

VECTORS AND SCALARS

Quantities are divided into two groups (types).

1. Scalar quantities which have magnitude or size only.

Example

- Distance
- Speed
- Mass
- Temperature

1. Vector quantities which have both magnitude and direction.

Example

- Displacement
- Velocity
- Acceleration
- Force etc

VECTOR DIAGRAM

Since a vector has a magnitude and direction it can be represented by a vector diagram i.e. line which is drawn to scale to represent the magnitude of the vector and an arrow on it to give its direction i.e. a particle displaced three to the north, this describes a displacement suppose our scale is 1cm well then draw a 3cm line pointing north ward



Vector addition

Since vectors can be represented by a vector diagram. It is very possible to add two vector or more. A vector which is a sum of a vector is called a resultant vector. It represents a number of vector in magnitude and direction. The effect of the single vector will be the same as that of a number of vectors.

Example

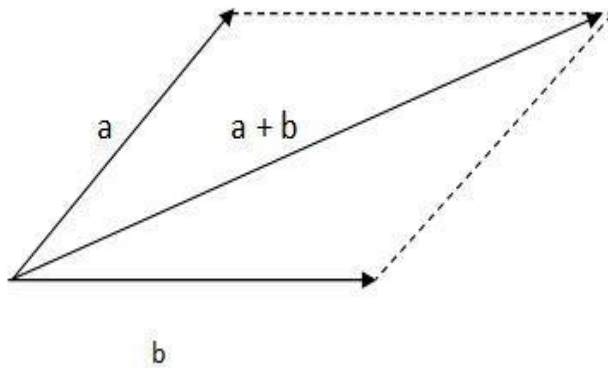
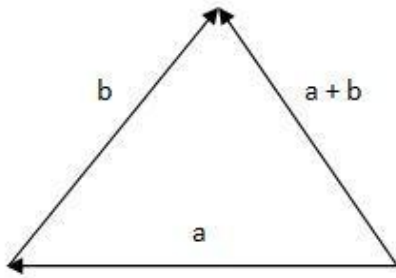
Let two ropes pull the same body in different directions. The resultant force will be the net effect of the two ropes acting on a body. There are two methods of vector addition

1. The triangle law of vector addition
2. The parallelogram law of vector addition usually we do use the head to tail of the second vector is placed at the head of the 1st vector and the tail of the 3rd vector at the resultant vector will then be formed by joining the tail of the 1st vector to the head of the last vector. Always drawing the vector to scale imagining to do and the proper direction.

THE TRIANGLE LAW OF VECTOR ADDITION

States that " If two vectors in sequence represent the two sides of triangle in magnitude then the third side of the triangle will give the resultant vector"

When drawing the head of the first vector should be followed by the tail of the second vector . The third side which represents the resultant vector should be drawn from the tail of one vector and the head of another vector .



The two vectors should be drawn in such away that, tail of one vector joins the tail of another vector and the resultant vector should be drawn from the common point .

Example :

1. Find the resultant force of the two forces $15n$ and $9n$ acting on a body making an angle of 60° between them

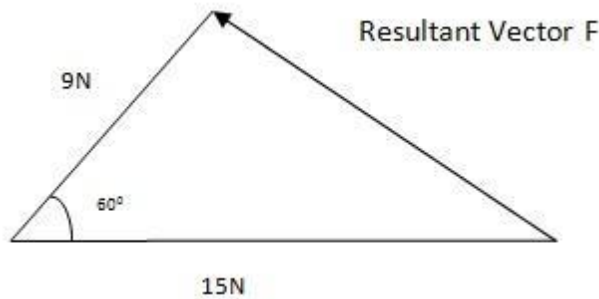
Solution

Choose scale

Let one centimeter represent $3n$

The 15N force will be represented by 5cm and the 9N force by 3cm

Draw a 5cm line using your ruler and pencil at its head measure an angle of 60° using your protractor and placing the tail of the 2nd forces draw a 3cm line



By Pythagoras theorem

$$F^2 = 6^2 + 8^2$$

$$F^2 = 36 + 64$$

$$F = 10 \text{ ans}$$

If properly drawn the length F in the diagram is 5cm

According to our scale the actual force will be $5 \times 2 = 10\text{N}$

So to count the two forces a force of 10N acting in the other direction F would be required

THE PARALLELOGRAM LAW OF VECTORS ADDITION

This law is also applicable on adding two velocities just like the triangle law it states that

If two adjacent sides of a parallelogram represent two vectors then the diagonal line of the parallelogram will represent the resultant vector through their common point.

Example

If two forces of 20N and 40N are acting on a body such that they make an angle of 45° between them find their resultant force by using the parallelogram law

Solution

As usual choose a scale 1st

Let 1cm=5N

The 20N force will be represented by 4cm and the 40N force by a line of 8cm

Then draw these two forces as adjacent side of the parallelogram with an angle of 45° between them.

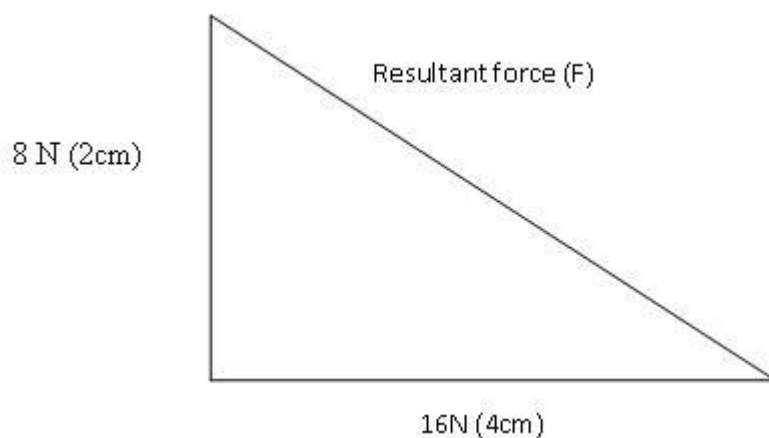
Then diagonal lines will represent the resultant force

Class work

Find the resultant force when two forces 8N and 16N from the following angles below

1. 45°
2. 60°
3. 120°

Solution



The resultant vector length is 3cm

The actual force is $3\text{cm} \times 4\text{N} = 12\text{N}$

The long resultant vector length is 3.5cm

The actual force is $3.5\text{cm} \times 4\text{N} = 12.20\text{N}$



The diagonal line of length 11.2cm and per our scale actual force(F)

$=11.2 \times 5$

$=56.0\text{N}$

So the resultant force is 56N

RELATIVE VELOCITY

Definition

This is the velocity of a body with respect to another moving body as observed by a stationary observer

Example

1. Speed of an air plane may be observed by a person observer on the ground to be increased by a tail wind or reduced by head wind. So the wind and the plane are both moving related to one another but the observer is stationary.
2. The speed of a boat in a river may also be observed by an observer at the river bank to be increased downstream or decrease up stream. Again the boat and the water are moving relative to one another but the observer stationary.

Example Suppose a plane is flying at a velocity of 100 km/hr and wind is blowing at a velocity of 25 km/hr if the blowing wind is a) head a) tail

Find the resultant plane velocity relative of to an observer on the grounds

Solution

1. Head wind is “opposing” and so will reduce the velocity

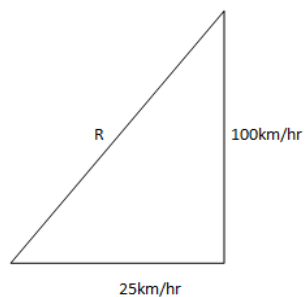
$$\begin{aligned}\text{Result velocity} &= 100 \text{ km/hr} - 25 \text{ km/hr} \\ &= 75 \text{ km/h}\end{aligned}$$

1. Tail wind “adding” or pushing agent so will increase the velocity

$$\text{Resulting velocity} = 100 \text{ km/hr} + 25 \text{ km/hr}$$

$$\text{These velocity} = 125 \text{ km/hr}$$

These velocities are of the plane relative to an observer on the ground



By Pythagoras theorem

$$R^2 = (100)^2 + (25)^2$$

$$=10000 + 625$$

$$R^2 = 10,625$$

$$= 103.1 \text{ KM/HR}$$

From the diagram to get directions of the resultant velocity were

$$\cos\theta = \frac{\text{ADJACENT}}{\text{HYPOTENUS}}$$

$$\cos\theta = \frac{100 \text{ km/hr}}{103.1 \text{ km/hr}}$$

$$\cos = 0.9708$$

$$\theta = 14^\circ$$

It will make an angle of 14° , with the south ward direction

RESOLVING VECTORS

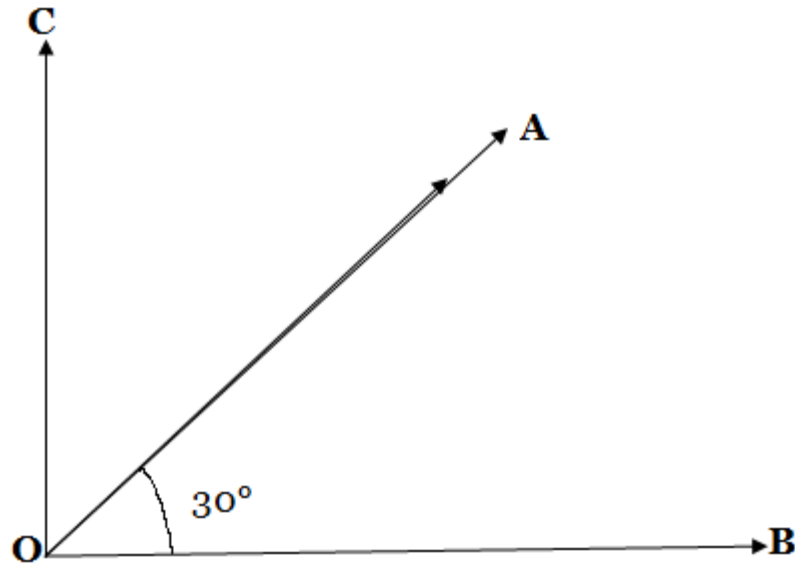
Vectors can be resolved in the vertical and horizontal components

This is because sometimes only part of the vector is used

Example

1. Suppose a lawn mower is pushed with a force missing at a direction of 30° to the ground. That of the force which pushes the mover horizontally is called its resolved horizontal component while the other part which presses the mover vertically into the ground is called its resolved vertical components.

The resolved components can be found by using the parallelogram law.



Force components of CB are represented by OA and OB, since OCAB is a rectangle so OB has no effect in the direction of the force component OC, likewise OC has no effect in the direction of OB.

The resolved components of OA, the vertical direction is OC and a horizontal direction is OB

$$\text{From } \cos 30^\circ = \text{OB/OA}$$

since OBA is a right angled triangle

$$\text{OB} = \text{OA} \cos 30^\circ$$

$$\text{OA} = \text{OB} / \cos 30^\circ$$

Note:

This downward force is balanced by the upward reaction of the ground

Example

Consider picture of weight 5N that is supported by a string on a nail at $\cos 50^\circ$

The tension T at A and B together support the weight. Let the string at A and B make angles of 50° with the vertical

The vertical component of T at A = $T \cos 50^\circ$

FRICTION

Definition

Friction:

Is the type of force which tends to oppose relative motion between two surface in contact.

When two bodies are in contact their molecules are so close so as to establish attractive force known as adhesive force, so far any movement between such bodies should overcome those adhesive forces.

Laws of friction.

These are laws governing Frictional force these include

1. Frictional Force is directly proportional to the normal reaction between the two surface in contact

i.e. $F \propto R$

$$F_f = R$$

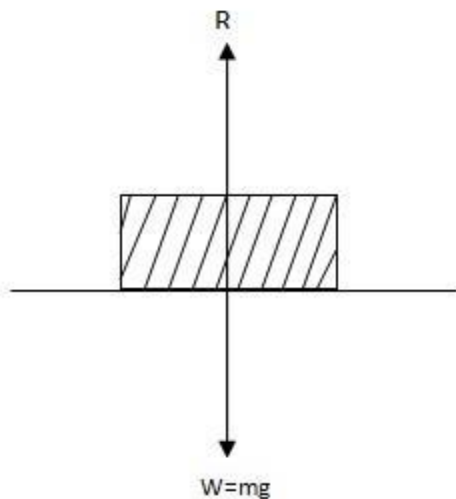
Where F_f = Friction Force

R = Normal reaction and

μ = Coefficient of friction

Note: The coefficient of friction depends on the types materials in contact.

NORMAL REACTION



Normal reaction (R) is that force which is equal weight of a body in magnitude but opposite in direction.

There are two main types of friction:

STATIC AND DYNAMIC

Static Friction

This one occurs when the bodies are trying to move relative to one another but not yet moving.

Dynamic (or kinetic) Friction

1. It occurs when the bodies in contact are already moving relative to one another.

Note

The coefficient of dynamic friction is less than the coefficient of static friction

2. Usually it requires less force for keeping an object that is already moving in motion than to make it start moving.

Coefficient of friction

From the law of friction we have seen that

$$F_f = \mu R = \mu F_f / R$$

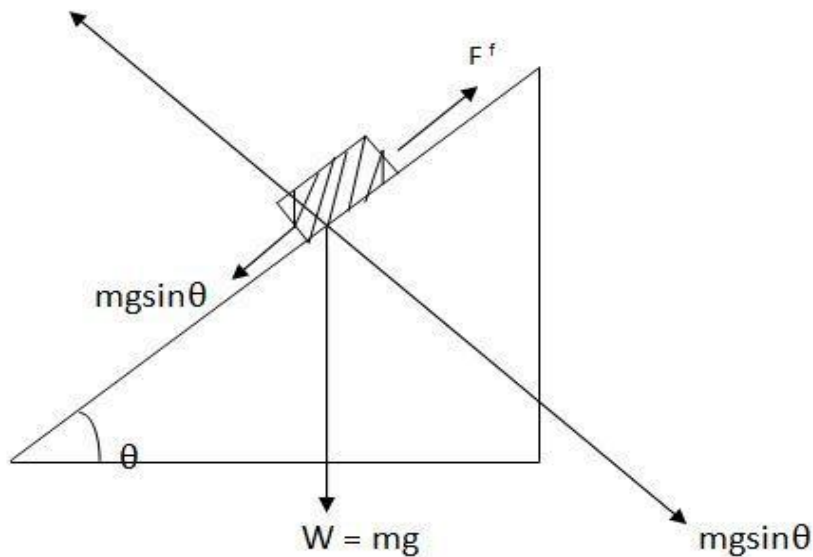
The coefficient of static Friction μ_s given by

$$\mu_s = \frac{\text{Static friction } F_f}{\text{Normal Reaction } R}$$

Likewise the coefficient of dynamic μ_k friction is given by

$$\mu_k = \frac{\text{Dynamic Friction } F_f}{\text{Normal Reaction } R}$$

Forces acting on an object on an inclined plane



Consider a body of mass M that is placed on an inclined plane whose angle of inclination is θ . The component of weight parallel to the inclined plane is given by $mg \sin \theta$. This horizontal component tends to pull the object down the slope. The second component of the object's weight is perpendicular to the inclined plane and is equal to $mg \cos \theta$. This is equal in magnitude to the normal reaction.

