PHYSICS NOTES FOR ‘O’ LEVEL

(S.2 WORK)

STRUCTURE OF MATTER

Matter is anything that occupies space and has weight. It exists in different forms/states of small items called atoms.

The three states are

- Solids
- Liquids
- Gas

According to kinetic theory matter is made up of small particles known as molecules which are in a state of continuous random motion. The speed of molecule is increased by increase in temperature.

FORCE BETWEEN MOLECULES

- **Cohesion /Cohesive force**

This is the force of attraction of molecules of the same substance e.g water- water molecules, mercury – mercury molecules

- **Adhesion/Adhesive force;**

This is the force of attraction between the molecules of different substances e.g water – glass molecules.

STATES OF MATTER

Solids;

The molecules are closely packed together, their particles are not free to move from place to another but can vibrate along their mean positions ie move to and fro about their mean positions. This is because their cohesive forces between molecules are strong. Molecules in solids are arranged in a regular pattern called lattice. They have shape and size.

Liquids;

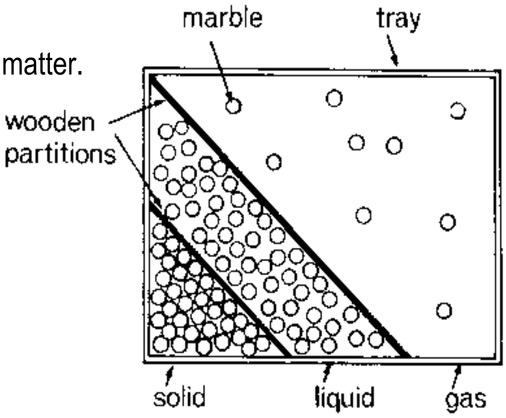
The molecules in liquids are slightly further apart than in solids. Particles are free to move about colliding with each other and with the walls of the container. The cohesive force holding the molecules are weaker than in solids.

They have no definite shape but take up shape of the container.

Gases;

In gases the molecules are much further apart and free compared to those in liquids and so free that they are in constant random motion moving with high speed as they collide with one another and with the walls of a container. The cohesive force is much weaker in gas and can spread easily to occupy the whole volume of a container. Gases lack definite shape and size.

Model; illustrating the states matter.

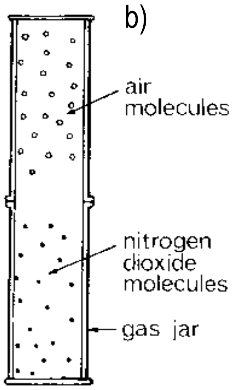


Diffusion;

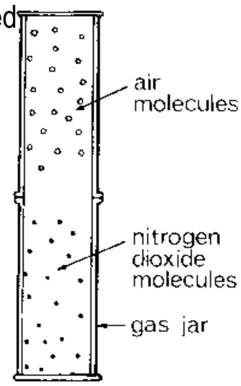
It is the movement of molecules of a substance from a region of high concentration to a region of low concentration.

Demonstration of Diffusion in Gases;

a)



b) Gas mixed

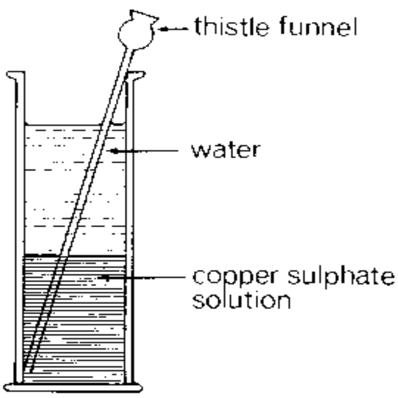


Two Gas jars one full of nitrogen dioxide and the other gas full of air as shown in (a) above.

When the gas cover is removed as shown in (b) the gases mix up and the whole become filled with the Brown gas(Nitrogen dioxide)

NB: The lighter gas diffuses faster than the heavier gas.

Demonstration of diffusion in liquids:

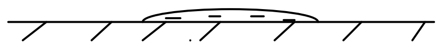


- Half fill a glass beaker with water
- Using a funnel with a long tube reaching the bottom, slowly pour saturated copper (II) sulphate solution down the tube to form a separate layer.
- Carefully remove the funnel so that the liquids are mixed.
- After some time, the blue colour spreads throughout the beaker. This is due to diffusion of liquid molecules.

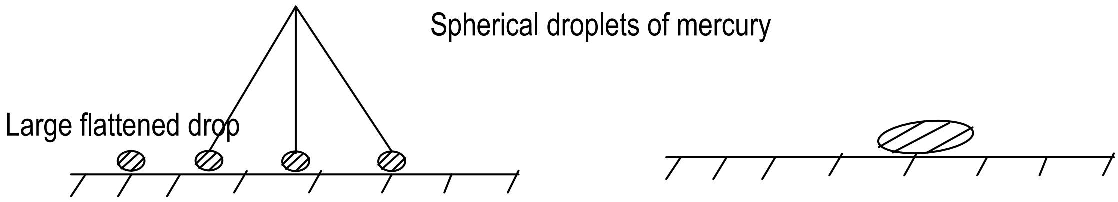
Note: The rate of diffusion increases when temperature is increased.

Behavior of liquids on the surface;

When water is dropped on a glass surface it wets it and spreads out in a thin surface because adhesive force between the water molecules and glass is greater than the cohesive force between water molecules.



When mercury is dropped on a glass surface it forms spherical droplets or large flatten drop because cohesive forces between mercury molecules is greater than adhesive forces between mercury and glass.



SURFACE TENSION

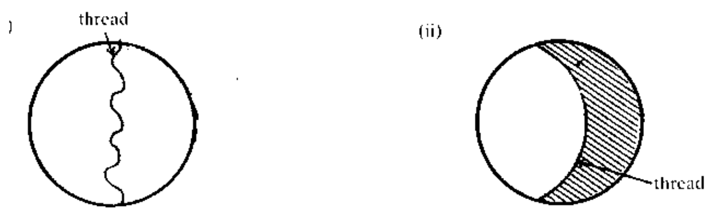
This is the effect of force on the surface of a liquid which makes it behave like a stretched elastic skin.

Or it is a tangential force on surface of a liquid acting perpendicularly per unit length across any line on the surface.

Effects of surface tension;

Because of surface tension,

1. Steel needle when carefully placed on top of water floats, despite its greater density.
2. Some birds and insects can walk on the surface of water.
3. Some drops of water from the top are in form of a spherical shape.
4. Soap film inside the cotton loop when broken makes or forms a circle as shown below



Make a ring of thin wire. Tie a thread loosely across the middle as shown in (i). Dip the ring in soap solution or liquid detergent so that a film forms across it. Break the film on one side of the thread. The thread pulls tight, forming a circle as shown in (ii).This because surface tension stretches molecules on the liquid surface farther apart than normal.

Explanation on surface tension:

Surface tension is due to molecules on liquid surface being slightly further apart like those in a stretched wire. Therefore experience attractive forces from their neighbours in liquid surface. The forces stretch the molecules on the surface, making it behave like a stretched elastic skin.

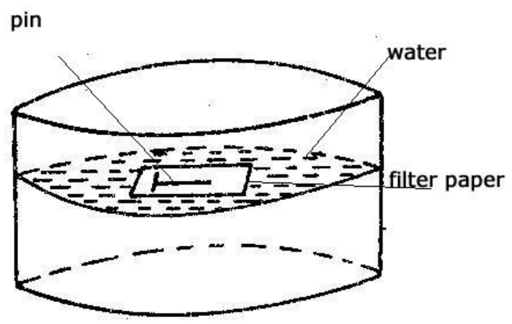
Reduction of surface tension;

Surface tension can be reduced by;

1. Increasing the temperature of the liquids
2. Addition of detergents or soap solution.

Experiment to demonstrate surface tension

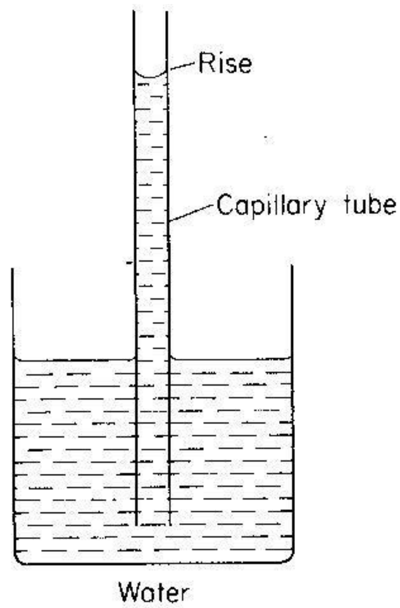
- Some water is poured in a clean trough
- It is then left to settle and a filter paper (blotting paper) is placed on the water surface.
- A pin smeared with Vaseline is carefully placed on top of the filter paper as shown below.



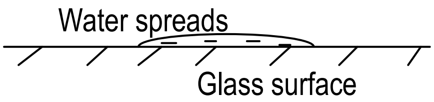
After sometime, the filter paper will absorb water and sink while the pin will remain floating on the water surface.

CAPPILARITY/CAPPILLARY ACTION:

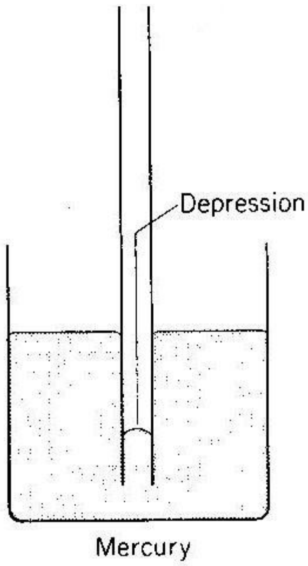
This is the rise or depression of a liquid in a capillary tube.



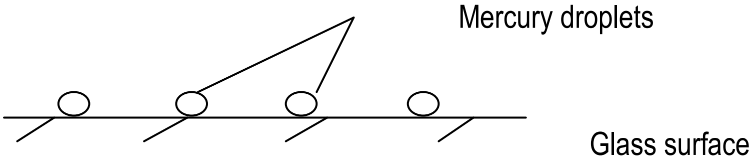
The rise of water in a capillary tube is because the cohesive force between the water molecules is less than the adhesive force between molecules of glass and water. It is also for this reason that water spreads over glass surface



When similar capillary tubes are dipped in mercury, each surface is depressed below the outside level of the beaker and the surface curves down wards as shown below.



Mercury is depressed more in narrow tube than in a large one. This is because cohesive forces between molecules of mercury are greater than adhesive forces between molecules of mercury and glass. It is also for this reason that mercury does not wet glass but forms droplets on glass as shown.



Application of capillarity;

1. The rise of oil in a lamp wick upwards.
2. Absorption of water in a towel.
3. The rise of water in mineral salts in plants
4. Action of a blotting paper.

Disadvantages of capillarity;

House bricks and concrete are porous. Capillary action is likely to draw water upwards from

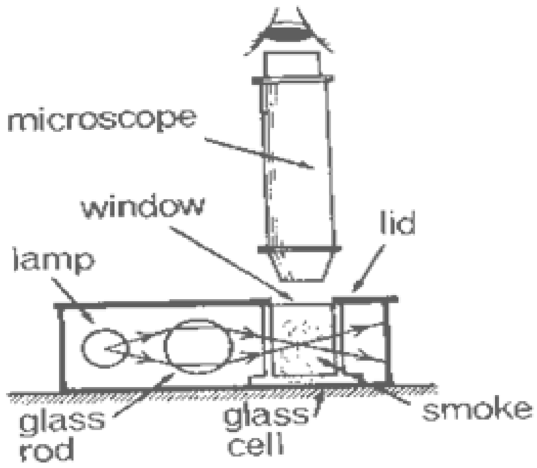
The ground through them, making the building dump (wet).This problem is overcome by putting

Water proof layer made from plastic that is placed in the layers of bricks at the bottom of the house.

BROWNIAN MOTION

It is the random movement of the molecules of a substance in a gaseous stage.

When smoke particles are suspended in air and observed through a microscope. They seem to be in a state of continuous random motion.



The smoke particles are seen as bright specks moving in continuous random motion. The bright specks are due to collision between smoke particles and gas molecules.

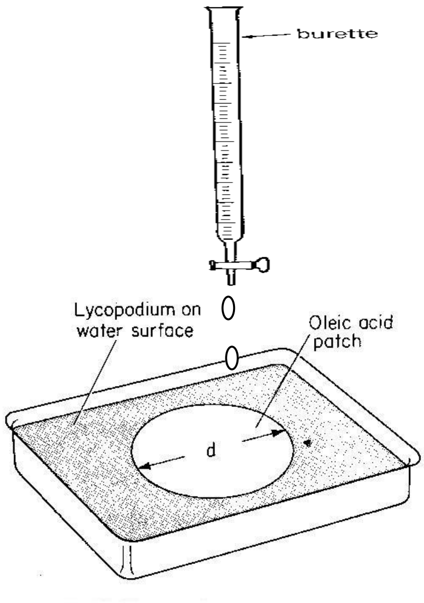
The random motion is due to smoke particles colliding with air molecules which were moving randomly.

When the temperature of the glass cell is increased the random motion increases (smoke particles are seen to move faster), showing that increase in temperature increase the kinetic energy of molecules.

OIL DROP EXPERIMENT

Estimation of the size of an oil molecule.

- A trough is cleaned thoroughly and clean water poured on it.
- Lycopodium powder is sprinkled on the water surface.
- Using a burette a drop of oil of known volume is allowed to gently fall on the surface of water.
- The oil spreads forming a circular film.



The diameter “d” of the patch is measured using a millimeter scale. Several experiments are performed using fresh water and the average diameter “d” of the patch is determined.

Since the patch is cylindrical, the volume of the patch is;

Where h – is the thickness of the oil patch.

$V = \pi r^2 h$

$= \pi(\frac{d}{2})^2 h$

$V = \pi \frac{d2}{4} h$

$4V = \pi d^2 h$

Therefore the thickness of oil drop

$$h = \frac{4V}{\pi d2}$$

Assumptions made in the experiment;

- The oil spreads to form a film of one molecule thick.
- The oil patch is cylindrical in shape.
- There are no air spaces between the molecules.
- The oil drop is spherical in shape.
- The volume of the oil drop is equal to the volume of oil patch.

Example;

1. In an oil drop experiment the radius of the oil was found to be 10cm and the volume of the used was

   $1.1 \times 10^{-5}cm^3$.Calculate;

   (i) The diameter of the film
   (ii) The thickness of the patch
   (iii) The size of the molecule

Answer

Diameter of the patch d = 2r= 2 x 10 = 20cm

Thickness of the patch h = $\frac{4V}{\pi d2}$

or Thickness h = $\frac{Volume}{Area}$

= $\frac{4x1.1x10-5}{3.14\ x20\ 2}$

= 3.5 x 10^{-8}cm

The size of the drop = thickness of the patch

= 3.5 x 10^{-8}cm

Note: Thickness h = $\frac{Volume}{cross\ sectional\ area}$

i.e h = $\frac{V}{A}$

2. A student made an oleic acid oil of volume 0.005cm^3 to make an oil film on the surface of water.

The average diameter of the oil film was found to be 10cm.Find the thickness of the oil film.

Thickness h = $4v/\pi d2$

= $\frac{4\ x\ 0.005}{3.14\ x\ 102}$

=6.37x10^{-5}m

3. Niah, picked on oleic acid oil drop of diameter 0.5mm using a wire and allowed it to drop on a water surface containing lycopodium powder in a circular patch had an average diameter of 200mm.Find the thickness of oil film.

Diameter = 0.5mm

Volume of spherical drop V = $\frac{4}{3}\pi r^3$

= $\frac{4}{3}\pi$ $(0.25)^3$

= 0.0208πmm^3

Volume of the patch = volume of spherical drop

$\pi r^2 h$ = 0.0208π

π $(100)^2$h = 0.0208π

h =2.08 x 10^{-6}cm

4. If $1.8 \times 10^{-4} cm^3$ of oil spreads to form a patch of area $150 cm^2$.Calculate the thicknesses of the oil patch.

Thickness h = $\frac{V}{A}$ = 1.8 x $\frac{1}{10000}$

= $\frac{0.0008}{150}$

= 1.2×10^{-6}cm

Moments and equilibrium

The turning of a force is the moment of force.

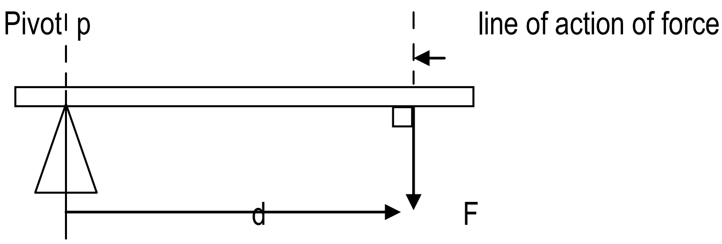
Moment of a force about a point depends on
i) The size of force
ii) On perpendicular distance from a line of action of force from the pivot.

Moment of a force is = force x perpendicular distance
M = f x d where m is moment of force f is the force and d is the perpendicular distance.

Definition

Moment of a force about a point is the product of the force and the perpendicular distance of it's line of action from the pivot S.I unit is Nm

ILLUSTRATION



Moment of force about p

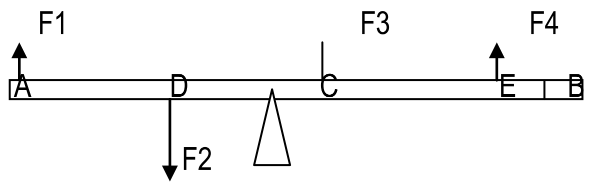
m = F x d

Types of moments

i) Clock wise moment
These are moments produce clockwise turning effects

ii) Ant clock wise effects
These are moments produce anti clock turning effects.

Static equilibrium
A body acted upon by a number of several forces in a static equilibrium when sum of clock wise moment about any point = sum of anti clock wise about the same point.



If AB is in equilibrium then:-

1. Sum of upward forces = sum of downward forces

   $F_1 + F_3 + F_4 = F_2$

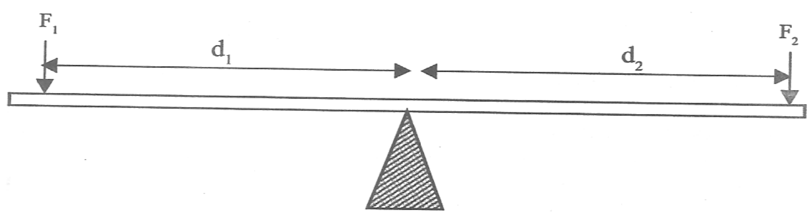
2. Sum of clockwise = sum of anti clock wise moment

$$F_1AC = F_2DC + F_4CE$$

Conditions of a body to be in a mechanical equilibrium

1. The resultant force on body must be zero
2. The sum of clock wise moment about a turning point must be equal to the sum of anti clock wise moments.

PRINCIPAL OF MOMENTS
It states that for a body in equilibrium , under the action of several forces , the sum of clock wise moments about a point is equal to the sum of anti clockwise moment about the same point.

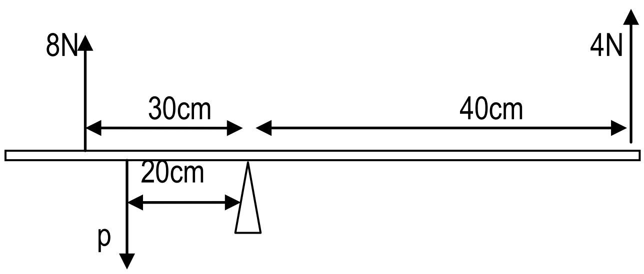


Sum of clock wise moment = sum of anti clock wise moment.

$$F_2 \, X d_2 = \quad F_1 \, X \, d_1$$

Example.1

Forces of 8Np and 4n act on a body as shown.



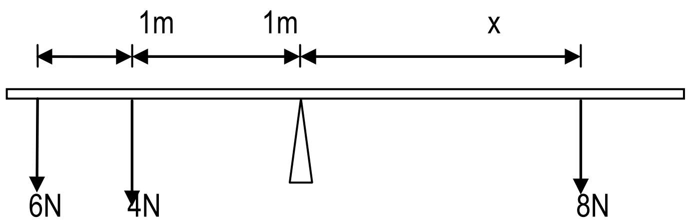
Find the value of P if the system is in equilibrium.

Anti clock wise moment = clock wise moment

4 x 40 + p x 20 = 8 x 30

P = 4N

3. Forces below act on the plant as shown.



If the body is in equilibrium find the distance x

Anti clock wise = clock wise moment
6 x 2 + 4 x1 = 8 x
X = 2m

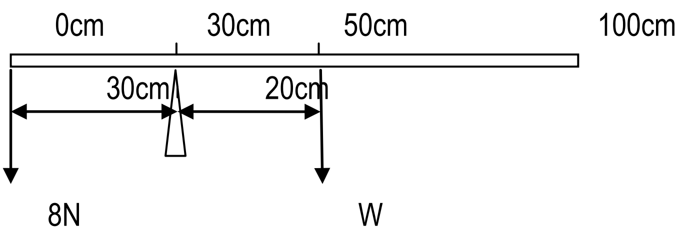
Center of gravity

Centre of gravity is a point on the body through which the weight of the body acts.

Object	**Centre of gravity**
Cube or Cuboid	It is the intersection of diagonals
Uniform rectangular square sheet.	At the intersectional of the diagonal
Uniform cylinder	At the centre of its axis
Uniform sphere	At the centre
Uniform rod or bar	At the centre

Example:

(a) What is meant by centre of gravity?
(b) (i) Define the moment of a force.
(i) A uniform metre rule is balanced at 30cm mark. When a load of 8N is hang at zero mark. Find the weight of a metre ruler

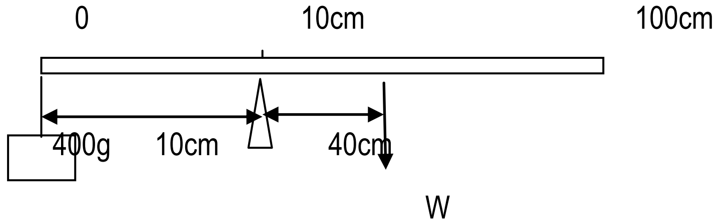


Sum of clockwise moment = Sum of anticlockwise moment

W x 2 = 8 x 30

W = 12N   W is the weight of metre rule.

2. A uniform metre rule pivoted at 10cm mark balances when a mass of 400g is suspended at 0cm mark as shown below.



Calculate the weight of the metre rule.

