASURING FOCAL LENGTH OF A CONCAVE MIRROR

METHOD 1:

Distant object method (rough method)

- Hold a concave mirror at one end focusing t he distant object.
- Hold a white screen in front of the mirror so that it receives rays reflected from it to reach the mirror from the object.



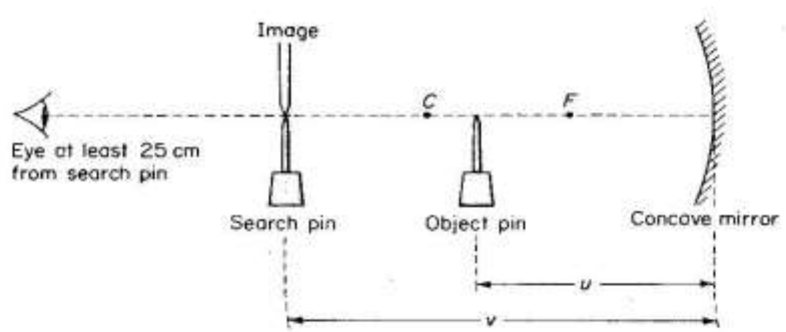
- Move the screen at different distances from the mirror until a sharp image is formed on the screen
- Measure the distance from the screen to the mirror with a metre rule.
- Repeat the experiment several times and find the average value of the distance between the screen and the mirror. This is the focal length (f) of the mirror

METHOD 2:

Using illuminated object at c

- With the mirror facing illuminated object, adjust the distance between them until a sharp image is formed on the screen alongside the object.
- Measure the distance between the object and the mirror
- Repeat the experiment for several attempts and find the average value. This is the radius of curvature so the focal length (f) is obtained from r =2f.

MIRROR FOMULA METHOD



- Two pins are required, one acts as an object pin and the other as a search pin.
- The object pin is placed in front of the mirror between F and C so that a magnified real image is formed beyond C.
- The search pin is then placed so that there is no parallax between it and the real image as shown in figure above
- The distance of the object pin from the mirror, u and that of the search pin, v is measured
- Several pairs of object and image distances are obtained in this way and the results recorded in a suitable table including uv and u+v
- A graph of uv against u+v is plotted
- The slope S is the focal length

Sign convention

All distances are measured from the pole of the mirror

Distances of real objects and images are positive

Distance of virtual objects and images are negative

A concave mirror has a real focus therefore focal length is positive

A convex mirror has a virtual focus therefore focal length is negative

Examples

1. Calculate the focal length of a concave mirror from the following results
   a) Object distance u = 30cm
      Image distance v = 20cm

   b) Object distance u = 8cm
      Image distance v = 24cm

   Solution (a)

   Using = +
   = + = =
   f = 12cm

   Solution to (b)

   = + = + f = 6cm
2. Find the image distance when an object is placed
   a) 12cm from the concave mirror of focal length 8cm
   b) 10cm from a convex mirror of focal length 10cm.

Solution (a)

For concave = + = = +

v = 24cm

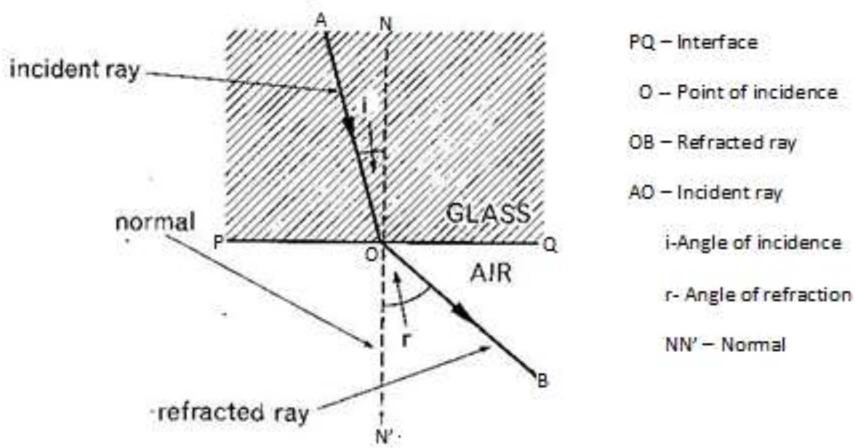
Solution to (b)

For convex = + = = +

V = -5cm

REFRACTION

This is the bending of light rays when it passes from one medium to another of different optical densities



Refraction can also be defined as the change in speed of light when it moves from one medium to another of different optical densities

N.B

When a ray of light enters an optically denser medium, it is bent towards the normal and when it enters a less dense medium it is bent away from the normal

LAWS OF REFRACTION OF LIGHT

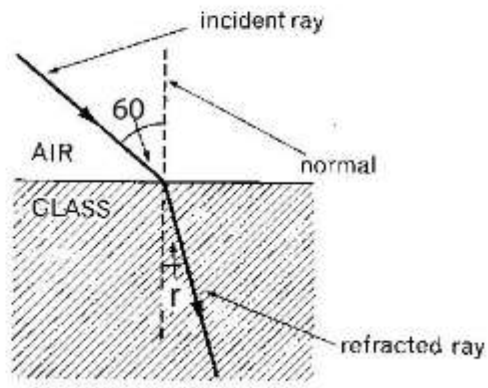
1. The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane
2. The ratio sine of angle of incidence to the sine of angle of refraction is constant for any given pair of media (Snell's law)
   i.e. = = constant (n) where n – refractive index of the medium containing the refracted ray

Refractive index

It is the ratio of sine of angle of incidence to the sine of angle of refraction for a ray of light moving from one medium to another of different optical densities

Example

1. A glass material has a refractive index n= 1.5. Find the angle of refraction, if the ray of light moves from air to glass as shown below



Refractive index n =

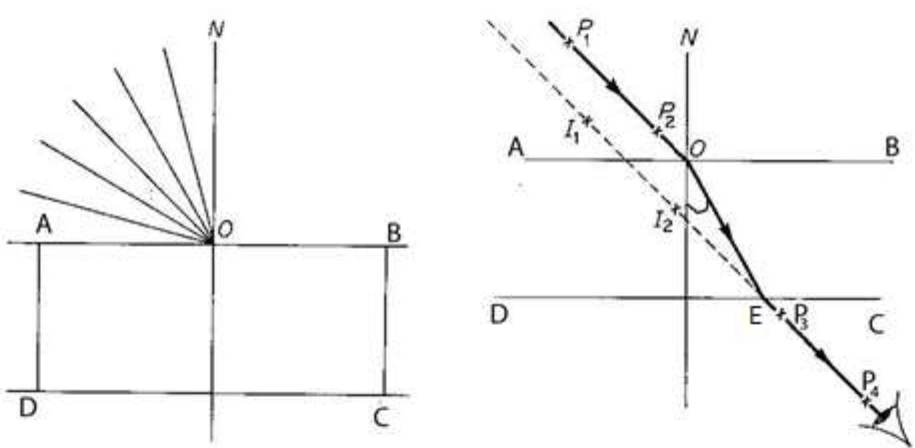
1.50 =

Sin r =

r = sin^{-1}[=

EXPERIMENT TO VERIFY SNELL'S LAW

A glass block is placed on a white sheet of paper and its outline ABCD drawn as shown below



The glass block is then removed

Using a protractor, the normal is drawn at a point to O along AB and an angle of incidence I = 10^0 measured.

Pins P_1 and P_2 are fixed on the line making an angle of I to the normal and the glass block replaced on its outline ABCD

While looking through side CD, two other pins p_3 and p_4 are fixed so as to appear in line with images of p_1 and p_2.

The glass block, pins p_3 and p_4 are removed and a line drawn through points where p_3 and p_4 were fixed. This line is called the emergent ray. It is drawn through O to meet CD at E

Point O is joined to E. The line is called the refracted ray.

The angle of refraction r is measured.

The experiment is repeated using other angles of incident 20^0, 30^0, 40^0, and 50^0.

The values of i, r, sini and sinr are tabulated as shown.

$i(^0)$	$r(^0)$	Sin i	Sin r
10			
20			
30			
40			
50			

A graph of sin i against sin r is plotted.

A straight line graph through the origin verifies Snell's law

NB: The slope of the graph gives the refractive index of the glass

Slope n =

Absolute refractive index

This is the ratio of sine of angle of incidence to the sine of angle of refraction for a ray of light moving from air (vacuum) to another medium of different optical density.

n = the angle incident i should be in air or vacuum.

REFRACTION ON PLANE PARALLEL BOUNDARIES

The refractive index n of the medium is denoted by ${}_1n_2$ for a ray of light moving from medium 1 to medium 2.The refractive index of a ray of light moving from glass to water is written as gw = where n_g and n_w are absolute refractive indices of glass and water respectively. So ${}_1n_2$ = =

$n_1 \sin i = n_2 \sin r$

Principal of reversibility of light

It states that when the direction of ray of light is reversed, it follows exactly the same path as before.

${}_a n_g$ …..(i)

g∩a = ……. (ii)

a∩g = or g∩a =

Question

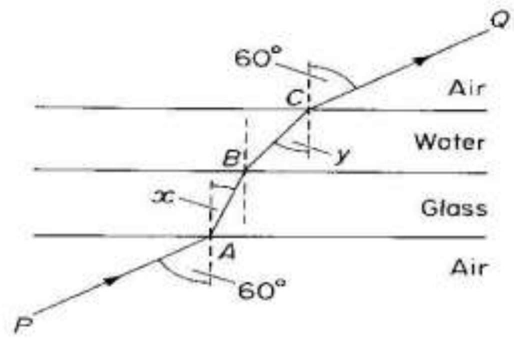


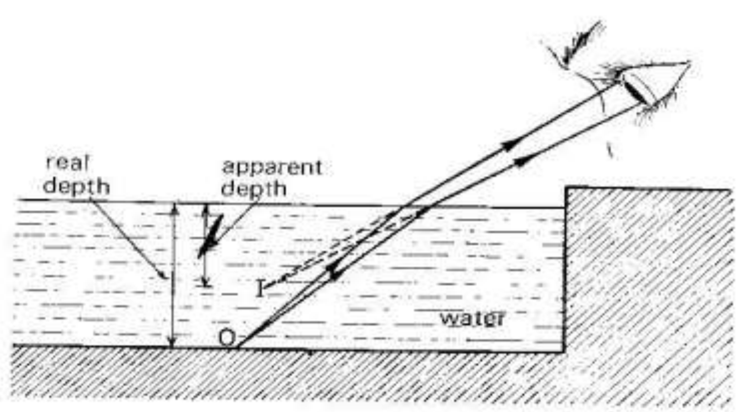
Figure above shows a glass slab of uniform thickness, lying horizontally. Above it is a layer of water. A ray of light PQ is incident upwards on a lower surface of the glass and is refracted successively at A, B and C, the points where it crosses the interfaces. Calculate

i. Angle x
ii. Angle y
iii. The refractive index for light passing from the water to glass. (Refractive indices of glass and water are 3/2 and 4/3 respectively)

EFFECTS OF REFRACTION ON PLANE SURFACES

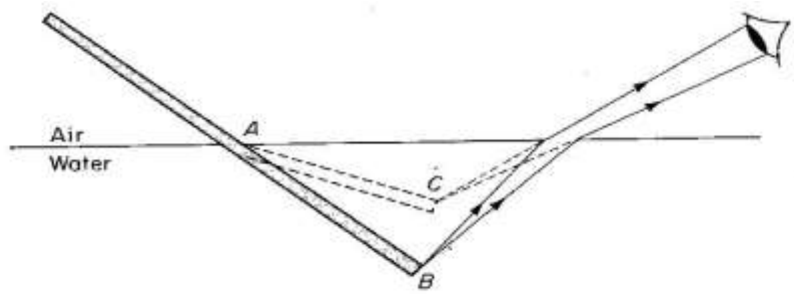
Refraction on plane surface causes

- A partially immersed stick in water at an angle to appear bent at the boundary between air and water.
- A stick placed upright in water appears shorter
- A swimming pool or well or pond appears shallower than its actual size



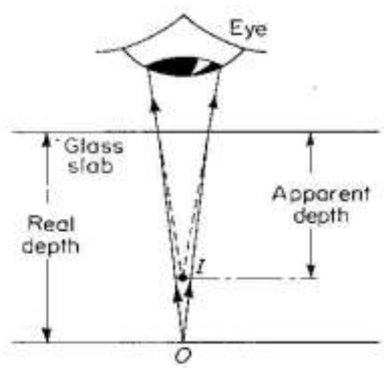
- An object placed under the glass block appears nearer

Explanation of the effects of refraction



Rays of light from point B on the stick move from water to air i.e. from a dense medium to a less dense medium. On reaching the surface of water, they are bent away from the normal. On entering the eye of the observer, rays appear to come from point C which is the image of B on the object.

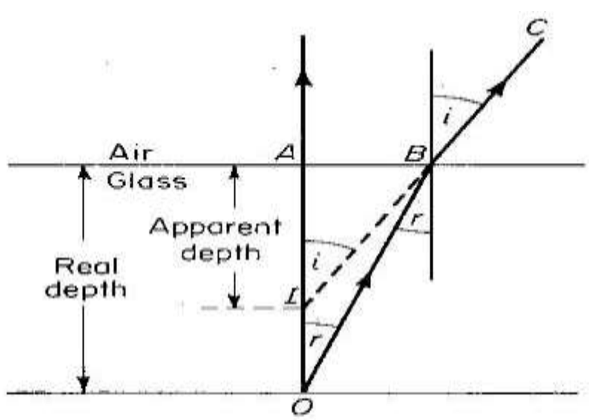
REAL AND APPARENT DEPTH



An object O placed below a water surface appears to be nearer to the top when viewed from above. The depth corresponding to apparent depth

The actual depth of an object, below the liquid surface is called the real depth.

Relationship between real apparent depth and refractive index



Refractive index $n = \frac{Real\ Depth}{Apparent\ Depth}$

Examples

1. A swimming pool appears to be only 1.5m deep. If the refractive index of water is $^4/_3$ calculate the real depth of water in the pool.

   n =

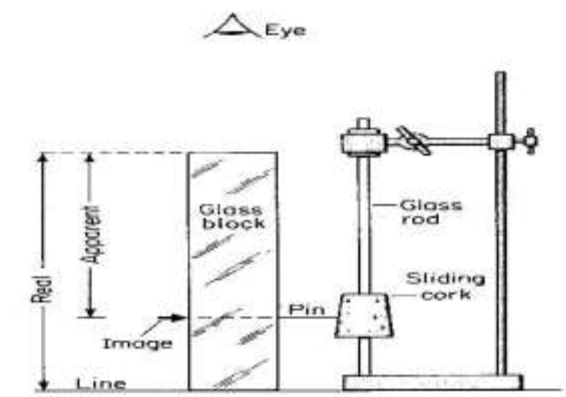
   $^4/_3$ = → r = = 2.0m

2. A coin is placed at the bottom of the beaker which contains water at a depth of 8cm. how much does the coin viewed from above appears to be raised (take n to be $^4/_3$)

Question

1. A pin at the bottom of the beaker containing a transparent liquid at a depth of 24cm is apparently displaced by 6cm. Calculate the refractive index of the liquid.