When the object is just about to start sliding down the slope

$$F_f = mg \sin \theta \text{ and } R = mg \cos \theta$$

$$\text{But } \mu = \frac{F_f}{R} = \frac{mg \sin \theta}{mg \cos \theta} = \tan \theta$$

$\mu = \tan \theta$

Examples

1. A block of mass 270kg is pulled on a horizontal surface. If the coefficient of kinetic friction between the one block and the surface is 0.4. What is the force acting on the block as it slides?

Solution

$$\text{Mass } m = 270 \text{ kg}$$

$$\mu_k = 0.4$$

$$g = 10 \text{ N/kg}$$

$$\mu_k = F_k / R$$

$$F_k = ?$$

$$F_k = \mu_k \times R$$

$$\text{But } R = mg$$

$$F_k = \mu_k \times mg$$

$$= 0.4 \times 270 \text{ kg} \times 10 \text{ N/kg}$$

$$\underline{F_k = 1080 \text{ N}}$$

2. A box of mass 2kg rests on a horizontal surface a force of 4.4N is required to just start the box moving what is the coefficient of static friction between the box and the surface? Take $g = 10 \text{ N/kg}$

Solution

$$\text{Mass } m = 2 \text{ kg}$$

$$F_s = 4.4 \text{ N}$$

$$g = 10 \text{ N/kg}$$

$$\mu_s = ?$$

$$F_s = \mu_s \times R$$

$$\text{But } R = mg$$

$$F_s = \mu_s \times mg$$

$$4.4 = \mu_s \times 2 \text{ kg} \times 10 \text{ N/kg}$$

$$0.22 = \mu_s$$

$$\underline{\mu_s = 0.22}$$

Limiting friction

It is special type of static friction

Limiting friction is defined as the maximum static friction which must overcome before body starts to move.

Limiting friction $F_R = \text{Coefficient of friction} \times \text{Normal reaction}$

Advantages of friction

1. It enables us to walk, also in movement of car tyres.
2. Moving objects are brought to stop by application of brakes which makes use frictional force.
3. Used to wear out unneeded layer part during sharpening and grinding of metal parts.

Disadvantages

1. Friction between movable parts of machines causes wear and tear in the machines.
2. Friction leads to loss energy in the form of heat and or sound in machines ref industrial.
3. It cause moving bodies to slow down
4. Heat cause by friction cause appliances to burn

Increasing friction

As we saw earlier some advantages and therefore sometimes it's necessary to increase the frictional force how?

1. By increasing the normal force (i.e. Reaction). Between the surface in contact. This can be achieved by pressing the surface together.
2. Changing the roughness of the surface in touch e.g. car type tyre increase friction between the tyre and the road also spics on football shoes increase friction between the shoes and the football pith/ Ground.

Adding grit to a sand paper improves it scrubbing ability

3. Scrubbing equipment is made rough to increase friction e.g. Steel wire for scrubbing "surface"
4. By using materials with a high coefficient of friction e.g. Rubber which used in making car trees has a high coefficient of friction.

Reducing Friction

We came cross some disadvantage of friction and hence there are situation where we have to minimize the friction. How?

1. By using lubricants e.g. Oils and greases helps to reduce tear and ware in machine parts.
2. Using speedy materials e.g. Teflon which have a low coefficient of friction

Note

Teflon – is a type of plastic that slide easily.

3. By using ball bearings and rulers. These are reducing the points of the contraction the object hence changing sliding friction into much smaller rutting friction.

Examples

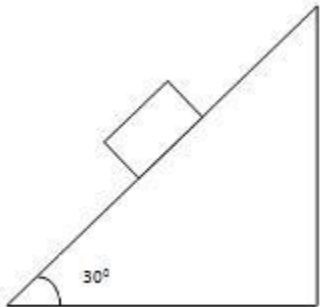
A box of mass 5kg at rest on a wooden floor. If the coefficient of static friction between the box and the floor 0.6, what minimum external force is required to set the box sliding ($g = 10 \text{ N/kg}$)

Solution

$$\begin{aligned} F_s &= \mu_s R \\ &= 0.6 \times 5 \text{ kg} \times 10 \text{ N/kg} \\ &= 30 \text{ N} \end{aligned}$$

Exercise

1. Find the coefficient static friction between a block of wood of mass 10 kg placed on a table. A minimum force of 50N is required to make the block just moved on the table.
2. A mass is placed on an inclined plane such that it can move at constant speed when slightly pushed. If the angle on the plane makes with the horizontal plane is 30° . Find the coefficient of dynamic friction



What is the normal reaction of a body of mass 10kg placed on an inclined plane of angle 30°

LIGHT

INTRODUCTION:

The simplest kind or types of mirrors are those which are of spheres. If the polished surface bulges outside, it is concave and if it bulges inwards it is a convex.

Concave mirrors

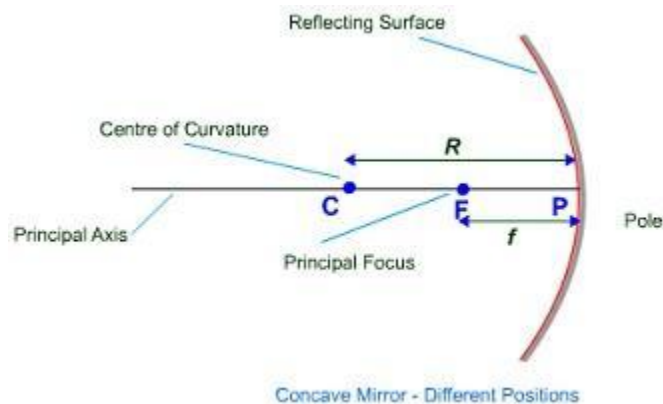
A concave mirror is formed by the silvering the outside part of a piece of glass which would form part of a hollow sphere.



NOTE: a concave mirror is sometimes referred to as converging mirror.

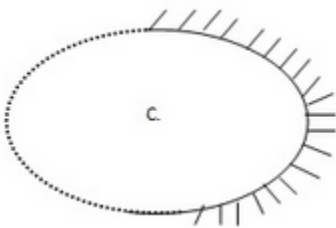
Useful terms on concave mirrors

In order to locate the position, size and nature of the image formed on the concave mirror, the following terms are very useful.



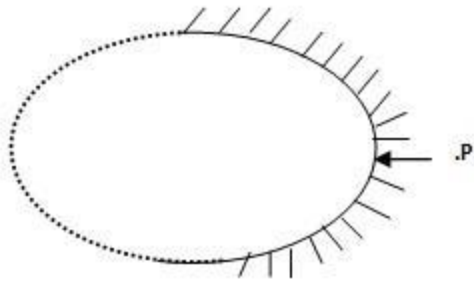
The center of the curvature

1. The centre of the curvature is the centre of the sphere on which the concave mirror is part of.



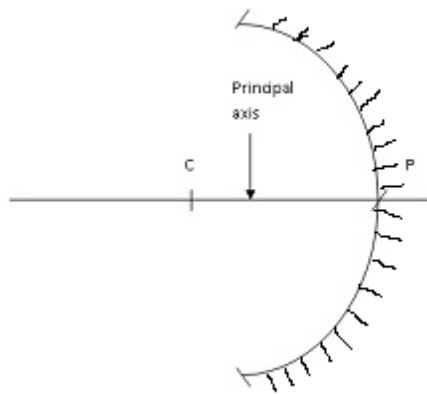
1. Pole p

The pole is the centre of the arc of the concave mirror.



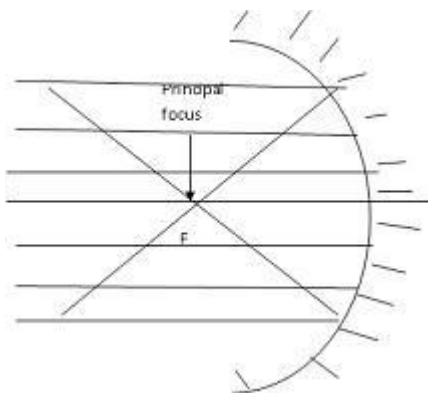
2. The principle axis

The principle axis is the line joining the centre of curvature C , and the pole P of the concave mirror.



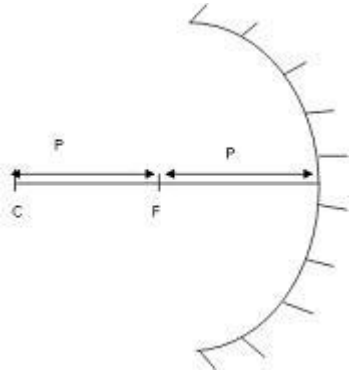
3. Principle focus(F)

The principle focus is the point where a beam of rays of light parallel to the principle axis falls on the concave mirror appears to converge after the reflection.



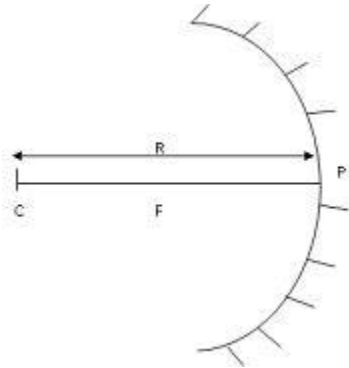
4. Focal length(f)

This is the distance between the principle focus (F) and the pole P



5. **Radius of curvature.**

This is the distance between the centre of curvature C and the pole P of the concave mirror



Such that

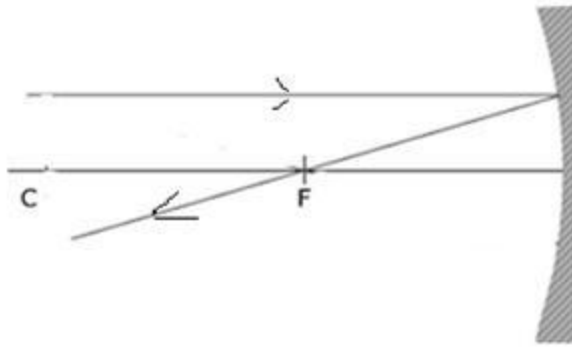
$$R = 2f$$

$$f = \left(\frac{1}{2}\right) R$$

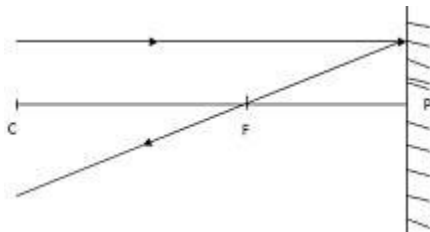
The formation of images on the concave mirror

The following rules are used to draw ray diagrams for concave mirrors.

1. Any ray parallel to the principal axis is reflected through the principal focus (F)

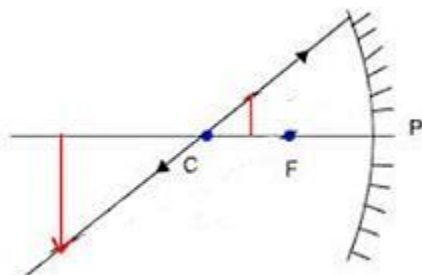


2. Any ray passing through the principle focus f is reflected parallel to the principle axis.



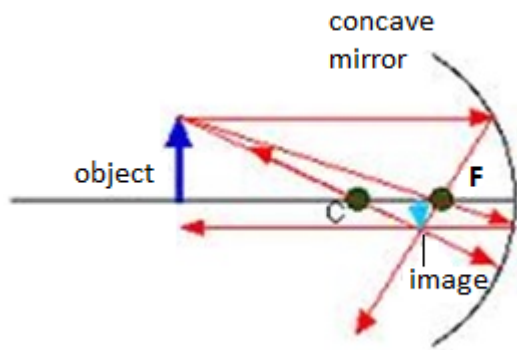
3. Any ray passing through the centre of curvature C hits the mirror at right angles and is reflected straight back through the centre of curvature C .

Note: the position, the size and the nature of the image formed on a concave mirror depends very much on the position of the object.



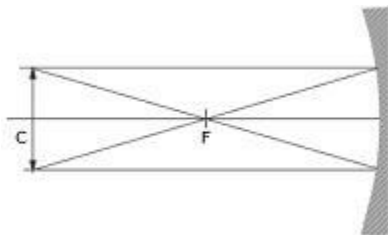
Example

1. When an object is placed beyond the centre of curvature



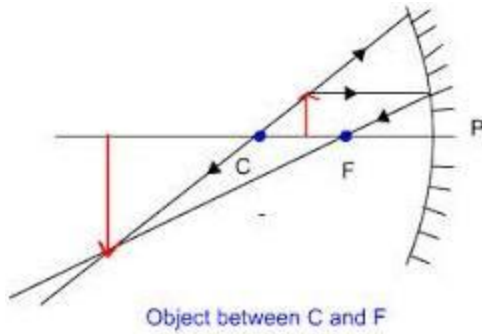
- The image I forms between C and F
- The image I is diminished.
- The image I is real
- The image I is inverted (upside down)

2. When an object is placed exactly at the centre of curvature C.



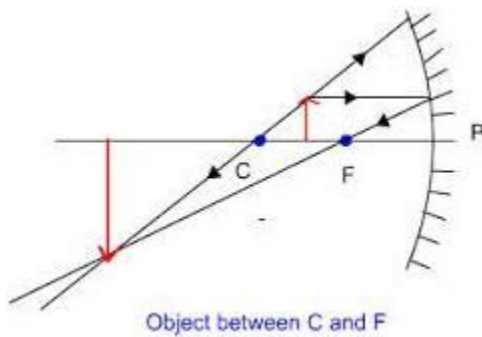
- The image I form at C.
- The image I is exactly the same size.