Sum of clockwise moment = Sum of anticlockwise moment

W x 40 = 400 x 10

W = 100g

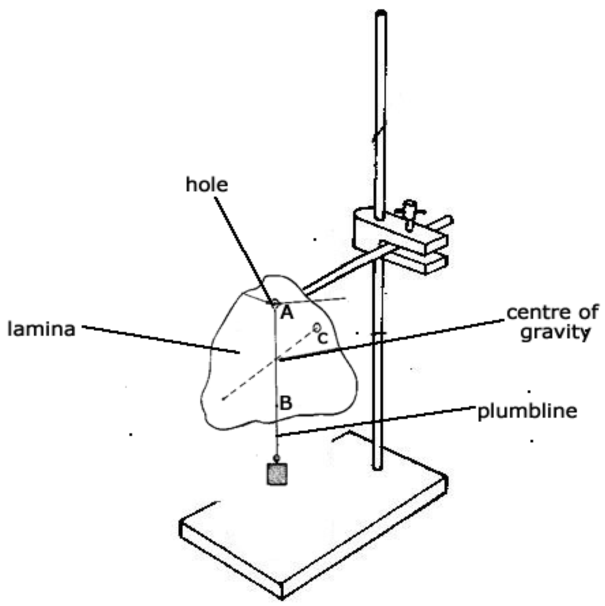
Weight = Mg

= 0.1 x 10

= 1N

Determination of centre of gravity of an irregular object e.g cardboard

Plumb line method;



- Make 3 holes A, B, C at different points near the edge of the lamina.
- Suspend the lamina in hole A and the plumb line on a nail on a retort stand.
- Mark point A, where the thread touches the opposite side of edge of the lamina.
- Repeat the procedure on hole B and C to get A and B.
- Draw line of intersection of lines AA, BB and CC this gives the centre of gravity (C.G)

STABILITY:

The stability of a body depends on entirely two factors namely:-

i) Position of the centre of gravity.
ii) Size of base area.

To increase the stability of on a body, the following should be done.

- Increase the base area.
- Lower the centre of gravity by making the base heavier

Types of stability equilibria

- Stable equilibrium
- Unstable equilibrium
- Neutral equilibrium

Stable equilibrium.

This occurs when the center of gravity is in the lowest possible position

The body doesn't over turn when slightly displaced but returns to its original position after the displacement.

When slightly displaced, the center of gravity is raised and the line of action of the weight acts with in the base.

Moment decreases when a body is slightly displaced.

Unstable equilibrium

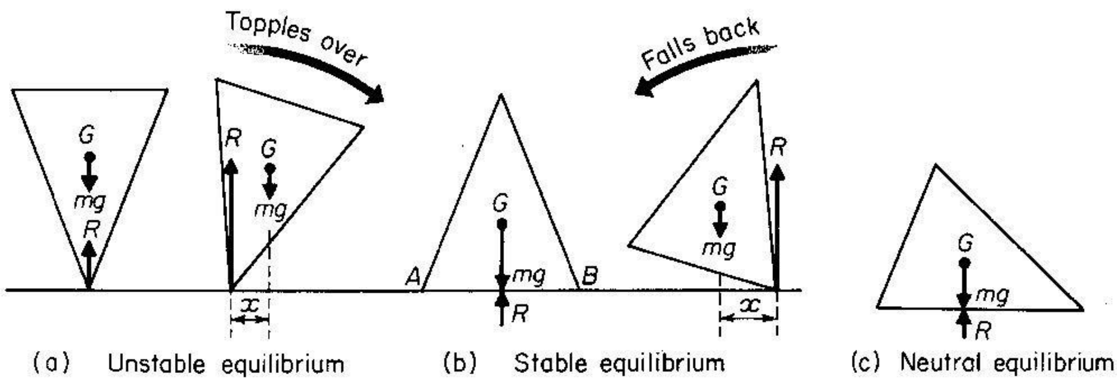
This occurs when the centre of gravity is in the highest position. The body overturns when slightly displaced.

When the center of gravity is lowered and the line of action of the weight acts outside the base.

Natural equilibrium

This is when a body is slightly displaced but the position of its center of gravity remain at the same height.

Illustration

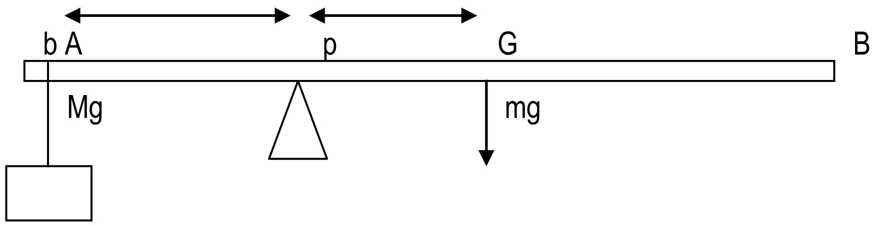


Application of principal of moments.

- Action of a beam balance / weighing scale.
- Action of a sea saw.
- Action of in determination of centre of gravity of a beam
- In determination of mass of the weight of a beam.
- In determination of relative density of a solid.

Determination of mass of a beam or rod or any straight material .

Setup



Procedure

- Locate the centre of gravity of the beam AB by balancing it horizontally on a knife edge.
- Note the position of the center of gravity .
- Again balance AB horizontally on a knife edge using a mass at point d as shown in the diagram
- Measure distance DP = a and PG = b.
- Calculate the mass from sum of clockwise moment = sum of anticlockwise.

Mg x b = Mg x a

$$M = \frac{Mga}{gb} = \frac{ma}{a}$$

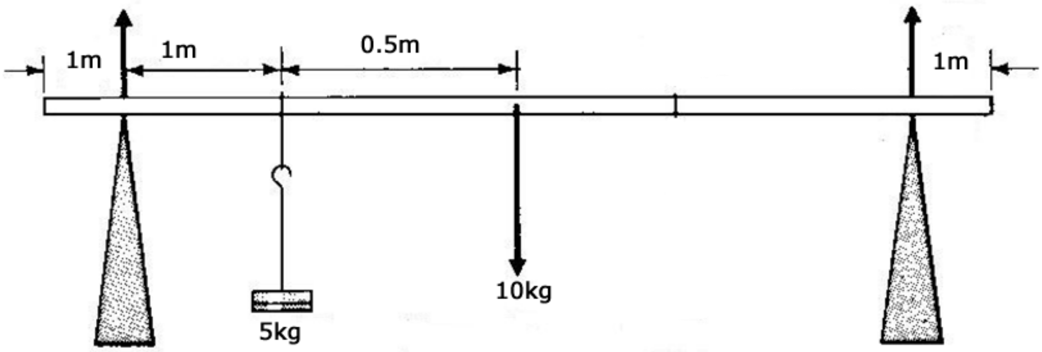
$$M = \frac{mga}{gb} = \frac{ma}{b}$$

$$To\ get\ weight\ of\ beam\ = W\ = Mg.$$

Example.

A uniform beam 5m long weighing 10kg is carried by 2 men each 1m from either ends of the beam if the mass of 5 kg rests 2m away from one end

i) *Draw a diagram showing all forces acting on the bar.*
ii) *Calculate the reaction due to the men acting on the bar.*



Taking moment at A

Sum of clockwise moment = sum of anticlockwise moment

50 x 100 x 1.5 = RB x3

200= 3RB

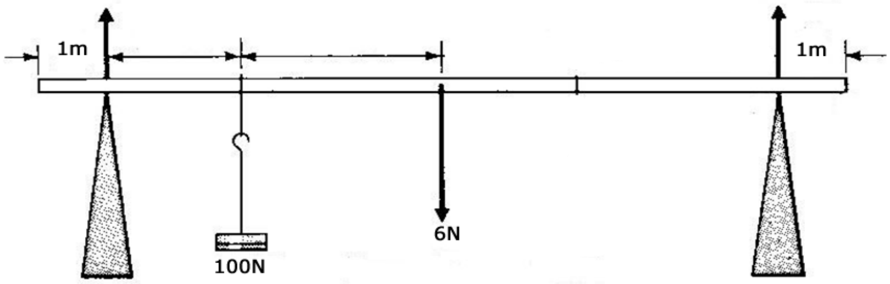
RB = $\frac{200}{3}$

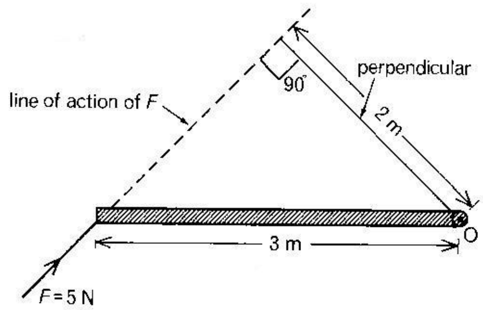
RB = 66.67N

Upward force = downward force
RA + RB = 50 + 100
RA + 66.67 = 150
RA = 83.33N.

Reaction at A= 83.33N
Reaction at B = 66.67N.

2.A uniform beam of weight 6N length BM rests on support p and q which are 1m 4m either ends weight over100N are placed at the ends of the rod as shown in the diagram. Calculate the reaction at p and q.





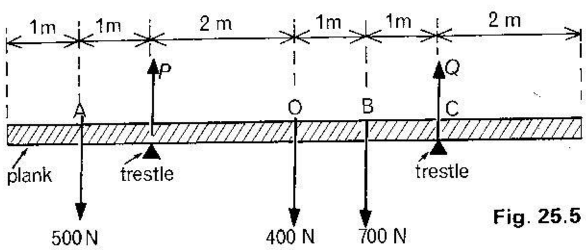


Fig. 25.5

MOTION

Terms used.

Speed

This is the rate of change of distance moved with time.

Speed $= \frac{distance\ moved}{time\ taken}$

S.I unit = m/s

Distance

This is the length moved between two points.

S.I units = metres

Displacement

This is the distance moved in the specified direction S.I unit meters

Velocity

This is the rate of change of displacement. OR is the rate of change distance moved in a specified direction.

S.I unit m/s

Acceleration

A body travelling with changing velocity is said to be accelerating

Acceleration is the rate of change of velocity.

Acceleration $a = \frac{change\ in\ velocity}{time}$

But change in velocity = final velocity – initial velocity

$= v - u$

Acceleration in velocity $a = \frac{v-u}{t}$ S.I unit: m/s^2

Example 1

A car increases its speed steadily from 30 km/hr to 60km/hr in one minute

a) Determine its average speed during this time in

i) km/hr

ii) km/min

iii) m/s

b) how far does it travel whilst increasing its speed

i) average speed $= \frac{v+u}{2}$ where v – final velocity / speed

$= \frac{60+30}{2}$

= 45km/ hr

ii) average speed $= \frac{45km}{1\ x60min}$

= 0.75km/min

iii) Average speed = $\frac{45\ x100m}{1\ x60\ x60}$

= 12.5m/s

b) Distance = speed x time
=12.5 x 60
=750m

2. A motor car is uniformly retarded and brought to rest from a speed of 108km/hr in 15 seconds. Find its acceleration

Initial velocity u = $\frac{108\ x1000}{1\ x60\ x60}$

= $\frac{1080}{36}$
= 30m/s

Final velocity = 0 m/s

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

= $\frac{0-30}{15}$

= $-2mls^2$

The minus (-) sign means the car is accelerating in opposite direction to its initial velocity i.e. the body is decelerating.

Uniform speed

A body is said to move with uniform speed if its rate of chance of distance moved with time is constant.

Uniform velocity

A body is said to move with uniform velocity if its rate of change of displacement is constant.

When a body moves uniform velocity, it travels equal distances in equal time intervals. A graph of distance against time is a straight line. its initial velocity must be equal to its final velocity.

Non uniform velocity

This is when the rate of change of displacement is changing. The body covers different distances in equal time intervals.

Uniform acceleration

This is when the change of velocity is constant. When a body moves with uniform acceleration, the final velocity is not equal to the initial velocity

Equations of motion (Newton's equations of motion)

Equation

1. Consider a body moving at initial velocity u accelerates with uniform acceleration a to the final velocity v in time t

   Then acceleration a = $\frac{change\ in\ velocity}{time}$

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

   V = u + at 1st equation.

2nd equation

A body moving with uniform acceleration has an average velocity equal to half of the sum of its initial velocity u and final velocity v.

Average velocity = $\frac{v+u}{2}$ substituting from v in equation 2

Total distance s = average velocity x time

S = ($\frac{v+u}{2}$) t but from equation 1, V = u + at

S = ($\frac{u+at+u}{2}$)t = ($u + \frac{at}{2}$)t

S = u t + $\frac{1}{2}$at² second equation.

3rd equation

This is obtained by eliminating time t from equation 1and2.

S =$\left(\frac{v+u}{2}\right) t$

S=($\frac{v+u}{2}$)($\frac{v-u}{a}$) ⇔ (v + u)(v - u) = 2aS

$V^2 = u^2+2aS$ 3rd equation.

The three equations of motion are

i) V= u + at
ii) S = u t +½at²
iii) $V^2 = u^2 + 2as$

Example

A car starts from rest and is accelerated uniformly at a rate of 1m/sec2 in 20 second.

a) Find its final velocity.
b) The distance covered.

a) $V = u + at$

$= 0+1 \times 20$

$= 20m/s$

b) $S = ut + ½at^2$

$= 0 \times 20 + ½ \times 1 \times 20^2$

$= 200m$

2. A car accelerates uniformly at a speed of 20mls for 4 seconds . find

   a) Final velocity if acceleration is $2m/s^2$

   b) Distance traveled.

   a) $V = u + at$

   $V = 20 + 2 \times 4$

   $V = 28m/s$

   b) $S = ut + ½at^2$

   $S = 20 \times 4 + ½ \times 2 \times 4$

   $S = 96m.$

3. A body moving with velocity of 20 m/s accelerates to a velocity of 40mls in 5 second. Find
   a) Acceleration 4m/s
   b) Distance traveled in 5s.

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

   $= \frac{40-20}{5}$

   $= 4m/s^2$

   $S = ut + ½at^2$

   $S = 20 \times 5 + ½ \times 4 \times 5^2$

   $S = 150m$

4. A body at rest at height of 20m falls freely to the ground. Calculate
   i) The velocity with which it hits the ground
   ii) The time before striking the ground.

   Solution

   i) $a = g = 10$

   $V^2 = u^2 + 2as$

   $V^2 = 0^2 + 2 \times 10 \times 20$

   $V = 20m/s$

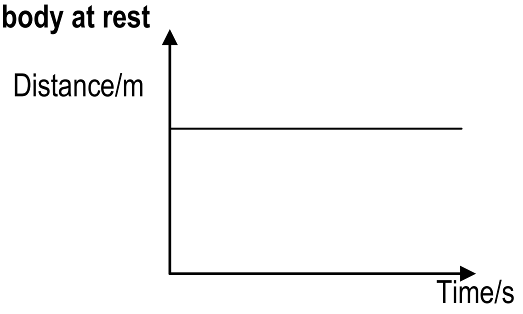
   ii) $V = u + at$

   $20 = 0+10 + t \quad \Leftrightarrow t = 2s.$

Graphs of motion

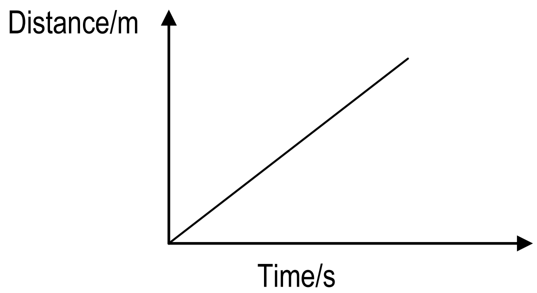
Distance – time graph

(i)For a body at rest



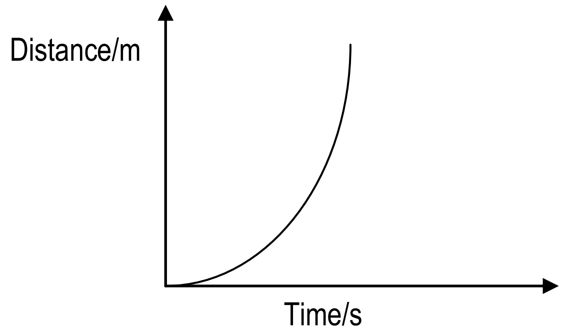
If a body is at rest its distance from a certain point does not change as time passes

ii) For a body moving with uniform velocity



If a body is moving with the same velocity it travels equal distance in equal intervals of time the object distance increases by equal increase in time.

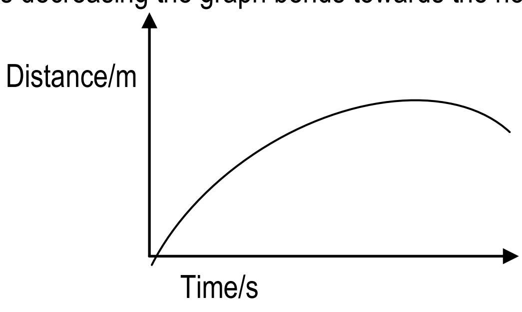
iii) Body moving with non uniform velocity



Velocity is increasing the distance travelled in each second increases

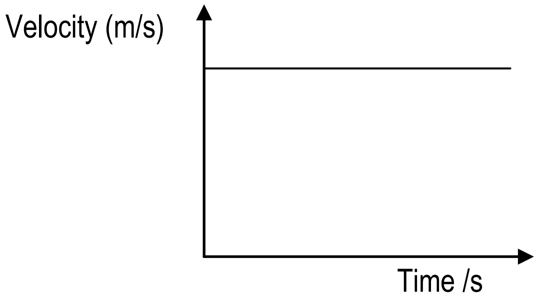
iv) Body moving with decreasing acceleration (retardation)

For a body whose velocity is decreasing the graph bends towards the horizontal. Velocity decreasing (retardation)

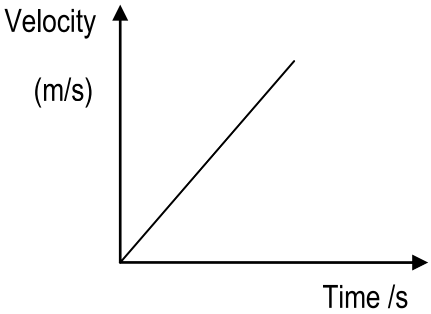


Velocity time graphs

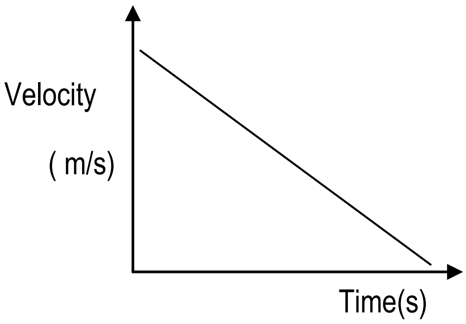
i) Body moving with uniform velocity



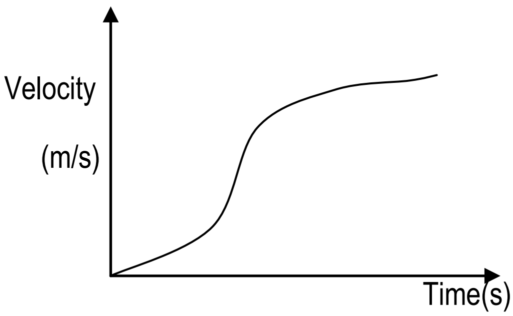
ii) Body moving with uniform acceleration



iii) Body moving with uniform deceleration.



iv) Body moving with non uniform acceleration.



Note i) the area under a velocity time graph gives the distance covered by the body.

ii) The slope of a uniform velocity time graph gives the uniform acceleration.

Example

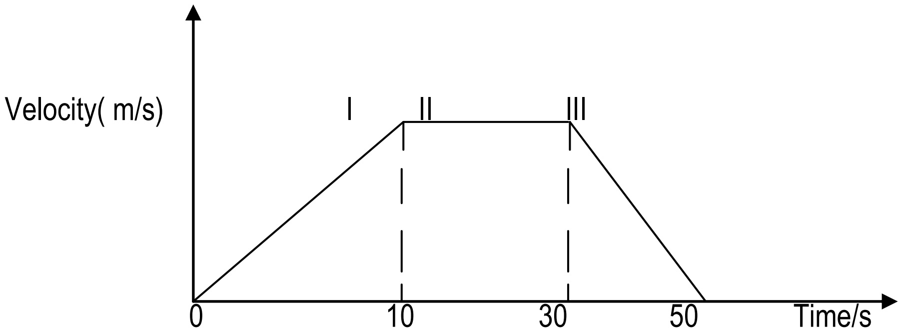
1. A car starts from rest and steadily accelerates for10s to a velocity of 20mls. It continues with this velocity for a further 20s before .it is brought to rest in 20s
   a) Draw a velocity time graph to represent this motion.
   b) Calculate

   i) Acceleration

   ii) Deceleration

   iii) Distance travelled

   iv) Average speed



b(i) acceleration

$a = \frac{v-u}{t} = \frac{20-0}{10} = \frac{-20}{10} = 2m/s^2$

ii) Deceleration

$a = \frac{v-u}{t} = \frac{0-20}{10} = \frac{-20}{20}$ =-1mls

Deceleration = -a = $1m/s^2$

iii) Distance

Distance traveled = area under a velocity time graph

S = ½bh+ L x w + ½bh

= ½ *x10 x20* + *20 x20*+½ x20 x 20

= 700m

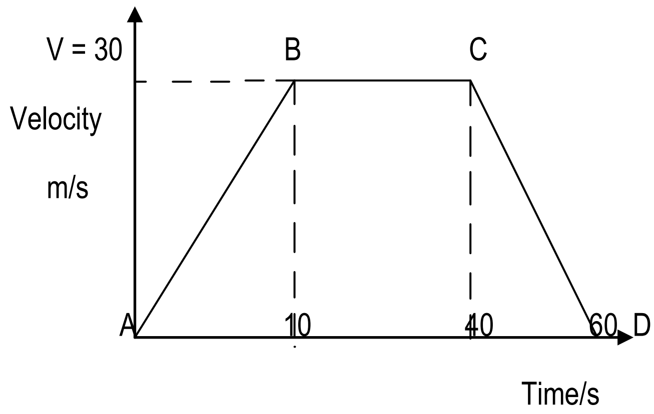
Iv) Average speed = $\frac{total\ distance}{total\ time}$

$= \frac{700}{50}$

= 14m/s

2. A car from rest accelerates to velocity 30mls in 10sit continues at uniform velocity for 30s and then decelerate so that it stops in 20s
   a) Draw a velocity time graph to represent its motion
   b) Calculate
      i) Acceleration
      ii) Deceleration
      iii) Distance travelled
      iv) Average speed.

a)



Acceleration a = $\frac{v-u}{t}$ = $\frac{30-0}{10}$ =3m/s^2

i) Deceleration

a = $\frac{v-u}{t}$ = $\frac{0-30}{20}$ = -1.5m/s^2 ⇔Deceleration = 1.5m/s^2

i) Distance travelled

Total distance = total area under a v –t graph

Covered

= ½bh + L x w +½bh

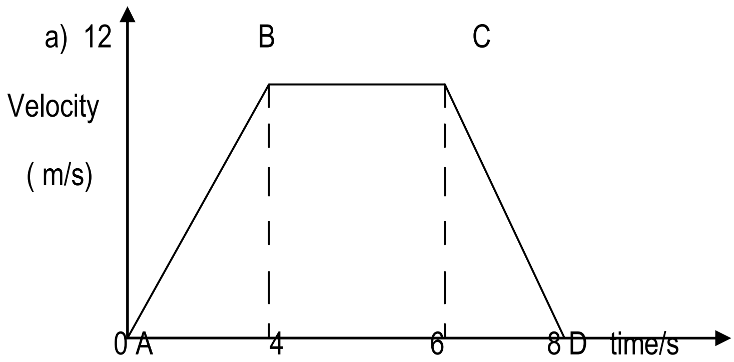
= ½ x10 x30 + 30 x30 +½x20 x30

= 1350m

ii) Average speed

Average speed = $\frac{total\ distance}{total\ time}$ =22.5m/s

3. A racing car starts from rest and moves with uniform acceleration of 3m/s 2 for 4 seconds. Then moves with uniform velocity for 2 second. it is brought to rest after a further 2 seconds
   a) Draw a velocity time graph for motion of the car
   b) Find total distance travelled
   c) Average speed.