Determination of refractive index by real and apparent depth method



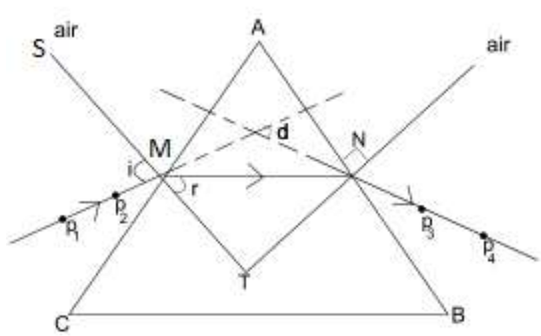
A glass block placed vertically over a cross (x) drawn on a white sheet of paper as shown above

A pin is clamped on a sliding cork adjacent the block, it is moved up and down until there is no parallax between it and the image of the cross (x) seen through the block.

The real depth and apparent depths are measured and the refractive index is then calculated from

Determination of refractive index using a triangular prism

A prism is placed on a white sheet of paper and its outline drawn as shown below



Two object pins p_1 and p_2 are fixed upright on side AC and while looking through the prism from side AB, two other pins p_3 and p_4 are fixed such that they appear to be in line with images of P_1 and P_2

The prism is removed and a line drawn through P_1 and P_2 and another drawn through P_3 and P_4.

Points M and N are joined by a straight line and normal ST drawn at a point M as shown

Angle i and r are measured

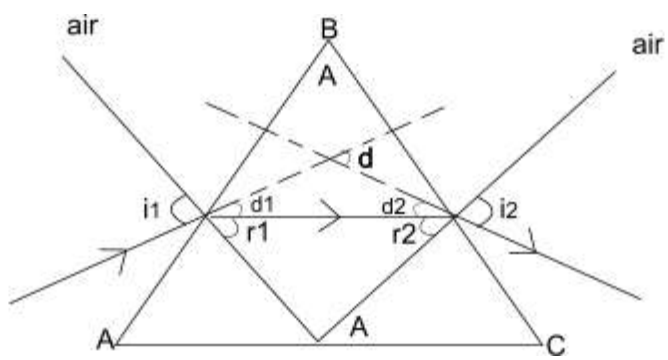
The procedure is repeated to obtain different values of i and r and the results tabulated as shown

i(°)	r(°)	Sin i	Sin r
	-	-	-
	-	-	-
	-	-	-

A graph of sin i against sin r is plotted. The slope of the graph is the refractive index of the prism

DEVIATION THROUGH PRISMS

A monochromatic light incident on a prism changes its direction (deviates) as it enters the prism as shown



Deviation on face AB, $d_1 = i_1 - r_1$

Deviation on BC, $d_2 = i_2 - r_2$

Total deviation $d = d_1 + d_2 = i_1 - r_1 + (i_2 - r_2)$

$$= (i, +i_2) - (r_1 + r_2)$$

But $A = r_1 + r_2$

Hence deviation $d = (i_1 + i_2) + A$

EXAMPLE 1

A prism of refractive index 1.5 and refracting angle $A = 60^0$ has an angle of refraction of 28^0 on the 1^{st} face. Determine

a) angle of incidence i
b) angle of refraction on 2nd face r_2
c) angle of emergency i_2
d) angle of deviation d

Solutions

a) = sin i = sin r

$1 \times \sin i = 1.5 \sin 28$

$i = \sin^{-1} (1.5 \sin 28) = 44.7^0$

b) $A = r_1 + r_2$

$60 = 28 + r_2$

$r_2 = 60 - 28$

$r_2 = 32^0$

c) Applying Snell's law on face 2

sin r = sin i_2

$1.5 \sin 32 = 1 \times \sin i_2$

$i_2 = \sin^{-1}(1.5 \sin 32)$

$i_2 = 52.64^0$

d) $d = d_1 + d_2$

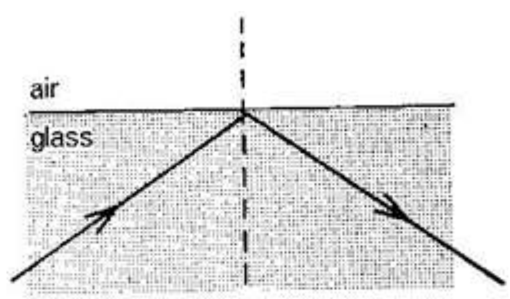
$= (i_1 + i_2) - A$

$= (44.7 + 52.64) - 60$

$= 37.34^0$

TOTAL INTERNAL REFLECTION

This is the phenomenon by which all light travelling from an optically dense medium to a less dense medium is reflected back in the dense medium, when the angle of incidence in the dense medium is greater than the critical angle.



Conditions for total internal reflection to occur

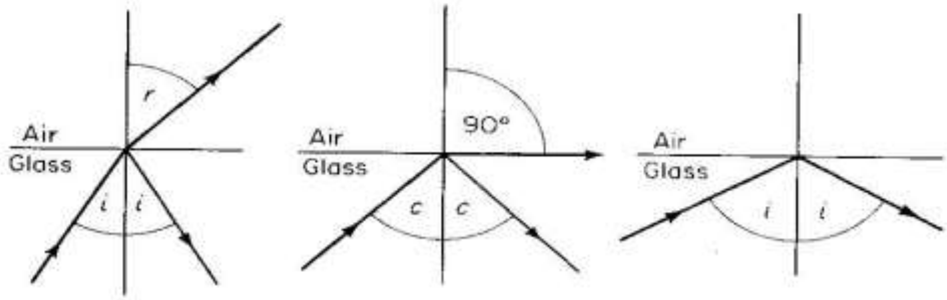
Light should travel from an optically dense medium to a less dense medium

The angle of incidence in the dense medium should be greater than the critical angle

How does total internal reflection arise?

Consider a ray of light in the dense medium for which the angle of incidence is less than the critical angle

The ray produces a weak reflected ray and a strong refracted ray as shown in (a)



(a) Refraction and internal reflection $i < c$ (b) Critical internal reflection $i = c$ (c) Total internal reflection $i > c$

When the angle of incidence is increased to a critical angle, the angle of refraction is 90^0 (fig. b.)

Critical angle c: this is the angle of incidence in a more optically dense medium for which the angle of refraction is 90^0

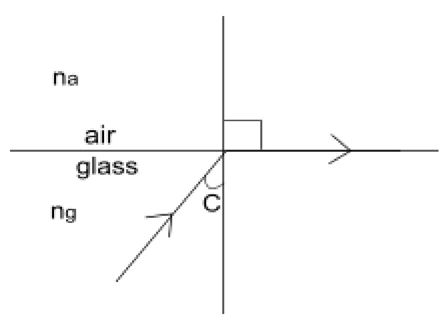
When the angle of incidence is increased beyond the critical angle, total internal reflection occurs as shown below in (c)

Relationship between Refractive index and critical angle

Applying Snell's law at the interface

$n_g \sin c = n_a \sin 90 = 1$

$n_g =$



Example:

1. Find the critical angle of a medium of reflective index 1.5

$\text{Sin } c =$ $c = \sin^{-1}(\ ) = \sin^{-1}(= 41.8^0$

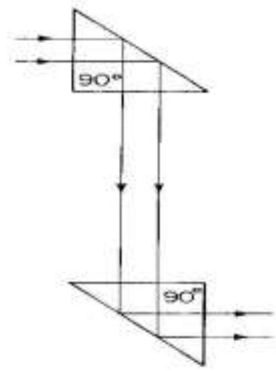
APPLICATION OF TOTAL INTERNAL REFLECTION

In refracting prisms which are in binoculars, periscopes and cameras

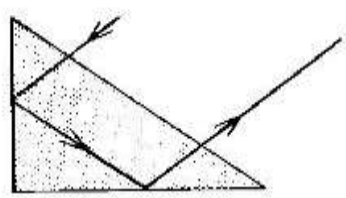
Examples

1. Turning a ray through 90^0

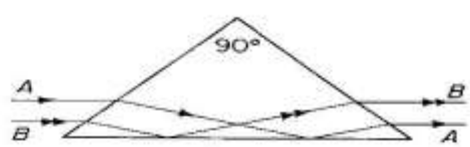
Prism periscope



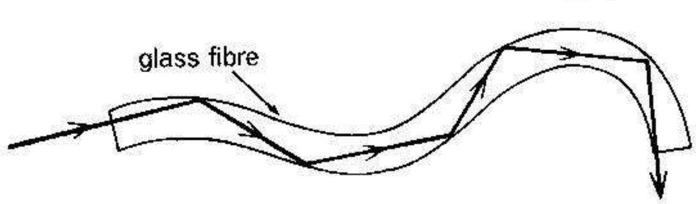
2. Turning a ray through 180^0



3. Turning a ray through 360^0



Optical light pipes



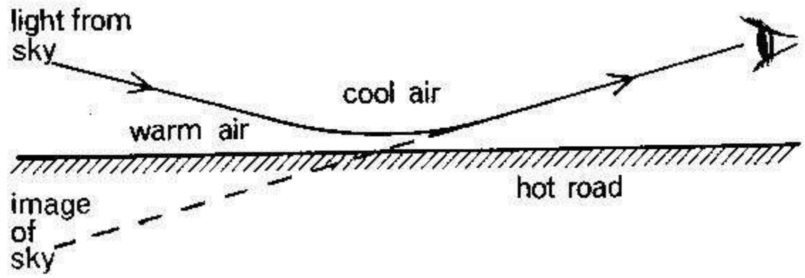
The inner surface has slightly higher refractive index than the outer surface making it slightly denser medium. Light can be trapped by total internal reflection inside a bent glass rod and piped along a curved path as shown above

Optical fibres can be used by doctors and engineers to light up some awkward spot for inspection Modern telephone cables are optical fibres using laser light

EFFECTS OF TOTAL INTERNAL REFLECTION

The mirage

This can happen when the air nearer the surface of the ground is less dense than that above. Cool air is dense than warm air.

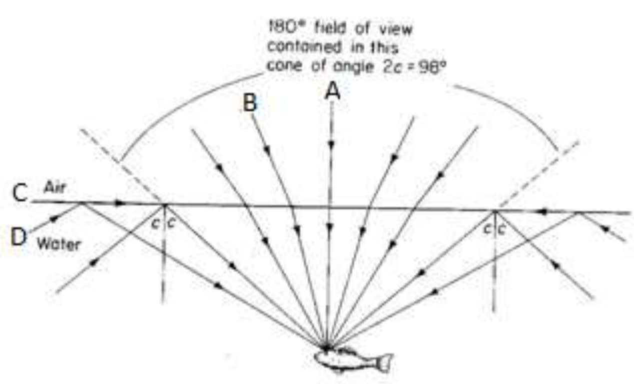


Light from the sky is gradually refracted away from the normal as it passes from denser layer of air to less dense layers

When light meets a layer at angles of incidences greater than the critical angle, it suffers total internal reflection.

The reflection of the sky forms an image which appears as a pool of water on the road

Fish's eye view



- A fish in water can have a wide field of view as it can see an object normally at A
- If angle i is less than the critical angle, it can see an object B by refraction.
- It can also see an object at the bank C of lake if the angle of incidence is equal to the critical angle.

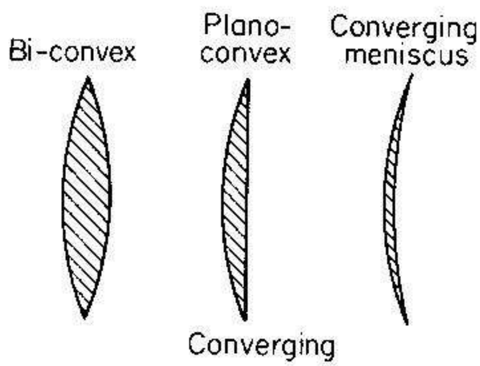
- If i is greater than the critical angle an object at D can be seen by total internal reflection.

LENSES

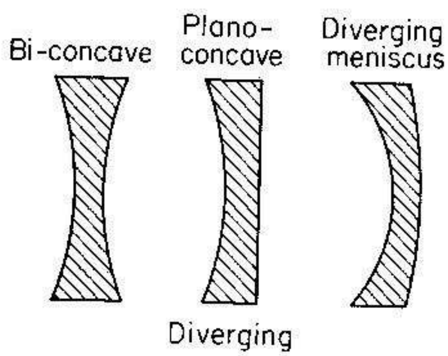
These are two types:

(i) Convex/converging lenses
(ii) Concave/diverging lenses

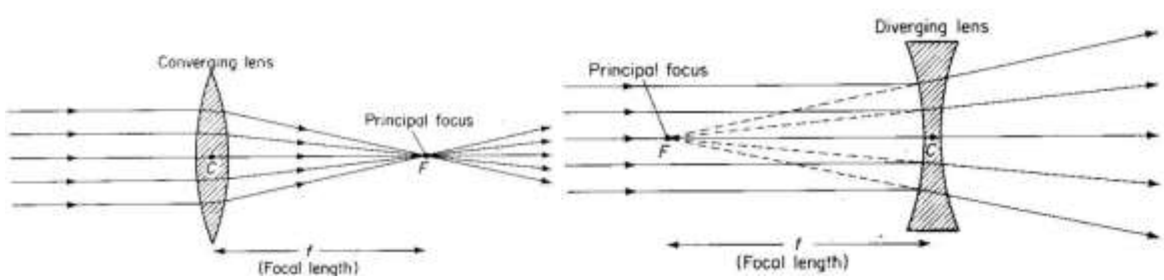
Convex lens



Concave lens



Terms used:



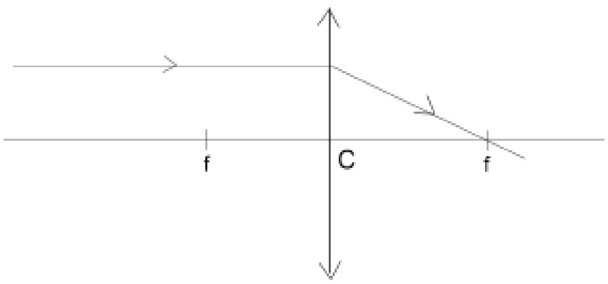
1. **Principal axis:** is a line joining the principal focus and the optical Centre
2. **Principal focus of a convex lens**: is a point on the principal axis to which all rays originally parallel and close to the principal axis converge after refraction by the lens
3. **Principal focus of a concave lens:** this is a point on the principal axis to which all rays originally parallel and close to the principal axis appear to diverge after refraction by the lens

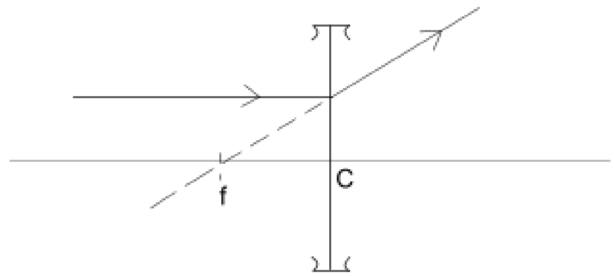
4. **Focal length:** this is the distance between the principal focus and the optical centre
5. **Optical centre:** this is the centre of the lens at which rays pass undeviated.