3. When an object is placed between the centre of curvature C and the principle focus F



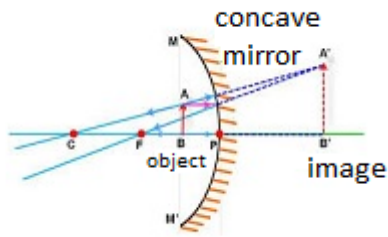
- The image I form beyond C
- The image I is magnified.
- The image I is inverted that means it's a real object.

4. When an object is placed exactly at F



- The image I is formed beyond the centre of curvature at infinity.
- The image I is highly magnified.
- The image I is real.
- The image I is inverted (upside down).

5. When an object is placed between F and P.



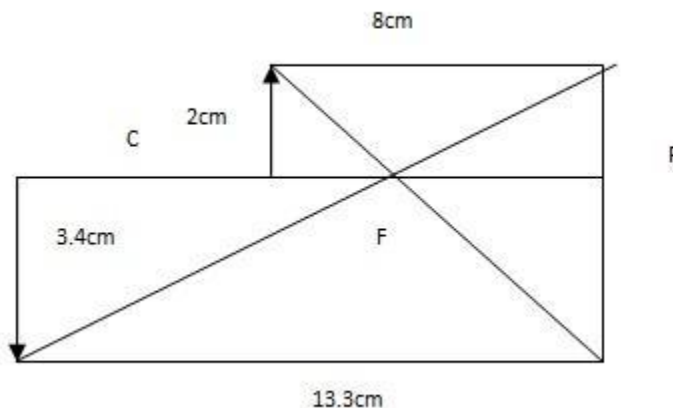
- The image is formed behind the mirror.
- It is vertical (erect upright)
- It is magnified
- It is real.

NOTE: in most cases the images formed on the concave mirror are real except that when objects are placed between the principal focus (F) and the pole (P), the image formed on the concave mirror is virtual.

THE FORMATION OF IMAGES BY GRAPHICAL METHOD

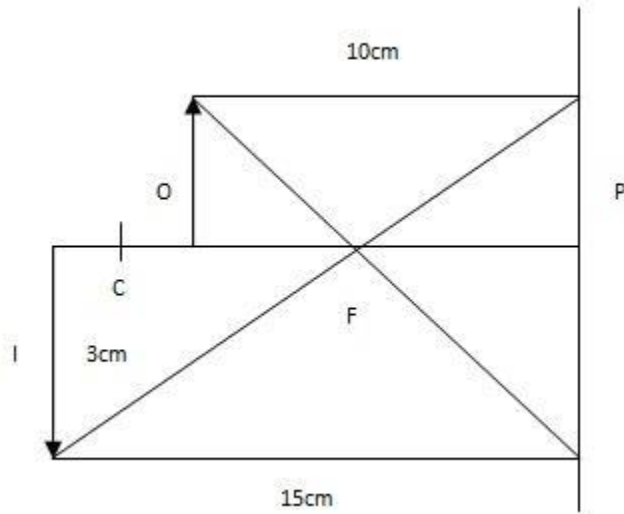
Questions

1. An object 2cm high is erected 8cm in front of a concave mirror of radius of curvature 10cm. by graphical method, find the position, size and nature of the image.



Therefore, the image is formed at 13.3 cm in front of a concave mirror and the size of the image is 3.4 cm. It is magnified because the object was 2cm but the image is 3.4 cm. The image is real.

2. A small spring is 4 cm long is kept at 10cm in front of the converging mirror of radius of curvature 12 cm. By scale drawing, determine the position, size and state the nature of the image formed.



This image is 15 cm in front of the mirror, height of 3 cm and it is magnified and is real.

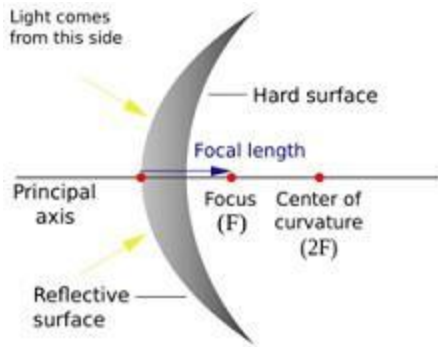
THE CONVEX MIRROR (Diverging mirror)

They are mirrors formed by silvering or painting the inside parts of the pieces of the glasses which would form parts of the hollow spheres.

Convex mirror

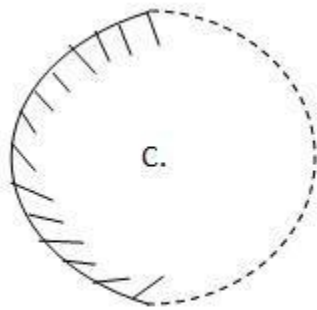


Useful terms in a convex mirrors.



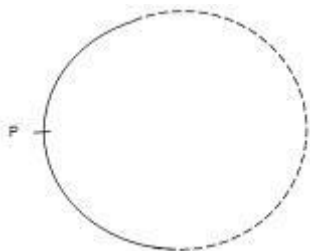
1. The centre of curvature.

The centre of curvature of the convex mirror is the centre of the hollow sphere in which the convex mirror is part of.



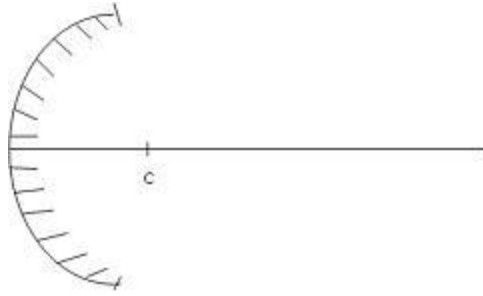
2. The pole of the convex mirror, P

This is the centre of the arc of the mirror.



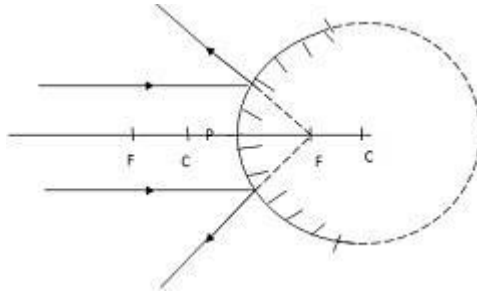
3. The principle axis of the convex mirror.

This is the line joining the centre of curvature C and the pole P of the convex mirror.



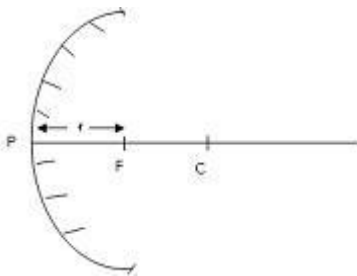
4. The principle focus f

The principle focus of the convex mirror is a point where a beam of rays of light parallel to the principle axis falls on the convex mirror appears to diverge after deflection.



5. Focal length.

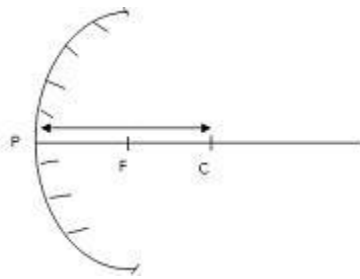
Focal length is the distance between the pole P and the principle focus f.



Such that $\overline{PF} = \overline{FC} = f$

6. Radius of curvature.

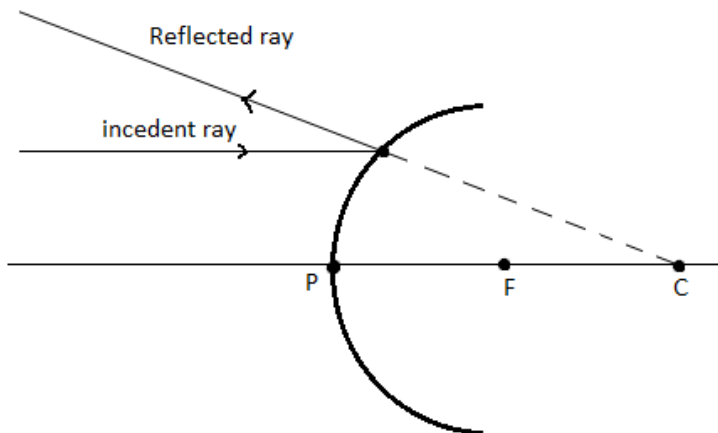
Is the distance between the centre of curvature C and the pole P.



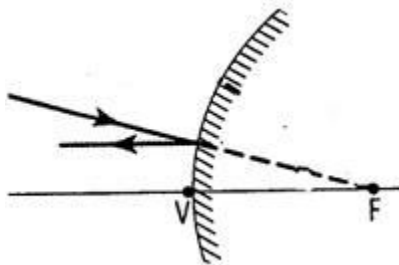
Such that; $2f = R$

RULES FOR THE RAY DIAGRAM CONSTRUCTION

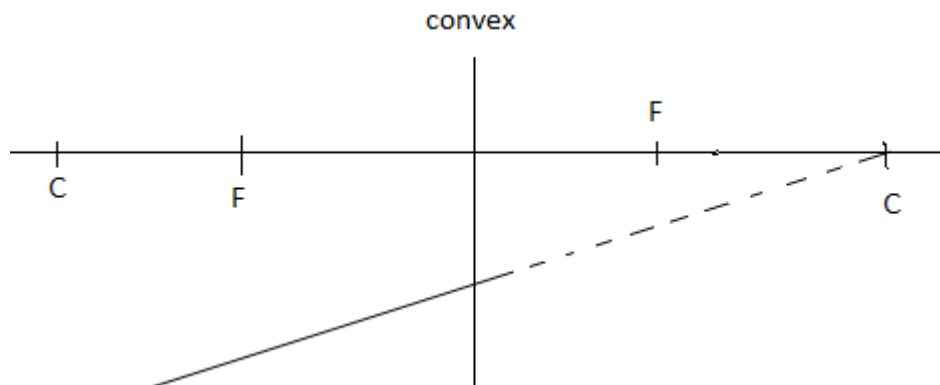
1. Any ray passing parallel to the principle axis appears to diverge from the principle of focus F after reflection.



2. Any ray passing through the principle of focus f appears to diverge parallel to the principle of axis.



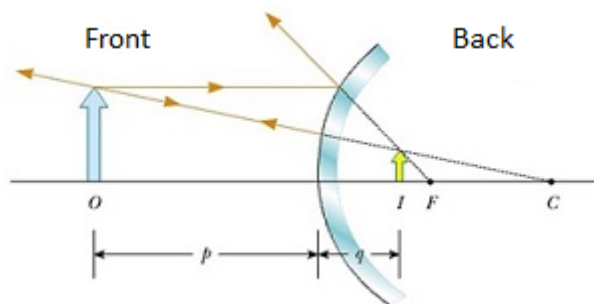
3. Any ray passing through the centre of curvature appears to come straight back.



Formation of images on the convex mirror

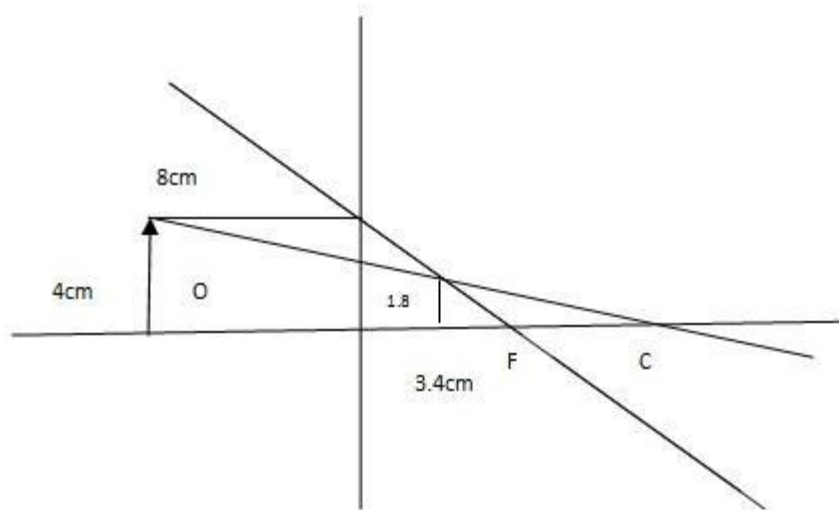
Image formed in a convex mirror are independent of the position always have the following characteristic.

1. Is smaller than object (diminished)
2. Formed between f and the mirror
3. Image is erect
4. Virtual image are formed (behind the mirror)



EXAMPLE

1. An object of 4 cm high is placed 8cm in front of a convex mirror of radius of curvature 12cm. By scale drawing, find the position, the size and the nature of the image formed.



The image formed is diminished by 1.8cm

The image is virtual (erect)

The image is formed between F and P by 3.4 cm.

THE MIRROR FORMULA

To express the qualitative relationship between the object distance (U) the image distance (V) and the focal length of the mirror shown by the letter (f). The following equation is appropriate.

$$\frac{1}{f} = \frac{1}{U} + \frac{1}{V}$$

REAL IS POSITIVE SIGN CONVENTION

FOR A CONCAVE MIRROR

- The focal length of the mirror is positive.
- The object distance is positive.
- The image distance may be positive or negative depending on the position of the object from the mirror. Why?

Because a concave mirror can produce both real and virtual images

FOR A CONVEX MIRROR

- The focal length of the mirror is negative.
- The object distance is positive.

- The image distance may be negative.

THE MAGNIFICATION OF THE IMAGE SHOWN BY “M”

The magnification of the image is the ratio of the image distance to the object distance.

Mathematically;

$$\text{Magnification} = \frac{\text{image distance}}{\text{object distance}}$$

$$M = \frac{V}{U}$$

OR

$$\text{Magnification} = \frac{\text{image height}}{\text{object height}}$$

$$M = \frac{H_I}{H_O}$$

Magnification of an image is the ratio of the image height to the object height.

Mathematically;

Lateral magnification.

EXAMPLES

1. A small pin 3cm high is placed 30 cm away from a concave mirror of focal length 12cm. By using the mirror formula, find the position, the height and the nature of the image formed.

Solution

Data; - using real is positive sign.