V = u +at
= 0 + 3 x4
= 12m/s

a) Total distance covered

Total distance = total area under a velocity time graph.

=½bh +Lx w + ½bh

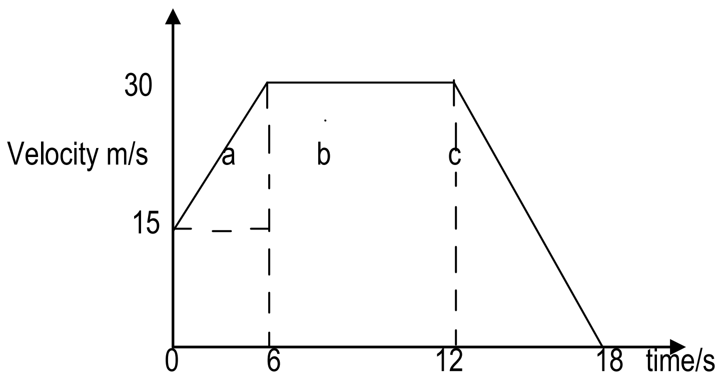
= ½ x4 x12 + 3 x12+ ½ x2x12

= 72m

Average speed = $\frac{tatal\ distance}{total\ time}$ = $\frac{72}{8}$ =9m/s

Question

1. The graph below represents a velocity time graph of a body in motion.



i) Describe the motion of the body.

A car moves with uniform acceleration of 15m/s for 6 seconds it then continues at uniform velocity of 6 seconds. It is then brought to rest in 6 seconds.

i) Calculate the total distance travelled
ii) Total distance travelled = total area under a v- t graph
iii) Determine the average speed.

2. A body of mass 60 kg starts moving with an initial velocity of 15 mls and accelerates at a rate of 4m/s in 5s, then maintains a constant velocity for another 5s and brought to rest in 7s.

i) Draw a velocity –time graph to represent this motion.

ii) Calculate the total distance travelled

iii) Calculate the retarding force

MOTION UNDER GRAVITY

For a body falling under gravity, acceleration due to gravity is positive but for a body thrown vertically upwards acceleration due to gravity is negative. At maximum height, the body is momentarily at rest therefore final velocity is 0

Equation of motion for a body falling freely under gravity (g)

$V = u+gt$

$S = ut + \frac{1}{2}gt^2$

$V^2 = u^2 + 2gs$

Equation of motion for a body thrown vertically up wards

$V = u - gt^2$

$S = ut - \frac{1}{2}gt^2$

$V^2 = u^2 - 2gs$

example

1.A stone is raised from rest at point 20m above the ground so as to fall freely vertically down wards. Find

a) Time to land on the ground.

b) Velocity

a) Using $s= u t + \frac{1}{2}gt^2$
$20 = 0 + \frac{1}{2} \times 10\, t^2$
t =2seconds

b) Using
$V = u + g t$
$= 0 + 10 \times 2$
= 20m/s

2. A ball is thrown vertically upwards with an initial velocity of 30mls find

a) The maximum height to reach the ground

$u = 30m/s$

$V^2 = u^2 - 2gs$

$0 = 900 - 2 \times 10 \times s$

$= 900 - 20s$

$S = 45m$

b) Time taken to reach the maximum height

$S = u\,t + ½gt^2$

$45 = 0 + ½ \times 10t^2$

$t = 3$ seconds

c) Time taken to return to the starting point.

$V = u + gt$

$30 = 0 + 10t$

$t = 3$ seconds.

3. A stone thrown vertically upwards with an initial velocity of 14m/s neglecting air resistance, find

a) The maximum height reached.

$0 = 196 - 2 \times 10s$

$0 = 196 - 20s$

$S = 9.8m$

b) The time taken before it reached the ground

$V = u + g\,t$

$14 = 0 + 9.8t$

$t = 1.4$ seconds

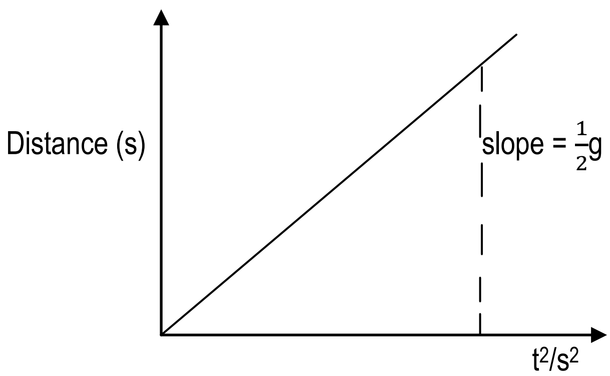
Acceleration of free fall is constant for a body falling from rest

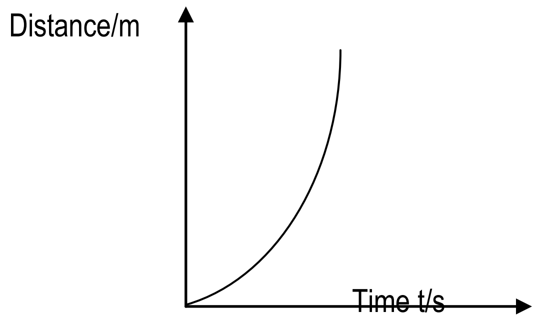
$S = u\,t + ½gt^2$

$S = ½gt^2$

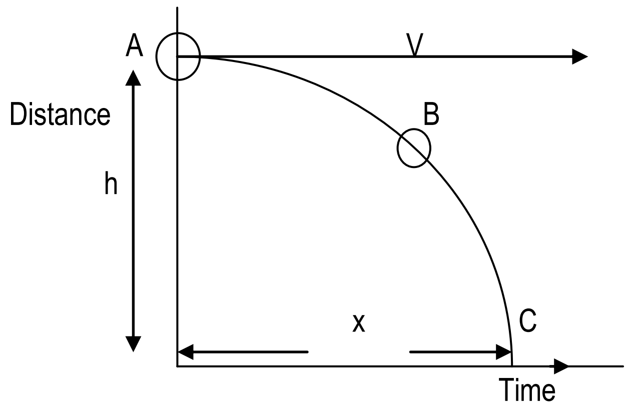
$S = (\text{constant})t^2$

$S \propto t^2$





Projectile motion



In projectile, the horizontal velocity of the body in motion remain the same throughout whole acceleration due to gravity continues to act on the body vertically downwards and it doesn't affect the horizontal motion of the body.

Horizontal motion, distance x =t

Vertical motion, distance is s =h

$h = \frac{1}{2}gt^2$

i.e. $S = u\,t + \frac{1}{2}gt^2$

S =h and u =0

$S = \frac{1}{2}gt^2$

Where v is horizontal velocity given the body and t is the time of flight.

Example

1. An object is dropped from a helicopter. if the object hits the ground after 2 seconds, calculate the height from which object was dropped

$t = 2s$, $g = 10mls$

$h = \frac{1}{2}gt^2$

$= \frac{1}{2} \times 10 \times 4 = 20m$

2. An object is dropped from helicopter at a height of 45m above the ground.
   a) If the helicopter is at rest, how long does the object take to reach the ground and what is its velocity on arrival.
   b) If the helicopter falls with a velocity of 1mls when the object is released, what would be the final velocity of the object?

a) $h = \frac{1}{2}gt^2$

$45 = \frac{1}{2} \times 10t^2$

$t = 3$ seconds

b) Velocity on arrival

$V = u + g t$

$= 0 + 10 \times 3$

$= 30m/s$

Question

1. An object is released from an air craft travelling horizontally with a constant velocity of 200m/s at a height of 500m ignoring air resistance

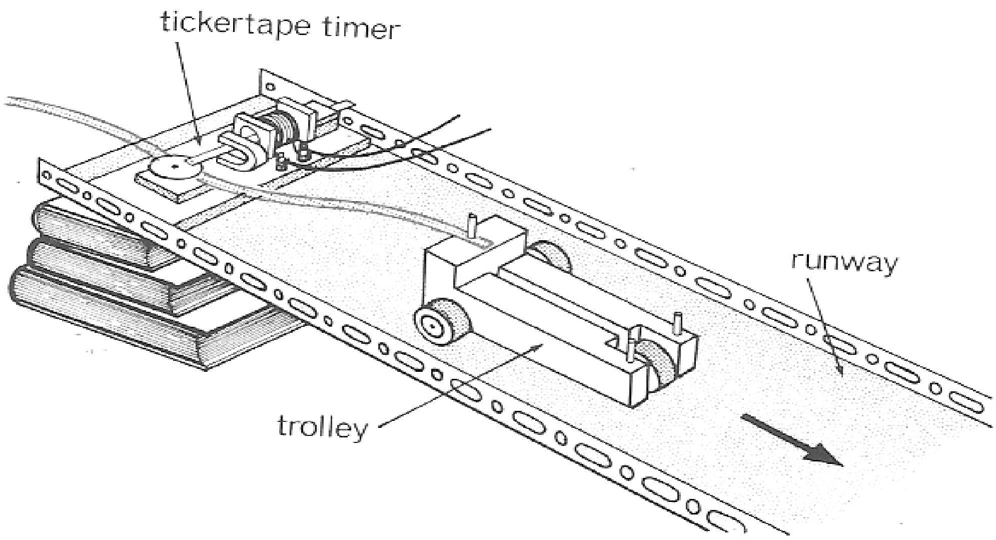
a) How long does it take the object to reach the ground?
b) Find the horizontal distance covered by the object leaving the air craft and reaching the ground.

TICKER – TAPE TIMER

A ticker timer is a steel strip which vibrates rapidly and print dots on a length of a paper tape pulled through it. It prints 50 dots on a tape every second (frequent (f) = 50Hz)

A tick timer is used to measure speed or velocity and acceleration of bodies in motion.

Experiment with a ticker – timer

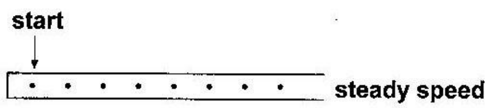


The paper tape is pulled by a trolley moving down an inclined plane as shown above.

Different results are obtained on the speed of the trolley.

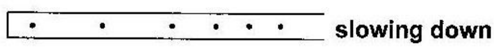
Typical results

- Trolley moving with uniform speed spacing between successive dots i.e. the same thru out.



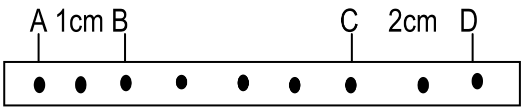
- The trolley is accelerating the spacing between dots gets bigger and bigger.

- Trolley decelerating, the spacing between successive dots get smaller and smaller.



Example

1. The paper tape shown below was made by a trolley moving with uniform acceleration. if the ticker timer operated with a frequency of 100Hz, determine
   i) Initial velocity
   ii) Final velocity
   iii) Acceleration.



i) t = $nx\frac{1}{f}$ = time taken to print successive dots, where n is the number of spaces between dots.

Number of spaces between AB = 2

Time taken a long AB =$\frac{2\,x1}{100}$ = 0.02s

Initial velocity or speed u = $\frac{distance}{time}$ = $\frac{0.01}{0.02}$ = 0.5m/s

Number of spaces between CD = 2

Time taken a long CD = $\frac{2\,X1}{100}$ =0.02

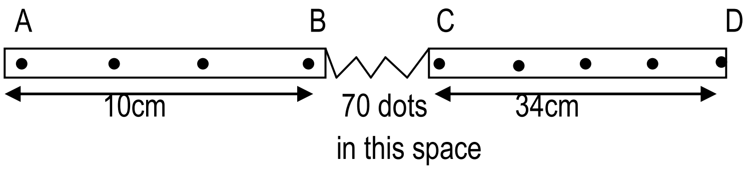
Final velocity / speed =$\frac{distance}{time}$ = $\frac{0.02}{0.02}$ = v =1m/s

ii) Acceleration a = $\frac{v-u}{t}$ where t is time taken from B –D

= $\frac{1-0.5}{0.1}$ and t = 10 x $\frac{1}{100}$ = 0.1s

= 5m/s^2

Below is a tape by a tickle – timer of frequency 50Hz



Calculate

i) Initial velocity
ii) Final velocity
iii) The acceleration of the trolley

Solution

i) Initial velocity

Time taken along AB = $\frac{3X1}{50}$ = 0.06s

Initial velocity or speed u = $\frac{distance}{time}$ = $\frac{0.1}{0.06}$ = 1.67m/s.

ii) Time taken long CD= $\frac{4\,x1}{50}$ = 0.08s

Final velocity 1 speed = $\frac{distance}{time}$ = $\frac{0.34}{0.08}$ =4.25m/s

iii) Acceleration a = $\frac{v-u}{t}$ where t is time taken from B to D

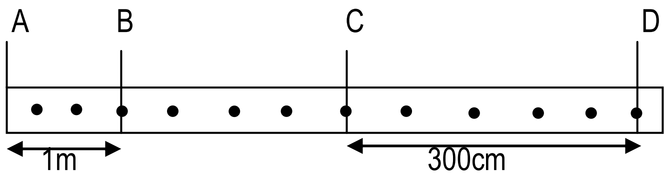
= $\frac{4.25-1.67}{1.46}$ t= $\frac{73\,x1}{50}$ =1 .46s

= 3.11m/s

= 1.77m/s^2

Note – usually, the first and last section of the tape are ignored in experiments because the motion of the trolley is unsteady and the dots are near each other.

2. The ticker timer below printed dots. Assuming it vibrates at frequency of 20Hz, calculate
   i) Initial velocity
   ii) Final velocity.
   iii) Acceleration



Solution

i) Time taken along AB = $\frac{2\,x1}{20}$ = 0.1m^2

Initial velocity or speed = $\frac{distance}{time}$ = $\frac{1}{0.1}$ =10mls

ii) Time taken a long CD = 5 X$\frac{1}{20}$ =0.25m

Final velocity or speed = $\frac{distance}{time}$ = $\frac{3}{0.25}$ = 12mls

iii) Acceleration a = $\frac{v-u}{t}$ where t is time taken from B to D

= $\frac{12-10}{0.45}$ = 4.5mls t = 9 x $\frac{1}{20}$ = 0.45m/s The figure below shows a tape produced by a ticker timer operating at a main frequency of 50Hz

Calculate the acceleration shown by the tape

Initial velocity

Time between AB = 1 x$\frac{1}{50}$ = 0.02 s

Initial velocity = $\frac{distance}{time}$ = $\frac{0.03}{0.02}$ = 1.5m/s

Time taken between CD = 1 x$\frac{1}{50}$ = 0.02s

Final velocity = $\frac{distance}{time}$ = $\frac{0.07}{0.02}$ =3.5m/s

Acceleration a = $\frac{v-u}{t}$ where t time taken from B – D

a= $\frac{3.5-1.5}{0.5}$ t = 25 x$\frac{1}{50}$ = 0.5s

= 4m/s^2

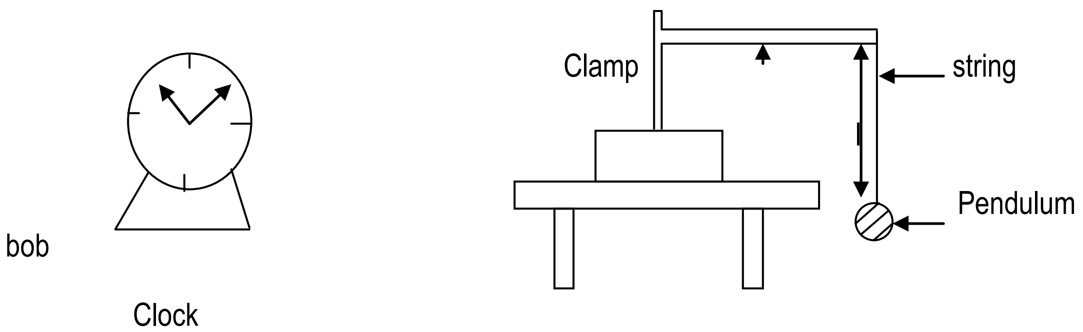
ACCELERATION DUE TO GRAVITY

Acceleration due to gravity is the rate of change of velocity with time of a freely falling object.

Experiment to determine acceleration due to gravity

Using a simple pendulum

The apparatus is arranged as below.



Measure the length holding bob from its center

Push the bob slightly, it will begin to accelerate

Note when it is on one side and start the stop clock while counting the oscillation until it makes about 20.

Stop the clock, read and record the time for 20oscillation. Repeat the procedure for various length of the pendulum l= 0.8m , 0.6m, 0.5m, 0.4m and 0.3m.

Record your results in a suitable table including T and T^2

Plot a graph of l against T^2.Obtain acceleration due to gravity from:

$g = -4\pi^2 S$ where S is the slope of the graph.

NEWTON'S LAW OF MOTION

1^{ST} law of motion (law of inertia)

It states that a body continues in its state of rest or motion in a straight line unless acted upon by an external force.

This law suggests that everybody has inertia.

INERTIA

Inertia is the tendency of the body to remain at rest or if moving, to continue in its motion in a straight line with uniform velocity

The larger the mass of the body, the greater is its inertia therefore the mass of the body is a measure of its inertia.

2^{nd} law of motion

It states that the rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction of the force.

Momentum of a body is the product of its mass and velocity i.e momentum = mass x velocity

S .I unit = kg m/s or kg ms^{-1}

Change in momentum = m v – mu = m (v –u) where m v – final momentum and

M u – initial momentum

Applied force $F \propto \frac{change\ in\ momentum}{time}$

$F \propto m\left(\frac{v-u}{t}\right)$

$F \propto ma$

$F = k\,ma$ Where k is constant of proportionality.

From the definition of a Newton – is a force which gives a mass of 1kg an acceleration of $1 m/s^2$.

If F = 1N, m = 1kg, a = $1mls^2$

$F = k\,ma \rightarrow 1 = k \times 1 \times 1 \rightarrow k = 1$ hence $F = ma$

Example;

1. A 20 kg mass travelling at 5mls is accelerating to 8mls in 10s. calculate
   i) The change in momentum.
   ii) The rate of change in momentum
   iii) The applied force.

i) M =20 kg u = 5mls v = 8mls t =10s

Change in momentum = m (v –u)
= 20 (8 – 5)
= 60 kg m/s

ii) Rate of change of momentum $=m\left(\frac{v-u}{t}\right) = 20\left(\frac{8-5}{10}\right) = 6N$

iii) Applied force = rate of change of momentum
= 6N

2. A body of mass 600g moving at 10mls is accelerated uniformly at 2mls 2 for 4s . calculate
   i) Change in momentum
   ii) Rate of change in momentum
   iii) The force acting on a body.

i) $M = \frac{600}{1000}kg$ a = 20m/s t = 4s

Change in momentum
V = u + at
= 10 + 2 x4
V = 18m/s

Change in momentum =m (v -u)

=0.6(18 -10)

= 4.8kgm/s

i) Rate of change in momentum.
$= m\left(\frac{v-u}{t}\right)$
$=0.6\left(\frac{18-10}{4}\right)$
= 1.2N

ii) The force acting on a body = rate of change of momentum
= 1.2N

3rd law of motion

It states that action and reaction are equal but opposite.
This means that when ever force acts on a body, an equal and opposite force act on the same o body.
Examples include:

i) A person walking exerts his weight (action on the ground and the ground exerts an equal upward force (reaction on him or her)
ii) Two cars which collide both get damaged because each car exerts equal but opposite force.

Example

1. A one turn car travelling at 20 m/s is accelerated at $2ms^2$ for 5 seconds. calculate
   i) Change in momentum
   ii) The rate of change of momentum
   iii) Accelerating force acting on a body.

i) Change in momentum = m(v –u)
= 1000(30 -20)
= 10000kgm/s

ii) The rate of change of momentum = $m(\frac{v-u}{t})$
= $1000 (\frac{2-20}{5})$
= 2000N

iii) Accelerating force acting on the body = rate of change of momentum
= 2000N

Question

1. A block of mass 500g is pulled 4m rest on a horizontal friction less bench by a steady force (F) and travels 8m in 2 seconds

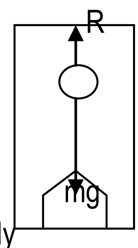
Find

(a) Acceleration

(b) Value of F.

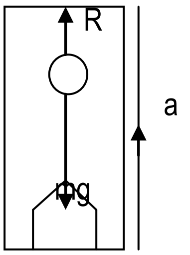
MOTION OF A BODY IN A LIFT

a) Lift at rest



R – Reaction of a body
Mg- person's weight
When the lift is at rest, a person feels his / her normal weight using
F = ma where F =R – Mg and a = 0
R – Mg = ma but a =0
R –mg =0
R =mg

b) Lift ascending (moving upwards)



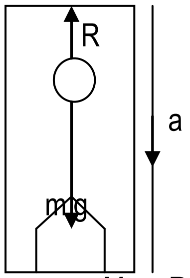
R – Mg =ma

R = Mg + ma

R = m (g + a)

The person feels heavier than his normal weight.

c) Lift descending (moving down wards)



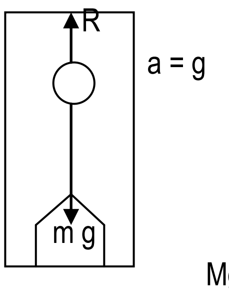
Mg – R = ma

R = Mg – Ma

R = M (g - a)

The person feels loss in weight

d) Lift descending with acceleration a = g



Mg – R =ma

R =Mg –mg

R=m (g –g)

ON

Some one feels weight less.

1. Find the reaction of a woman of mass 70 kg standing in a lift if the lift is

   (a) at rest
   (b) ascending upwards with uniform acceleration with $4mls^2$
   (c) moving down wards with uniform acceleration with $4mls^2$

Solution

a) $R = mg$
   $= 70 \times 10$
   $= 700N$

b) $R - Mg = ma$
   $R = ma + mg$
   $= m(a + g)$
   $= 70(4 + 10)$
   $= 980N$

c) $Mg - R = mg$
   $R = mg - mg$
   $R = m(g - g)$
   $= 70(10 - 10)$
   $= 0N.$

d) $R = m(g - a)$
   $= 70(10 - 4)$
   $= 420N.$

COLLISION AND LINEAR MOMENTUM

Linear momentum is the product of mass and velocity for bodies moving in a straight line. S.I units: kg m/s.

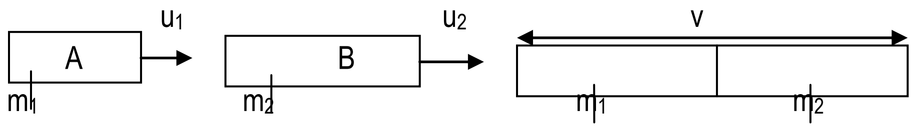
Collision

There are two types of collision

i) Inelastic collision
ii) Elastic collision

INELASTIC COLLISION

This is a type of collision where colliding bodies stick together and move with in the same velocity after collision e.g. a bullet shot at a thief etc.