CONSTRUCTION OF RAY DIAGRAM

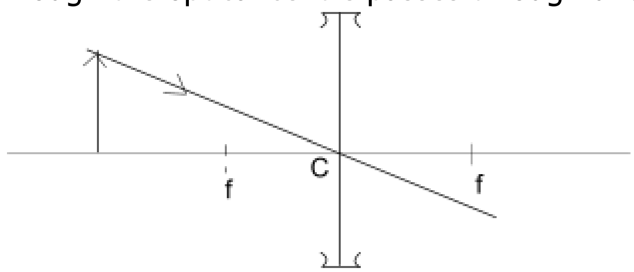
In constructing ray diagrams, 2 of the 3 principal rules are used.

1. A ray parallel to the principal axis is refracted through the focal point

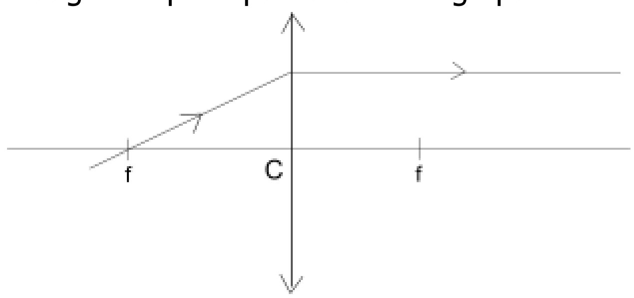




2. A ray through the optical centre passes through undeviated i.e. is not refracted



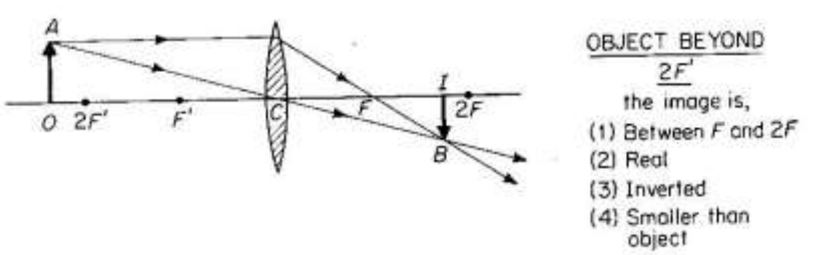
3. A ray through the principal focus emerge parallel to the principal axis after refraction



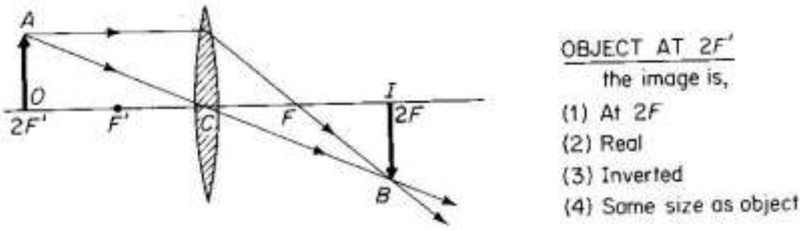
Images formed by convex lenses

The nature of the image formed in a convex lens depends on the position of the object from the lens

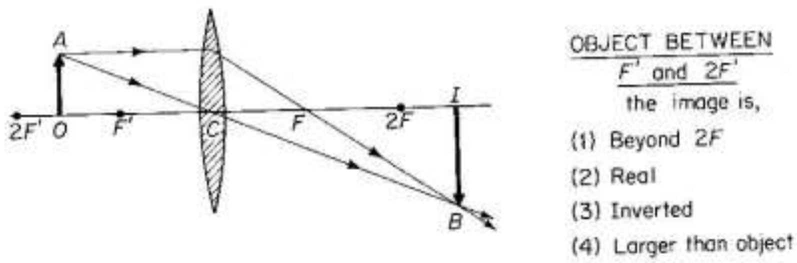
a. Object beyond 2f



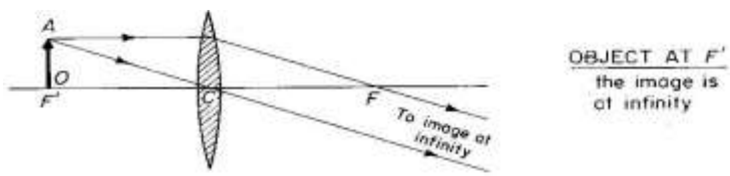
b. Object at 2f



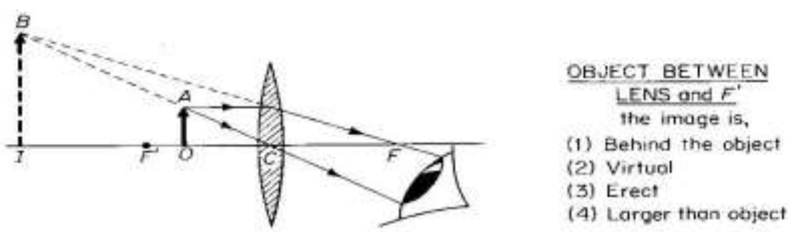
c. Object between f and 2f



d. Object at f

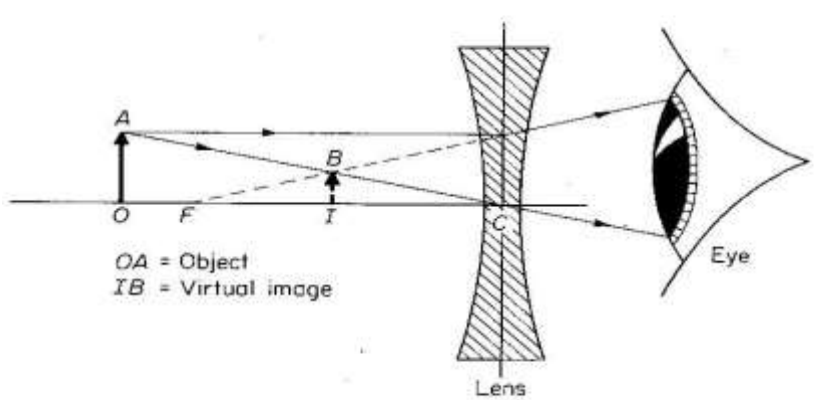


e. Object between F and C



When the object is placed between f and c, the image is magnified and this is why the convex lens is known as a magnifying glass

Image Formation in a Concave Lens



Power of a lens

It is defined as the reciprocal of focal length in metres

Power of lens = where f is focal length of the lens in metres

S.I units of power of the lens is dioptres (D)

Example

1. Calculate the power of the focal length 10cm.

   P = =

   = 10D
2. Find the power of the lens whose focal length is 20cm

   P =   =

   = 50D

Magnification of the lens

It is defined as the ratio of the image height to object height

M =

OR

It is the ratio of image distance to object distance from the lens

M = where v – image distance

U – Object distance

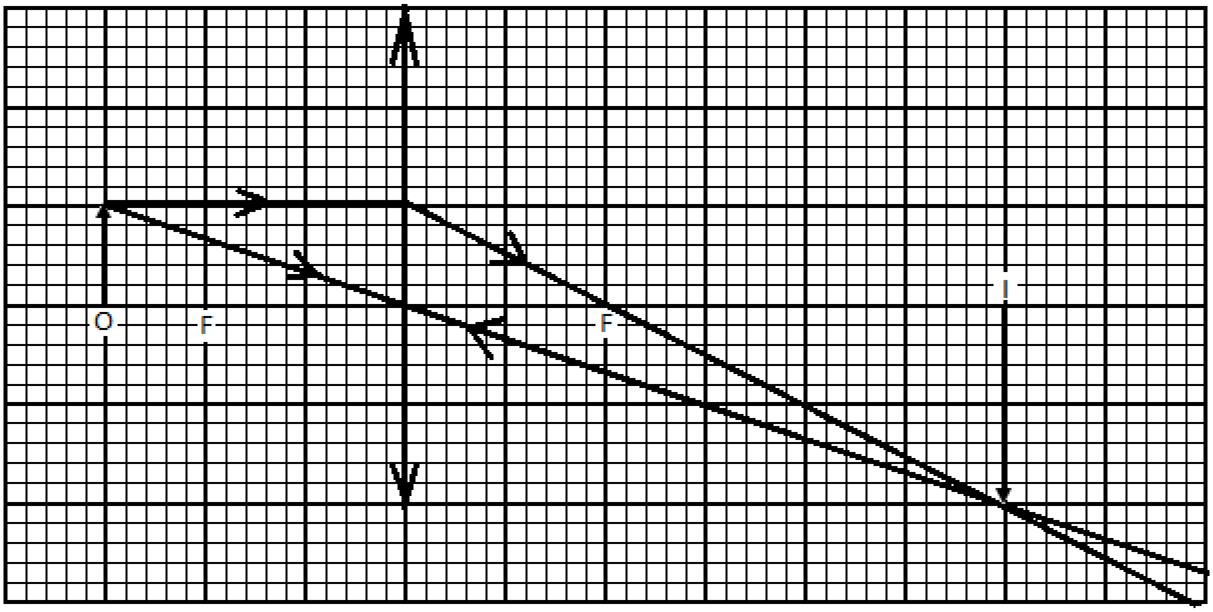
Determination of image position by graphical method

Same rules are used

A lens is represented by a line on a graph paper. Scale must be used.

Example

Object 5cm tall is placed 15cm away from a lens of focal length 10cm. By construction;



Determine the position, size and nature of the final image (use a scale 1cm: 5cm)

Question

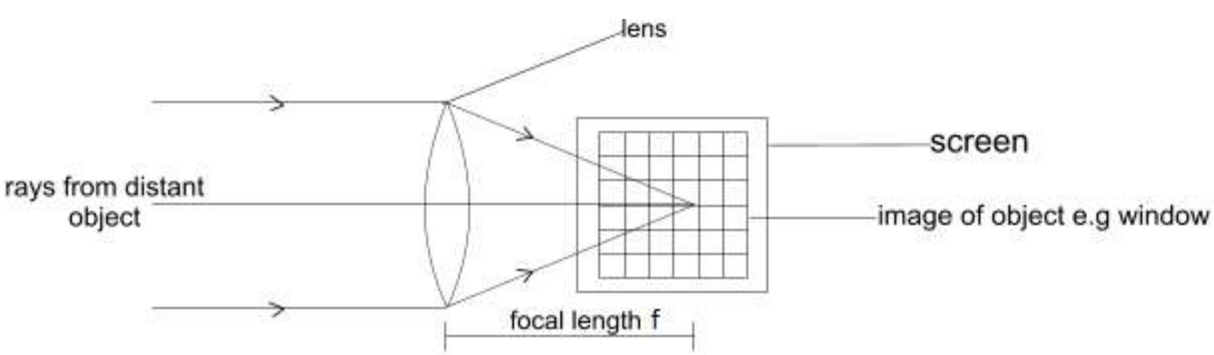
1. A simple magnifying glass of focal length 5cm forms an erect image of the object 25cm from the lens. By graphical method
   a. Find the distance between the object and image
   b. Calculate the magnification
2. An erect object 5cm high is placed at a point 25cm from a convex lens. A real image of the object is formed 25 cm high. Construct a ray diagram and use it to find the focal length of the lens
3. An object is placed at right angle to the principal axis of a thin covering lens of focal length 10cm. A real image of height 5cm is formed at 30cm from the lens. By construction, find the position and height of the object (use 1cm: 5cm)

Determination of focal lens of a convex lens

a) Method 1: Rough method

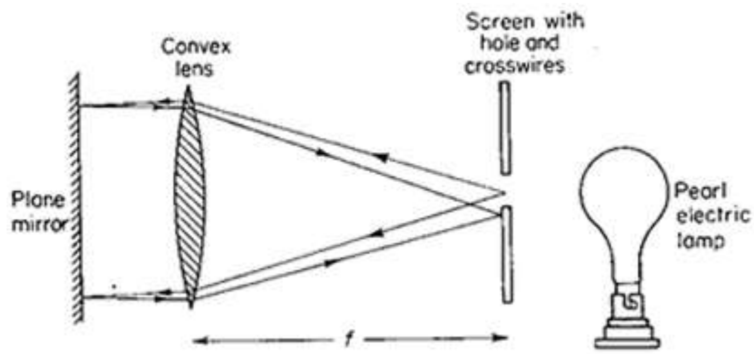
Procedure

A converging lens with a screen on one side is placed some distance from the distant object e.g. a window as shown.



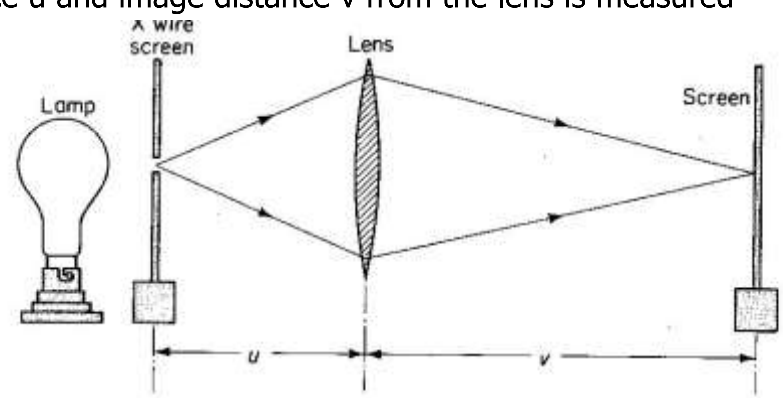
The screen is moved away or towards the lens until a clear image of the window is formed on the screen
The distance between the lens and the screen is measured and this is its focal length f
N.B – the value of f obtained by the above method is not very accurate because rays of light from the window are assumed to be parallel but may not be perfectly parallel.

b) **Determination of focal length using on illuminated object**



Procedure
- A lens is set up in a suitable holder with a plane mirror behind it so that light passing through the lens is reflected back as shown above
- Across wire is used as the object in a hole of a white screen. It is illuminated by the bulb
- The position of the lens is adjusted until a sharp image of the object is formed on the screen alongside the object
- The distance between the lens and the screen is measured, this gives the focal length of the lens

c) **Using lens formula method**
- The lens is set up in front of an illuminated object so that a real image is formed on a white screen placed on the opposite side.
- The lens is then adjusted so that the image is sharply in focus.
- The object distance u and image distance v from the lens is measured



- Several pairs of values of u and v are found and the results entered in a suitable table, including values of   and the mean value of   = +   determined.
- Focal length is calculated from: f =

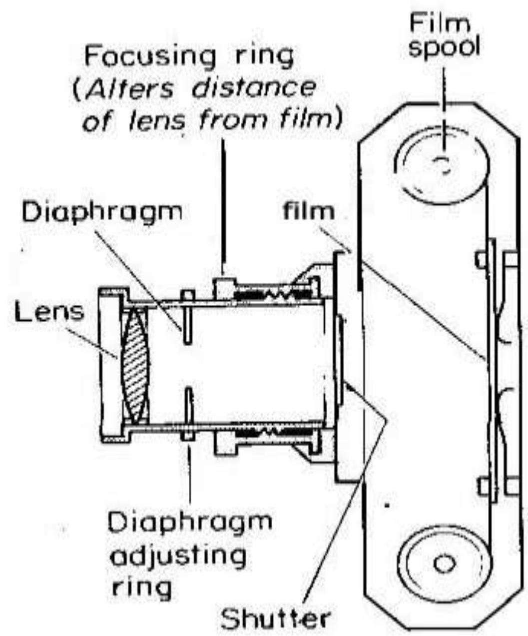
Application of lenses
Lenses are used in

- Lens camera
- Slide projectors
- Spectacles (used by people with eye defects)
- Microscopes and telescopes.