- Focal length $f = + 12 \text{ cm}$
- Object distance $= 30\text{cm}$
- Image height $H_i =$
- Object height $H_o = 3\text{cm}$
- Image distance $V = ?$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{12} = \frac{1}{30} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{12} - \frac{1}{30}$$

$$\frac{1}{v} = \frac{1}{20}$$

$$v = 20$$

$$m = \frac{v}{u} = \frac{H_i}{H_o}$$

$$m = \frac{20}{30}$$

$$m = \frac{2}{3}$$

$$m = \frac{H_i}{H_o}$$

$$H_i = 3 \times \frac{2}{3}$$

$$H_i = 2$$

The position of the image is 20cm in front of the mirror and is 2cm high and is real, inverted and diminished.

2. An object 3cm high is placed 20cm in front of a concave mirror of focal length -25cm. Describe the image formed.

1. Solution

Real is positive sign convention

Object distance $U = 20\text{cm}$

Image distance $V = ?$

Height of object = 3cm

Focal length = -25cm

Image height $H_i = ?$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$-\frac{1}{25} = \frac{1}{20} + \frac{1}{v}$$

$$\frac{1}{v} = -\frac{1}{25} - \frac{1}{20}$$

$$\frac{1}{v} = \frac{-4-5}{100}$$

$$\frac{1}{v} = -\frac{9}{100}$$

$$v = -11.1$$

The image is formed 11.1 cm behind the mirror.

$$m = \frac{v}{u}$$

$$m = \frac{11.1}{20}$$

=

$$M = 0.555$$

$$m = \frac{H_i}{H_o}$$

$$H_i = 0.555 \times 3$$

$$H_i = 1.665$$

The image is upright, diminished and virtual, plus it is formed behind the mirror.

3. An object 2cm high is situated on and perpendicularly to the axis of the concave mirror of radius of curvature 30cm and is 10cm from the mirror, Find by calculation the position and size.

1. Solution

DATA: real is positive sign convention.

Focal length = 15

Object distance V=

Image distance U =

Height of image H_i =

Height of object H_o =

Image height = 2cm

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{15} = \frac{1}{10} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{15} - \frac{1}{10}$$

$$\frac{1}{v} = \frac{2-3}{30}$$

$$V = -30$$

APPLICATIONS OF REFLECTION IN LIFE

1. Driving Mirrors

The convex mirrors produce a very wide field of views but the images are diminished. The convex mirrors therefore are used as driving mirrors (side mirrors) in the cars.

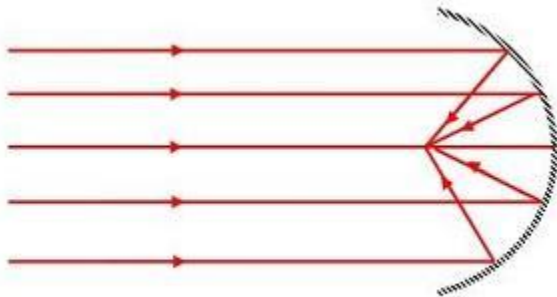
2. Shaving Mirrors

The concave mirrors are used as shaving mirrors

3. Reflectors of Light

The concave mirrors are used as reflectors of lights such as in car head lamps or in the torch.

In the parabolic mirror/ reflector is required in order to produce a wide and strong parallel beam of light.



Parabolic mirror focuses all rays onto the principal focus, without spherical aberration.

The filament of the torch or bulb is placed at the principle focus of the parabola reflector.

The concave mirror curved parabolic reflects are used for amplification purposes such as satellite dishes.



Satellite dishes

EXPERIMENT

To determine the focal length of the concave mirror by non parallax method

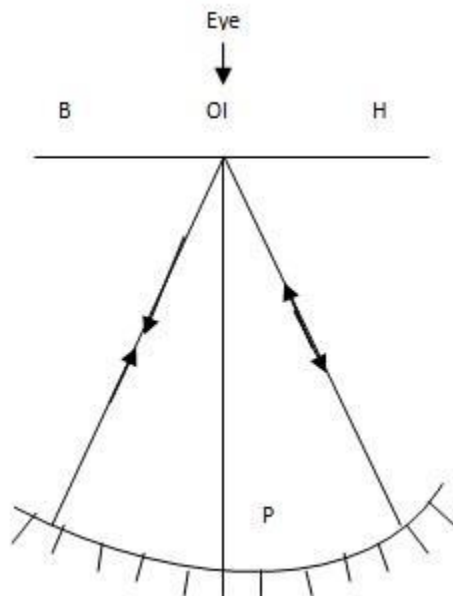
1. Place a concave mirror on a table with its reflecting surface facing upwards.
2. Clamp an optical pin OB above the mirror so that the tip of the pin is directly above the pole P of the mirror.
3. Looking down at the arrangement from above move the optical pin OB up until an inverted image IM of the object is seen.
4. Move the pin up and down until it coincides with its sharp image.
5. Looking from above, move your head from side to side to check if there is any relative motion (parallax) between the optical pin and its image.
6. If there is no relative motion (no parallax) between the pin and its image, then the pin and its image are both at the centre of the curvature of the mirror.
7. Measure the distance from the tip of the pin to the pole P of the mirror, this is the radius of curvature of the mirror.

Focal Length

In this position, the object and its image are of the same size.

The focal length of the concave mirror is obtained by dividing the distance r by 2. Thus focal

length $f = r/2$.



THE REFRACTION OF LIGHT

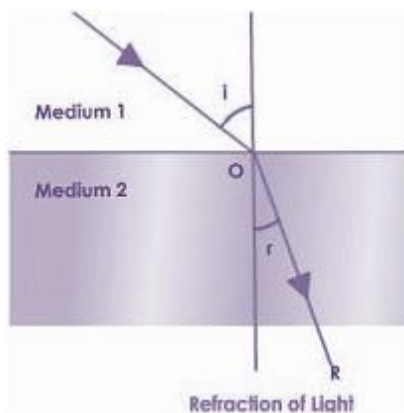
Introduction

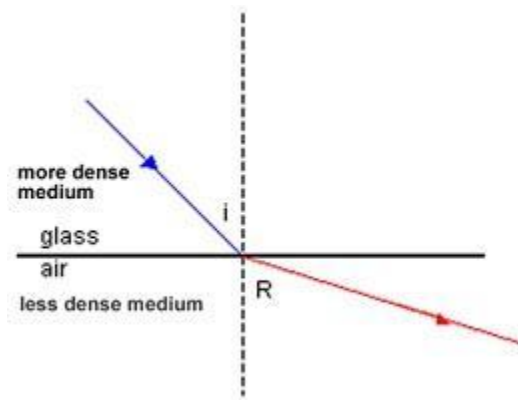
Light travels in a straight line if and only if the medium through which the light travels does not alter/ change. If the light travels from one medium to another, the direction of travel changes at the point through which it crosses the first medium to the second. Light bends when traveling in different medium due to the change in speed caused by the densities of different media.

Definition

Refraction: Is the tendency in which light bends or changes its direction of travel when crossing from one medium to another.

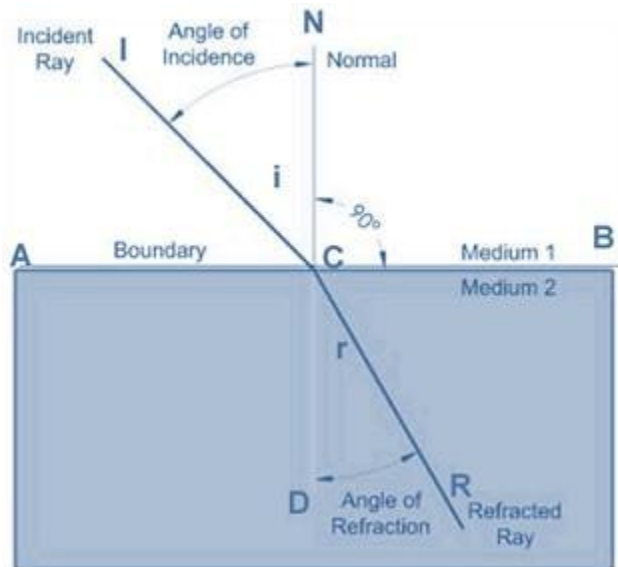
NB: Even though the light bends when crossing from one medium to another, it still travels in a straight line in the same medium.





KEY CONCEPTS

Consider the diagram below.

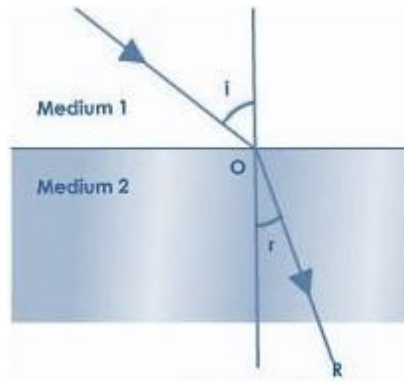


1. The beam of light IC is called incident ray which is always in the first medium.
2. The beam of light CR is called refracted ray which should always be in the second medium.
3. The line ACB is called a plane of incidence or boundary or line which separates the two media.
4. The line perpendicular to AB is the line NB which is called the normal ray (this intersects with line AB at right angles at point C)
5. The angle between the incident and the normal ray is called an angle of incidence (i) measured in degrees.

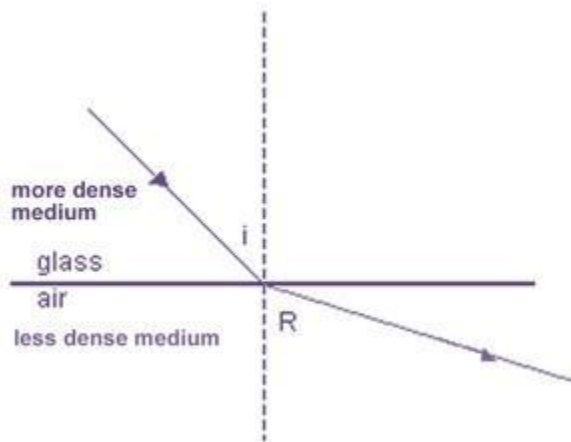
6. The angle between the refracted ray and the normal ray is called the angle of refraction (r) measured in degrees.

1. The Characteristics of the refraction of light

1. The beam of light is refracted towards the normal if and only if it travels from a less dense medium to a high dense medium due to the fact that the light travels faster in less dense medium than in high dense medium.

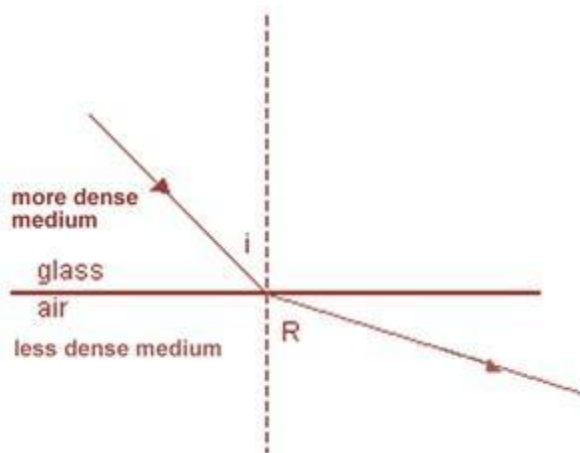


2. The beam of light is refracted away from the normal if and only if it travels from high dense medium to low dense medium due to the fact that light travels faster in less dense media than in high dense media.



LAWS OF REFRACTION OF LIGHT

The first law states that; “*the incident ray, normal ray and refracted ray all are located on the same plane of incidence.*”



NOTE: conduct a simple experiment where by a beam of light is allowed to travel from one medium (less dense) to another medium (high dense). Record different angles of incidence and refraction in the table below

I	r	Sin i	Sin r	Sin i Sin r
i_1	r_1	$\sin i_1$	$\sin r_1$	C
i_2	r_2	$\sin i_2$	$\sin r_2$	C
i_3	r_3	$\sin i_3$	$\sin r_3$	C
i_4	r_4	$\sin i_4$	$\sin r_4$	C
i_5	r_5	$\sin i_5$	$\sin r_5$	C
i_6	r_6	$\sin i_6$	$\sin r_6$	C
i_7	r_7	$\sin i_7$	$\sin r_7$	C

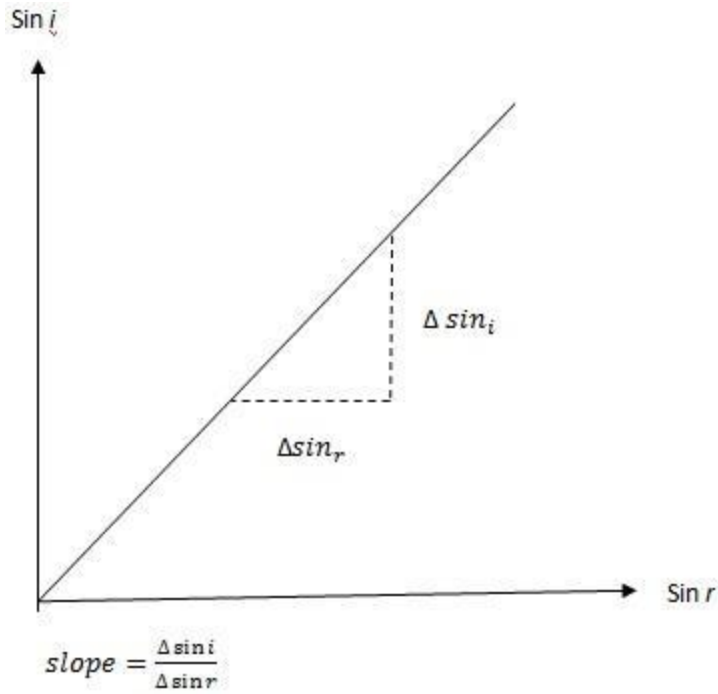
OBSERVATION

It will be noted that the ratio of $\sin i$ to $\sin r$ for values of i and r for a given pair of medium is constant.

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

NOTE; when the graph of $\sin i$ against $\sin r$ is plotted, the line graph passes through the origin.

i.e. slope is constant.



i.e. slope is constant.

The second law states that (Snell's law) *"the ratio of the sin of an angle of incidence to the sin of an angle of refraction is a constant for a given pair of medium"*

NB: the physical meaning of constant is the refractive index denoted by μ

Refractive index

This is the measure to what extent the light bends or changes direction from one medium to another.