$m_1 u_1 + m_2u_2 = (m_1 +m_2)\ v$

ELASTIC COLLISION

This is a type of collision where colliding bodies separate after collision and move with independent velocities

$m_1u_1+ m_2u_2 = m_1v_1 +m_2v_2$ where u_1 and u_2 are initial velocities v_1 and v_2 are final velocities

PRINCIPLE OF CONSERVATION OF LINEAR MOMENTUM

It states that when two or more bodies collide, the total momentum of bodies remains constant provided no external forces act i.e.

Total momentum before collision = total momentum after collision.

Example

1. A body of mass 2kg travelling at 8m/s, collide with a body of mass 3kg travelling at 5m/s in the same direction. If after collision the two bodies move together. Calculate the velocity which the two bodies move.

By principal of linear momentum

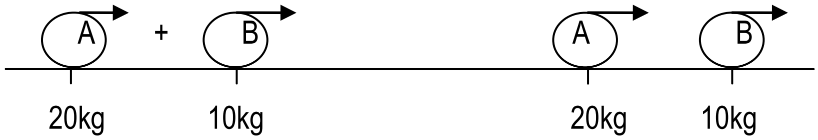
Total momentum before collision= total momentum after collision

$M_1u_1 +m_2u_2 = (m_1+m_2)v$

$2 \times 8 +3 \times 5 = (2 + 3)v$

$V = 6.2\text{m/s}$

2. A body of mass 20 kg travelling at 5mls collides with another stationary body at a mass of 10kg and they move separately in the same direction if the velocity of the 20 kg mass after collision was 3mls, calculate the velocity with which 10kg mass will move.



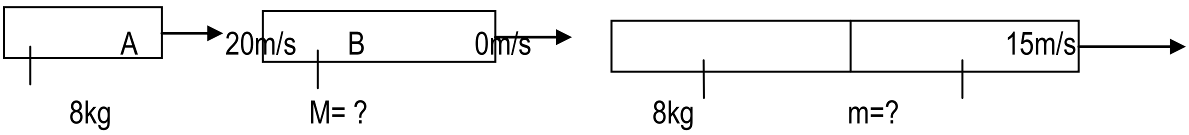
Momentum before collision = momentum after collision

$M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$20 \times 5 + 10 \times 0 = 20 \times 3 + 10v_2$

$V_2 = 4m/s$

3. A body of mass 8kg travelling at 20mls collides with a stationary object and they move together with a velocity of 15mls Calculate the mass of the stationary body.(2.7kg)



$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

$8 \times 20 + 0 = (8 + m_2)v$

$M_2 = 2.7kg$

EXPLOSION

Momentum is conserved in explosions such that which occur when a rifle is fired. Before firing, the total momentum is zero since both rifle and bullet are at rest.

During firing, the riffle and the bullet receive equal but opposite momentum, so the total momentum after firing is zero

$M_f V_f + M_b V_b = 0$

$M_b V_b = -M_f V_f$ where M_b –mass of bullet

M_f – mass 0f riffle

V_b- velocity of bullet

V_f – recoil velocity of the riffle.

Recoil velocity.

When the bullet leaves the barrel, the total momentum must be conserved there fore the bullet moves forward, the gun jokes backwards (recoils) with a velocity called recoil velocity.

Example

1. A bullet of mass 50g is fired with a velocity of 400mls from a gun of 5kg. Calculate the recoil velocity of a gun.

   $M_g\, v_g + m_b\, v_b = 0$

   $0 \text{ X } vg + \frac{50}{1000} \text{x}400 = 0$

   Vg =-4m/s (-ve means opposite direction)

2. A 50kg girl jump out of a rowing boat of mass 300kg to the bank with a horizontal velocity of 3mls. With what velocity does the boat begin to move backwards

   $M_g\, v_g + m_b\, v_b = 0$
   300 x vg +50 x3 = 0
   Vg = -0.5m/s

Question

1. (a) Out line the similarities and the differences between elastic and inelastic collisions

b) Fatimah of mass 60running at 64 km/hr jumps on a stationary trolley of mass 20kg. if the collision is perfectly inelastic. Find

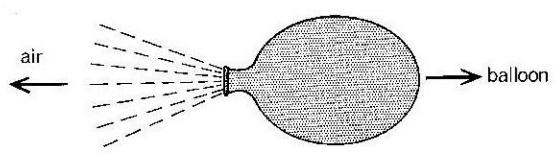
i) Loss in kinetic energy

ii) Final kinetic energy

APPLICATION OF NEWTON'S 3RD LAW OF MOTION AND CONSERVATION OF MOMENTUM

i) Inflated balloon

When a balloon filled with air is released in space so that the air can escape from the balloon. The balloon darts forward in space until all the air has escaped.



Explanation

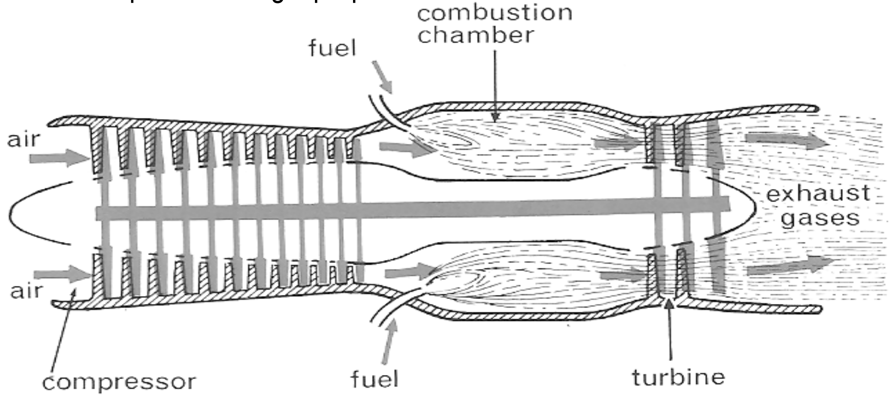
As air escapes from the balloon at a high speed backwards, it does so with a big force. According to Newton's law of motion, the air exerts a reaction on the balloon causing it to move forward with the same force.
From the principle of conservation of momentum, a backward momentum due to the air escaping sets up equal but opposite forward momentum, on the balloon causing it to move forward.

ii) **Rocket and jet engines.**

Jet engine

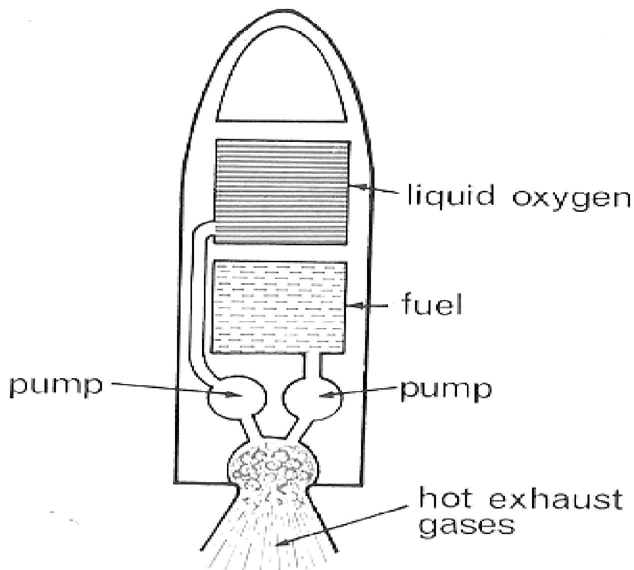
To start the engine, an electric motor sets the compressor to rotate. The compressor is like a fan; its blades draw in and compress air at the front of the engine. Compression raises the temperature of the air before it reaches the combustion chamber.

Then fuel (kerosene) is injected and burns to produce a high speed stream of hot gas which escapes from the rear of the engine, as a result, the gaseous product set a reaction of equal but opposite momentum to the plane making it propel forward.



Rocket engine

Rockets, like jet engines, obtain their thrust from the hot gases they inject by a fuel. They can however, where there is no air since they can carry the oxygen needed for burning instead of taking it from the atmosphere as does the jet engine. Space rockets use liquid oxygen (at -183°C). Common fuels are kerosene and liquid hydrogen (at -253°C), but solid fuels are also used.



Differences between a rocket and jet ingine

A jet engine doesn't go outside atmosphere because it uses atmospheric oxygen to burn its fuel while, a rocket engine goes out of atmosphere since it burn fuel when it is in space because it can be loaded with liquid oxygen cylinders.

ARCHIMEDES AND FLOATATION

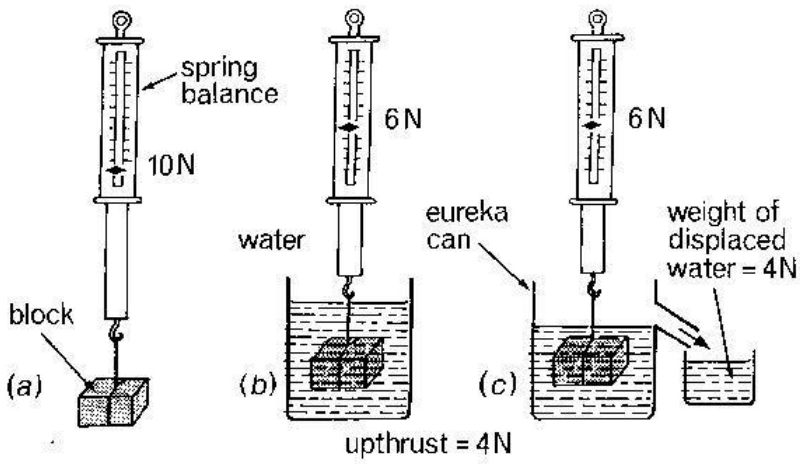
ARCHMEDE'S PRINCIPLE

It is an upward force due to the fluid resisting being compress when any object is immersed or submerged into a fluid, its weight appears to have been reduced because it experiences on a upthrust from the fluid.

Statement of Archimedes's principal

It states that when a body is wholly or equal to weight of the fluid displacement i.e upthrust = weight of fluid displaced.

Experiment to verify Archimedes's principal.



An object is weighed in air using a spring balance to obtain w_1 – the eureka can is completely filled with the liquid and a beaker is put under its spout. The body is then immersed in the liquid.

The new weight w_2 is also load on the spring balance.

The liquid collected in the small beaker is weighed to determine its weight w3. it is found that w3 = w1 – w2.

The weight of the body which completely immersed or submerged is called the apparent weight. The apparent weight is loss then the weight of the body because when the body is immersed it experiences up thrust.

Examples

1. A glass block weighs 25N. When wholly immersed in water block appears to weigh 15 N calculate the up thrust.

Upthrust = weight in air – weight in a fluid (apparent weight)

$= W_a – W_f$

= 25 – 15

= 10N.

2. A body weighs 1N in air of 0.3N when wholly immersed in water. Calculate the weight of displaced water.

   Up thrust = $W_b - W_f$
   = 1 – 2.8
   = 0.2N.

For a body completely immersed.

Volume of the body immersed = volume of displaced fluid

M = p x v where p – density of displaced fluid

V – Volume of body = volume of displaced fluid

But up thrust = weight of fluid displaced

= mg

U = ρvg

Example

A metal weights 20N in air and 15N when fully immersed in water. Calculate

a) Up thrust.
b) Weight of displaced water
c) Volume of displaced water (density = 1000kg/m^2)
d) Volume of metal
e) Density of metal.

a) Up thrust = weight in air – weight in water
= 20N – 15N
= 5N
b) Weight of displaced water = up thrust
= 5N
c) Volume of displaced water
Upthrust = weight of displaced water
S = p x v xg
S = 1000 x v x 10
V = $\frac{5}{10000}$
V = 0.0005 m^3

d) Volume of metal = volume of displaced water
= 0.0005m^3

e) Density of metal $= \frac{mass}{volume}$
$= \frac{2}{.0005}$
= 4000kgm^{-3}

Application of Archimedes's principal

1. Measurement of relative density of solids
2. Measurement of relative density of a liquid

Measurement of relative density of a solid

- $weigh\ the\ object\ in\ air\ and\ note\ it\ to\ be\ Wa$
- $weigh\ the\ object\ in\ water\ and\ note\ it\ to\ be\ Ww$
- $determine\ the\ upthrust\ \ U\ =\ Wa - Ww$
- $relative\ density\ of\ solid\ \ =\ \frac{weight\ in\ air}{upthrust}$

$$RD = \frac{wa}{Wa - Ww}$$

EXAMPLE

An object 5.6 N in air and 4.8N in water find its relative density

$$RD = \frac{Wa}{Wa-Ww}$$

$$= \frac{5.6}{0.8}$$

$$= 7$$

An object of relative density 7 and 70N in air .what is its weight in water.

$$RD = \frac{Wa}{Wa-Ww}$$

$$7 = \frac{70}{70-Ww}$$

Ww = 60N

3. An object of relative density 9 weighs 40N in water find its weight in ai.

$$RD = \frac{Wa}{Wa-Ww}$$

$$9 = \frac{Wa}{Wa-40}$$

Wa = 45N

Determination of RD of a liquid

- Let an object find its weight in air Wa using a spring balance
- Weigh the object in the liquid whose RD is to be determined, label in Wa
- Weigh the object in water, call it Ww
- Find the up thrust in liquid = Wa – Ww
- Find the up thrust in water = Wa – Ww
- Obtain RD of a liquid from RD = $\frac{upthrust\ in\ liquid}{upthrust\ in\ water}$

RD = $\frac{Wa-Wl}{Wa-Ww}$

Example

1. An object 5.6 in air, 4.8 in water and 4.6 when immersed in a liquid. Find the R.D of the air

$$RD = \frac{Wa-Wl}{Wa-Ww}$$

$$= \frac{5.6-4.6}{5.6-4.8}$$

$$= \frac{1}{0.8}$$

2. An object weighs 100N in air and 20N in a liquid of RD 0.8. Find its weight in water.

$$RD = \frac{Wa-Wl}{Wa-Ww}$$

$$0.8 = \frac{100-20}{100-Ww}$$

Ww = 0N.

FLOATING OBJECTS

These are two vertical a forces which act on an object when immersed in water Ww and upthrust U

If W is lees than U, the object floats

If W is equal to upthrust U objects rise

If W is greater than upthrust U object sink

Therefore floating objects weigh equal to upthrust from Archimedes principal, upthrust is equal to weight of a fluid displaced. Therefore for floating objects, weight of objects should be equal to weight of fluid displaced.

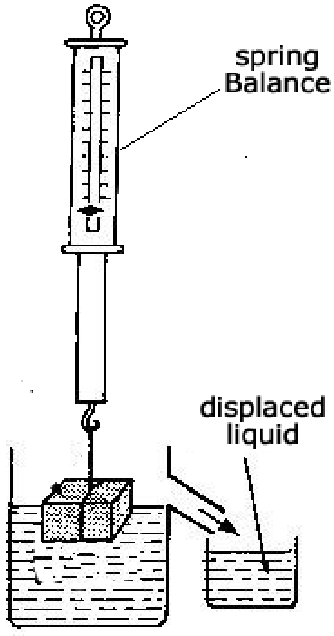
Law of floatation

It states that a floating object displaces its own weight of the fluid in which it floats

Experiment to verify law of floatation

Method

- Weigh the object in air and note its weight Wa
- fill the overflow can until water just overflow from the spout
- Place an empty measuring cylinder under the spout after dropping of water has stopped.
- Gently lower the object into the overflow can collect the
  Displaced water and weigh it.



It is found out that

Weight of water displaced = weight of object Wa

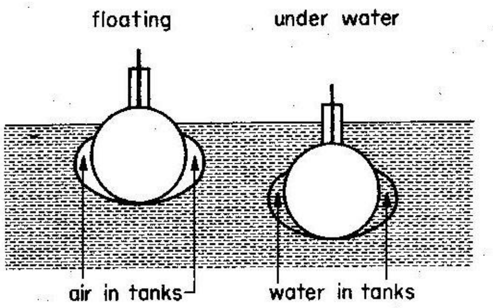
Application of law of floatation

1. Ship

A ship floats when the upthrust of the water it displaces equals its weight,
Weight of floating ship =weight of water displaced
While a ship is being loaded, it sinks lower and displaces more water to balance the extra load. While steel does not float, steel ship floats this is because steel ship is hollow (i.e. consists of steel, wood, and air) and its average density is less than the density of water. There fore hollow steel displaces many times its volume of water.

2. Submarines

A submarine has ballast tanks which can be filled with water or air/ when full of water, the average density average density of the submarine is slightly greater than the density of sea water and it sinks



When air is pumped into the tanks, the average density of the submarine falls until it's the same or slightly less than that of water around it. The submarine therefore stays at one depth or rises to the surface

Balloons and air ships

A balloon is an airtight, light bag with hydrogen or helium. These gases are less dense than air. An airship is a large balloon with a motor to move it and fins to steer it.

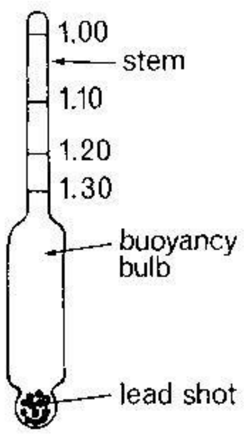
The down ward force on the balloon equals to the weight of the bag plus the weight of gas in it.
The balloon rises if the upthrust is greater than the downward force
The lifting power= up thrust –total weight

= weight of air displaced –weight of (bag + gas)

-balloons that carry passengers control their weight by dropping ballast to make them rise and by letting gas out of the gas bag to make them fall. As the balloon rises, the atmospheric pressure on it becomes less. The gas in the balloon tends to expand. Therefore the gas bag must not be filled completely when the balloon is on the ground.

4. Hydrometers

A hydrometer is a floating object used to find the density of liquids by noting how far it sinks in them.



No weighing is necessary. It consists of a longer glass tube with a bulb at the bottom mercury or lead is in the bulb so that the hydrometer floats up right. The stem is long and thin and is graduated.

The thin stem means that the hydrometer is sensitive i.e. it sinks to different levels even in two liquids whose densities are almost the same.

Uses of a hydrometer

It is used for measuring the densities of milk (lactometer) , beer, wines, acids in cars batteries(the acid in a fully charged accumulator should have a density of $1.25g/cm^3$, if it falls below 1.18, the accumulator needs recharging).

Experiment to measure density of a liquid using the hydrometer

- mark a simple hydrometer in cm beginning at the end that sinks
- place it in a tall jar of water. Mark the level to which it sinks
- measure the length that was in the water
- Remove the hydrometer, dry it and place it in a jar of another liquid. A gain measure the depth to which it sinks

Obtain density of liquid = $\frac{\text{liquid of hydrometer immersed in water}}{\text{length of hydrometer immersed in liquid}}$

Worked out examples

1. The mass of a piece o cork ($0.25g/cm^3$) is 20g. What fraction of the cork is immersed when it floats in water?

Solution

Mass of cork = mass of water displaced

= ρ v

20 = 1 x v ⟶ volume of water displaced $=20cm^3$ =volume of cork immersed.

But volume of cork = $\frac{mass}{density}$ $=\frac{20}{0.25}$ = 80 cm^3

Fraction of cork immersed = $\frac{20\ cm3}{80\ cm3}$ = ¼

2. A solid of volume 1 $x10m^3$ floats on water of density 1 x10 kgm^{-3} with $\frac{3}{5}$of its volume submerged. Find

i) The mass of solid
ii) The density of solid

Solution

i) Mass of the solid = mass of liquid displaced

$= \frac{3}{5}v \times p$

$= \frac{3}{5} x10^{-4} x\ 1x10^3$

= 0.06kg

ii) Flotation of the body = $\frac{density\ of\ body}{density\ of\ liquid}$

Immersed

$= \frac{3}{5} = \frac{d}{1000\ (1\ x10)}$

Density of the body $= \frac{3 \, x 1 \, x 10}{5}$

= 600kgm^3

3. A rubber balloon of mass 5 x 10^{-3}kg is inflated with hydrogen and held stationary by means of a string. If the volume of the inflated balloon is 5 x10^{-3}, calculate the tension in the string (density of hydrogen = 0.8m^3) (density of air1.15kgm^3)

Solution

Up thrust U = weight of fluid displaced

= ρ_a vg

=1.15 x 5x10 $^{-3}$ x 10

= 0.0575N

Weight of balloon fabric = mg

= 5 x10-3 x10

= 0.05N

Weight of hydrogen = ρ_h v g = 0.08 x 5 x10 $^{-3}$ x 10= 0.004N

Total weight of balloon W =0.05 + 0.004

= 0.54N

Tension T = U – W

= 0.0575 – 0.054

= 0.0035N

4. A body of mass 2kg is suspended from a spring which reads 17N when is completely submerged in water,

i) What is the upthrust of the water in the body
ii) What is the mass of water displaced by the body
iii) If the density of water is 1000kg lm3, what is the volume of water displaced
iv) Calculate the density of the material of which the body is made.
v)

SOLUTION

Wa = mg

= 2 x 10 and U = Wa - Ww = 20 - 17

= 20N = 3 N

i) Upthrust = weight of fluid displaced

= 3N

W = mg

3 = m x10 hence M = $\frac{3}{10}$ = 0.3 kg

ii) Upthrust = weight of fluid displaced

U = ρ v g

3 = 1000 x v x 10

V = $\frac{3}{10000}$

= 3.0 x$10^{-4}$$m^3$

iii) Density =$\frac{mass}{volume}$

= $\frac{2}{3.0\ x\ 10m3}$

= 6.7 x10^3 kg/m^3

5. When a metal is completely immersed in liquid A its apparent weight is 5N. When immersed in another liquid B the apparent weight is 16N if the density of B is $\frac{9}{8}$ times that of A calculate the mass of the metal.

Solution

(i) Up thrust in A

U_1 = W a – Ww

U = (Wa – 20)

Up thrust in B

U_2 = Wa - Ww

= (Wa – 16)

Upthrust = weight of fluid displaced

U = weight of fluid displaced

Wa – 20= pa x Vg …….. (i)

Wa -16 = $\frac{9}{3}$ Pa Vg…………(ii)

Divide (i) by (ii)

= $\frac{Wa-20=pA\,Vg}{Wa-16=\frac{9}{8pA\,Vg}}$

= $\frac{Wa-20}{wa-16}$ = $\frac{8}{9}$

8(wa – 16) = 9(wa – 20)

Wa = 52N

Mass of solid = $\frac{wa}{g}$ = $\frac{52}{10}$

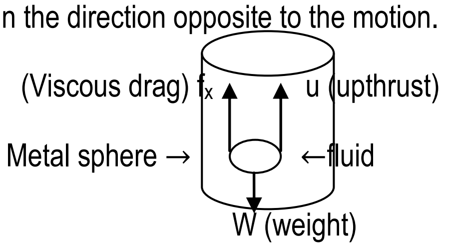
= 5.2kg

Motion of a body through fluids

When a body fall through a fluid its is acted on by forces namely

a) Weight of the body
b) Viscous force
c) Upthrust

The weight of the body acts downwards towards the earth. Upthrust acts upwards and viscous force acts in the direction opposite to the motion.