OPTICAL INSTRUMENTS

1. **The lens camera**

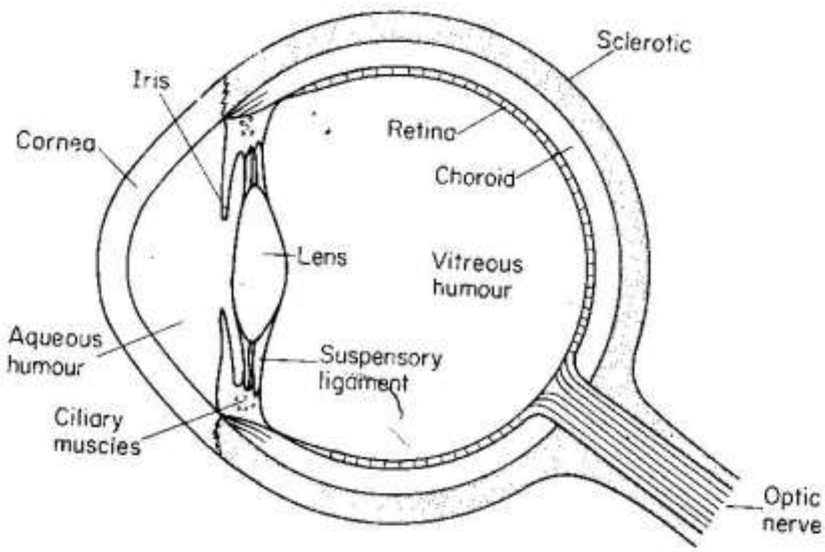
This is an optical instrument like the eye; light enters the camera through the convex lens which focuses light onto the film
The film contains a chemical that changes behavior on exposure to light.
It is developed to give a negative from which a photograph is made by printing.



The camera is focused by varying the distance between the lens and the film. The lens is mounted on a screw thread so that it can be moved in and out
For near objects, the lens is moved away from the film.
The amount of light entering the camera is controlled by the

1. Shutter, which opens for a certain length of time to expose the film to the light
2. Aperture (hole) through which light enters the camera by varying its size
3. Diaphragm, this changes the size of the aperture. a stope is made of a sense of metal plates which can be moved to increase the aperture size

THE EYE



Functions of the parts of the eye

1. Lens

The lens inside the eye is convex. It changes in order to focus light

2. Ciliary muscle

These alter the focal length of lens by changing its shape so that the eye can focus the image on the retina.

3. **The iris**

This is the coloured position of the eye. It controls the amount of light entering the eye by regulating the size of the pupil

4. The retina

This is a light sensitive layer at the back of the eye where the image is formed

5. The optic nerve

It is the nerve that transmits the image on the retina to the brain for interpretation

6. The cornea: It is the protective layer and it also partly focuses light entering the eye

Accommodation

This is the process by which the human eye changes its size so as to focus the image on the retina. This process makes the eye to see both near and far objects.

EYE DEFECTS AND THEIR CORRECTIONS

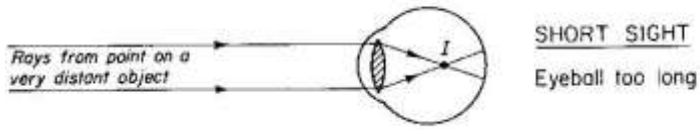
The normal eye can see objects clearly placed at infinity (far point) to see objects in greater details the eye sees it at the near point i.e. 25cm

TYPES OF EYE DEFECTS

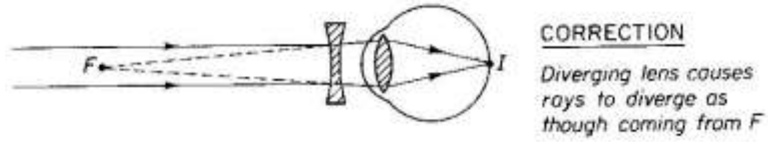
a) Short sightedness
b) Long sightedness

SHORT SIGHTEDNESS

A person with short sightedness can see near objects clearly but distant objects are blurred. The furthest point at which one can see the objects clearly is the far point. An object which is further than the far point is focused in front of the retina.



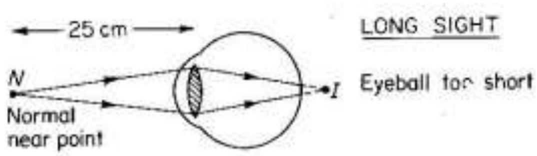
Correction of shortsightedness



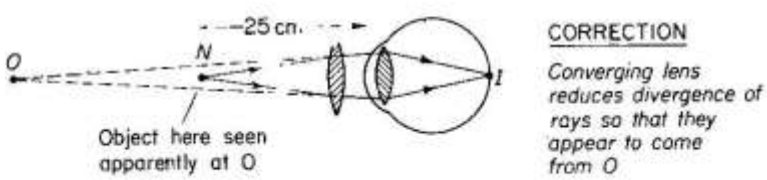
A concave lens is placed in front of the eye to make the light diverge so that it appears to come from the near point when it is actually coming far away as shown above

LONG SIGHTEDNESS

A long sighted person can see distant objects clearly but those that are near are blurred. The nearest point at which the person can see an object clearly is called near point. An object placed nearer than the near point is focused behind the retina as shown below



Correction of long sightedness



A convex lens is placed in front of the eye to make the light parallel, so that it appears to come from a distant object as shown above.

Similarities and differences between the eye and camera

a) **Similarities**

The camera consists of a light proof box painted black. Inside the eye it is fitted with a black pigment in to it to prevent stray reflection of light

Both have converging lenses that focus light from the external objects

Both have light sensitive parts, the camera has a film while the eye has a retina

Both have a system that controls the amount of light entering them, in the eye, iris is responsible and diaphragm does the same function in the camera.

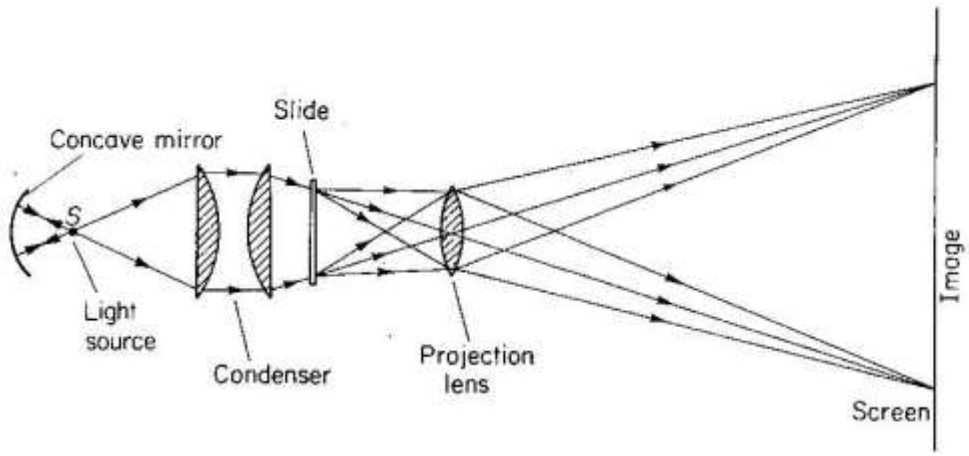
Differences

The eye lens is a biological organ while that of a camera is made out of glass

The distance between the eye lens and the retina is fixed while that between the camera lens and the film can be varied

The eye focuses image by changing the shape of the lens, in a camera the image is focused by changing the distance between the lens and the film

THE SLIDE PROJECTOR

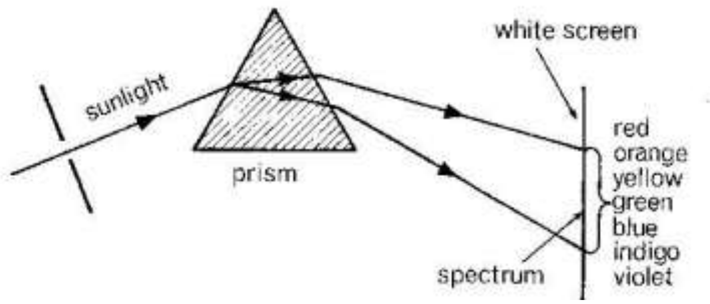


Functions of the parts of the slide projection

1. Lamp – it gives small but very high intensity source of light. It is suitable at the center of curvature of a convex mirror
2. Concave mirror- it is placed behind the light source. It reflects all lights forward
3. Condenser lens – it converges light through the slide on to the projector lens
4. Convex projector lens – it focuses the image of the slide on the screen
5. The fan- cools the light source once a lot of heat is produced
6. Heat shield – it shield the slide from heat produced by the light source
7. The slide – this is where the object is placed
8. Screen – this is where the object is formed. The size of the image on the screen increases as the projector is moved back from it. The image is focused by altering the distance between the slide and the lens. The projector lens is mounted on the screw thread so that it can be moved in and out to focus the image.

DISPERSION OF LIGHT

This is the separation of white light into various colours listed in order. The colours are red, orange, yellow, green, blue, indigo, and violet. The bundle of colours formed is called a spectrum. Visible light spectrum can be made by passing a beam of white light through a glass prism

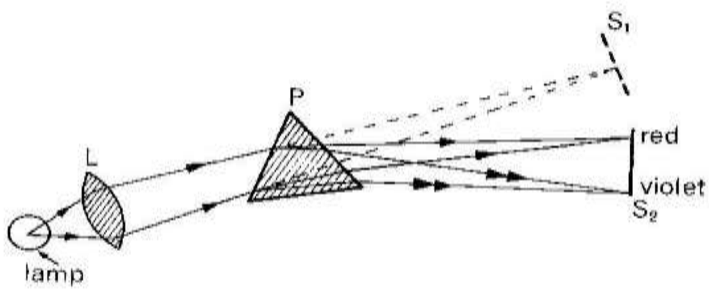


Dispersion occurs because each colour is refracted in glass by different amount i.e. each colour has different refractive index. So red is refracted least and violet is refracted most.

HOW TO OBTAIN A PURE SPECTRUM

The spectrum obtained above is impure i.e. the colours of the spectrum overlap one another

Apure spectrum is one in which light of one colour only forms each part of the image on the screen without overlap. This can be achieved by placing a convex lens in front of the prism to increase on the deviation of the colours as they pass through the prism



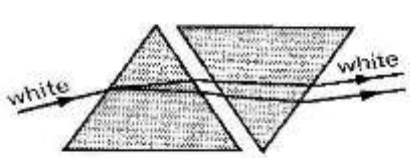
Lens L produces parallel beam of white light. The light is then dispersed and deviated at the prism sprinting up into various colours.

Lens B collects the different coloured lines so that the parallel beam of each separate colour is focused on the screen.

RECOMBINATION OF THE SPECTRUM:

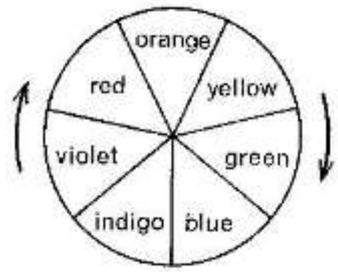
The colours of the spectrum can be recombined by;

(i) Arranging a second prism so that the light is deviated in the opposite direction.



(a)

(ii) Using an electric motor to rotate at high speed, a disc with spectral colours from its sectors as shown below.



The white light is slightly grey because paints are not pure colours.

Colours of objects:

The colour of an object depends on;

- The colour of light falling on it.
- The colour it transmits or reflects e.g. an object appears blue because it reflects blue light into the eyes and absorbs the other colours of the spectrum. Similarly, an object appears red because it reflects red light into the eyes and absorbs all other colours.
- A white object reflects all the colours of the spectrum into the eyes and absorbs none.

Types of colours:

a. Primary colours
These are colours that can't be obtained by adding two different colours of light. They include red , blue and green

b. Secondary colours
These are colours which are obtained by adding 2 primary colours together. They include yellow, peacock blue and magenta.
NB:- peacock blue is at times called cyan or tachois.

c. Complementally colours
These are two different colours which when added produce white light. One of them is a secondary colour and the other must be a primary colour. The pairs are

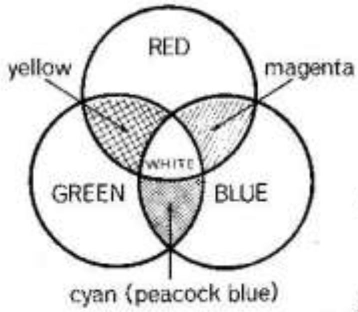
Red + peacock blue → white light

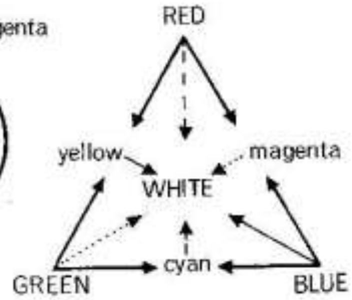
Green + magenta → white light

Blue + yellow → white light

From the complementally colours it is noted that when the three primary colours are joined, they produce white light.

SUMMARY OF COLOURED LIGHTS

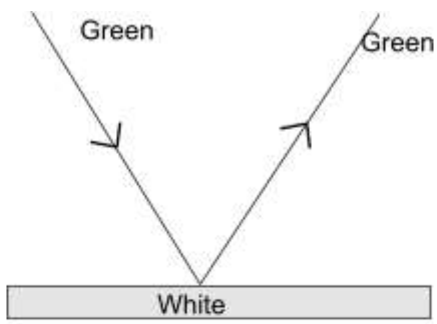




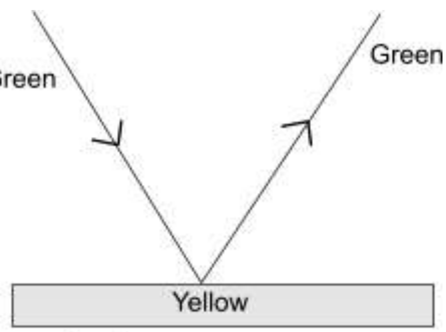
Coloured objects in white light

A coloured object reflects and transmits its own colour and absorbs other colour incident on it.

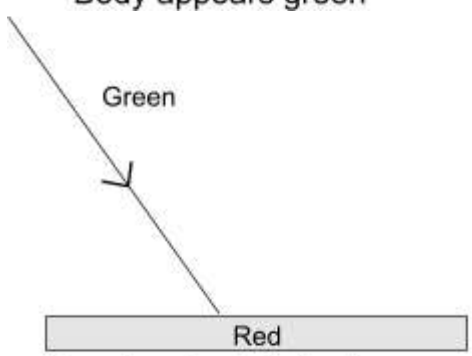
Examples:



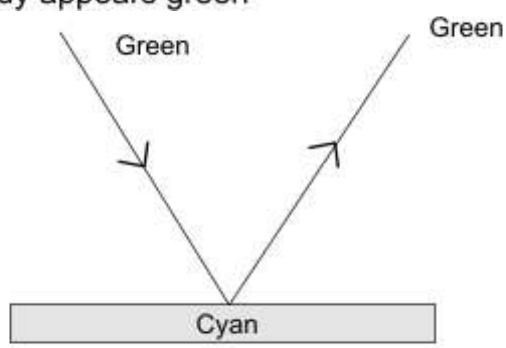
Body appears green



Body appears green



None is reflected, body appears black



Body appears green

N.B:- primary colour +primary colour = black

Primary colour + secondary colour = primary

Secondary colour + secondary colour = common primary colour.