Hence

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

Or

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

Or

Suppose light travels from our medium to glass.

$${}_a\mu_g = \frac{\Delta \sin i}{\Delta \sin r}$$

Suppose light travels from air to water.

$${}_a\mu_w = \frac{\Delta \sin i}{\Delta \sin r}$$

Suppose light travels from glass to water.

$${}_g\mu_w = \frac{\Delta \sin i}{\Delta \sin r}$$

NOTE: the refracting index can be given in terms of the ration of the velocity of light in air to the velocity of light in a different medium.

Mathematically;

$${}_a\mu_{\text{medium}} = \frac{\text{velocity of light in air}}{\text{Velocity of light in medium}}$$

$${}_a\mu_{\text{medium}} = \frac{v_a}{v_{\text{Medium}}}$$

The light from air to glass.

$${}_a\mu_g = \frac{v_a}{v_{\text{Medium}}}$$

The light from water to glass.

$${}_w\mu_g = \frac{v_w}{v_{\text{Medium}}}$$

NB: the refractive index between vacuum or air and any other material is called absolute refractive index.

Or simply b

Refractive index of second medium.

E.g. the light from air to glass

$${}_a\mu_g = \mu_g$$

Generally

$${}_a\mu_{\text{medium}} = \mu_{\text{medium}}$$

NB: if none of the two media is air or vacuum, the refractive index is called relative refractive index.

Suppose light travels from water to glass, the refractive index of glass with respect to water is

$${}_w\mu_g = \frac{v_w}{v_g}$$

Some refractive index of mediums

Medium	Refractive index
Ethyl alcohol	1.36
Glass	1.52
Quartz	1.55
Water	1.33 or 4/3
Air	1.00

NB: the refractive index for light traveling from a dense medium to a less dense medium is equal to the reciprocal of the refractive index for light from the less dense to the denser medium.

Example 1

The refractive for light traveling from air to water is 1.3. fin the refractive index of light travelling from water to air.

Solution

Data

$${}_w\mu_a = \frac{1}{{}_a\mu_w}$$

$${}_w\mu_a = \frac{1}{1.3}$$

$${}_w\mu_a = 0.7693$$

Example 2

If the light has a velocity of 3×10^8 and has a velocity 1.97×10^8 m/s in the glass.

1. What is the refractive index of the glass?
2. Calculate the refractive index for light traveling from glass to air.

Solution

- 1.

$$\begin{aligned}
 {}_a\mu_g &= \frac{V_a}{V_g} \\
 &= \frac{3 \times 10^8}{1.97 \times 10^8} \\
 &= 1.52
 \end{aligned}$$

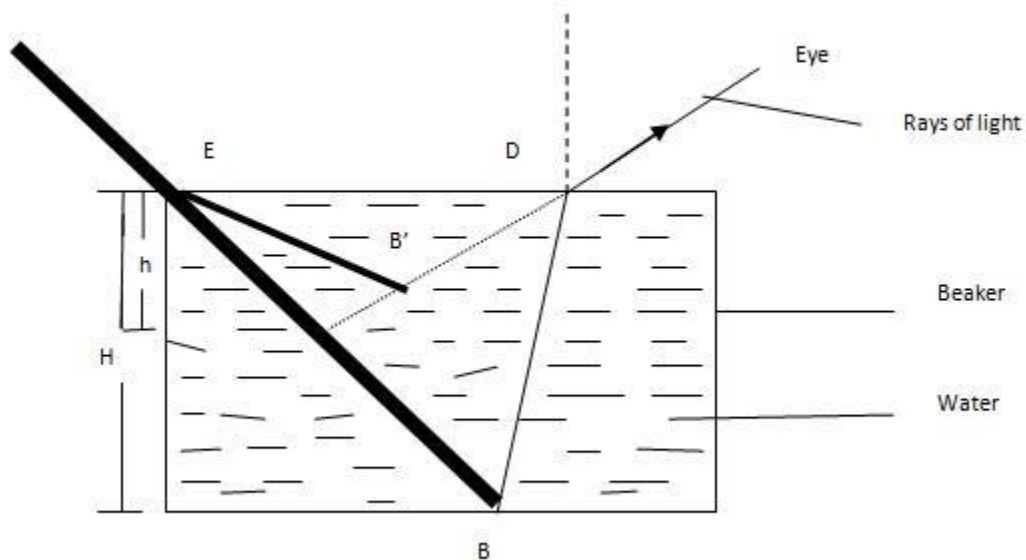
2.

$$\begin{aligned}
 {}_g\mu_a &= \frac{1}{{}_a\mu_g} \\
 &= 1/1.52 \\
 &= 0.6458
 \end{aligned}$$

THE IMAGE FORMED BY REFRACTION OF LIGHT

1. The apparent upward bending of a stick when placed in water.

See the diagram below;



Where H = real depth

h = apparent depth

The rays of light from end B of the stick pass from water to air and are bent away from the normal since they are passing through to a less dense medium.

On entering the eye, the rays appear to be coming from B' above B. B' is the image of B as a result of the refraction of light.

The shape of the stick is AEB this is true for any point inside the container.

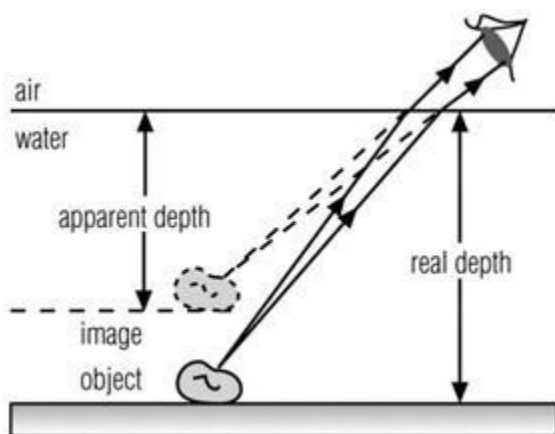
Real and apparent depth

Definitions;

Real depth of an object is the actual height measured without taking into account any refraction of light denoted by H .

Apparent depth of an object is the depth at which an object is the depth at which an object appears to be raised denoted by letter h .

NB: an apparent depth inside a liquid is usually less than the corresponding real depth when the point is observed oblique. That is why the water pond appears shallow than it really is.



MEASUREMENT OF THE REFRACTIVE INDEX OF WATER BY APPARENT DEPTH METHOD

APPARATUS

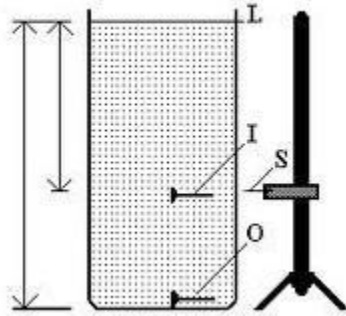
- Optical pin
- Container
- Water
- Ruler
- Slider with a wire.

Setup

1. Place an optical pin at the bottom of the beaker and then fill the beaker with water ($\frac{2}{3}$ full)
2. Keep a straight ruler close to the beaker

3. Move a straight ruler of thin wire horizontally up and down along the ruler.(slider)
4. Place your eye at “0” with respect to the beaker.

28.124

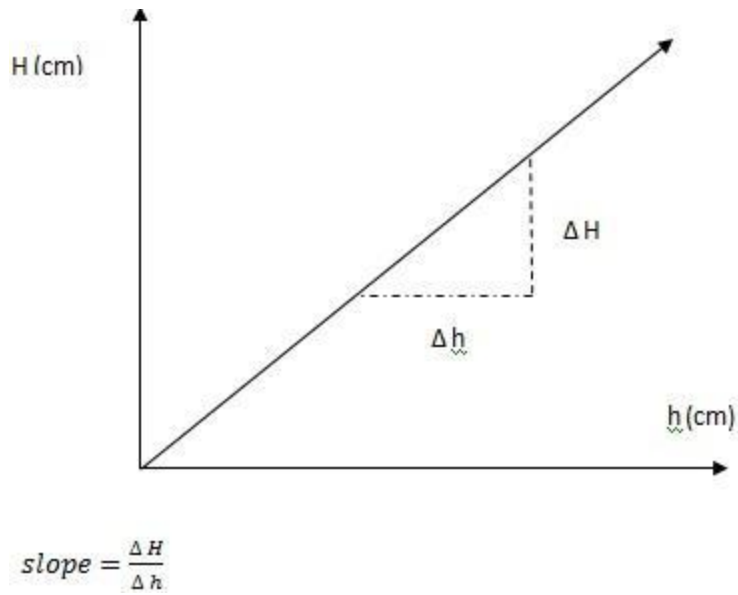


Procedures

1. Measure the real depth.
2. Measure the apparent depth (h) of the optical pin by using a ruler by moving your eye from side to side; adjust the vertical position of the thin horizontal wire until there is no relative motion between the image of the optical pin and the wire.

Data analysis/ relative motion calculations

- finding the ratio of H to h
- Change the amount of water 3 to four times and then repeat all the procedures above.
- Calculate the average value of H/h
- When the graph of real depth against apparent depth is plotted, a line is produced.



The slope represents the refractive index of water.

Observation

The average value of H/h is 1.333 and hence the refractive index of water ${}^a\mu_w = 1.333$

Example

1. The apparent depth of a certain point at the bottom of water pond is 25cm. find the real depth of this point given that the refractive index is $\frac{4}{3}$

Solution

Apparent depth, $h = 25\text{cm}$.

$${}^a\mu_w = \frac{4}{3}$$

Real depth = ?

From

$${}^a\mu_w = \frac{H}{h}$$

*The real depth of the point is 33.3**

2. Given that the refractive index of ethyl alcohol is 1.36*

Find the apparent depth in the beaker if the real depth of the optical pin is 52cm.

Solution

From

$$n_w = \frac{H}{h}$$

$$1.36 = 52/h$$

$$h = 52/1.36$$

$\therefore$ the apparent depth is 38.23 cm

3. A fish is located 10m deep in the liquid when viewed from the top. The depth of the fish is 8m. Find the refractive index of the liquid.

Data given

Real depth (H) = 10 CM

Apparent depth (h) = 8 m

Refractive index = ?

Solution:

$$\text{refractive index} = \frac{H}{h}$$

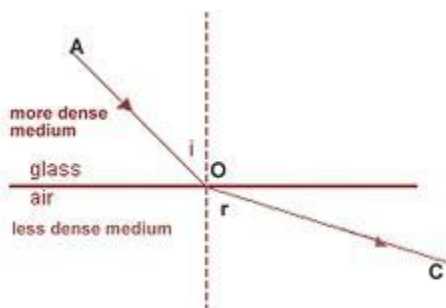
$$\text{refractive index} = \frac{10}{8}$$

$$\text{refractive index} = 1.25$$

$\therefore$ the refractive index is 1.25

THE CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION

Consider the diagram below where by a beam of light is traveling from high dense medium to low dense medium.



Where AO = incident ray

OC = refractive ray

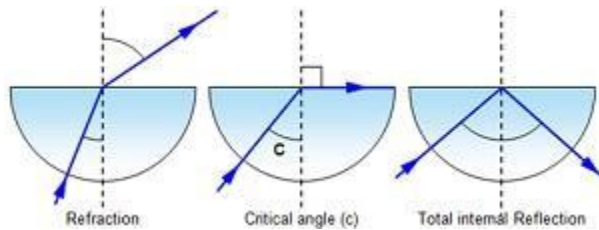
i = angle of incidence.

r = angle of refraction.

Definition

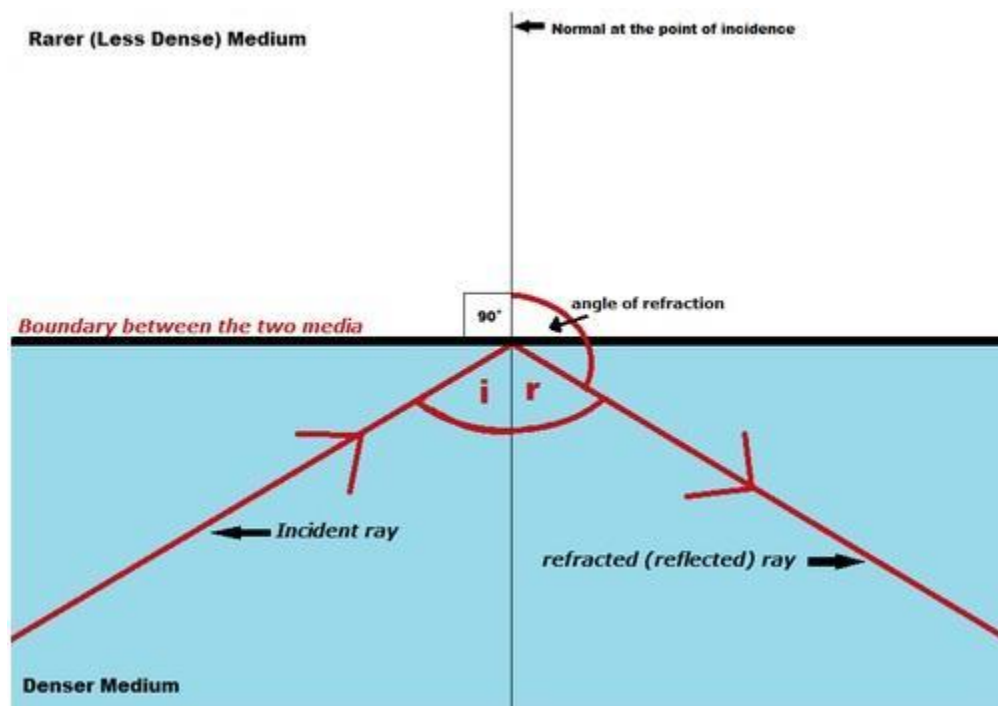
Critical angle

This is an angle of incidence whose corresponding angle of refraction is equal to right angle (90°) when the light travels from a high dense medium to a low dense medium.



What are the necessary conditions for a critical angle to form?

The critical angle forms when the light travels from a high dense medium to a low dense medium such that $r = 90^\circ$, its corresponding angle of incidence is called critical angle denoted by “c” or “ i_c ”



NOTE: When the critical angle is reached, the refracted ray travels along the line of interface, the line separating the two medium.