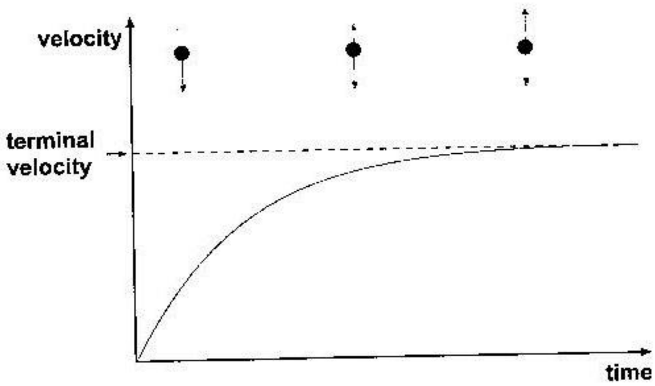
As the body falls, it accelerates first with net resultant force

$F = w - (f_x + u)$

As the body continues to fall, it attains a uniform velocity called terminal velocity. When the weight of the body w = fx + u
At this stage the resultant force or net force of the body is zero.

Terminal velocity

This is a constant or uniform velocity with which a body falling thru a fluid moves such that the upward forces acting on it are equal to its weight
OR is the uniform velocity attained by a body falling thru a fluid when the net force on the body is 0.
Incase o a balloon or a rain drop falling, the resisting force or retarding force on the body is called air resistance



LIGHT

Light is a form of energy used in vision 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. 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

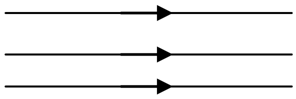
- It undergoes reflection
- It undergoes refraction
- It undergoes diffraction.
- It undergoes interference.
- Can be polarized
- Travels in a straight line
- It has a velocity of $3.0 \times 10^8 ms^{-1}$ in vacuum.
- Can travel through vacuum.

A ray: this is a path taken by light from an object to another. A ray is represented by a thin line with an arrow to indicate the direction of light.

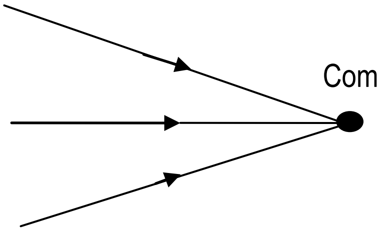
Beams of light: a beam is a collection of light rays moving in the same direction.

TYPES OF BEAMS

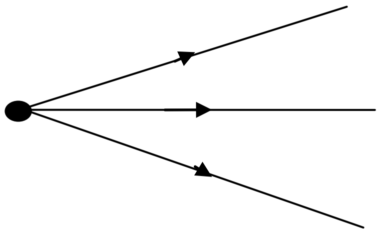
i) Parallel beam



ii) Convergent beam.



Common point where
Rays originate from



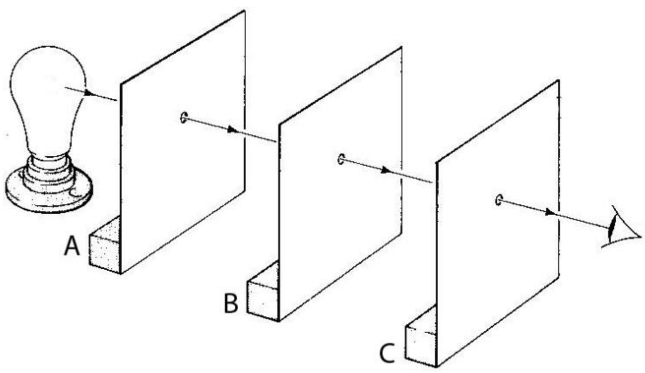
RECTLINEAR PROPAGATION OF LIGHT

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 ASTRAIGHT LINE



PROCCEDURE

Three (3) identical card boards A, B and C each with a hole in its centre, are arranged with holes in a straight line as shown above using a thread.

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.

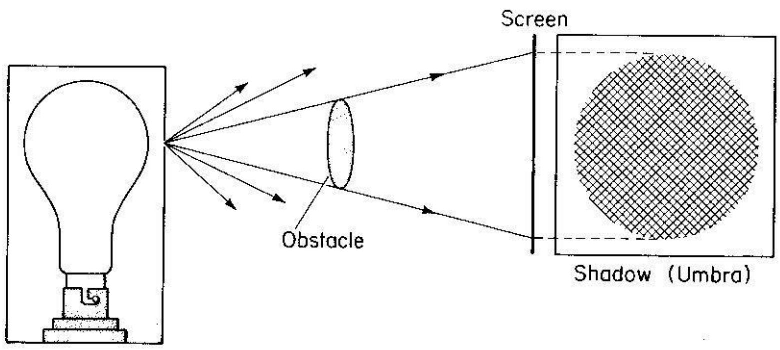
If one of the holes is displaced out of the straight lines by adjusting one of the cardboards, light from the source can't reach the eyes of the observer.

This shows that light travels in a straight line.

SHADOWS

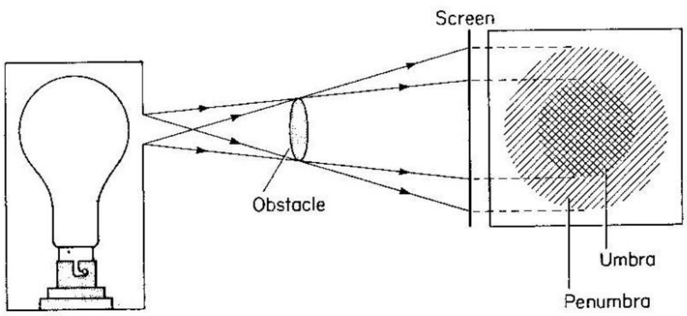
Shadows are formed when light rays are obstructed by an opaque object

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 light light from the source

ECLIPSE

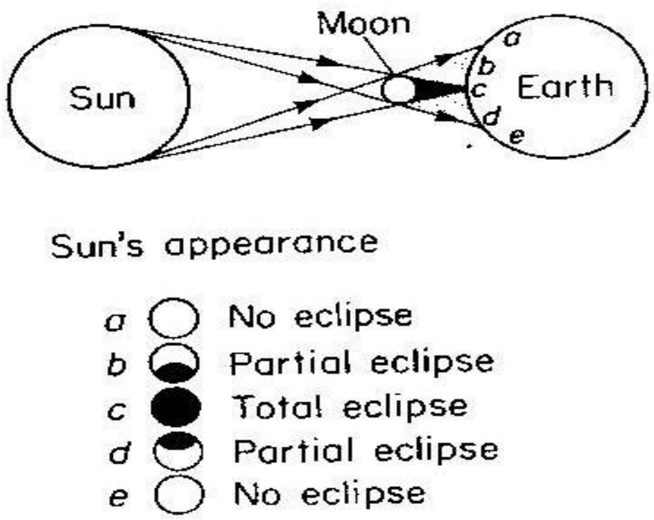
An eclipse occurs when the sun, moon and earth are in a straight line. It is a natural effect of the rectilinear propagation of light.

TYPES OF ECLIPSE

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



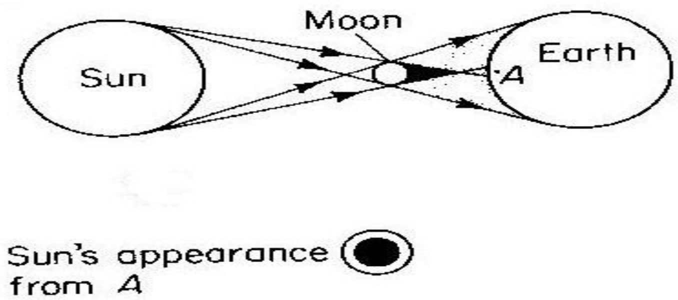
Region **c** represent total eclipse i.e. no light from the sun reaches the earth and the sun is not visible.

Regions **b** and **d** represent partial eclipse i.e. little 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

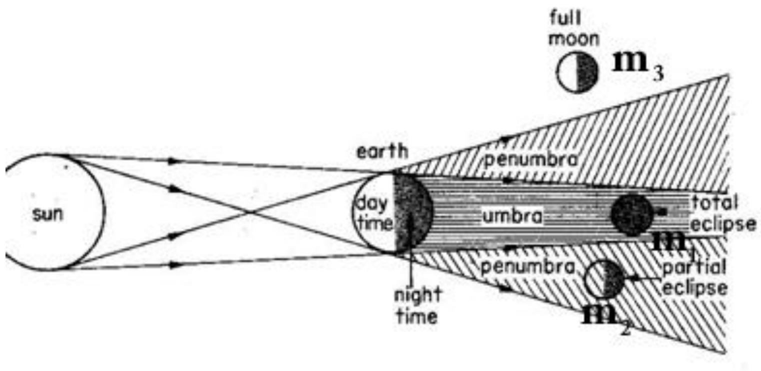
This is a solar eclipse where the shadow of the moon fails to reach the earth. The sun appears as an annulus.



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 rotates about the earth, along it's 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.

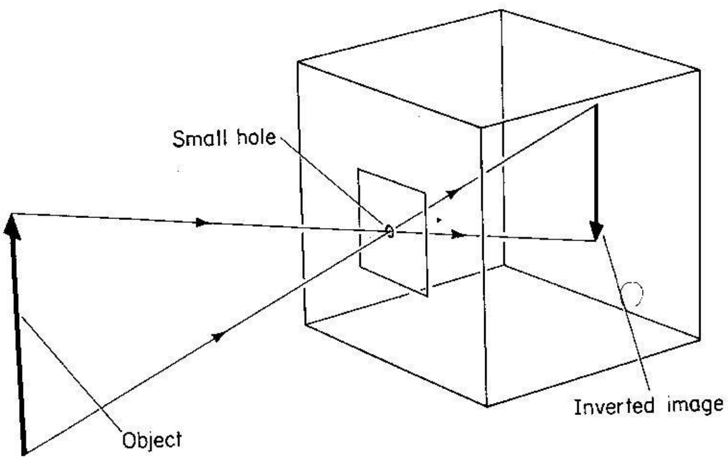
But the moon is visible with a copper like colour due to some light refracted by the earth at position m_1



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 hole decreases and vice verse.

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

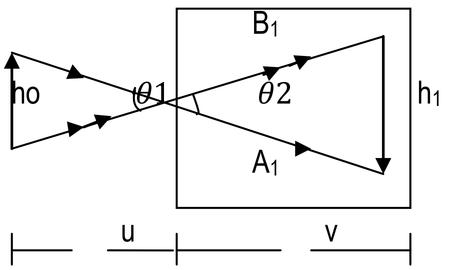
The image becomes blurred (not sharp) and brighter because more light is admitted into the pinhole camera. It has no effect on the size of the image.

MAGINIFICATION

This is the ratio of image size to object size

M = $\frac{Image\ height(h_I)}{object\ hieght(h_o)} = \frac{h_I}{h_o}$

Note



For $\theta_1 = \theta_2$ (vertically opposite)

By Proportionality

$\frac{h_1}{h_o} = \frac{v}{U}$ = M

$M = \frac{V}{U}$ Where V – Image distance from pin hole to screen

U – Object distance from pinhole to object.

Example

An object 20cm high forms an image on a screen of the pin hole camera. If the distance between the object and screen is 24cm and the distance between the object and the pin hole is 6cm find

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

i) H_1 = 2cm , u = 6cm v = 24cm

Magnification $M = \frac{v}{u} = \frac{24}{6} = 4$

ii) $M = \frac{h_1}{h_o} = 4 = \frac{h_1}{2} = h_1 = (4 \times 2) = 8$ cm

REFLECTION OF LIGHT ON A PLANE SURFACE

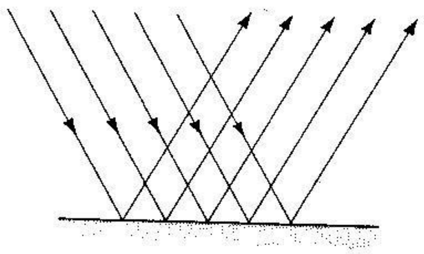
It is the bouncing of light from a shiny smooth surface.

TYPES OF REFLECTION

There are two types of reflection

i) Regular reflection
ii) Diffuse / irregular reflection.

Regular reflection

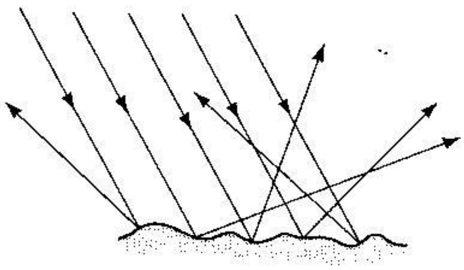


Regular reflection is the type of reflection in which a parallel beam of light is incident on a smooth surface is reflected as a parallel beam.

The angles of incidence are equal all rays

Diffuse reflection

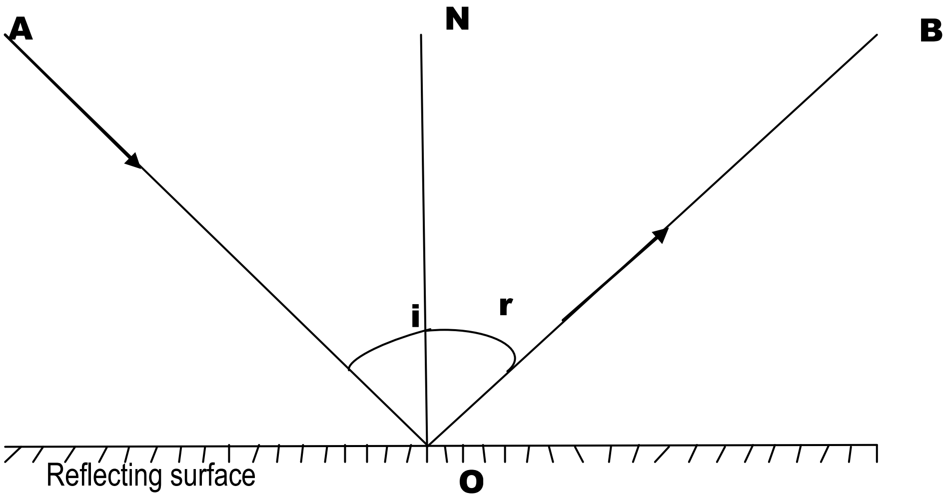
This is a type of reflection in which a parallel beam of light incident on a rough surface is reflected as a scattered beam. Angle of incidence are different from the angles of reflection.


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 **0** (point of incidence)

This is the point on the reflecting surface where the incident ray is directed.

ii) Normal (**0N**)

Is a line drawn from point 0 perpendicular to the reflecting surface?

iii) Incident ray (**A0)**

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 (**0B**)

Is the path along which light incident on a surface is reflected

vi) Angle of reflection (**r**)

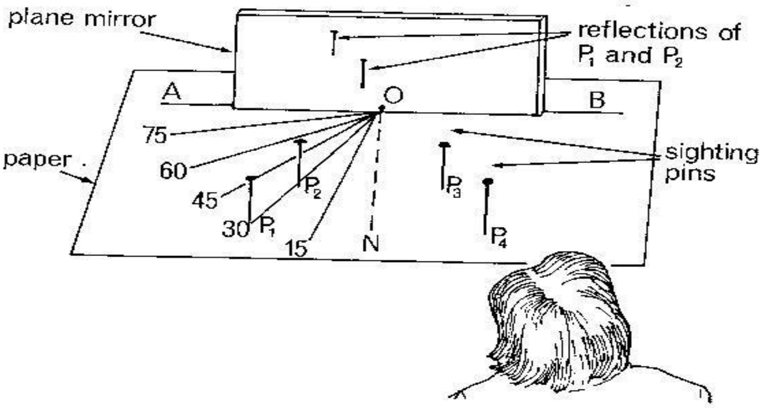
This is an angle between the reflected ray and the normal at the point of incidence.

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 on the plane.
2. The angle of incidence is equal to the angle of reflection

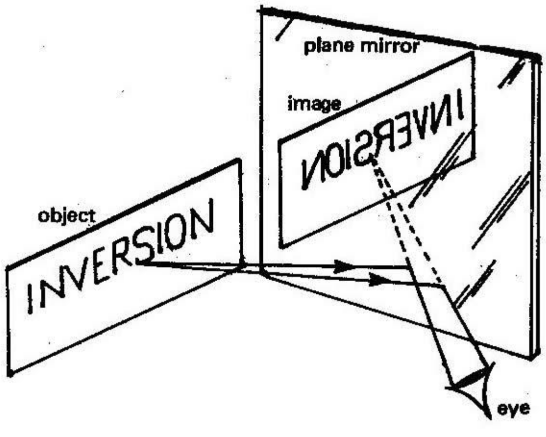
EXPERIMENT TO VERIFY LAWS OF REFLECTION



- Put the white piece of paper on the soft board using pins.
- Draw lines AB and ON perpendicular to each other on white sheet of paper.
- Measure angle of incidence equal to 30^o at point **O** and draw line **IO**
- Fix things **p_1** and **p_2** vertically along line **IO**.
- Insert a plain mirror along AB with the reflecting surface facing you.
- Looking through the plain mirror, fix pins **p_3** and **p_4** such that they appear to be in line with images of **p_1** and **p_2**.
- Measure the angle of refection using a protractor
- The procedure above is repeated for angles of incidence 45^0 and 40^0
- It is observed that angle of incidence is equal to angle of reflection, this proof the second law.
- Also since lines **I0 (**incident ray**)**, **0N** (Normal line) and **OR** (reflected ray) is drawn on the same sheet of paper and they meet at the same point, this proofs the first law.
- Thus the above experiment varies the laws of reflection

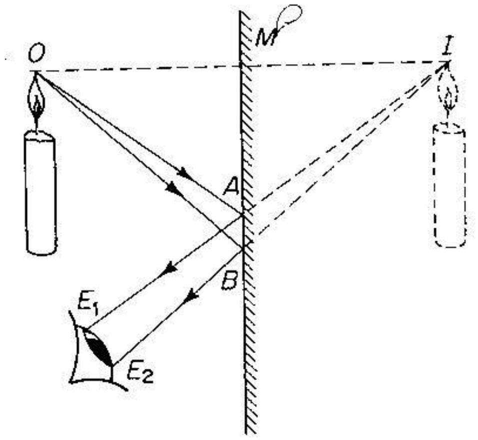
NATURE OF IMAGE FORMED ON PLAIN MIRROR.

- 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 lateral inverted.



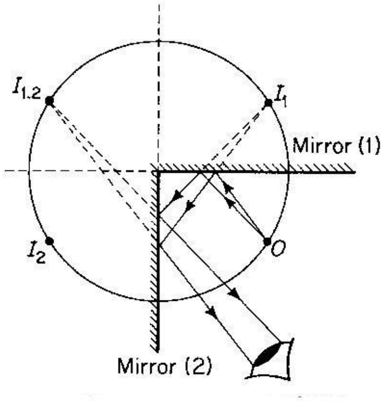
- It is virtual i.e. can't be found on the screen.

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**

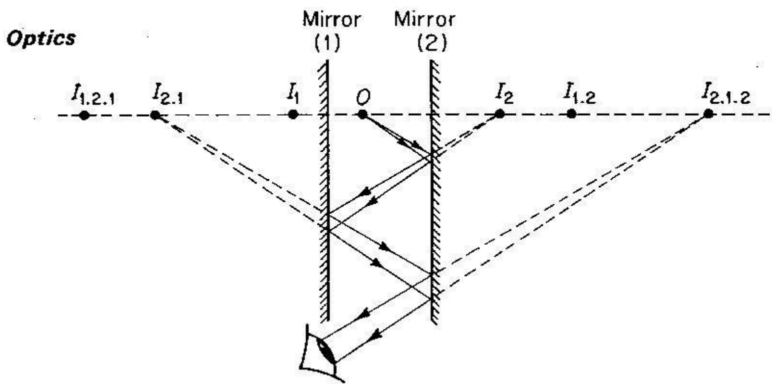
Image formed in two plane mirrors inclined at 90⁰



When two mirrors are inclined at 90^0 to each other, two images **I_1** and **I_2** are formed by a single reflection in mirrors **1** and **2** respectively. In addition an extra image is formed when image **I_1** acts as an object in mirror **2** to form image **$I_{1,2}$** as shown in the diagram above.

c) Image formed in parallel mirrors

An infinity number of images are formed when an object is placed between two parallel mirrors. Each image seen in one mirror will acts as virtual object to the next (opposite) mirror.



- The object **0** gives rise to image **I_1**, in mirror **m_1** and **I_2** in mirror **m_2**.
- Image **I_1** acts as a virtual a 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_1**
- Image. **$I_{(1,2)}$** acts as a virtual object to give an image **$I_{(1,2,1)}$** after reflection in **m_1** while image **$I_{(2,1)}$** gives an image **$I_{(2,1,2)}$** after reflecting in Mirror **m_2**.
- The above process goes on for each new image formed thus obtaining an infinity number of images.

Image formed by an inclined mirror at an angle θ

When two mirrors are inclined to each other at an angle θ between them, the number of images in the mirrors is obtained using the formula below;

$$N = \left(\frac{360}{\theta} - 1\right)$$

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

Angle between mirrors θ/°	Number of image in (n)	$=\frac{360}{\theta}$	$= \frac{360}{\theta} - 1$
90	3	4	3
60	5	6	6
45	7	8	7
30	11	12	11
15	23	24	23
0	Infinity	Infinity	Infinity

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^o, find the angle of inclination θ.

solutions

1. $N = \left(\frac{360}{\theta} - 1\right)$

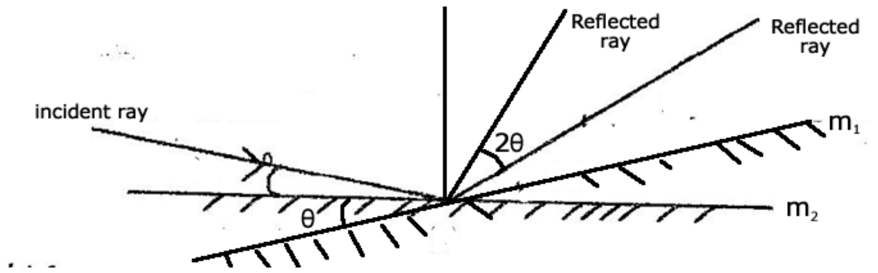
$N = \left(\frac{36}{50} - 1\right)$ = 7.2 -1= 6.2 images.

2. $N = \frac{360}{\theta} - 1$

$79 = \frac{360}{\theta} - 1$

$\theta = 4.5^o$

ROTATION OF REFLECTED RAY



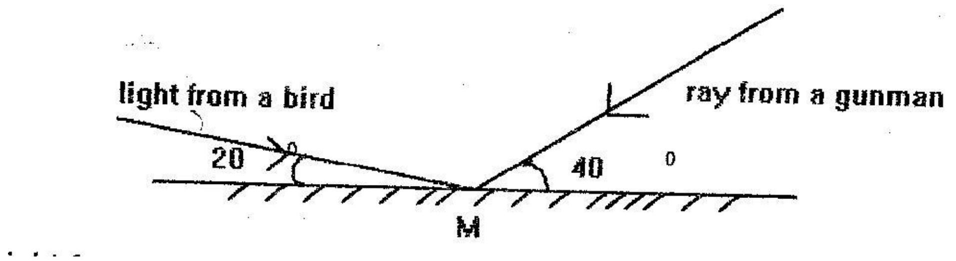
When a mirror is rotated through an angle θ, the reflected ray will rotate through an angle 2θ provided the direction of the incident ray remains the same .

e.g. the angle between a fixed 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 = 2θ = 2 x 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 on the reflecting surface.