Question 1

Describe and explain the appearance of a red tie with blue spots when observed in;

a. Red light
b. green light

Solution

a) **Green light** – <u>the red tie appears black because both colours are primary colours and non is reflected</u>

b) **Red light** – in the red light the tie appears red and blue spots appear black.This is because the red reflects the red colour and observes blue colour.

Question 2

A plant with green leaves and red flowers is placed in

a) green
b) blue
c) Yellow

What colour will the leaves and flowers appear in each case . Assume all colours are pure

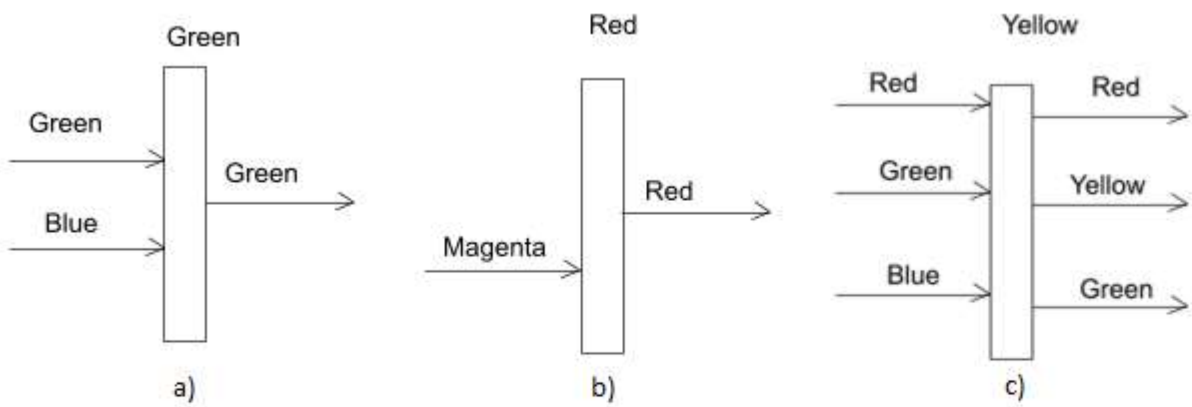
a. **green** -: the leaves remain green but the flowers black

b. **blue** -: the leaves will appear black and flowers black

c. **Yellow** -: the leaves appear green and flowers appear red

FILTERS (COLOUR)

A filter is a coloured sheet of plastic or glass material which allows light of its own type to pass through it and absorbs the rest of the coloured lights i.e. a green filter transmits only green, a blue transmits only blue, a yellow filter transmits red, green and yellow lights.



MIXING OF COLOURED PIGMENTS

A pigment is a substance which gives its colour to another substance .A pigment absorbs all the colours except its own which it reflects. When pigments are mixed, the colour reflected is the common to all e.g. blue + yellow $\rightarrow$ green

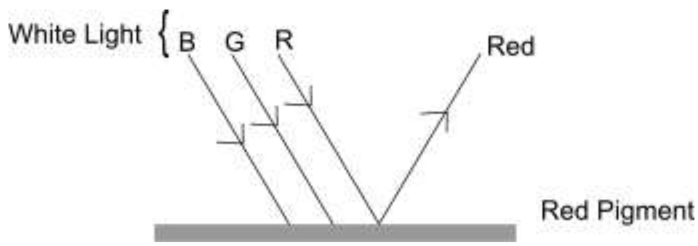
Yellow + orange $\rightarrow$black

Green + indigo $\rightarrow$ blue

The blue reflects indigo and green, its neighbour in the spectrum as well as blue
Yellow reflects green, yellow and orange, only green is reflected by both

Mixing coloured pigments is called colour mixing by subtraction
Pigments appear black because none of the colours are reflected

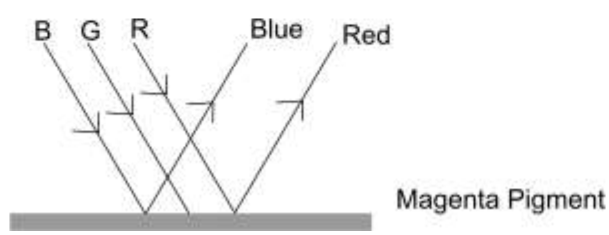
APPEARANCE OF COLOUR PIGMENT IN THE WHITE LIGHT



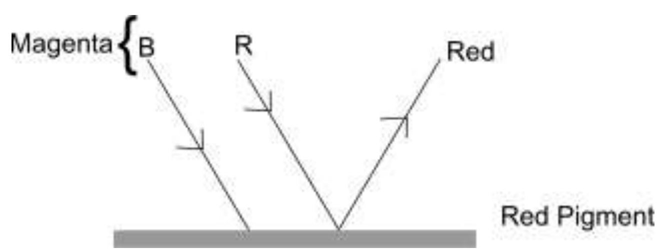
A colour pigment reflects only one colour

APPEARANCE A COLOUR PIGMENT IN COLOURED LIGHT

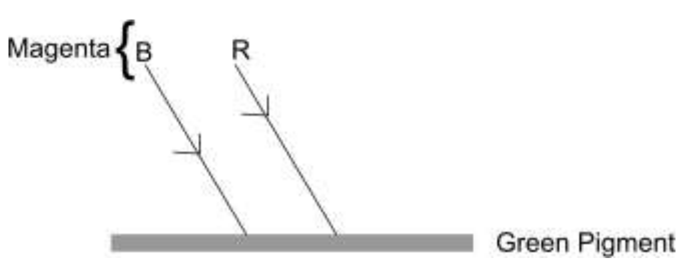
a. Magenta pigment reflects two colours of light i.e. blue and red when white light is incident on it



b. Red pigment reflects only the red colour when magenta light is incident on it



c. The pigment appears black because none of the colours in the magenta light is reflected



WAVES

A wave is a disturbance which travels through a medium and transfer energy from one point to another without causing any permanent displacement of the medium itself e.g. water waves, sound waves, waves formed when a string is plucked.

Many waves are invisible but have visible effects. In this chapter, you will study the properties and characteristics of waves and their effects on matter**.**

Types of waves:

We can classify all waves into two categories:

1. Mechanical waves

This is a type of waves produced by physical disturbance and requires a material medium for its propagation. Examples of mechanical waves include water ripples, sound waves, waves on strings and ultrasonic waves.

2. Electromagnetic waves

This type of waves does not require any medium for propagation and are caused by electrons undergoing any energy change. Examples of electromagnetic waves include light waves, infra-red rays and ultra-violet rays

Note: All waves are as a result of vibrations caused in the medium.

WAVE MOTION

When a wave is set up on the medium, the particles of the medium vibrate from about a mean position as the wave passes. The vibrations are passed from one particle to the next until the final destination is reached

FORMS OF WAVES

There basically two broad forms -:

a) progressive waves
b) stationary waves

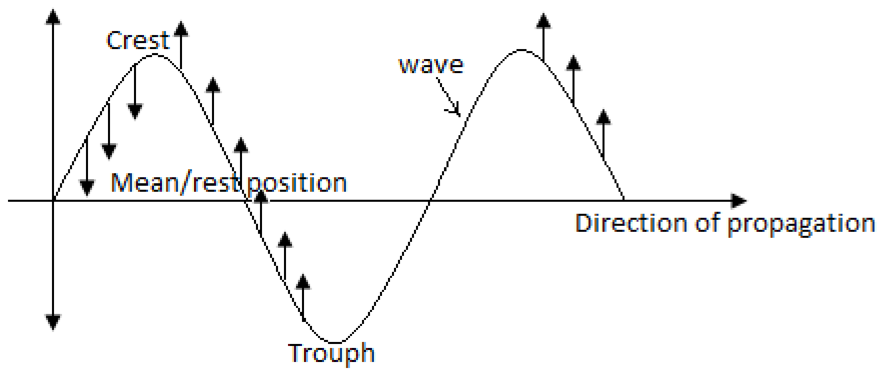
PROGRESSIVE WAVES

This is a wave which moves away from its source through a medium and spreads out continuously. There are two kinds of progressive waves namely:

- Transverse waves
- Longitudinal waves

i. TRANSVERSE WAVES

These are waves in which particles vibrate perpendicular to the direction of propagation of the wave e.g. water waves, light waves, waves formed when a rope is moved up and down.



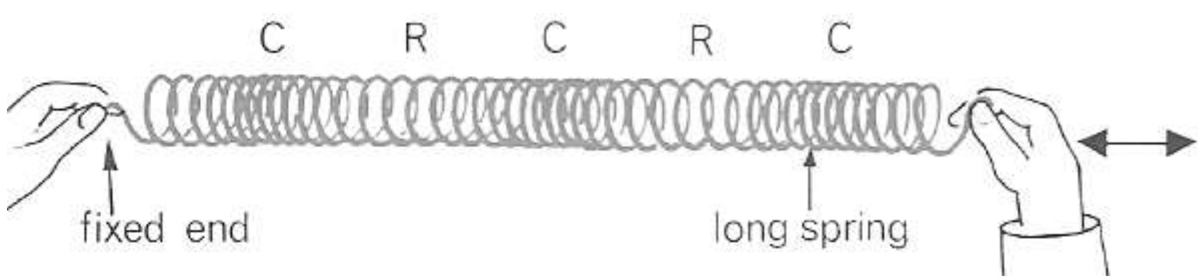
ii. LONGITUDINAL WAVES

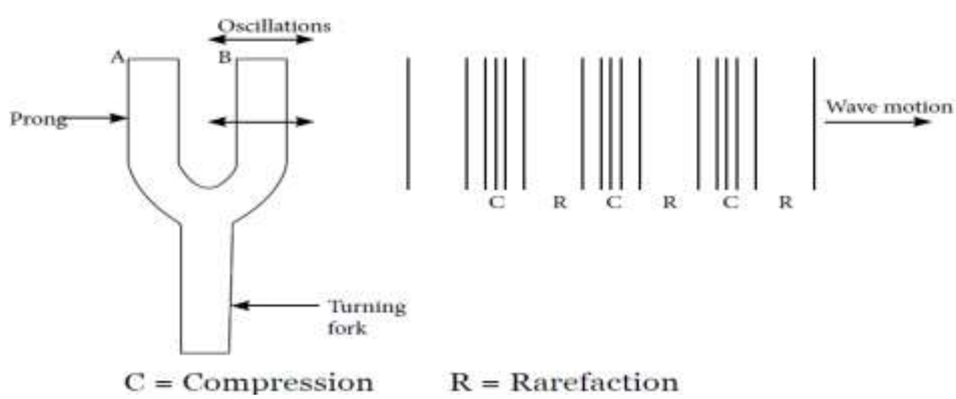
These are waves in which the particles of the media vibrate in the same direction as the wave

OR

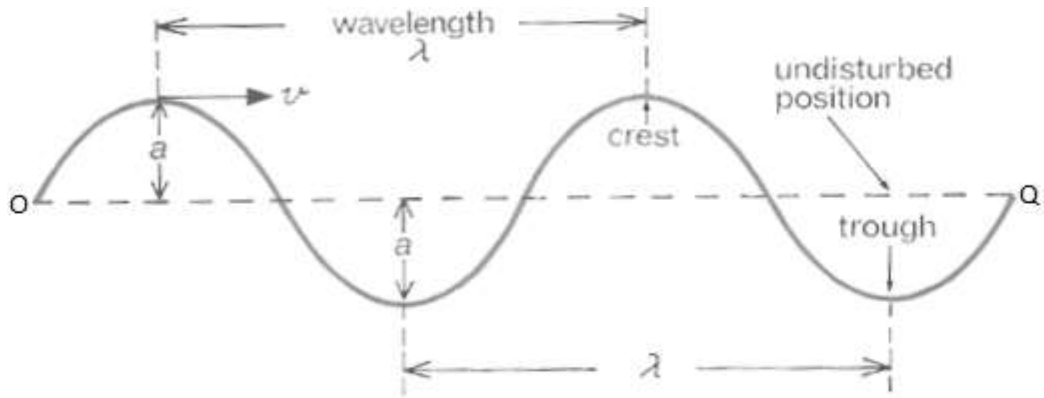
These are waves in which the particles of the media vibrate parallel to wave motion e.g. sound waves, waves from a slinky spring.

Longitudinal waves travel by formation of compressions and rare factions. Regions where particles crowd together are called compressions and regions where particles are further apart are called rare factions.





General representation of a wave



TERMS USED IN DESCRIBING WAVES

1. Rest position (Mean position)

This is the line OQ where particles are stationary or displacement of a particle is zero (0)

2. Amplitude (a)

This is the maximum displacement of a particle from the rest position.

Displacement is the distance the object or particle is displaced from the undisturbed position or rest position.

3. Cycle

This is one complete oscillation of the wave.

4. Wave length (λ)

- ✓ This is the distance between two successive crests or two successive troughs.
- ✓ This is the distance covered by one complete cycle of a wave.
- ✓ This is the distance between two particles of a wave vibrating in phase
- ✓ This is the distance between two successive compressions or rare factions.

5. Period

Is the time taken by a wave to perform one complete cycle, i.e. T= where n is number of cycles.

6. Frequency

This is the number of cycles a wave completes in one second i.e. F=

S.I. unit = Hertz (Hz)

8. Crest

It is the maximum displaced point above the line of 0 (zero) disturbance.

9. Trough

It is the maximum displaced point below line of zero disturbance.

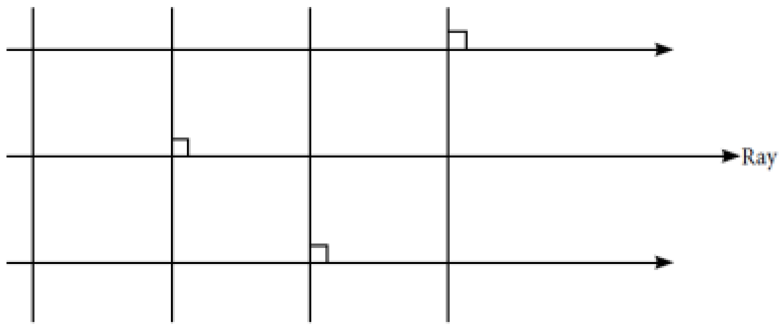
Ray: A ray is a direction or a path taken by a wave. It is represented by a line with an arrow pointing in the direction of the wave.

Phase: This is the state of vibration of a particle in a wave. Two particles are said to be vibrating in phase if their state of vibration is the same.