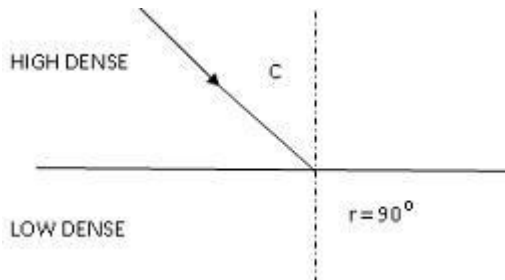
Suppose that

The angle of incidence is made bigger than the critical angle; the refraction of light doesn't take place. Because the whole incident ray reflects back into high dense medium

NOTE: this phenomenon is called **total internal reflection**. A situation where by a beam of light travelling from high dense medium to low dense medium reflecting fully into high dense medium at the (line of separating medium) is called total internal reflection.

Total internal reflection is a situation where by a beam of light is travelling from high to low medium reflected fully into high dense medium at the line of separating medium.

NB: consider the diagram below



Snell's law

$$\frac{\sin c}{\sin 90^\circ} = {}^i\mu_{ii}$$

Since; $\sin 90^\circ = 1$

Then $\sin c = {}^i\mu_{ii}$ condition; $\sin$ at any angle should be $-1 \leq 0 \leq 1$

$$\text{Also } \sin C = 1/{}^i\mu_{ii}$$

$$C = \sin^{-1} 1/{}^i\mu_{ii}$$

EXAMPLES

1. Calculate the critical angle for air and water medium if the refractive index of water is $4/3$.

Data

Critical angle $C = ?$

Angle of refraction $= 90$

$${}^a\mu_w = 4/3$$

By Snell's law

$${}^a\mu_{ii} = (\sin i)/(\sin r)$$

$$\sin C = 1/{}^a\mu_w$$

$$\sin C = 3/4$$

$$C = \sin^{-1} ()$$

$$C = 48^{\circ} 38'$$

The critical angle is $48^{\circ} 38'$

1. Given that the refractive index of glass is 1.5, what is the value of the critical angle?

Solution

Data

Refractive index = 1.5

Critical angle = ?

Refractive angle = 90°

By Snell's law

$$\frac{\sin C}{\sin r} = {}^a\mu_g$$

$$\sin C = \frac{1}{1.5 \times \sin 90}$$

$$\sin C = 0.6667$$

$$C = \sin^{-1} (0.6667)$$

$$C = 41^{\circ} 49'$$

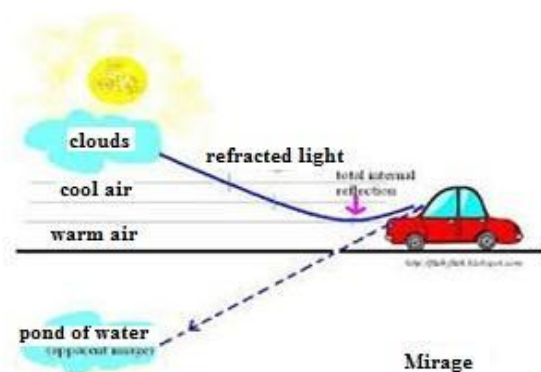
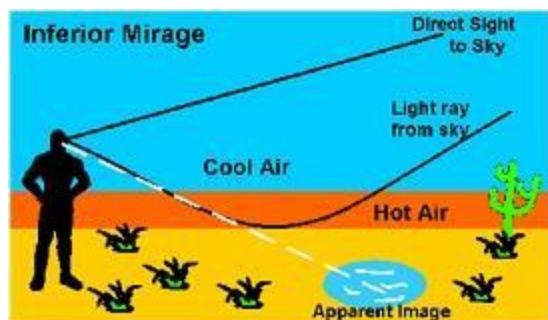
The critical angle is $41^{\circ} 49'$

MIRAGE

This is a form of total internal reflection. This is the appearance of water on a high way during a clear hot summer day. The air cools rapidly with height. The hotter air is optically less dense medium as has less dense.

The rays of light passing from high dense to less dense medium i.e. from colder air to warmer air bend gradually from the incident direction until it enters a layer of hot air at certain height where the total internal refraction occurs.

Its reflection, that is the image is also blue, this interpretation that the light is from the blue sky as if it is coming from the high way, hence looks like blue water.



The same type of mirage is often seen at desert areas and has given false hope to many thirsty travelers.

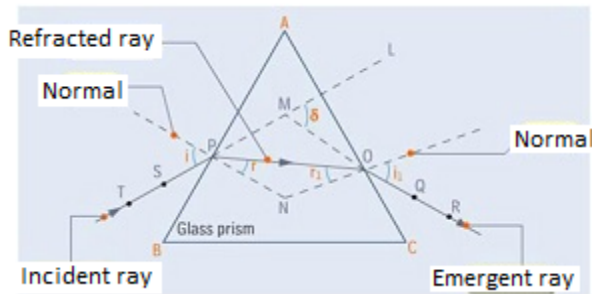
ASSIGNMENT

Pools of water which dry up when approached appear to be on a surface on the tarmac road on a Sunday. Explain this phenomenon.

This is due to the total internal reflection of light. The rays of light passing from high dense to low dense medium that is from colder air to warmer air bend as they pass the layer of hot air where total internal reflection occurs.

The refraction by triangular prism

Consider the ray of light incident on the prism from one side. It gets refracted on entering the prism. When it reaches the other side the light bends away from the normal.



When a beam of light travels from air to prism, it bends towards the normal and bends away from the normal on leaving the prism.

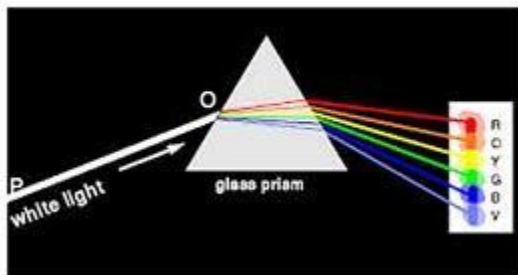
THE DISPERSION OF WHITE LIGHT

Introduction

The dispersion of white light is the separation of color from a mixture. Consider a white light PO being dispersed at O by the first surface of the prism into its various colors. The coloured rays are then refracted without further color change at the second surface of the prism but the amount of dispersion is increased. The emerging light is deviated towards the base of the prism.

The dispersion of white light is due to the different speeds in glass of various colors.

Dispersion of White Light by Glass Prism



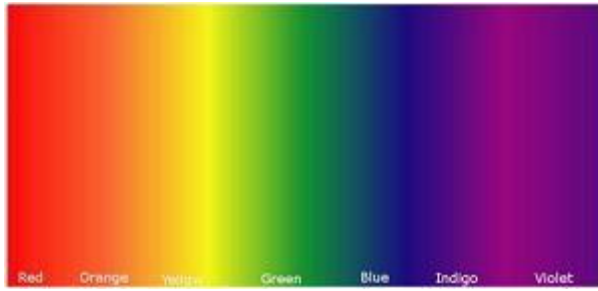
Note; red color is deviated the least by the refraction and violet is deviated the most by refraction.

The light consisting of only one color is called **monochromatic light** such as red light, green light, yellow light.

The light consisting of several colors is called **polychromatic light** such as sunlight.

Pure spectrum

Pure spectrum is a spectrum in which each part has only one color. There are no overlapping colors.



NO OVERLAPPING COLORS

Impure spectrum

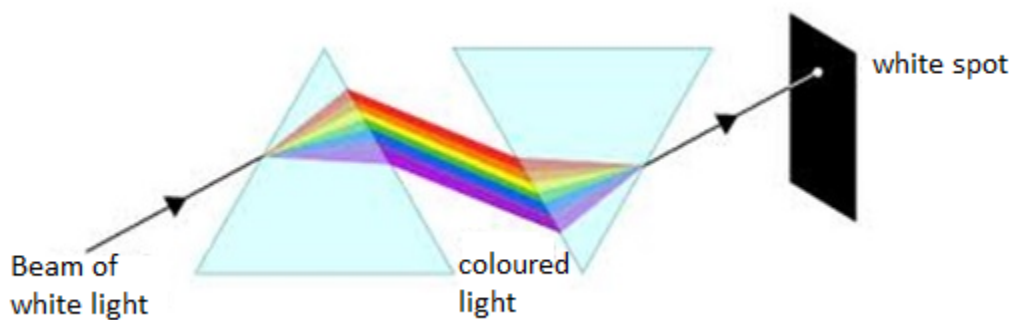
This is a spectrum in which different colors of white light are overlapping each other and only the edges are distinct. The spectrum gives a continuous band of colors.



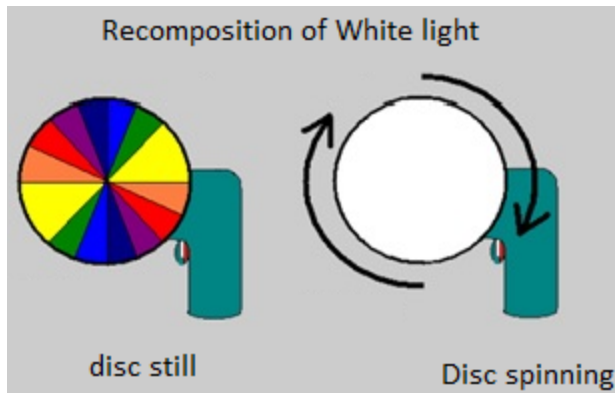
The middle band colors overlap.

The recombination of colors of light

When another prism is placed with its apex angle pointing in the opposite direction to the first one and the two facing prism sides are parallel, the colors from an incident white light(W), tend to recombine. The dispersion due to one prism is now neutralized by another.



NOTE: the recombination of colors may also be demonstrated by the use of Newton's color disk, this consist of sections painted with different colors of the spectrum. When the disk is allowed to spin about its axis at very high speed, all the color of the spectrum recombine to form white light. When it is slowed down, the individual colors of the spectrum are seen again.



Newton's color disk

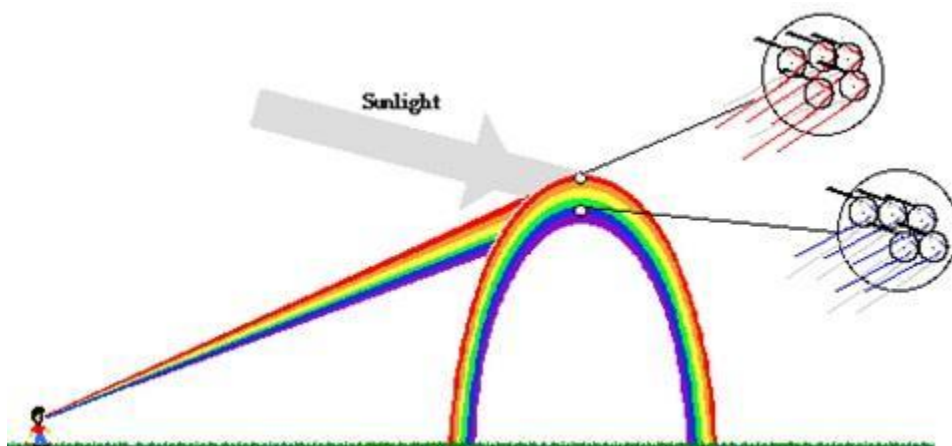
THE RAINBOW

The rainbow is an arc formed out of a spectral band of colors with the violet on the inside and the red on the outside, this is a natural phenomenon of the dispersion of light.

Formation of the rainbow

Whenever there are water droplets in the air and the sunshine's from behind, the observer at low altitude or at an angle can observe the rainbow.

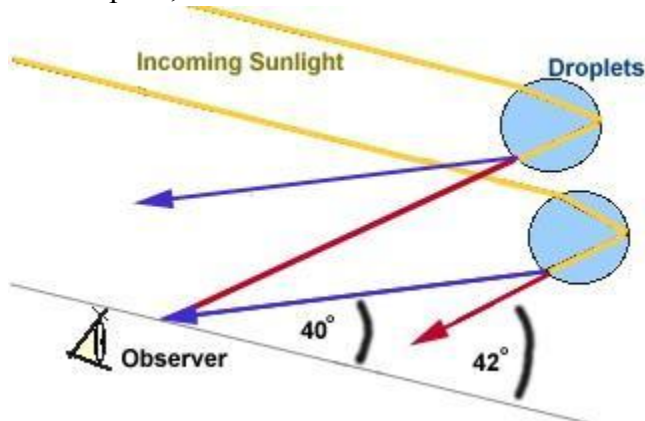
This is caused by the dispersion of sunlight as it is refracted and reflected by the rain drops which are roughly in shape.



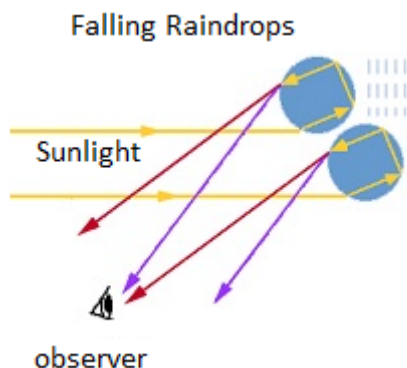
NB ; all rain drops refract and reflect the sunlight in the same way but only the light from some drops reach the observers eyes.

PRIMARY AND SECONDARY RAINBOW

The primary rainbow is formed as a result of light that has undergone one total internal reflection in water droplets, violet color is inside and red color is outside.



The secondary rainbow is due to light that has undergone two total internal reflections in the water droplets.



VISIBLE SPECTRUM AND COLORS

Visible spectrum (ROYGBIV)

Color is the property of light that reaches our eyes. The objects can absorb certain colors of light that fall on them and reflect other colors. The color of an object depends on the light falling on it and the color it absorbs or reflects. This phenomenon is called **SELECTIVE ABSORPTION AND REFLECTION**.

Example

1. A blue flower or coat absorbs all colors of light except blue which it reflects. If all the colors falling on an object are reflected, then the entire object will appear white. The objects appear black if and only if it absorbs the colors and doesn't reflect any color.

NOTE; when a colored object is viewed under a colored, it appears blue in blue light and red in red light, but if an object is blue in color and is viewed in red light, it appears black

PRIMARY AND SECONDARY COLOUR OF LIGHT

Primary colors of light

They are colors like red, blue and green because they can be used successfully in the color matching.

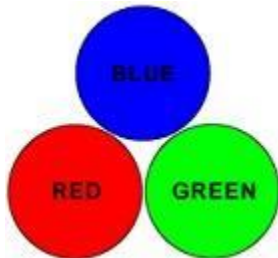
Definition;

A primary color of light is a color that cannot be created by mixing other colors.

NB: a primary filter is the one that transmits light of one of the primary colors when white color falls on it.