Questions



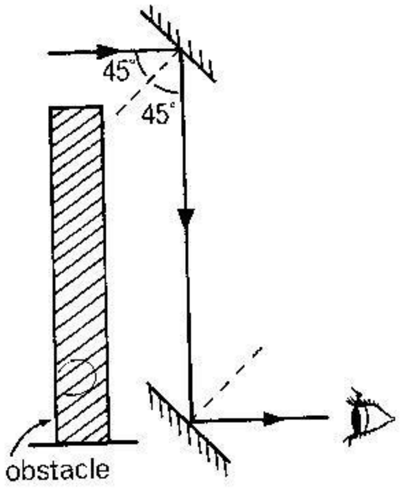
An incident may make an angle of 20^0 with the plane mirror in position m1 as shown in the diagram

a) What will the angle of reflection be if the mirror is rotated through 6^0 to position m2 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 obstacles. It is made of two (2) plane mirrors inclined at 45^0 when they are facing each other. It is used in submarines, war tankers e.t.c.



REFLECTION BY CURVED MIRRORS

There are two types of curved mirrors

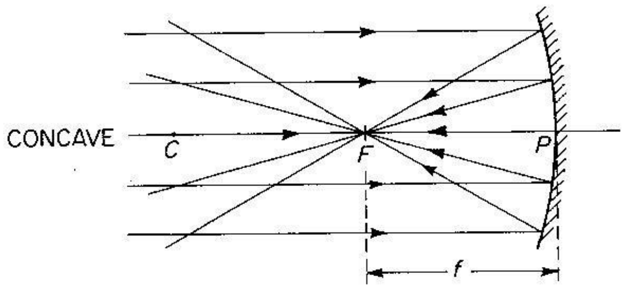
i) Concave / converging mirror (curve inwards)

ii) Convex (diverging mirror (curve outwards)

CONCAVE MIRRORS

A concave mirror is one with the reflecting/slivery surface on the inner side of the mirror. A concave mirror is also called a converging mirror because it converges parallel rays to a point called principal focus.

A concave mirror has a **real** principal focus because light actually pass through it as they converge after reflection.



P - Pole of mirror

F - Principal focus

C - Center of curvature

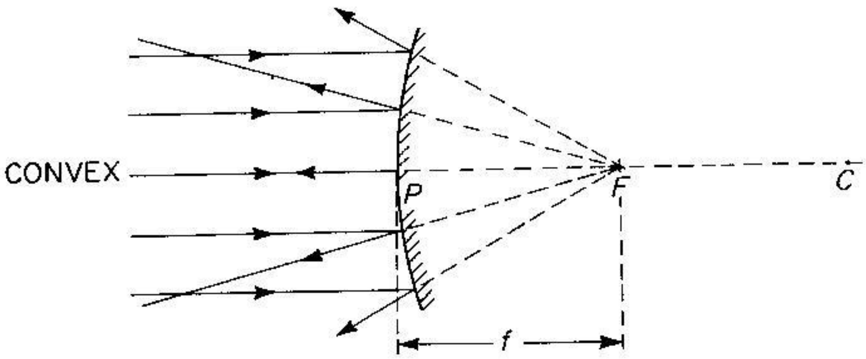
R - Radius of curvature

F - Focal length

CONVEX MIRRORS

A convex mirror is one with the reflecting/slivery surface on the outer side of the mirror. A convex mirror is also called a diverging mirror because it diverges parallel rays to appear like they are diverging from point called principal focus.

A convex mirror has a **virtual** principal focus because light appear diverge, originate or come from it after reflection.



Terms used

- **The pole (P)** : is the center of reflecting surface
- **Center of curvature(C)** .it is the center of sphere of which the mirror formed part of.
- **Principal axis**: is the imaginary line that passes through the pole, principal focus and the center of curvature of the mirror.
- **Radius of curvature (r)**: this is the radius of sphere of which the mirror formed part of.

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. $r = 2f \quad or\ f = \frac{r}{2}$

- **Aperture**. This is the width of the mirror.

- **Principal focus / focal point(f)**:

a) For a concave mirror.

It's a point on the principal axis where all incident rays parallel and close to the principal axis will converge to after reflection.

b) For a convex mirror.

It's a point on the principal axis where all incident rays parallel and close to the principal axis appear to diverge from after reflection.

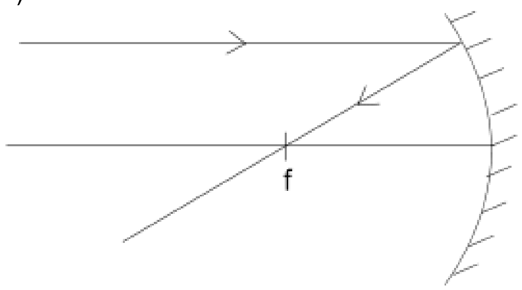
***Note**: F is real for a concave mirror and virtual for a convex mirror.*

- **Real image:** Is one which can be formed on the screen. It is formed by actual intersection of rays.
- **Virtual images**: it is one which cannot be formed on the screen. It is formed by apparent inter section of rays.

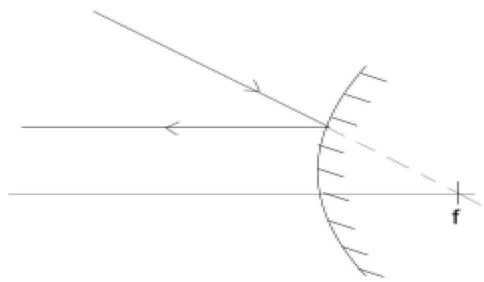
CONSTRUCTION OF RAY DIAGRAMS

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

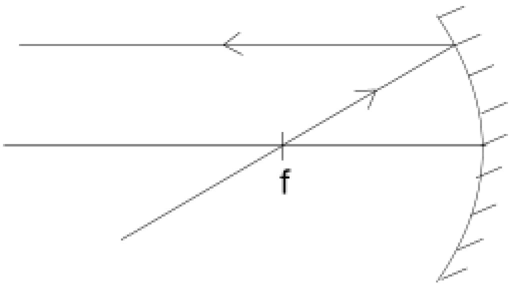


b) For a convex mirror

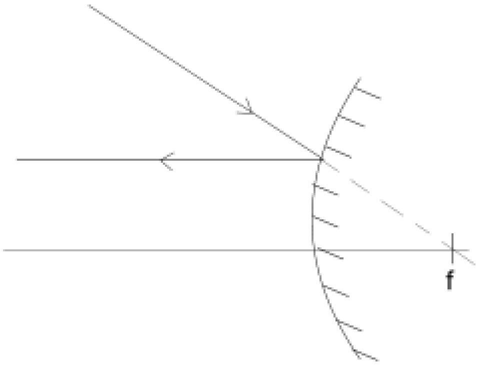


2. A ray through the principal focus is reflected parallel to the principal axis .

a) For a concave mirror

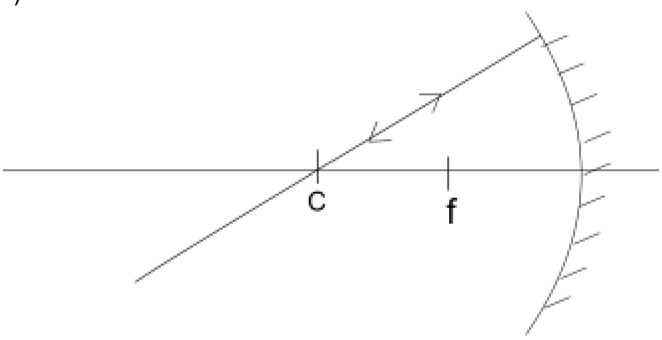


b) For a convex mirror



3. A ray through the center of curvature is reflected along the same path.

a) For a concave mirror



b) For a convex mirror

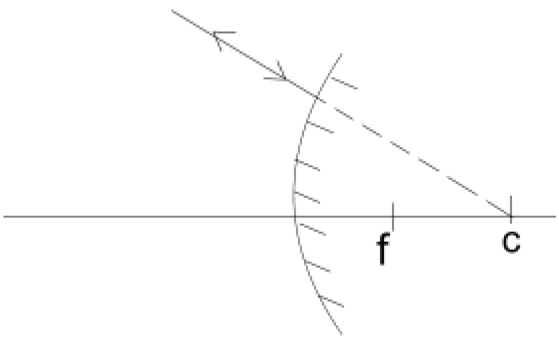
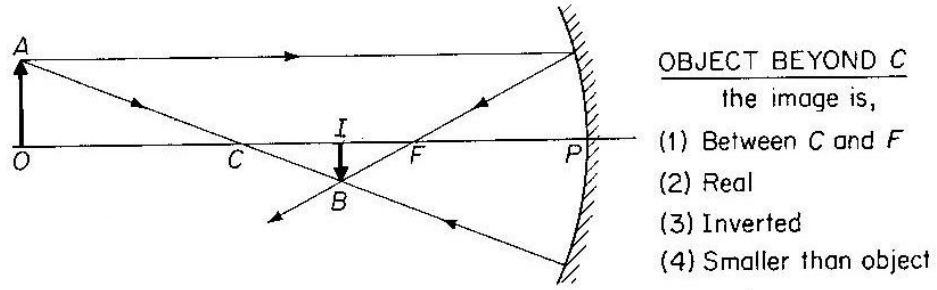


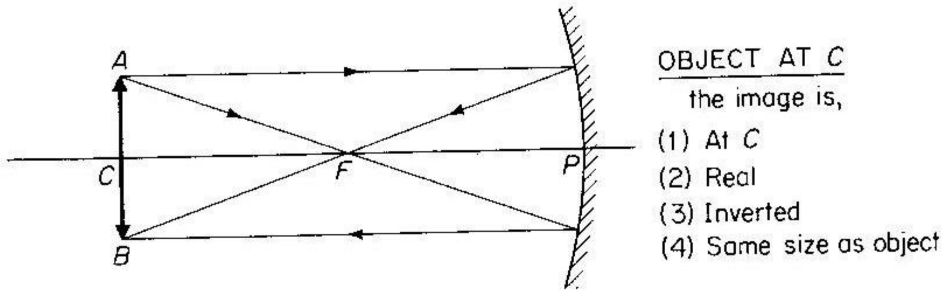
Image formation by concave mirror

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

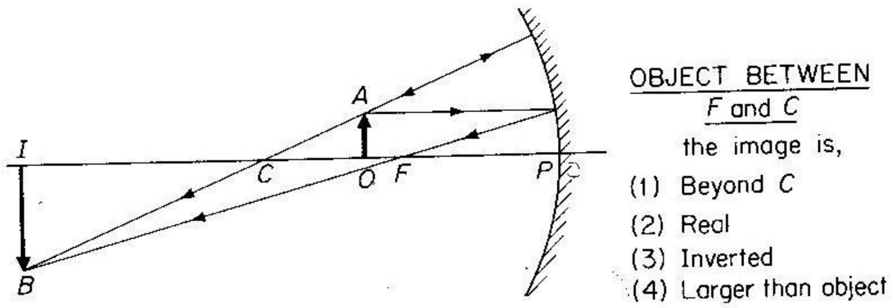
1. Object 0 beyond C



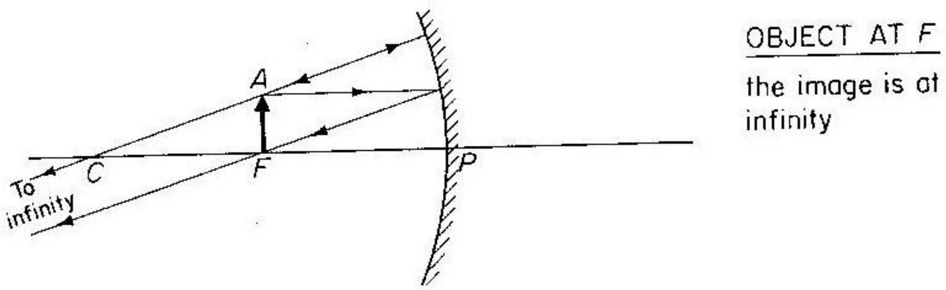
2. Objects 0 at C



2. Object 0 between C and F



3. Object 0 at F



4. Object 0 between F and P

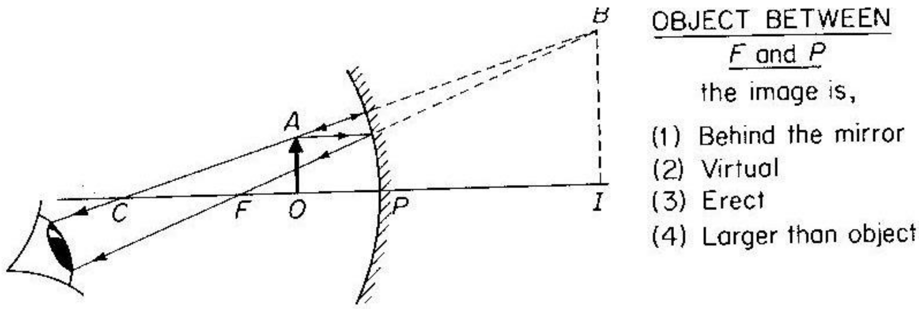


Image formation by convex mirror

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

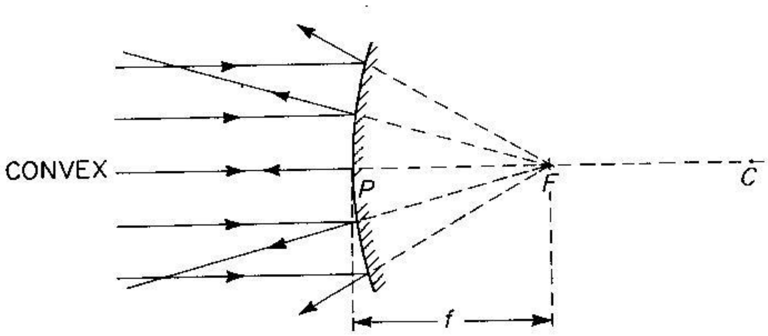


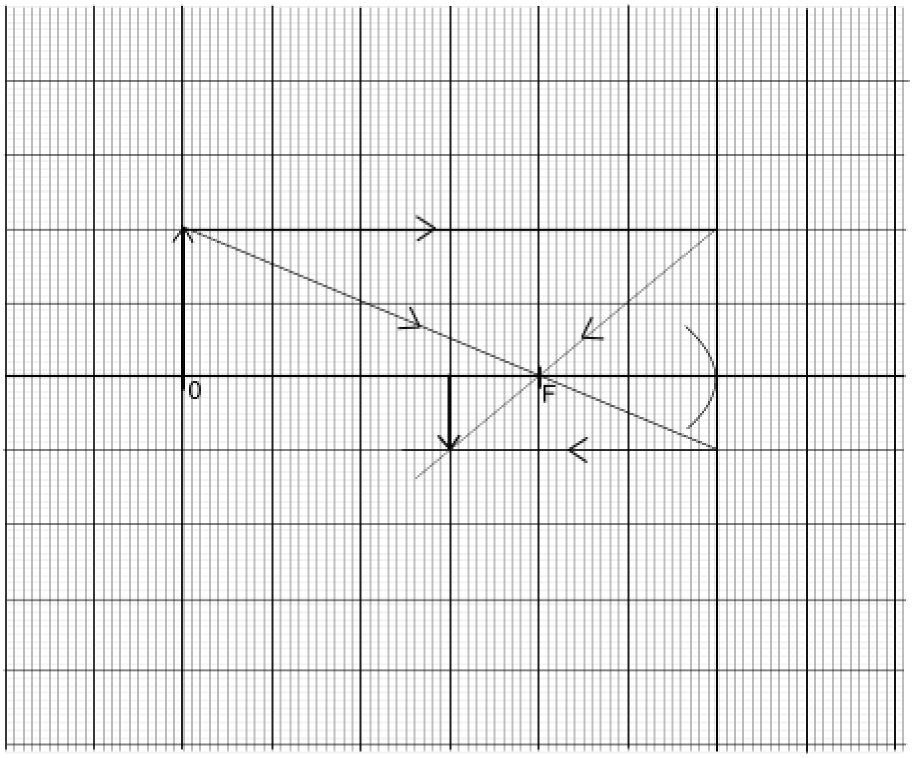
Image formed is virtual, diminished,
Upright (erect) and formed between F and P.

Construction of ray diagrams to scale.

Example

1. 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
2. An object 3cm high is placed at angles to principal axis a concave mirror with focal length 7.5cm. if the object is 30cm from the pole, construct a ray diagram to obtain the position size and nature of image (use a scale 1cm : 3cm)

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.

$M = \frac{h1}{ho}$ where h_1 – 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.

$M = \frac{v}{u}$ 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)

USES OF CURVED MIRRORS

a) Convex mirrors

They are used as driving mirror because

i) They give a wide field of view

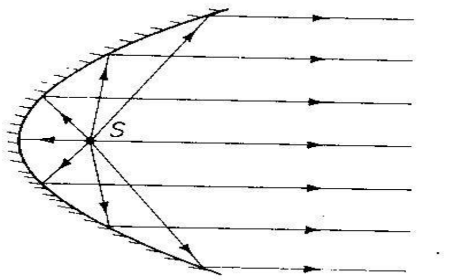
ii) They give upright images of the object

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

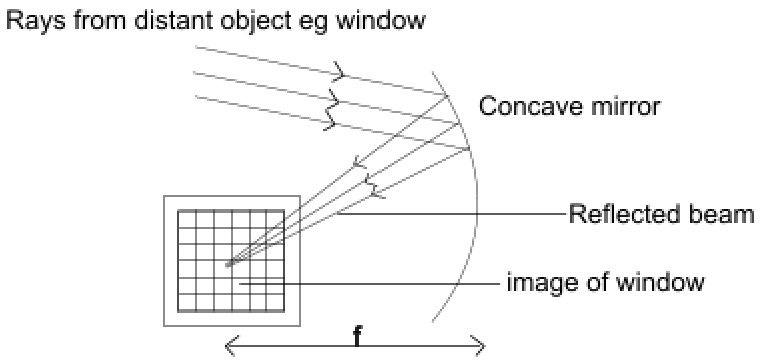


- It can be used as sharing mirror
- Used by dentists for magnification
- Can be used in astronomical telescope (reflecting type)
- Can be used as solar concentrators.

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.

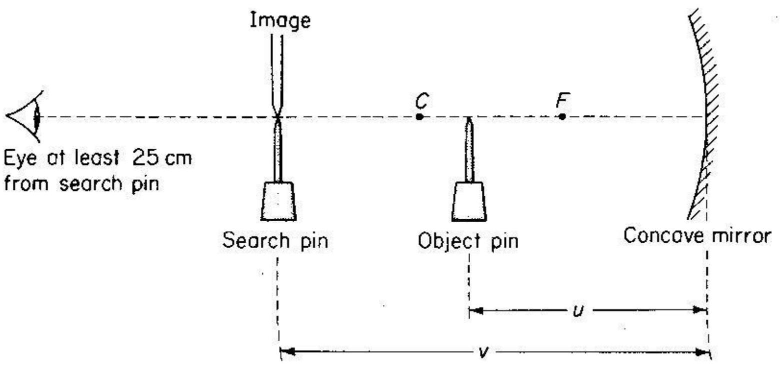


- Move the screen at different distances from the mirror until a sharp image is formed on the screen
- Measure the distance from the screen to the mirror with a metre rule.
- Repeat the experiment several times and find the average value of the distance between the screen and the mirror. This is the 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 a 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 in a suitable table including* $\frac{1}{u}, \frac{1}{v}$*, and* $\frac{1}{u}+\frac{1}{v}$
- *A mean for focal length f is obtained from the mirror formula*
    - $f = \frac{uv}{u+v}$

REFRACTION

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

PQ – Interface

O -- Point of incidence

OB – Refracted ray

AO – Incident ray

i-Angle of incidence

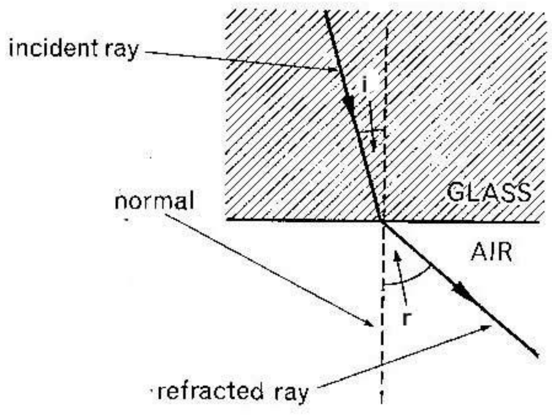
r- Angle of refraction

NN' – Normal

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 ray at the point of incidence all lie on the same plane.
2. The ratio sine of angle of incidence to the sine of angle of refraction is constant (snell's law) for any given pair of media

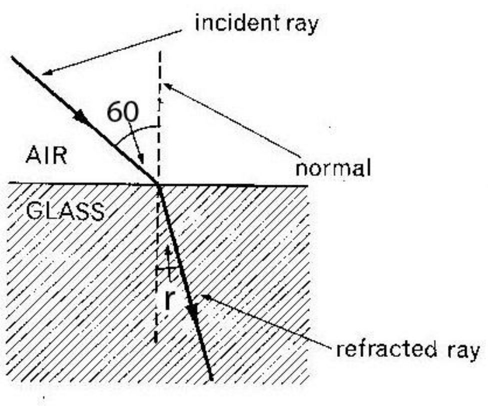
i.e. = $\frac{sin\ i}{\sin r}$ = constant (n) where n – refracted index of the medium containing the refracted ray.

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 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 = $\frac{\sin i}{\sin r}$

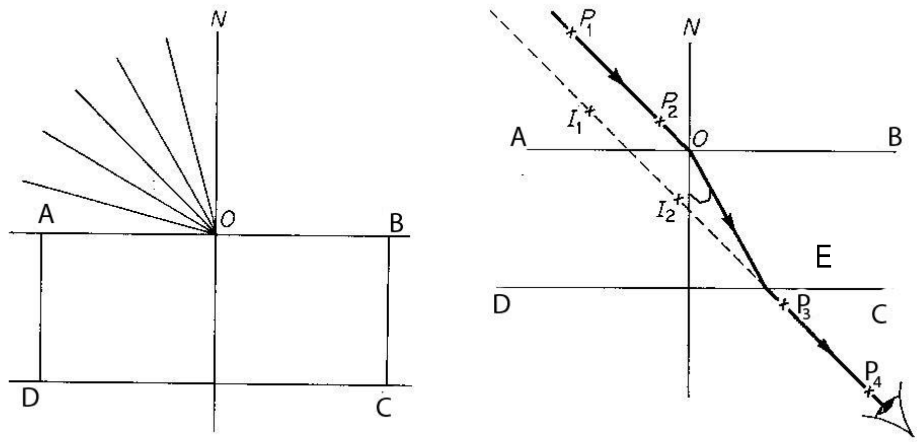
1.50 $= \frac{\sin 60}{\sin r}$

Sin r = $\frac{\sin 60}{1.50}$

r = $\sin^{-1}[\frac{\sin 60}{1.50}]$=

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 0 along AB and an angle of incidence i 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 lines of images 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 0 to meet CD at E.
- Point 0 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, 30, 40, and 50.
- The values of i, r 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 = $\frac{sini}{sinr}$

Absolute refractive index

Is the ratio of sine of angle 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 = $\frac{sini}{sinr}$ the angle incident i should in air or vacuum.