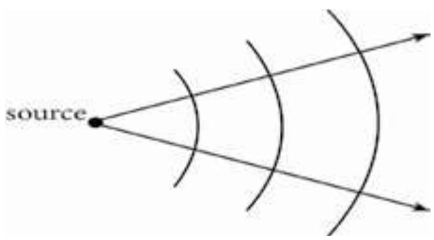
Wavefront: This is a line or a section through an advancing wave in which all the particles in that line are vibrating in the same phase

Example

Straight wavefronts



Circular wavefronts



10. Wave velocity

It is the distance which the wave travels in one second in a given direction. S.I unit is m/s.

THE WAVE EQUATION

From the wave speed v = …..(i)

If the wave describes n cycles in time t

Then the distance covered d= nλ …. (ii)

Substituting for d in … (i) → v =

But f = hence v = fλ wave equation

Examples

1. A radio station produces waves of wave length 10m. If the wave speed is 3×10^{8}m/s, calculate

(i) Frequency of radio wave.

(ii) Period T

(iii) Number of cycles completed in 10s

(i) λ = 10m , v = 3×10^{8}m/s t = 10s

v = f λ → f = =

$f = 3\times10^{7}$

(ii) Period T = = 3.3×10^{-8}Hz

(iii) Number of cycles → f = → n = f t

$= 3\times10^{7} \times 10$

$= 3\times10^{8}$cycles

2. The distance between 10 consecutive crests is 36cm. Calculate the velocity of the wave if the frequency of the wave is 12Hz.

Since;

d = (n – 1) λ

0.36 = (10 - 1) λ

0.36 = 9 λ

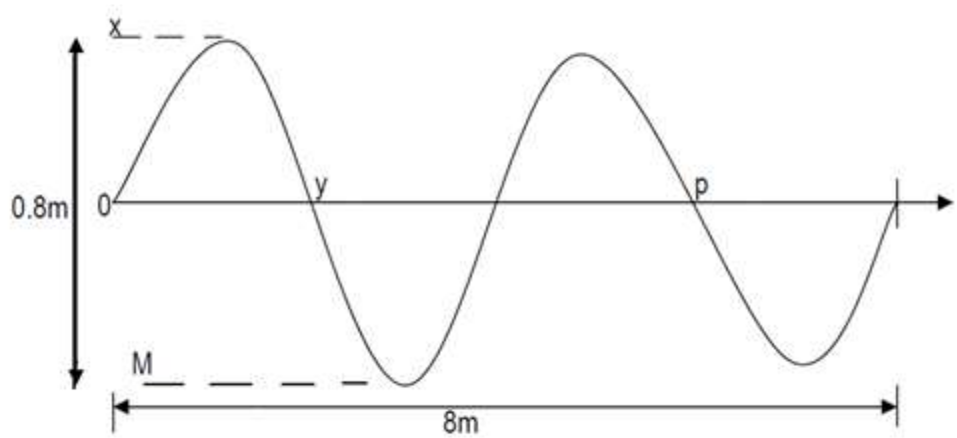
λ = = 0.04m

V= f λ

= 12×0.04

= 0.48m/s

3. The diagram below shows a wave travelling in water.



(a) Name (i) Any two points on the wave which are in phase

(ii) Label M and x

(b) (i) Determine the amplitude of the wave.

(ii) If the speed of the wave is 80m/s, determine the frequency of the wave.

Questions

A vibrator produces waves which travel 35 m in 2 seconds. If the waves produced are 5cm from each other, calculate;

(i) the wave velocity

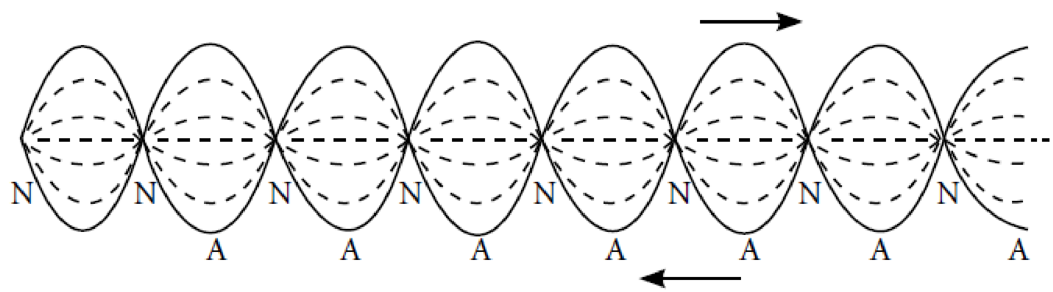
(ii) wave frequency

(i) v = f λ → =

(ii)v = f→f =

Stationary waves

These are waves formed when two progressive waves of nearly the **same amplitude and frequency** moving in **opposite directions** meet e.g. when an incident wave meets its own reflection from a barrier. Stationary waves are formed in pipes and on stretched strings.

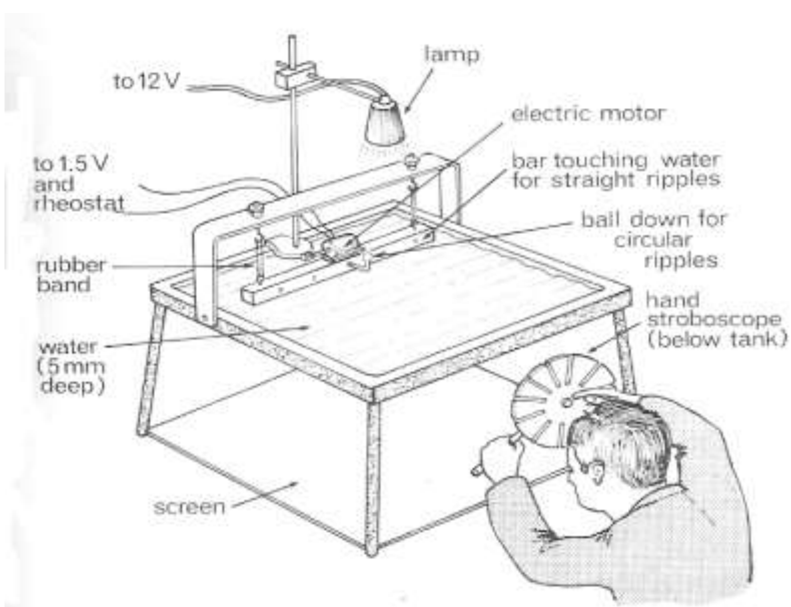


The distance between two neighbouring nodes is

Characteristics of stationary waves

- The stationary wave comprises of points where the displacement of particles is permanently zero. They are called nodes (N).
- Between the nodes, particles are vibrating in phase, but they do not attain the same amplitude.
- Particles half-way between the nodes attain maximum amplitude. They are called antinodes (A). (The broken lines show how the displacements of individual particles vary with time.)
- The peaks are always at the same position.

THE RIPPLE TANK



A ripple tank is an instrument used to study water wave properties. It is a shallow glass trough which is transparent. The images of the wave are projected on the screen which is placed below it.

The waves are produced by means of a dipper which is either a strip of a metal or a sphere. When the dipper is moved up and down by vibration of a small electric motor attached to it. The sphere produces circular wave fronts and the metal strip is used to produce plane waves.

A stroboscope helps to make the waves appear stationery and therefore allows the wave to be studied in detail.

N.B The speed of the wave in a ripple tank can be reduced by reducing the depth of water in the tank. The effect of reducing speed of waves is that wave length of water reduces but frequency does not. The frequency can only be changed by the source of wave.

WAVE PROPERTIES

The wave produced in a ripple tank can undergo.

(a) Refraction

(b) Reflection

(c) Diffraction

(d) Interference

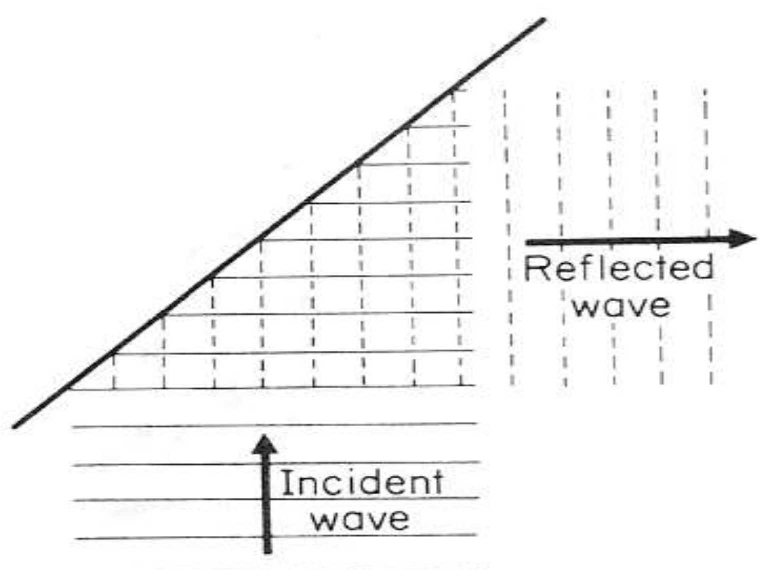
REFLECTION OF WAVES

A wave is reflected when a barrier is placed in its path. The shape of the reflected wave depends on the shape of the barrier.

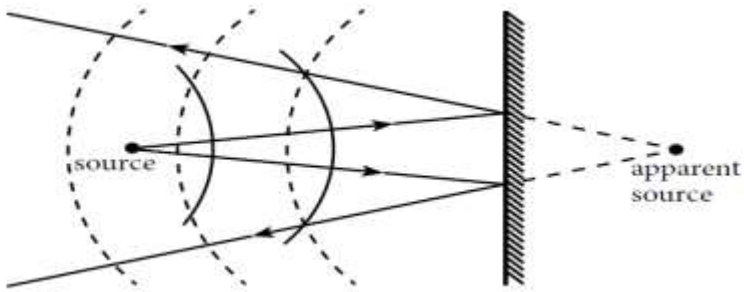
The laws of reflection of waves are similar to the laws of reflection of light.

(i) Reflection by plane reflectors

(a) Reflection of straight wave front.



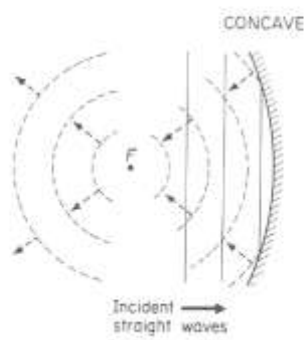
(b) Reflection of circular wave front



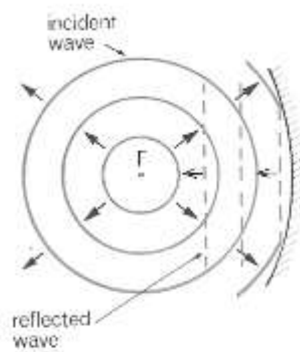
(ii) Reflection by curved reflectors

(a) By Concave reflector

i. Reflection of straight wave front

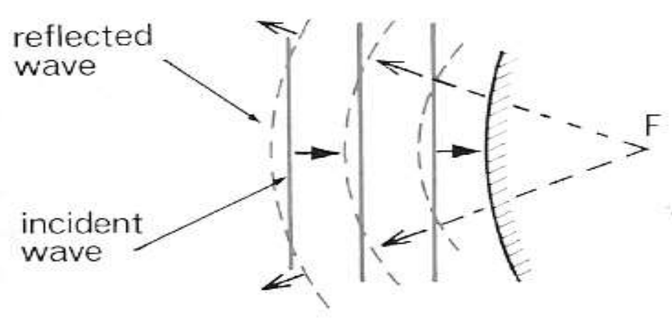


ii. Reflection of circular wave

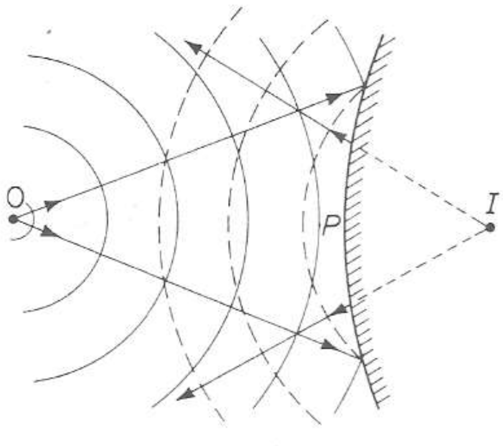


(b) By a Convex reflector

i. Reflection of plane wave



ii. Reflection of circular wave

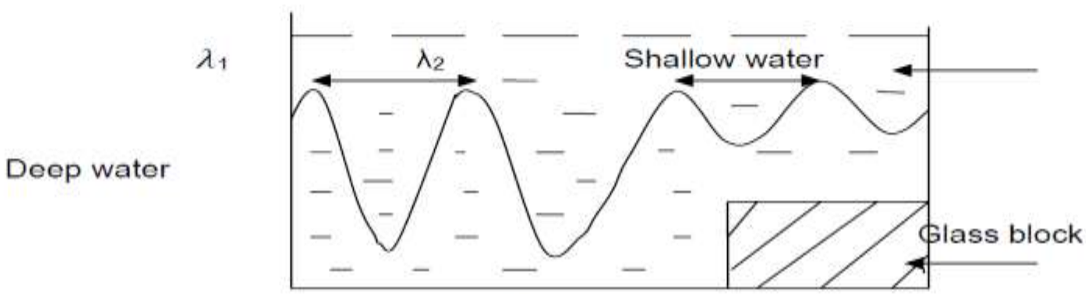


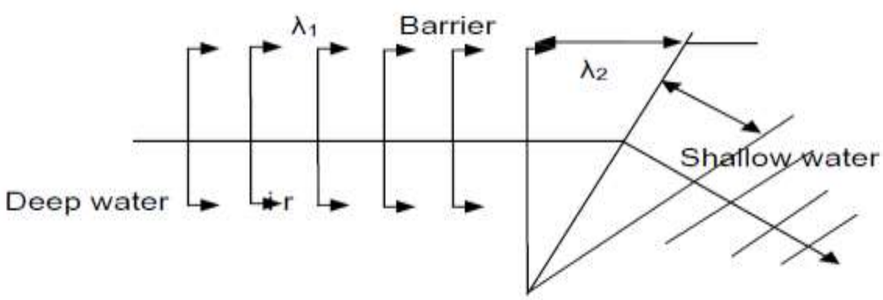
Note

During reflection of water waves, the frequency and velocity of the wave does not change.

REFRACTION OF WAVE

This is the change of in direction of wave travel as it moves from one medium to another of different depth. It causes change of wave length and velocity of the wave. However, the frequency and the period are not affected. In a ripple tank, the change in direction is brought about by the change in water depth.





λ_1 = wave length in deep water

λ_2 = wave length in shallow water

Note (i) $\lambda_1 > \lambda_2$

(ii) $v_1 = f\lambda$ and $v_2 = f\lambda_2$

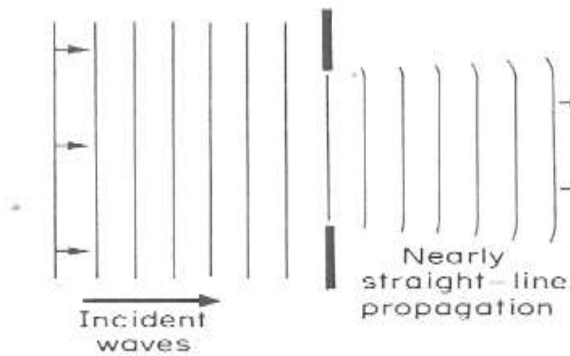
(iii) $v_1 > v_2$ When f – is constant.