Examples; traffic light and car indicators etc

Primary color



SECONDARY COLORS

Mixing 2 primary colors produces a secondary color such as magenta cyan and yellow.

1. **Blue + green = cyan**

Primary secondary

Colors color



2. **Red + green = yellow**

Primary secondary

Colors color



3. **red + blue = magenta**

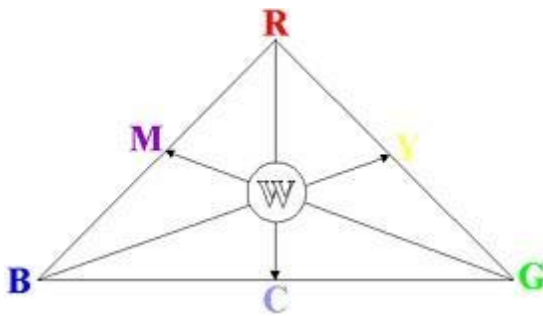
Primary secondary
Colors color



COMPLEMENTARY COLORS OF LIGHT

These are any 2 colors that when mixed together (primary color and secondary color) produce a white color.

I.e. primary color + secondary color = white light



When all 3 primary colors of light are mixed together, the result draws to white.

ADDITIVE AND SUBTRACTING MIXING OF COLORS

ADDITIVE COLOR MIXING (COLOUR OF LIGHT)

This is the mixing of colored light. Increasing the number of colours can be obtained by adding different colors of light together. More colors of light added together, the closer the result draws to white.

PIGMENTS

These are substances which give color to paints by reflecting light of certain colors only and absorbing all other colors. Most pigments are impure; they reflect more than one colour when they are mixed. The color which is reflected is common to all.

NOTE:

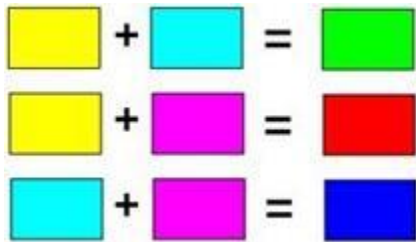
The primary colors of pigments are the same as the secondary spectrum colors of light.

The primary colors of pigments are

- Magenta pigment
- Cyan pigment
- Yellow pigment

The secondary colors of pigments are

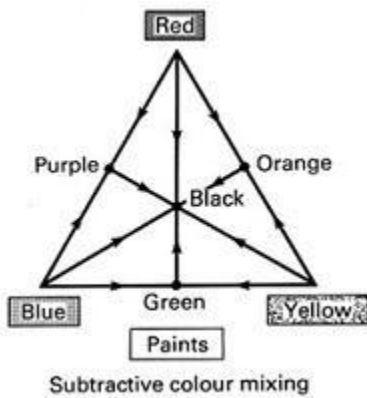
- Red pigment
- Blue pigment
- Green pigment.



NB: the mixing of all 3 primary colors of pigments produces BLACK. As the entire beam of white light is complementarily dissolved.

SUBTRACTIVE COLOR MIXING (PIGMENT OF COLORS)

- When subtracting process of color mixing is the one in which when mixing different colour pigments most of the colour pigments are absorbed because each colored pigments absorbs (subtracts) certain colors of light. More subtraction gives black (no light).



NOTE:

Recall complementary colors

1p. Blue (B) + yellow (R+G) = white.

2. Red + Cyan = white

THE REFRACTION OF LIGHT THROUGH THIN LENSES

Lens

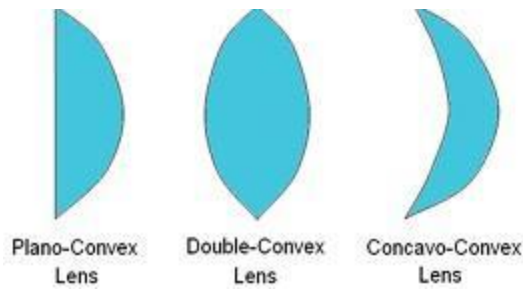
This is a transparent or translucent material or medium that alters the direction of light passing through it.

Types of lenses

1. Convex lenses
2. Concave lenses

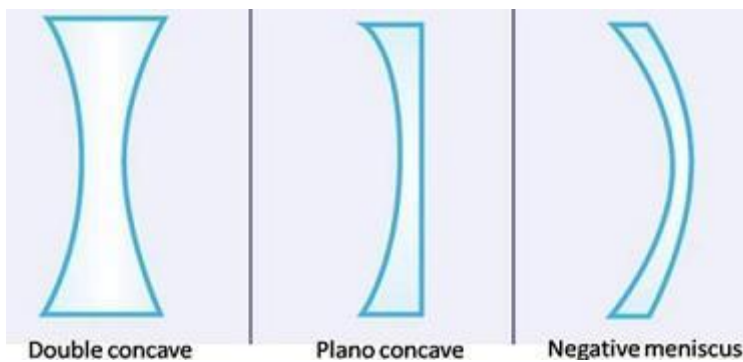
1. Convex lenses (converging lenses)

Are thicker in the middle than near the edges



2. Concave lenses (diverging lenses)

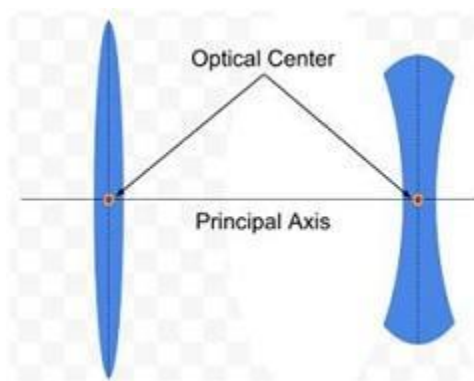
These are thinner in the middle than near the edges.



Definition of the terminologies

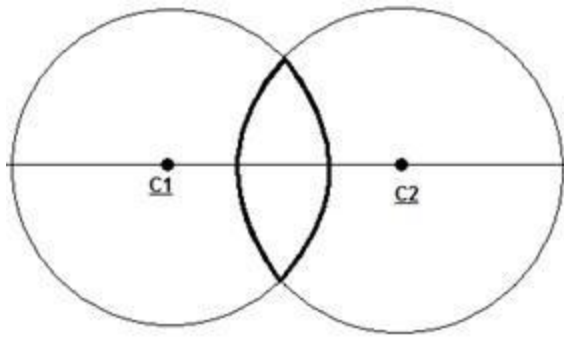
1. Optical centre

This is a geometric centre of a lens.



2. Centre of curvature.

This is a geometric centre of the sphere of which the lens surface is a part of. Since the lens has 2 surfaces, it has two centers of curvatures.



Centre of curvature of convex lens

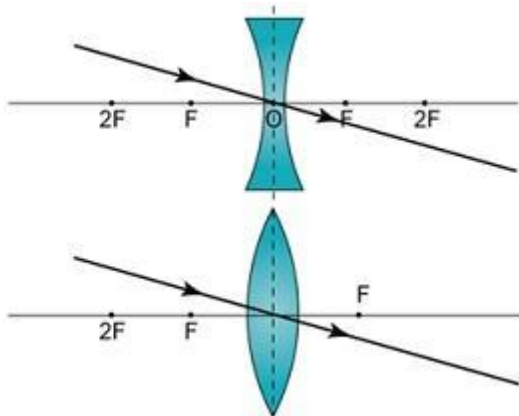
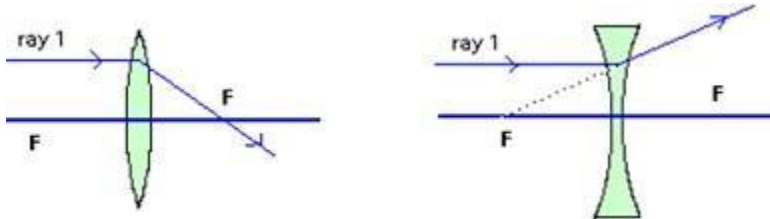


IMAGE FORMATION BY THIN LENSES

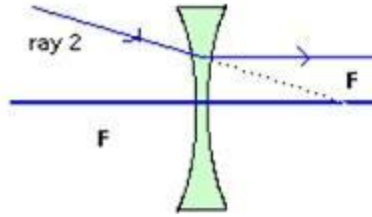
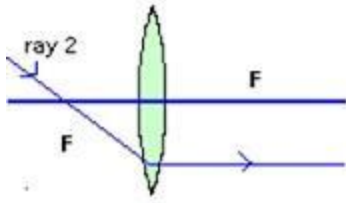
The way in which lenses form images of the object can be shown by means of ray diagram constructions.

The following are 3 important rules which are used in the construction of ray diagrams.

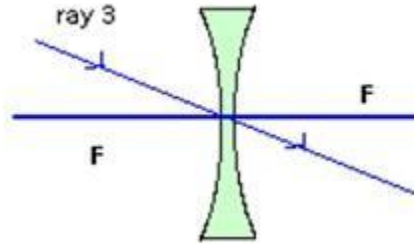
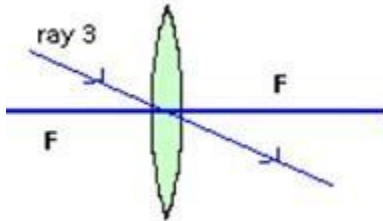
1. Any ray parallel to the principle axis passes through or appears to diverge from the principle focus after the reflection through the lens.



2. Any ray of light incident on the principle focus of the length is refracted parallel to the principle axis.



3. Any ray through the optical centre of the lens continues through undeviated.



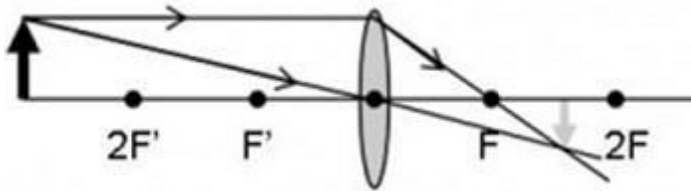
NB: The location of the image formed by the convex lens depends on the position of the object relative to the principle focus of the object.

The image formed by the concave lens are virtual erect and diminished in size.

CONVEX LENSES

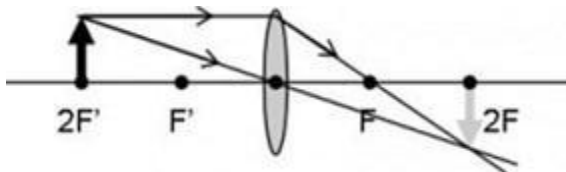
1. Case A

When an object is beyond centre of curvature



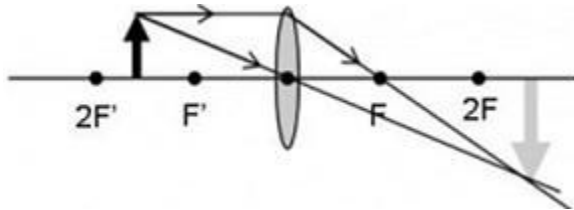
2. Case B

When an object is at c



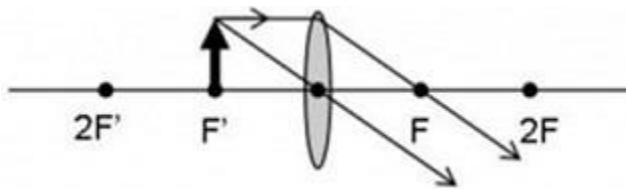
3. Case C

When an object is between c and f



4. Case D

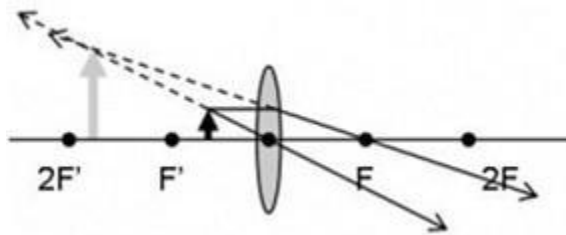
When an object is at f



- The image is real and inverted
- The image is highly magnified
- The image is formed beyond infinity.

5. Case E

When an object is between f and O

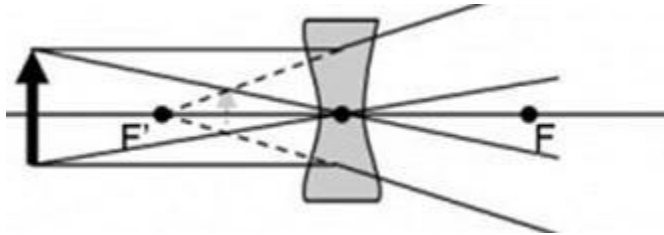


- The image is virtual
- The image is erect
- The image is magnified
- The image forms between c and f .

CONCAVE LENSES (DIVERGING LENSES)

Image which formed in concave lens have the following properties independent of position of an object

- The image is virtual
- The image is diminished
- The image is erect
- The image is formed between f and O
- As the object distance increases from pole to infinity the image distance increases from the pole to f.



THIN LENS FORMULA

$$1/F = 1/U + 1/V$$

Real image is positive sign convention

For convex lenses

$$U = +ve$$

$$F = +ve$$

$$V = +ve \text{ or } -ve$$

For concave lens

$$U = +ve$$

$$F = -ve$$

$$V = -ve \text{ (always)}$$

Examples

1. The object is placed 20 cm from a converging lens for focal length 15cm . find the position, the magnification and the nature of the image

Solution:

$$u = 20\text{cm}$$

$$f = 15\text{cm}$$

$$v = ?$$

$$m = ?$$

From;

$$1/F = 1/U + 1/V$$

$$1/15 = 1/20 + 1/V$$

$$1/V = (4-3)/60$$

$$1/V = 1/60$$

$$V = 60\text{cm}$$

$$m = v/u$$

$$m = 60/20$$

$$m = 3$$

$\therefore$ The position is 60 cm from the lens, the magnification is 3 and the nature is a real image

2. Find the nature and position of the image of an object, placed 10cm from a diverging lens of focal length 15cm (concave).

Solution:

$$U = 10\text{cm}$$

$$V = ?$$

$$F = 15\text{cm}$$

$$M = ?$$

Using:

$$1/F = 1/U + 1/V$$

$$1/(-15) = 1/10 + 1/V$$

$$1/V = (-3-2)/30$$

$$1/V = (-6)/30$$

$$V = -6\text{cm}$$

$$M = V/U$$

$$M = (-6)/10$$

$$M = 0.6$$

The position is -6 cm from the lens, the magnification is 0.6

1. An object stands vertically on the principle axis of a converging lens of focal length 10mm and at a distance of 17mm from the lens. Find the position, size and nature of the image.