REFRACTION ON PLANE PARALLEL BOUNDARIES

The refractive index of 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 g ∩ w = $\frac{nw}{ng}$ where ng and nw are absolute refractive indices of glass and water respectively. So $_1n_2$ = $\frac{\sin i}{\sin r}$ = $\frac{n2}{n1}$ ↔ $n_1 \sin i = n_2 \sin r$

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∩g = $\frac{\sin i}{\sin r}$ (i)

g∩a = $\frac{\sin r}{sini}$ (ii)

a∩g = $\frac{1}{g∩a}$ or g∩a = $\frac{1}{a∩g}$

Question

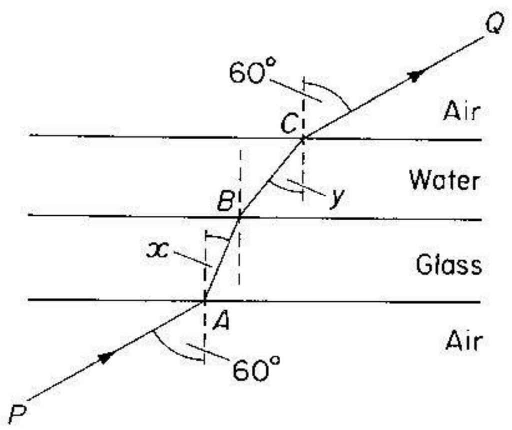


Figure above shows a glass slab of uniform thickness, lying horizontally. Above it is a layer of water. A ray of light PQ is incident upwards on a lower surface of the glass and is refracted successively at A, B and C, the points where it crosses the interfaces. Calculate

(i) angle x,

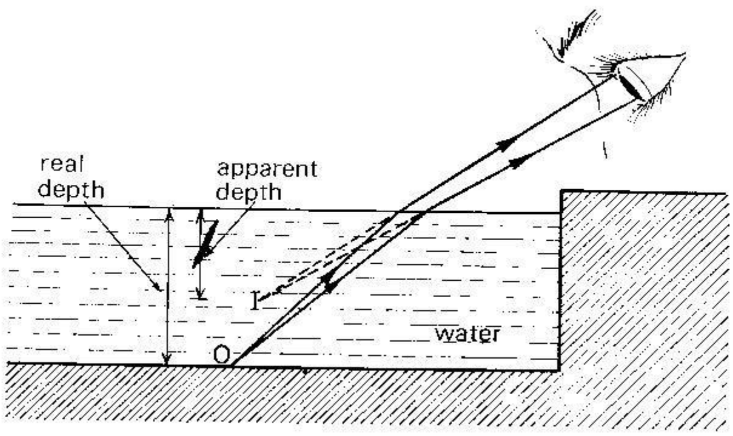
(ii) angle y, and

(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

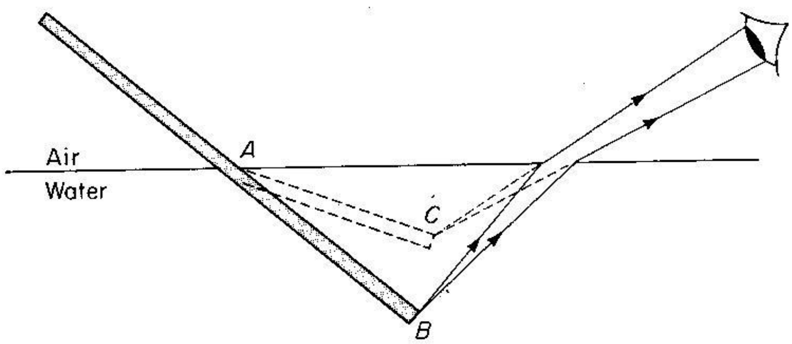
Refraction on plane surface causes

- 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 it's actual size



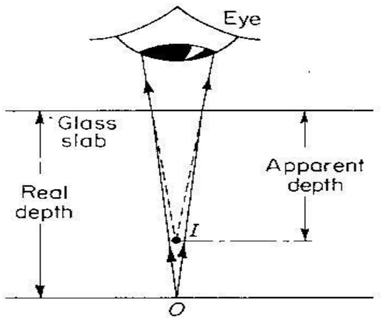
- An object placed under the glass block appears nearer

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.

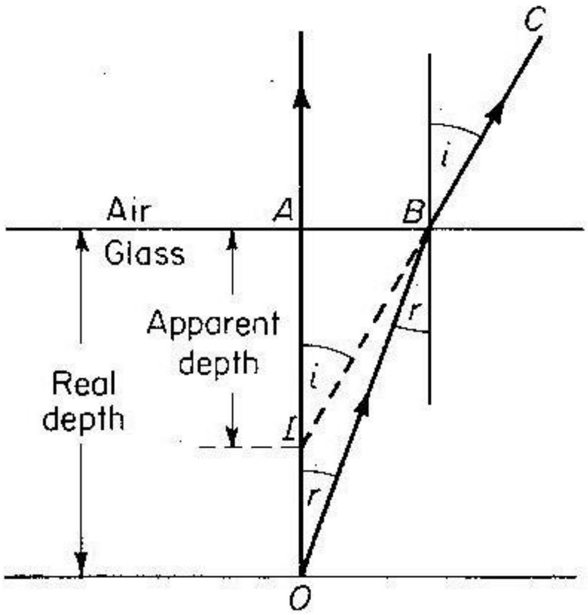
REAL AND APPARENT DEPTH



An object 0 placed below a water surface appears to 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 =$\frac{\sin i}{\sin r}$

Using the principal of reversibility of light sin i = $\frac{AB}{BI}$, sin r = $\frac{AB}{BO}$

$$n= \frac{AB}{BI} \div \frac{AB}{BO}$$

$$= \frac{AB}{BI} X \frac{BO}{AB} \quad \Leftrightarrow \quad n= \frac{BO}{BI}$$

if B is close to A, BO =A0 and BI = AI

n = $\frac{AO}{AI}$ but A0 is the real depth

AI is the apparent depth

Hence n = $\frac{real\ depth}{aparent\ depth}$

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 = $\frac{real\ depth}{apparent\ depth}$

$^4/_3 = \frac{r}{1.5}$ ⇔ r = $\frac{4x1.5}{3}$ = 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.

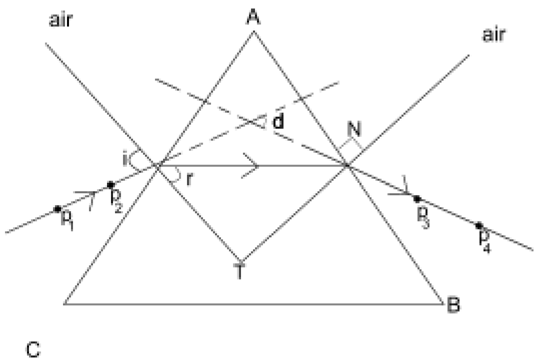
A pin is clamped on a sliding cork adjacent the block, it is moved up and down until there is no parallax between it and the image of the cross (x) seen through the block.

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

$$n = \frac{real\ depth\ (y)}{apparent\ depth\ (x)}$$

Determination of refractive index using a triangular prism

A prism is placed on a white sheet of paper and it's 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 for 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, a line drawn through P_1 and P_2 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

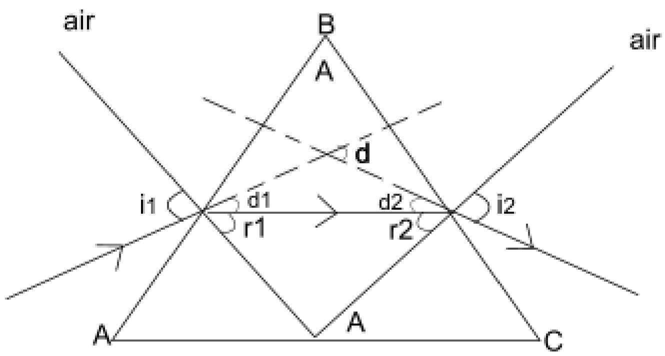
The procedure is replaced to obtain different values of i and r and the results tabulated as shown.

$i/^0$	$r/^0$	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 mono chromatic light incident on a prism changes its direction (deviates) as it is entering 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 1.5 and refractive angle 60^0 has an angle of refraction of 28^0 on the 1st 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) = $\cap_a$ sin i = $\cap_g$ sin r

1 x sin i = sin1.5 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

$\cap_g$ sin r = $\cap_a$ sin i_2

1.5 sin 32= 1xsin i_2

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

$i_2 = 52.64^0$

d) $d = d_1 + d_2$

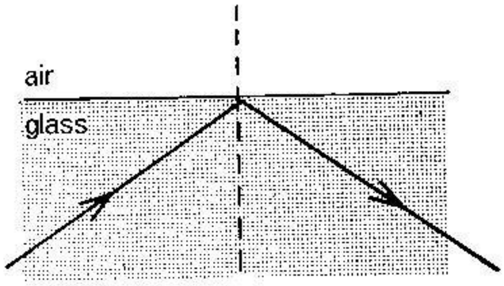
$= (i_1 + i_2) - A$

$= (44.7 + 52.64) - 60$

$= 37.34^0$

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.



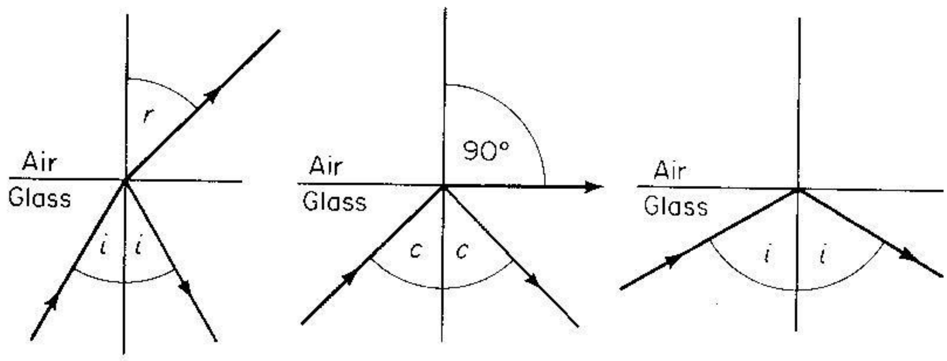
Conditions for total internal refraction to occur

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 reflected ray as shown in (i)



(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

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

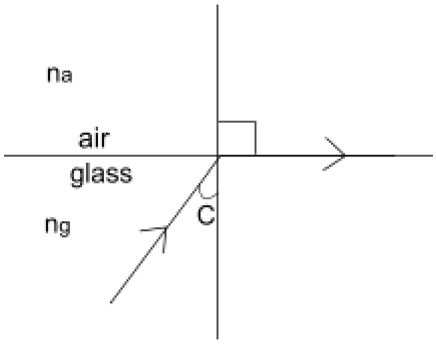
When the angle of incidence is increased beyond the critical angle, total internal reflection occurs as shown below in (ii)

Relationship between Refractive index and critical angle.

Applying Snell's law at the interface,

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

$n_g = \frac{1}{\sin c}$



Example:

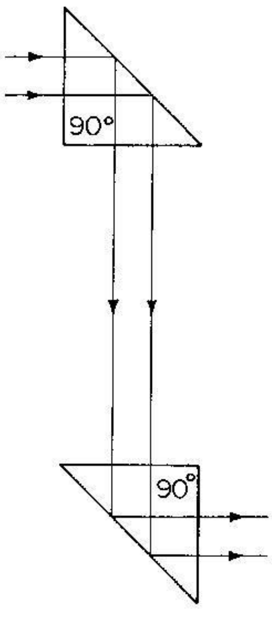
1. Find the critical angle of a medium of reflective index 1.5

$\text{Sin C} = \frac{1}{n} \quad \Rightarrow \quad C = \sin^{-1}(\frac{1}{n}) = \sin^{-1}(\frac{1}{1.5}) = 41.8^0$

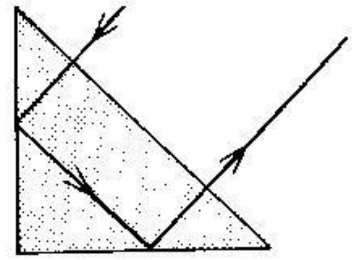
APPLICATION OF TOTAL INTERNAL REFLECTION

In reflecting prisms which are in binoculars, periscopes and cameras e.g i) Turning a ray through 90^0

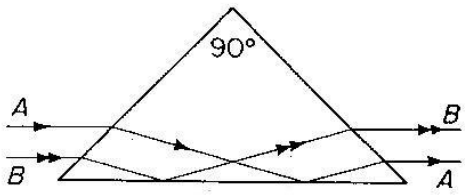
Prism periscope



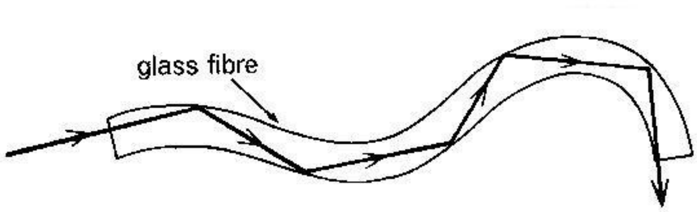
ii) Turning a ray through 180^0



iii) Turning a ray through 360^0



Optical light pipes



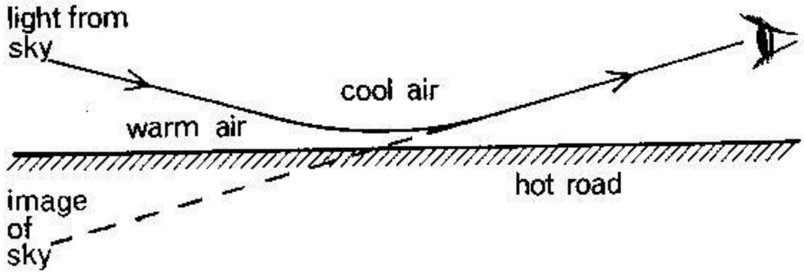
The inner surface has slightly higher refractive index than the outer surface making it slightly denser medium. Light can be trapped by total internal reflection inside a bent glass rod and piped along a curved path as shown above.

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 the above. Cool air is dense than warm air.

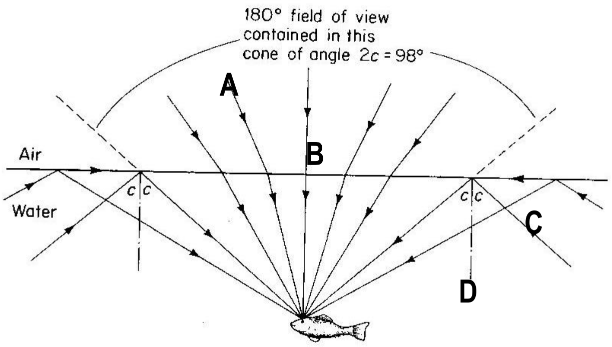


Light from the sky is gradually refracted away from the normal as it passes from denser layer of air to less dense layers

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 water 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 reflection.

It can also see an object as the bank C of lake if the angle of incidence is equal to the critical angle.

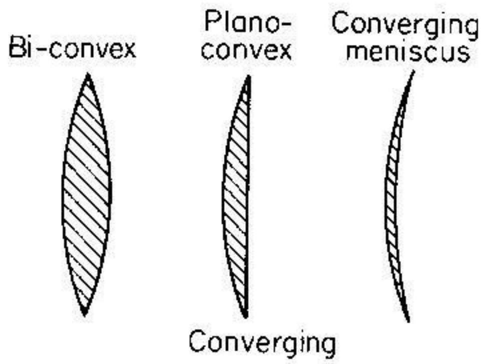
And if i is greater than the critical angle an object at D can be seen by total internal reflection.

LENSES (Refraction on circular surfaces)

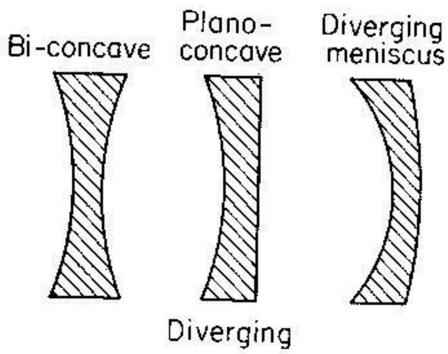
These are two types:

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

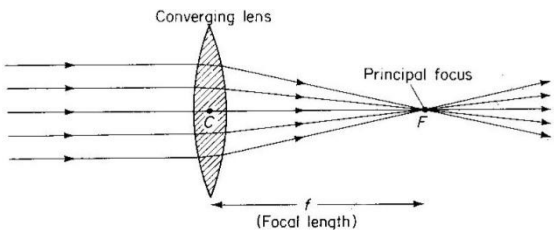
Convex lens

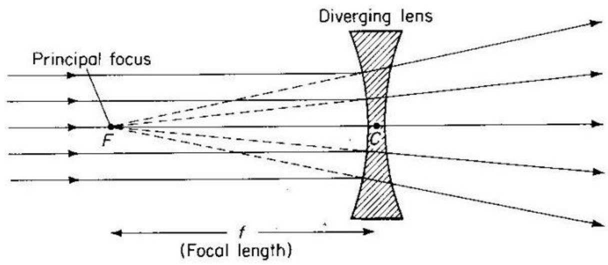


Concave lens



Terms used:



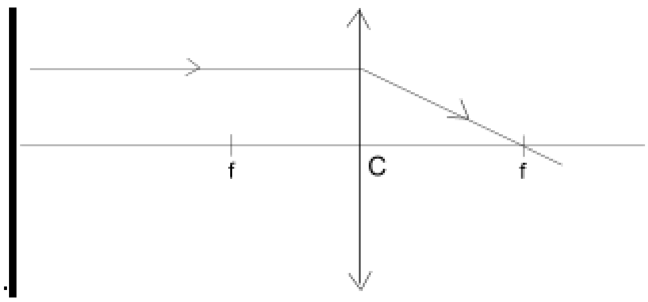


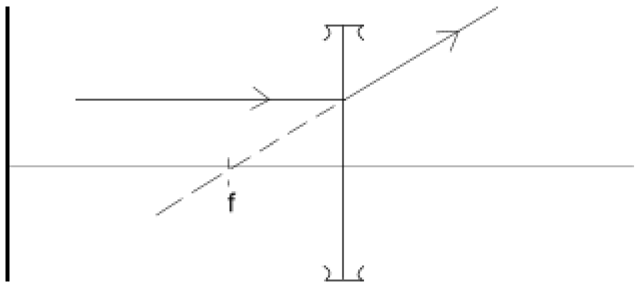
1. Principal axis is a line joining the principal focus and the optical Centre.
2. Principal focus of a convex lens is a point on the principal axis to which all rays originally parallel and close to the principal axis converge after refraction by the lens.
3. Principal focus of a concave lens: This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

CONSTRUCTION OF RAY DIAGRAM

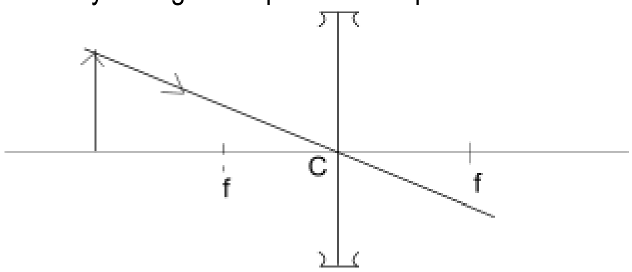
In constructing ray diagram, 2 of the 3 principal rules are used.

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

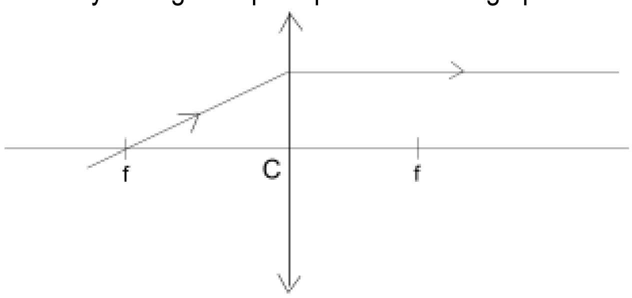




2. A ray through the optical centre passes un deviated i.e. i[redacted]s not refracted.



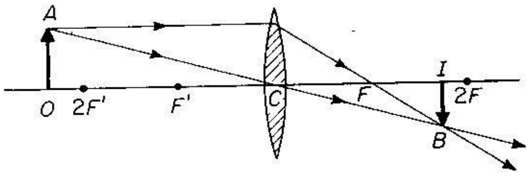
3. A ray through the principal focus emerge parallel to the principal axis after refraction.



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

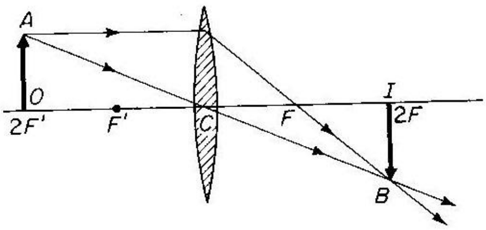


OBJECT BEYOND 2F'

the image is,

(1) Between F and 2F
(2) Real
(3) Inverted
(4) Smaller than object

(b) Object at 2f

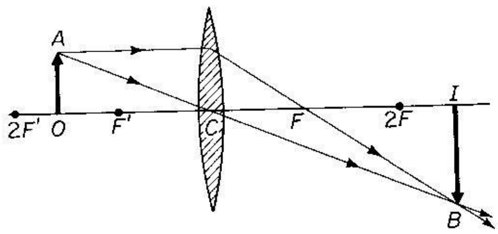


OBJECT AT 2F'

the image is,

(1) At 2F
(2) Real
(3) Inverted
(4) Same size as object

C) Object between f and 2f

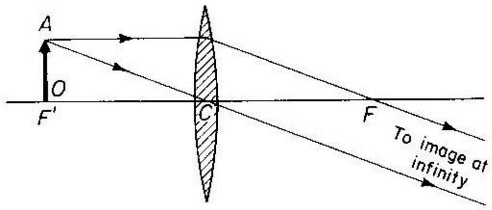


OBJECT BETWEEN F' and 2F'

the image is,

(1) Beyond 2F
(2) Real
(3) Inverted
(4) Larger than object

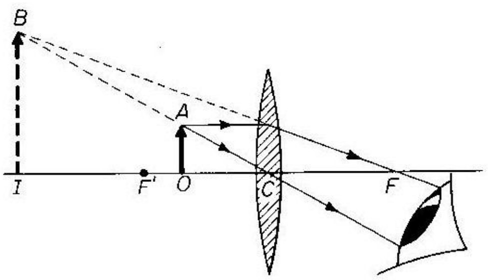
(c) Object at f



OBJECT AT F'

the image is at infinity

(d) Object between F and C



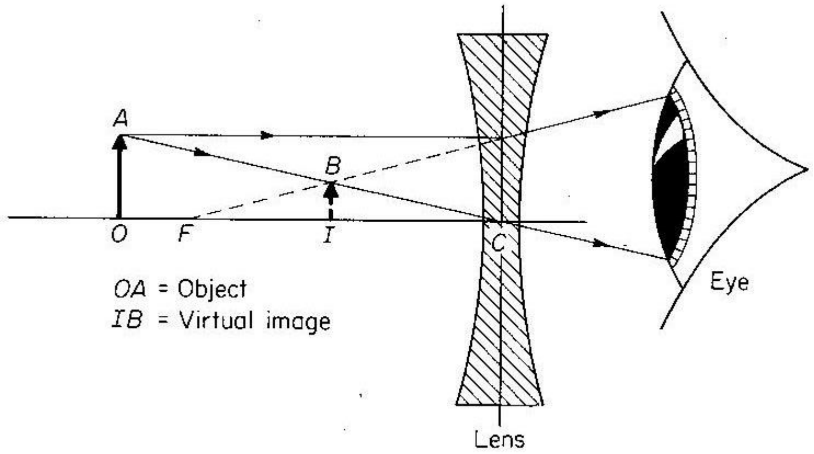
OBJECT BETWEEN LENS and F'

the image is,

(1) Behind the object
(2) Virtual
(3) Erect
(4) Larger than object

When the object is placed between f and c, the image is magnified and this is why the convex 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 metes

Power of lens = $\frac{1}{f}$ in meters where f – length.