Refractive index,

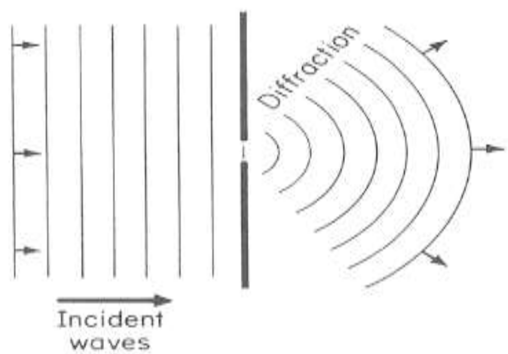
DEFRACTION OF WAVES

This is the spreading of waves as they pass through holes, round corners or edges of obstacle. It takes place when the diameter of the hole is in the order of wave length of the wave i.e. the smaller the gap the greater the degree of diffraction as shown below.

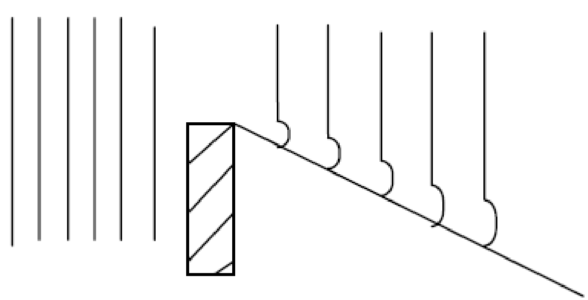
(a) Wide gap



(b) Narrow gap



(c) Edge of obstacle



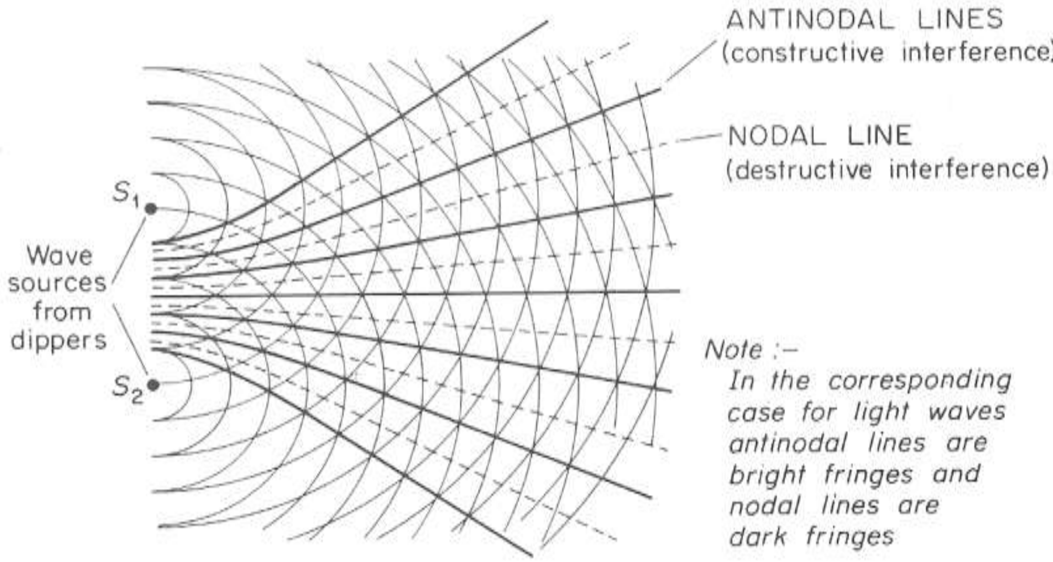
Sound waves are more diffracted than light waves because the wave length is greater than that of light.

Therefore sound can be heard in hidden corners.

N.B - When waves undergo diffraction, wave length and velocity remain constant.

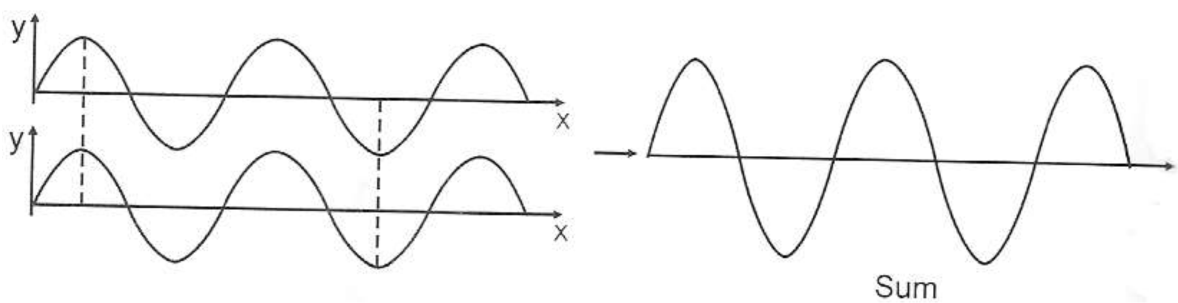
INTERFERENCE OF WAVES

This is the superposition of two identical waves travelling in the same direction to form a single wave with a larger amplitude or smaller amplitude. The two waves should be in phase (matching).



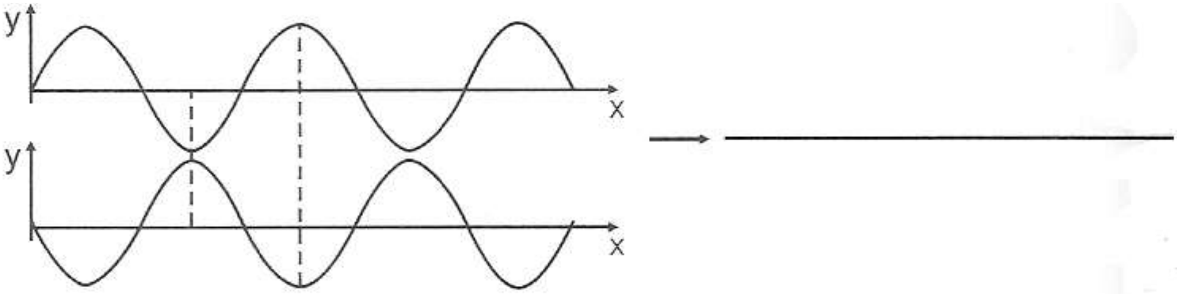
CONSTRUCTIVE INTERFERENCE

This constructive interference occurs when a crest from one wave source meets a crest from another source or a trough from one source causing reinforcement of the wave i.e. increased disturbance is obtained. The resulting amplitude is the sum of the individual amplitudes.



DESTRUCTIVE INTERFERENCE

This occurs when the crest of one wave meets a trough of another wave resulting in wave cancelling i.e.

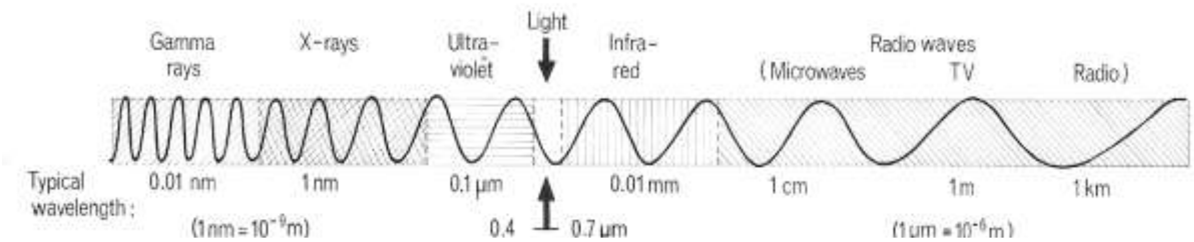


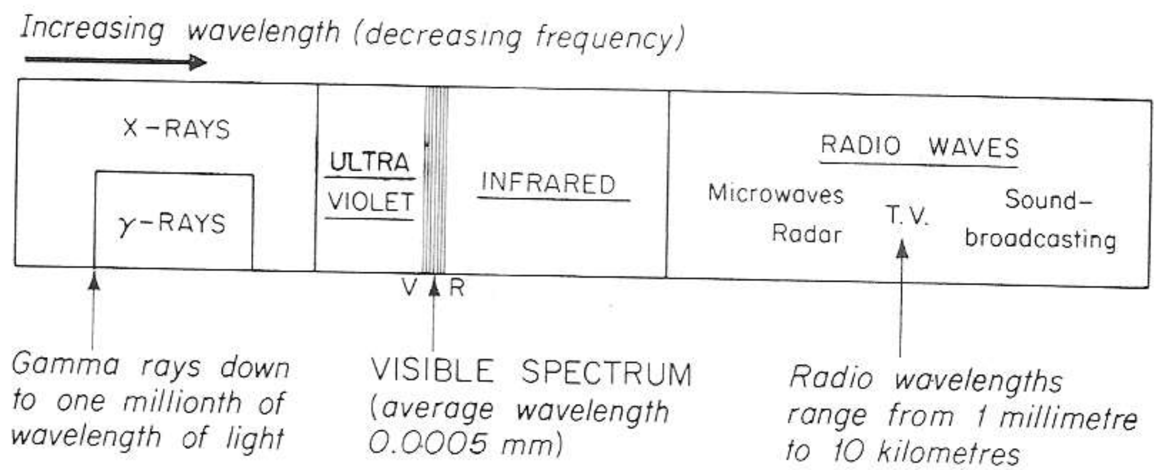
ELECTRO MAGNETIC WAVES

This is a family of waves which is made by electric and magnetic vibrations of very high frequency. Electromagnetic waves do not need a material medium for transformation i.e. they can pass through a vacuum.

SPECTRUM OF ELECTRO MAGNETIC WAVES

In decreasing frequency





PROPERTIES OF ELECTROMAGNETIC WAVES

- They are transverse waves.
- They can travel through vacuum.
- They travel at a speed of light (3.0×10^8m/s).
- They can be reflected, refracted, diffracted and undergo interference.
- They possess energy.

EFFECTS OF ELECTROMAGNETIC WAVES ON MATTER

(a) Gamma rays.

- They destroy body tissues if exposed for a long time.
- They harden rubber solutions and lubricate oil to thickness.

(b) X- rays

- Causes barriers/curtains to give off electrons.
- Destroys body tissues if exposed for a long time.
- Used in industries to detect leakages in pipes and in hospitals to detect fractures of bones.

(c) Ultra violet

• Causes sun burn

• Causes metals to give off electrons by the process called photoelectric emission.

• Causes blindness.

(d) Visible light

• Enables us to see.

• Changes the apparent colour of an object.

• Makes objects appear bent to refraction.

(e) Infrared

• Causes the body temperature of an object to rise.

• It is a source of vitamin D.

(f) Radio waves

• Induces the voltage on a conductor and it enables its presence to be detected.

Wave band	**Origin**	**Source**
Gamma rays	Energy changes in modes of atoms	Radio active substance
X- rays	Electrons hitting a metal target	X – ray tube
Ultra- violet	Fairly high energy changes in atoms	Very hot bodies Electron discharge Through gases especially mercury Vapour
Visible light	Energy changes in electron structure of atoms	Lamps, flames etc
Infrared radiation	Low energy changes in electrons of atoms	All matter over a wide range of temperature from absolute zero onwards.
Radio waves	High frequency Oscillating electric current Very low energy changes in electronic structures of atoms.	Radio transmission aerials.

SOUNDS WAVES (LONGITUDINAL WAVES)

Is a form of energy which is produced by vibrating objects e.g. when a tuning fork is struck on a desk and dipped in water, the water is splashed showing that the prongs are vibrating or when a guitar string is struck.

SPECTRUM SOUND WAVES

Frequency	$0H_Z$	$20H_Z$	$20{,}000H_Z$
Type of sound	Subsonic sound	Audible sound waves	Ultra sonic sound wave.

SUBSONIC SOUND WAVES

These are not audible to human ear because of very low frequency of less than 20Hz

AUDIBLE SOUND WAVES

These are audible to human ear. This frequency ranges from
20Hz- 20 KHz.

ULTRASONIC SOUND WAVES

These are sound waves whose frequencies are above 20Hz. They are not audible to human ears. They are audible to whales, Dolphins, bats etc.

APPLICATION OF ULTRASOUND WAVES

- They are used by bats to detect obstacles e.g. buildings a head.
- Used in spectacles of the blind to detect obstacles.
- Used in radiotherapy to detect cracks and faults on welded joints.
- Used in industries to detect rocks in seas using sonar.
- Used to measure the depth of seas and other bodies.

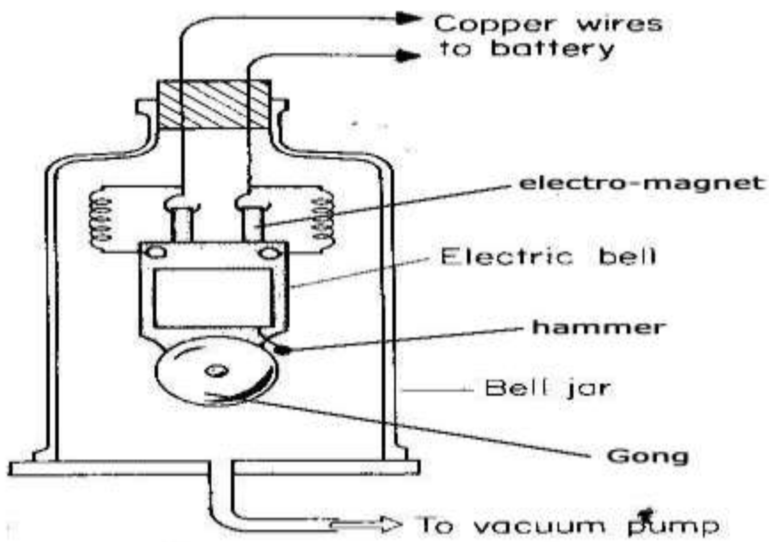
PROPERTIES OF SOUND WAVES

- Cannot travel in a vacuum because of lack of a material medium
- Can cause interference.
- Can be reflected, refracted, diffracted, planes polarized and undergo interference.
- Travels with a speed V = 330m/s in air.

TRANSMISSION OF SOUND

Sound requires a material medium for its transmission. It travels through liquid, solids and gases, travels better in solids and does not travel through vacuum.

EXPERIMENT TO SHOW THAT SOUNDS CANNOT PASS THROUGH A VACCUM.



- Arrange the apparatus as in the diagram with air in the jar.
- Switch on the electric bell, the hammer is seen striking the gong and sound is heard.
- Gently withdraw air from the jar by means of a vacuum pump to create a vacuum in the jar.
- The sound produced begins to fade until it is heard no more yet the hammer is seen striking the gong.
- Gently allow air back into the jar, as the air returns, the sound is once again heard showing that sound cannot travel through vacuum.

Note: The moon is sometimes referred to as a silent planet because no transmission of sound can occur due to lack of air (material medium).

The speed of sound depends on;

(i) Temperature

Increase in temperature increases the speed of sound i.e. sound travels faster in hot air than in cold air.

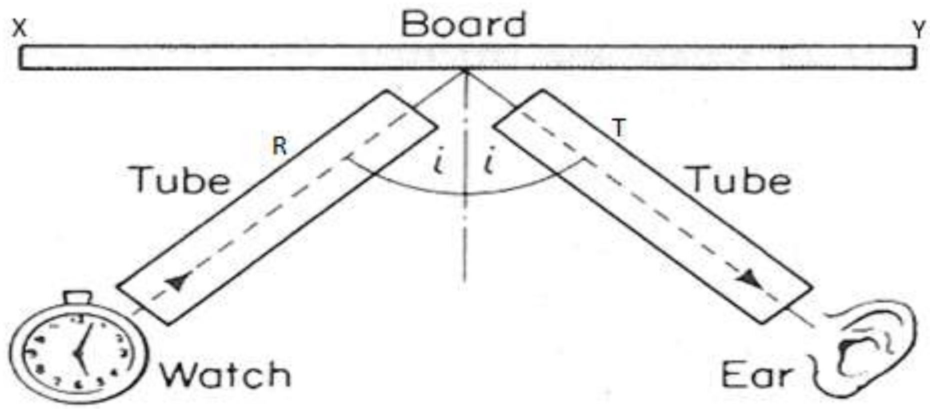
(ii) Wind

Speed of sound is increased if sound travels in the same direction as wind.

(iii) Density of medium.

Speed of sound is more in denser medium than in less dense. Change in pressure of air does not affect speed of sound because density is not affected by change in pressure.

EXPERIMENT TO VERIFY THE LAWS OF REFLECTION OF SOUND



R – Closed tube

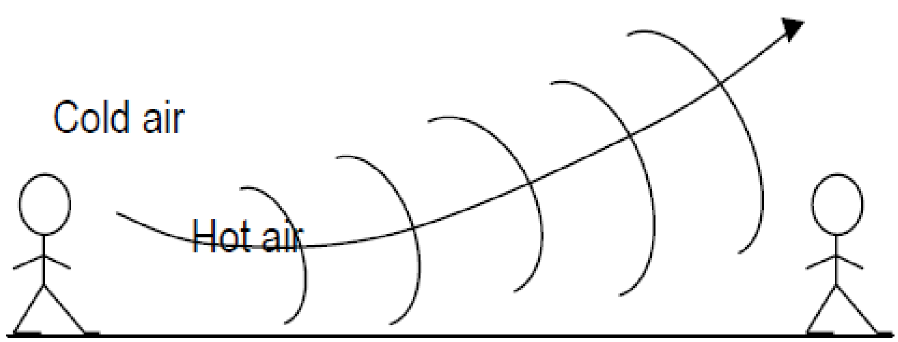
T – Open tube

- Put a ticking clock in tube R on a table and make it to face a hard plane surface e.g. a wall.
- Put tube T near your ear and move it on either sides until the ticking sound of the clock is heard loudly.
- Measure angle i and r which are the angles of incidence and reflection.
- From the experiment, sound is heard distinctly due to reflection.
- Angle of incidence (i) and angle of reflection (r) are equal and lie along XY in the same plane.
- This verifies the laws of reflection.

REFRACTION OF SOUND WAVES

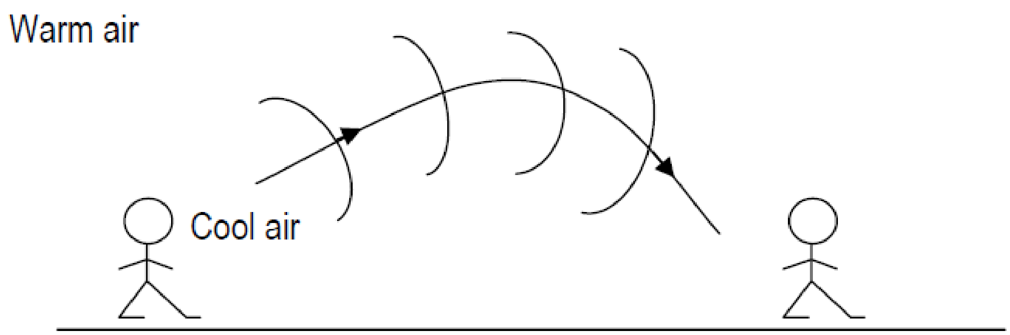
Refraction occurs when speed of sound waves changes. The speed of sound in air is affected by temperature. Sound waves are refracted when they are passed through areas of different temperature. This explains why it is easy to hear sound waves from distant sources at night than during day.

REFRACTION OF SOUND DURING DAY



During day, the ground is hot and this makes the layers of air near the ground to be hot while that above the ground is generally cool. The wave fronts from the source are refracted away from the ground.

REFRACTION OF SOUND DURING NIGHT



During night, the ground is cool and this makers layers of air near the ground to be cool while above to be warm. The wave fronts from the source are refracted towards the ground making it easier to hear sound waves over long distances.

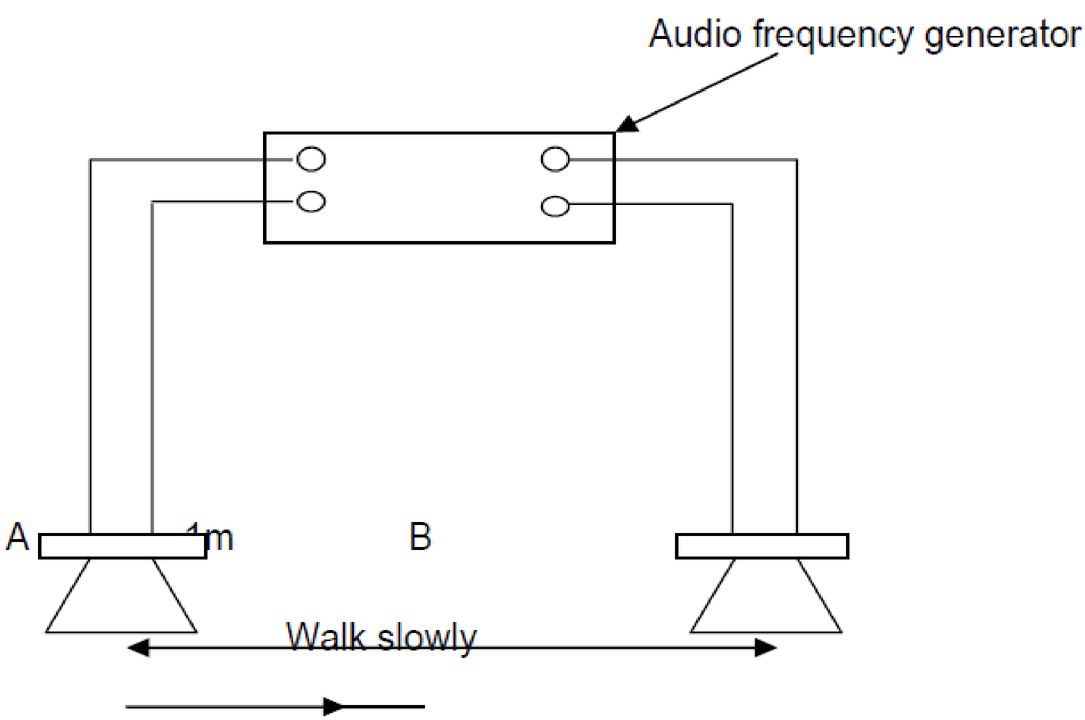
DEFRACTION OF SOUND

This refers to the spreading of sound waves around corners or in gaps when sound waves have wave length similar to the size of the gap. It is due to refraction that a person behind the house can hear sound from inside.

INTERFERENCE OF SOUND

When two sound waves from two different sources overlap, they produce regions of loud sound and regions of quiet sound. The regions of loud sound are said to undergo constructive interference while regions of quiet are said to undergo destructive interference.

EXPERIMENT TO SHOW INTERFERENCE OF SOUND



ECHOES

An echo is a reflected sound. Echoes are produced when sound moves to and fro from a reflecting surface e.g. a cliff wall. The time taken before an echo arrives depends on the distance away from the reflecting surface.

In order for a girl to hear the echo; sound travels a distance of 2d.

Velocity =

For an echo; velocity of sound,v =

Examples

1. A girl stands 34m away from a reflecting wall. She makes sound and hears an echo after 0.2 seconds. Find the velocity of sound.

   v =

   v =

   = 340m/s

2. A person standing 99m from a tall building claps his hands and hears an echo after 0.6 seconds. Calculate the velocity of sound in air.

   v =

   v =

   = 330m/s

3. A gun was fired and an echo from a cliff was heard 8 seconds later. If the velocity of sound is 340m/s, how far was the gun from the cliff?

   v =

   340 =

   1360 = d

   d = 1360m

4. A student is standing between two walls. He hears the first echo after 2 seconds and then another after a further 3 seconds. If the velocity of sound is 330m/s, find the distance between the walls.

   V =

   V =

   Distance between the walls = $d_1 + d_2$

d_1 =330m

d_2 = 825m hence

Distance between the walls = $d_1 + d_2$ = 330+825 = 1155m

5. A man is standing midway between two cliffs. He claps his hands and hears an echo after 3 seconds. Find the distance between the two cliffs.

   (Velocity of sound = 330m/s)

   V= 3 × 165 = 990m

   d_1

   d_1=495m

   $d_1=d_2$

   d_1+d_2 = 495+495

MEASUREMENT OF VELOCITY OF SOUND USING AN ECHO METHOD

Method;

A person stands a certain distance d from the reflecting surface (tall wall), then measure that distance.

Make a sharp clapping sound by banging two blocks of wood together.

Repeat the sound at regular time intervals to coincide exactly with the echo.

Count the number of claps in a given time t

Find the time taken for one clap i.e.

Velocity =

Velocity =

Velocity =

Example

A student made 50 claps in one minute. If the velocity of sound is 330s, find the distance between the student and the wall.

Velocity =

d=198m

REVERBERATION

In a large hall where there are many reflecting walls, multiple reflections occur and cause or create an impression that sound lasts for a longer time such that when somebody makes a sound; it appears as if it is prolonged. This is called reverberation.

Definition of Reverberation

Reverberation is the effect of the original sound being prolonged due to multiple reflections.

ADVANTAGES OF REVERBERATION

In grammar, reverberation is used in producing sound. Complete absence of reverberation makes speeches inaudible.

DISADVANTAGES OF REVERNERATION

During speeches, there is a nuisance because the sound becomes unclear.

PREVENTION OF REVERBERATION

The internal surfaces of a hall should be covered with a sound absorbing material called acoustic material.

WHY ECHOES ARE NOT HEARD IN SMALL ROOMS?

This is because the distance between the source and reflected sound is so small such that the incident sound mixes up with the reflected sound making it harder for the ear to differentiate between the two.

Question

1. Outline four properties of electromagnetic waves.
2. Distinguish between
   i. sound waves and light waves.
   ii. sound waves and water waves
3. A man standing midway between two cliffs makes a sound. He hears the first echo after 3s. Calculate ‛the distance between the two cliffs (Velocity of sound in air = 330m/s)

Musical notes

Music

This is an organized sound produced by regular vibrations.

Noise

This is a disorganized sound produced by irregular vibrations.

Musical note

This is a single sound of a certain pitch made by a musical instrument or voice.

Characteristics of musical notes

Pitch

This is the loudness or softness of sound. It depends on the frequency of sound produced, the higher the frequency the higher the pitch.

Timber

This is the quality of sound produced, it depends on the number of overtones produced, the more the number of overtones, the richer and the sweeter the music and therefore the better the quality.

Overtone

This is a sound whose frequency is a multiple of a fundamental frequency of the musical note.

Beat

This refers to the periodic rise and fall in the amplitude of the resultant note.

Loudness

This depends on the amplitude of sound waves and sensitivity of the ear.

Amplitude

This is the measure of energy transmitted by the wave. The bigger the amplitude, the more energy transmitted by the wave and the louder sounder sound produced.

Sensitivity of the ear

If the ear is sensitive, then soft sound will be loud enough to be detected and yet it will not be detected by the ear which is insensitive.

Pure and impure musical notes.

Pure refers to a note without overtones. It is very boring and only produced by a tuning fork.

Impure refers to a note with overtones. It is sweet to the ear and produced by all musical instruments.

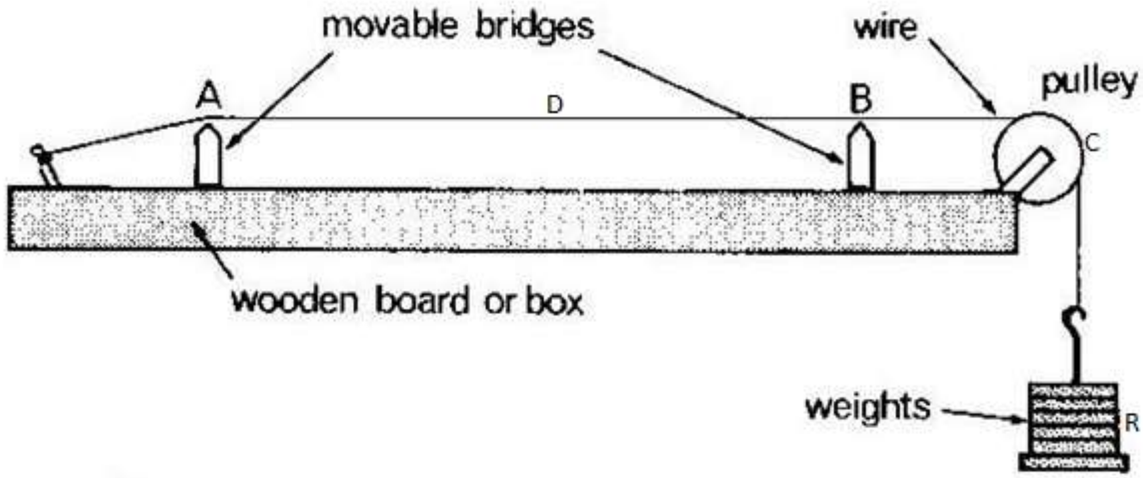
VIBRATION IN STRINGS

Many musical instruments use stretched strings to produce sound. A string can be made to vibrate by plucking it like in a guitar or in a harp in pianos. Different instruments produce sounds of different qualities even if they are of the same note.

Factors affecting the frequency of the stretched string

(a) Length

For a given tension of the string, the length of the string is inversely proportion to the frequency of sound produced. This can be demonstrated by an instrument called sonometer as shown below.



A- Fixed bridge

B- Movable bridge

C- Wheel

D- Stretched string

R-Load

By moving bridge B, higher frequency can be obtained for a short length AB and lower frequency for a long length AC. The relation can be expressed as f

(b) Tension

Adding weights or removing them from its ends at load R varies the tension of the sonometer wire. It will be noted that the higher the tension, the higher the frequency of the note produced.

(c) Mass per unit length (m)

Keeping length (l) and tension (t) constant, the frequency of sound produced depends on the mass per unit length of the string. Heavy strings produce low frequency sounds. This is seen in instruments such as guitar, base strings are thicker than solo stings. If the tension and length are kept constant, the frequency of sound is inversely proportional to the mass per unit length of the strings thus a thin short and taut string produces high frequency sound. (f)