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

Example

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

P = $\frac{1}{f}$ = $\frac{1}{0.01}$

= 10D

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

P = $\frac{1}{f}$ = $\frac{1}{0.2}$

= 50

OR

F = 20cm = $\frac{50}{100}$ = 0.2m

Magnification of the lens

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

M = $\frac{hI}{ho}$

OR

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

M = $\frac{v}{u}$ where –v – image distance

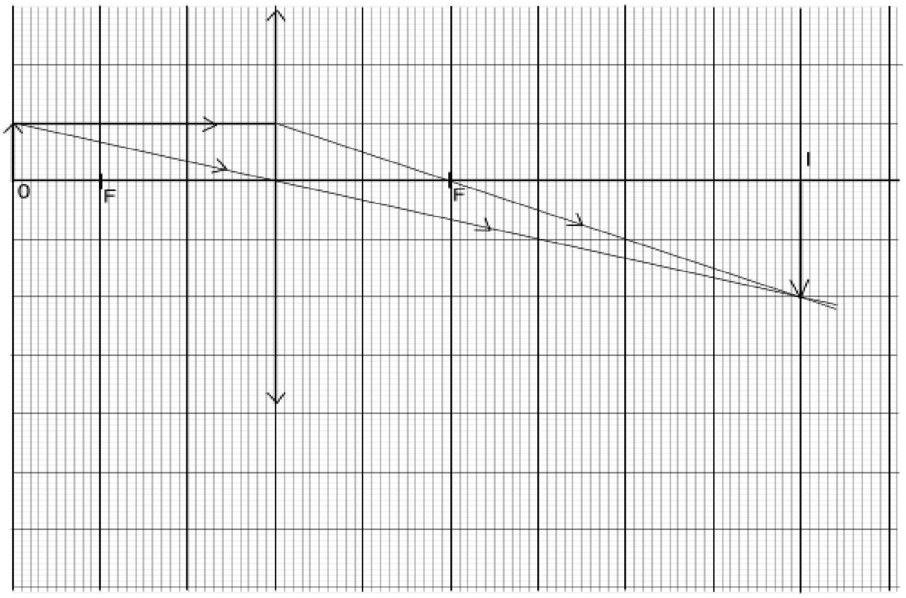
U – Object distance

Determination of image position by graphical method

Same rules are used.

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

E.g. object 5cm tall is placed 15 cm away from a lens of focal length 10cm by construction.



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

Question

1. A simple magnifying glass of focal length 5cm forms an erect image of the object 25cm from the lens. By graphical method, find the distance between the object and image

   Calculate the magnification.
   Diag

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

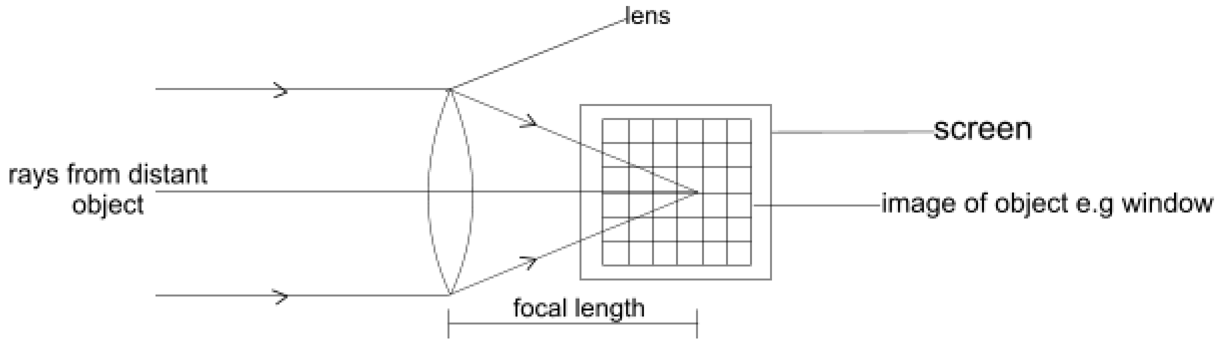
3. An object is placed at right angle to the principal axis of the thin covering lens of focal length 10cm. a real image of height 5cm is formed at 30cm on a lens . by construction, find the position and height of the object (use 1cm :5cm)

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.



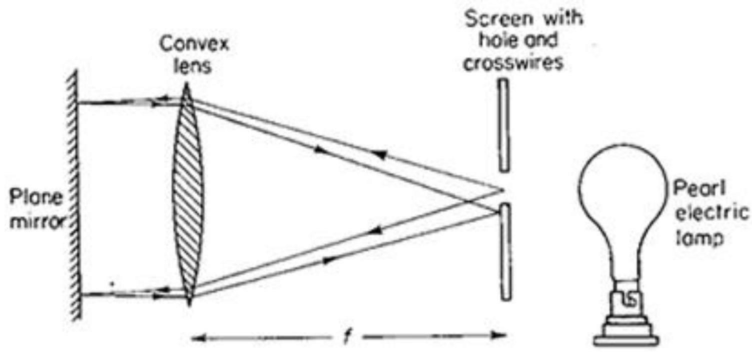
f – focal length

The screen is moved away or towards the lens until the sharp 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 obtain by above method is …because rays of light from the window are assumed to be parallel 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 along side the object.
- The distance between the lens and the screen is measured, this gives the focal length of the lens .

Application of lenses

Lenses are used in

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

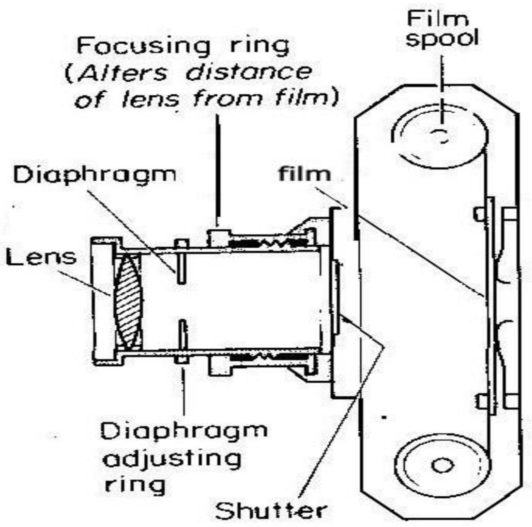
OPTICAL INSTRUMENTS

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 light.

It is developed to give a negative from which a photograph is made by printing.

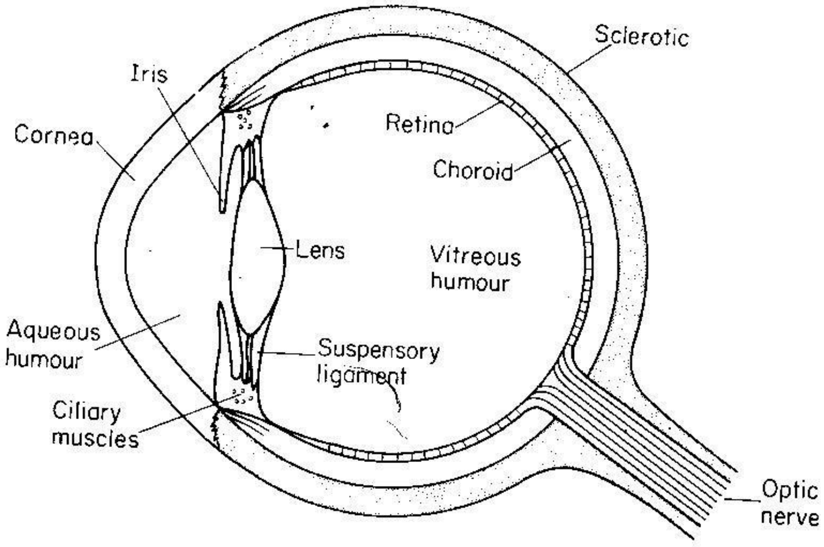


The camera is focused by varying the distance between the lens and the film. The lens is mounted on a screw thread so that, it can be moved in and out for near objects, the lens is moved away from the film.

The amount of light entering the camera is controlled by the

1) shutter, which opens for a certain length of the 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's sharp , 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 on 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

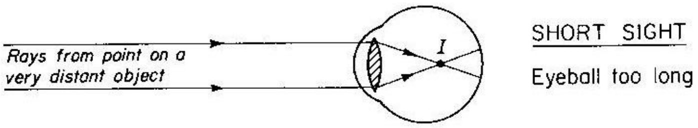
The normal eye can see objects clearly placed at infinity (far point) to see objects in greater details the eye sees it at the near point i.e 25cm

TYPES OF EYE DEFECTS

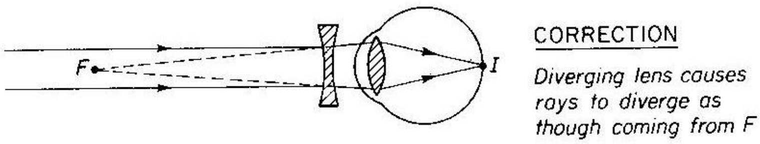
a) Short sightedness
b) Long sightedness

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.



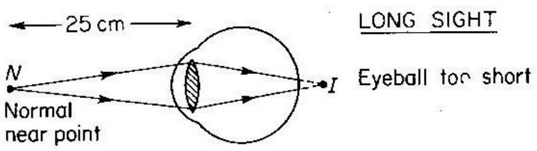
Correction of shortsightedness



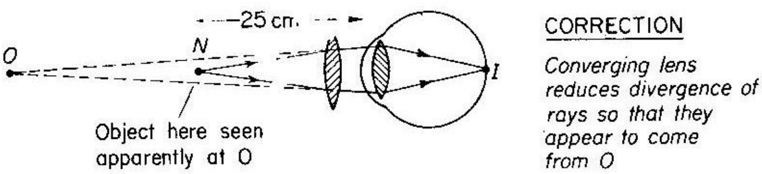
A concave lens is placed in front of the eye to make the light diverge so that it appears to come from the near point when its actually coming far away as shown above.

LONGSIGHTEDNESS

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 near 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

Similarities

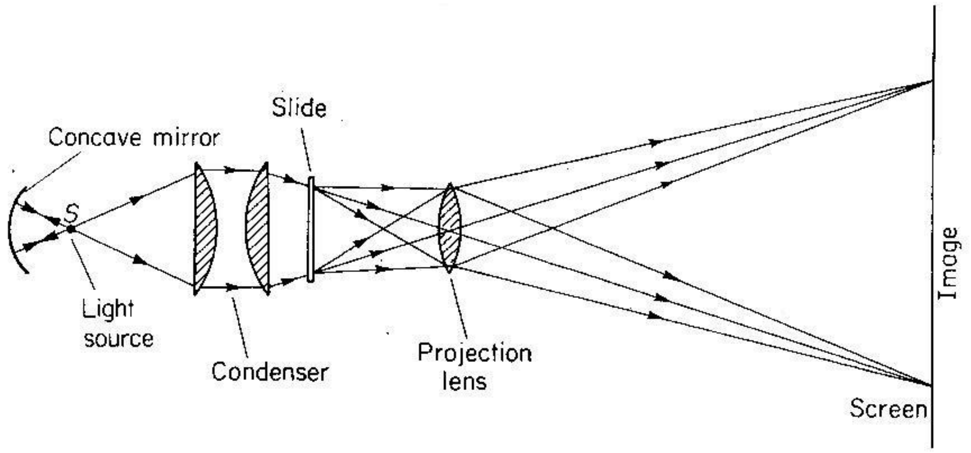
- The camera consists of the (a) light proof box painted blck inside the eye it is fitted with a black pigment in to it to prevent stray reflection of light
- Both have converging lens that focus light from the external objects
- Both have light sensitive parts, the camera has a film while the eye has 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

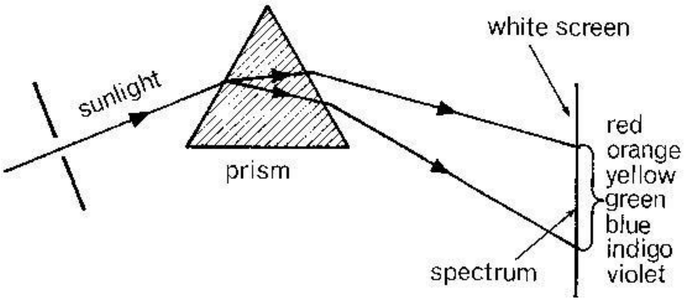


Functions of the parts of the slide projection

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. Th 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 colour formed is called a spectrum. Visible light spectrum can be made by passing a beam of white light through a glass prism.

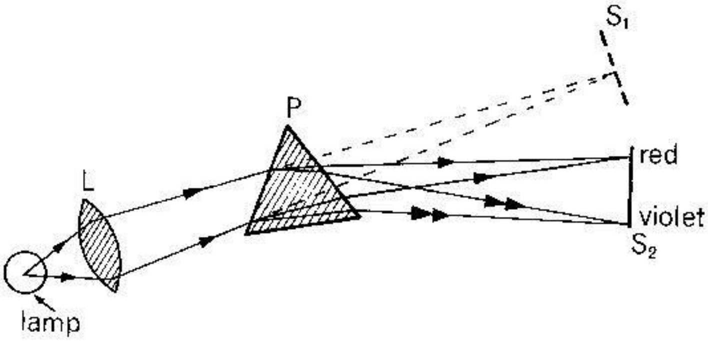


Dispersion occurs because each colour is refracted in glass by different amount i.e. each colour has different refractive index. So red is refracted least and violet is refracted most.

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 playing a convex lens in front of the prism to increase on the deviation of the colours as they pass through the prism.



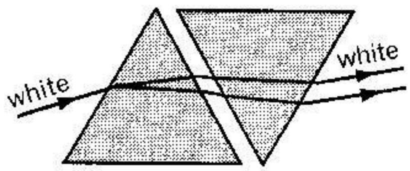
Lens L produces parallel beam of white light. The light is then dispersed and deviated at the prism sprinting up into various colours.

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:

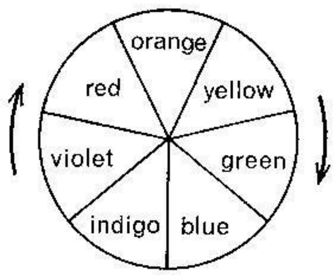
The colours of the spectrum can be recombined by;

(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 whiteness is slightly grey because paints are not pure colours.

Colours of objectives:

The colour of an object depends on;

(i) The colour of light falling on it.
(ii) The colour it transmits or reflects eg 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 light into the eyes and reflects all other colours.
(iii) A white object reflects all the colours of the spectrum into the eyes and absorbs none.

A body appears white because it absorbs all colours and reflects 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 colour

These are colours which are obtained by adding 2 primary colours together. They include yellow, peacock blue and magenta.

NB :- peacock blue is times called cyan or tachois.

c) Complementally colours

There 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

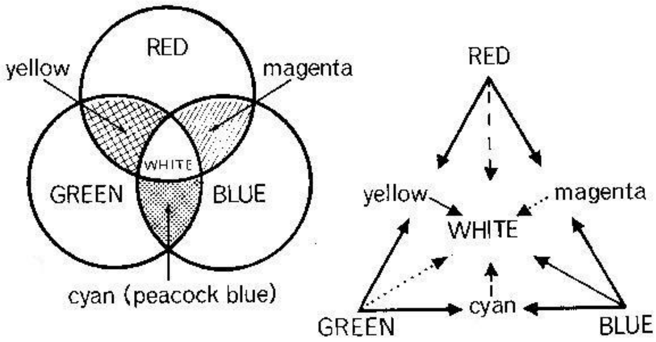
Green + magenta → white light

Blue + yellow → white light

Complementally colours

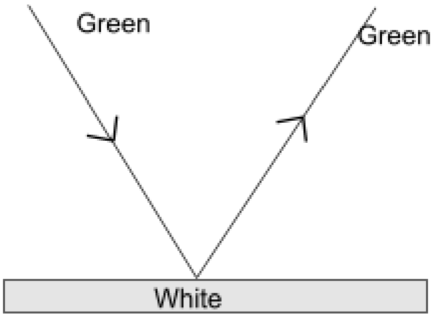
From the complementally colours it is noted that when the three primary colours are joined, they produce white light.

SUMMARY OF COLOURED LIGHTS

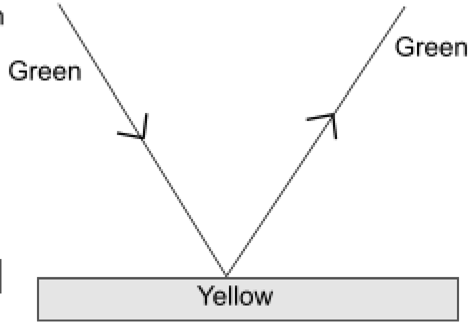


Coloured objects in white light

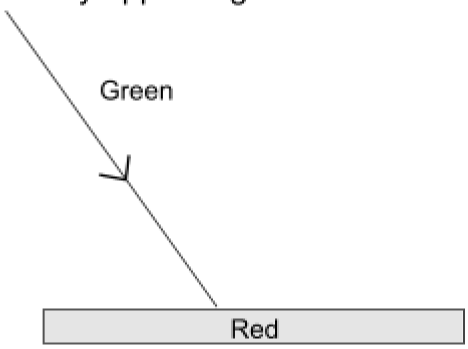
A coloured object reflects and transmits its own colour and absorbs other colour incident on it. Examples:



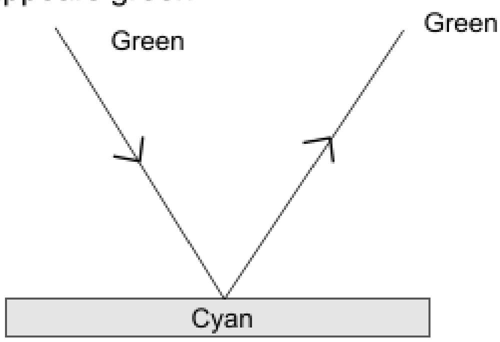
Body appears green



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

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

a) Red light
b) Green light – **the whole tie appears because both colours are primary colours and non is reflected black**
c) Red light – **in the red light the tie appears red and blue spots blacks.**
This is because the red reflects the red colour and observes blue colour.

Question2

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

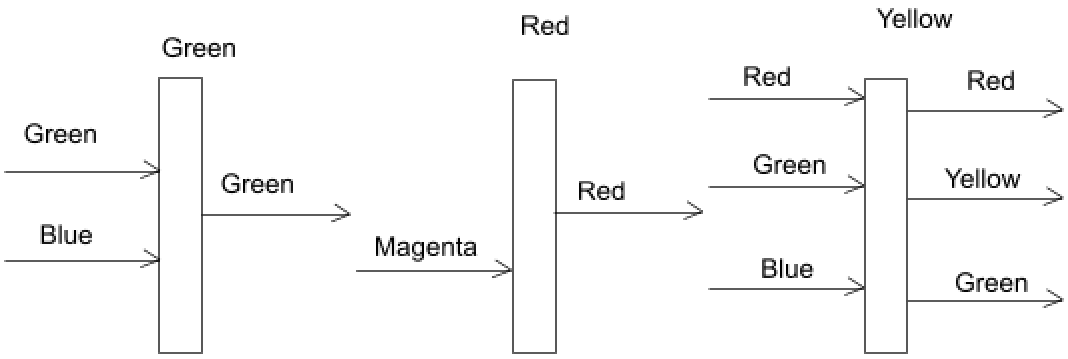
a) green -: the leaves remain green but the flower black

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 → green

Yellow + orange →black

Green + indigo → blue

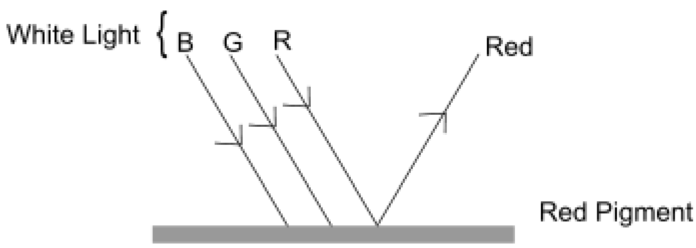
The blue reflects indigo and green its neighbour in the spectrum as well as blue

Yellow reflects green, yellow and orange only green is reflected by both

Mixing coloured pigment is called colour mixing by subtraction

Pigments appears black because non of the colours are reflected.

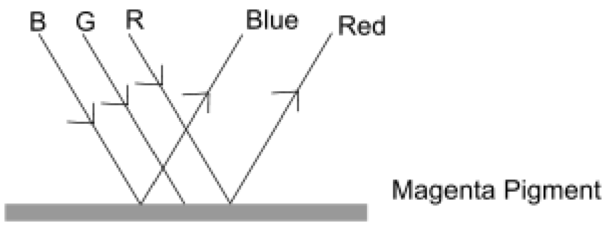
APPEARANCE OF COLOUR PIGMENT IN THE WHITE LIGHT .



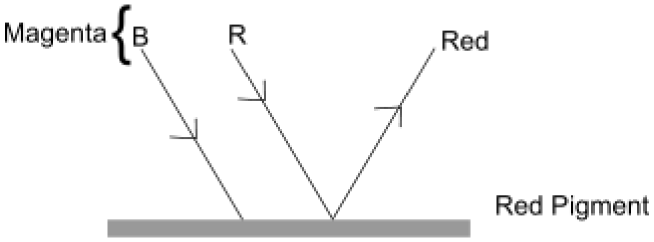
A colour pigments reflects only one colour .

APPEARANCE A COLOUR PIGMENT IN COLOURED LIGHT

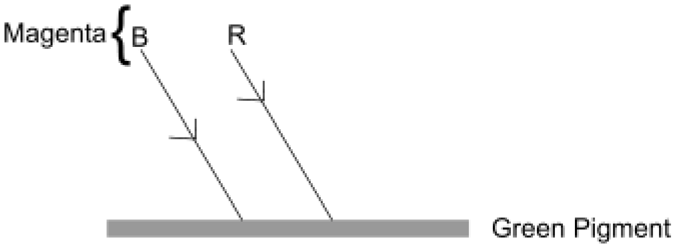
(a.) Magenta pigment reflects two colours of light i.e. blue and red when white light is incident on it



(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.



- 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, take away and saloons to give a false magnification as a result of multiple reflections.