Solution:

$$U = 17\text{mm}$$

$$F = 10\text{mm}$$

$$V = ?$$

$$H_1 = ?$$

$$H_0 = 10\text{mm}$$

$$M = ?$$

By Using:

$$1/F = 1/U + 1/V$$

$$1/10 = 1/17 + 1/V$$

$$1/v = 1/10 - 1/17$$

$$1/v = (17 - 10)/170$$

$$V = 170/7$$

$$V = 24.3$$

We get $V = 24.14$

$$M = V/U$$

$$M = 24.4/7$$

$$M = 3.5 \text{ mm}$$

$$M = H_1/H_0$$

$$3.5 = 10/H_0$$

$$3.5H_0 = 10$$

$$H_0 = 10/3.5$$

$$H_0 = 2.9$$

∴ The position is 24.14 cm from the lens, the size is 2.9 mm and the image is real.

OPTICAL INSTRUMENTS

These are the instruments which are used to help human eye to view small objects or distant objects more clearly.

These include instruments like:-

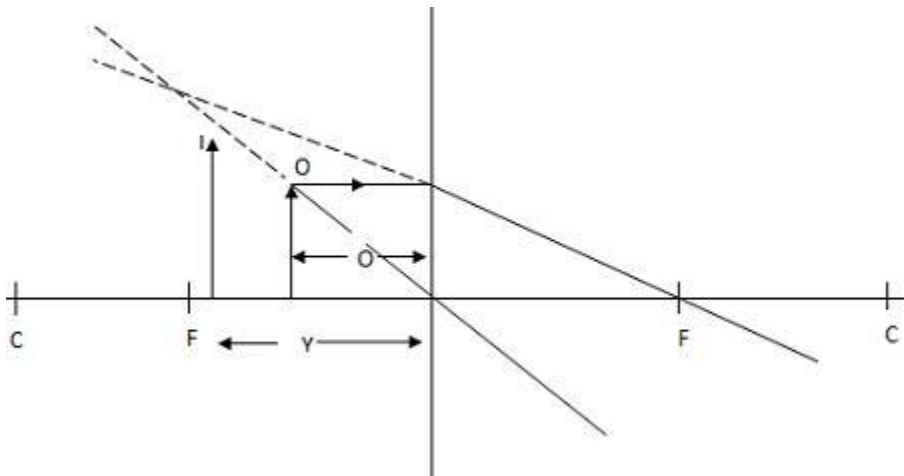
- Simple microscope
- Compound microscope
- Telescope

- Lens camera
- Projector
- Human eye

NB: The instruments consist of convex lens (the converging lens)

1. SIMPLE MICROSCOPE (MAGNIFYING LENS)

The simple microscope consists of converging lens of short focal length. The object is nearer to the lens than its focal length. The image is viewed directly by the eye is erect virtual.



-Image I is erect

-Image I is virtual

-Image I is highly magnified

NB: The thin lens formula obeys

LINEAR MAGNIFICATION

The ratio of the image distance to the object distance is called linear magnification (M).

$$\text{I.E } M = \frac{\text{image distance}}{\text{object distance}}$$

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

LATERAL MAGNIFICATION

The ratio of the image height or size to the object height or size is called lateral magnification.

$$M = \frac{\text{image height}}{\text{image distance}}$$

$$M = \frac{H_i}{H_o}$$

$$\text{Thus; } M = \frac{v}{u} = \frac{H_i}{H_o}$$

NEAR POINT

It is the least distance whereby an image appears clearest (sharpest). The image appears clearest when it is about 25 cm from the eye. The distance is called **near point**.

When the image is at the near point; $v = 25$. From thin lens formula:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{25} \quad \text{Real is positive sign convention}$$

Since image I is virtual

$$\frac{1}{u} = \frac{1}{f} + \frac{1}{25}$$

Multiplying by v through out

$$\frac{v}{u} = \left(\frac{1}{f} + \frac{1}{25} \right) v$$

$$M = \frac{1}{f} + \frac{1}{25}$$

$$M = \frac{25}{f} + \frac{25}{25}$$

$$M = \frac{25}{f} + 1$$

Example:

1. If the focal distance of the converging lens is 5 cm the object distance is 4 cm. Find the magnification of the image.

Solution

$$M = \frac{25}{f} + 1$$

$$M = \frac{25}{5} + 1$$

$$M = 6$$

The magnification of the object is 6 cm

- Given that the focal length of the simple microscope is 12cm. Find the magnification of the image of the object distances.

Solution

$$M = \frac{25}{f} + 1$$

$$M = \frac{25}{12} + 1$$

$$M = \frac{25+12}{12}$$

$$M = \frac{37}{12}$$

$$M = \frac{V}{U}$$

$$\frac{37}{12} = \frac{25}{U}$$

$$\frac{12}{25} \times 25 = U$$

$$U = 8.1$$

The magnification is $M = \frac{37}{12}$ object distance is 8.1

APPLICATION OF SIMPLE MICROSCOPES

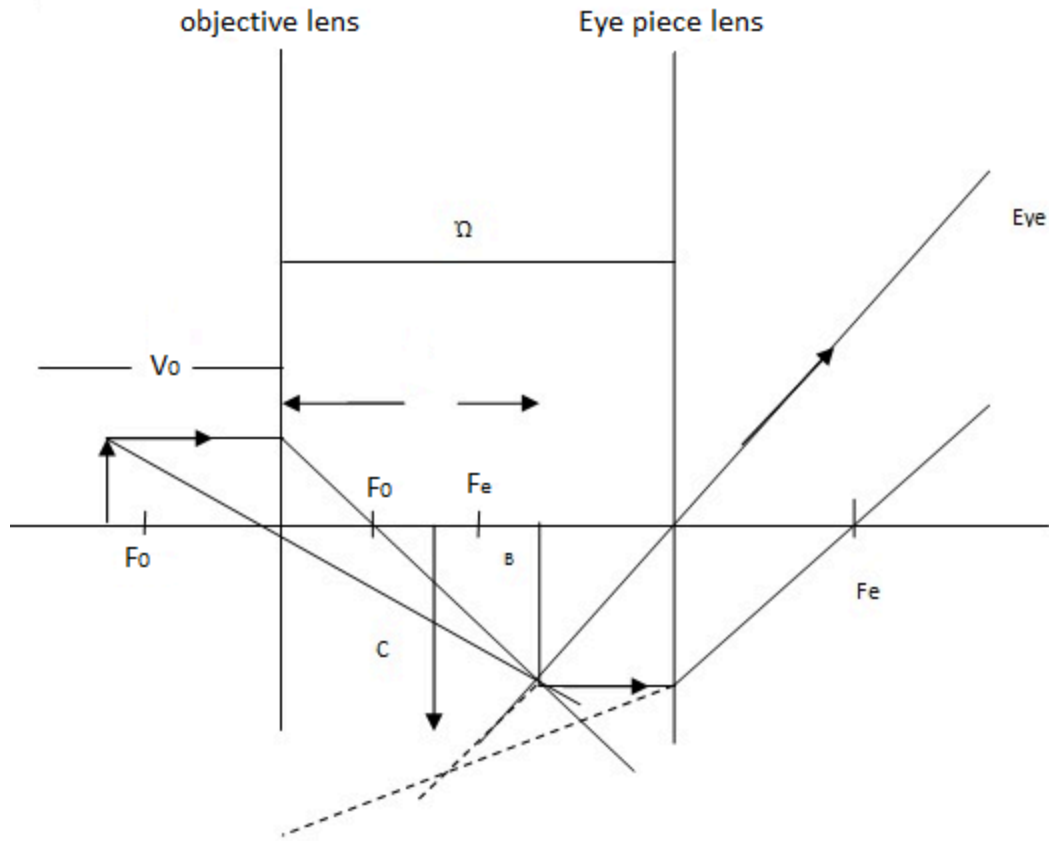
- The simple microscope are used to view specimens in laboratory
- The simple microscopes are used to reads small prints

2. COMPOUND MICROSCOPE

It produces a much greater magnification more than the simple microscope. It has an objective lens and eye piece lens which are both convex lenses and of short focal length.

CONSTRUCTION

An object A is placed just beyond the principle focus (F_o) of the objective lens which forms magnified image B. The eye piece is used as a simple magnified glass to increase the magnification further that a large inverted image is seen as point C.



The image C is magnified

The image C is virtual

The image C is inverted as the object B

MAGNIFICATION

The magnification produced by the objective lens is given by

$$M_o = \frac{\text{image distance } (V_o)}{\text{object distance } (U_o)}$$

-The magnified image acts as the object for eye piece lens then let L is the distance between 2 lenses.

-The distance V_o for the objective lens is approximately equal to

$$V_o \approx L - f_e$$

where L is the distance between the 2 lenses i.e.

$$M_o = \frac{L - f_e}{U_o} \text{ also } U_o \approx f_o$$

Hence

$$M_o = \frac{l - f_e}{f_o}$$

The eye piece lens acts as a simple microscope hence

$$M_e = \frac{25}{f_e} + 1$$

-The total magnification M is given by the product of the magnification of the objective lens and magnification of the eye force lens.

Hence

$$M = M_o + M_e$$

$$M = \left(\frac{l - f_e}{f_o} \right) \left(\frac{25}{f_e} + 1 \right)$$

Note: For very large magnification f_o and f_e must be very small as compared to L.

$$\text{Thus, } l - f_e \approx l$$

-When this happens the object distance $V_o \approx f_e$ and $U_e \neq f_e$.

$$\text{Hence } M = M_o M_e$$

$$\text{From } M = \left(\frac{l - f_e}{f_o} \right) \left(\frac{25}{f_e} + 1 \right)$$

$$\text{So that } M = \left(\frac{l}{f_o} \right) + \left(\frac{25}{f_e} + 1 \right)$$

Applications of a compound microscope

- i) It is used to magnify small objects
- ii) The compound microscope it is used to observe the Brownian motion in science
- iii) It is used to study the characteristics of the micro-organism and cells in biology
- iv) It is used to analyze the laboratory samples in hospitals such as tissues or body fluids to check for infections caused by micro-organism

Example:

A compound microscope has an objective lens of focal length 2 cm and eye piece lens of focal length 6cm. An object is placed 2.4 cm from an objective lens. If the distance between the objective lens and eye piece lens is 19 cm. Find

- a) The distance of the final image from the eyepiece lens

b) Compound magnification

Solution

a)

$$\frac{1}{f_o} = \frac{1}{v_o} + \frac{1}{v_o}$$

$$\frac{1}{2} = \frac{1}{2.4} + \frac{1}{v_o}$$

$$\frac{1}{v_o} = \frac{1}{2} - \frac{1}{2.4} = \frac{1.2 - 1}{2.4}$$

$$\frac{1}{v_o} = \frac{0.2}{2.4} = \frac{1}{12}$$

$$v_o = 12 \text{ cm}$$

$$v_e \approx f_e = 6 \text{ cm}$$

$$\frac{1}{f_e} = \frac{1}{v_e} + \frac{1}{v_e}$$

$$\frac{1}{6} = \frac{1}{6} + \frac{1}{v_e}$$

$$\frac{1}{v_e} = \frac{1}{6} - \frac{1}{6} = 0$$

$$v_e = \infty$$

The final image from the eye piece lens is at infinity.

(b)

$$M = \left(\frac{L - f_e}{f_o} \right) (\infty)$$

$$\therefore M = \infty$$

Example:

A certain microscope consists of 2 converging lenses of focal length 4 cm and 10 cm for objective 3 eyepiece lenses respectively. The 2 lenses are separated by the distance of 30cm. The instrument is focused so that the image is at infinity. Calculate the position of the object and the magnification of the objective lens.

Solution:

a)

$$\frac{1}{f_o} = \frac{1}{u_o} + \frac{1}{v_o}$$

$$\frac{1}{f_o} = \frac{1}{u_o} = \frac{1}{L} - f_e$$

$$\frac{1}{4} = \frac{1}{u_o} + \frac{1}{30} - 10$$

$$\frac{1}{4} = \frac{1}{u_o} + \frac{1}{20}$$

$$\frac{1}{u_o} = \frac{1}{4} - \frac{1}{20} = 5 - \frac{1}{20}$$

$$\frac{1}{u_o} = \frac{4}{20}$$

$$u_o = 5 \text{ cm}$$

$$M_o = \frac{l - f_e}{u_o}$$

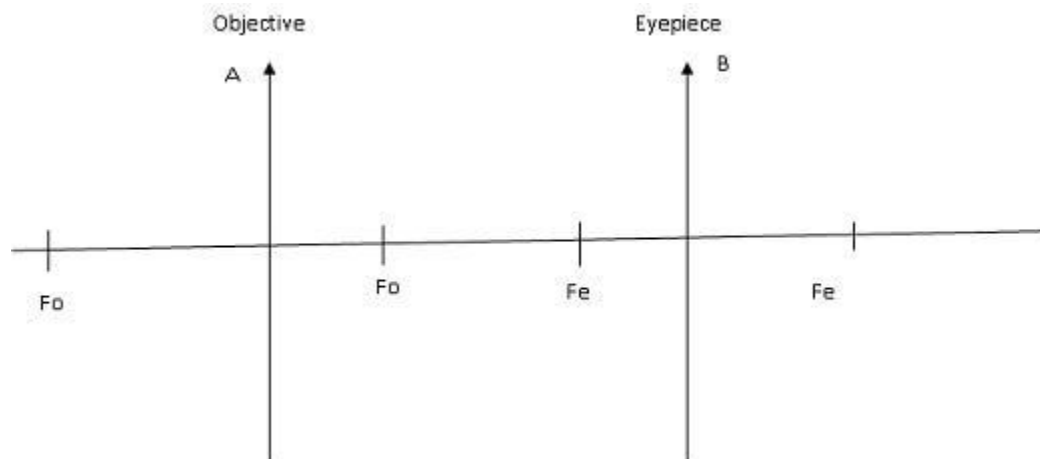
$$M_o = \frac{30 - 10}{5}$$

$$u_o = 5 \text{ cm}$$

$$M_o = 4$$

$\therefore$ The magnification produced by the eye piece lens is 4

E.g. The following diagram represents a compound microscope



(a). Identity A and B are objective and eyepiece lenses

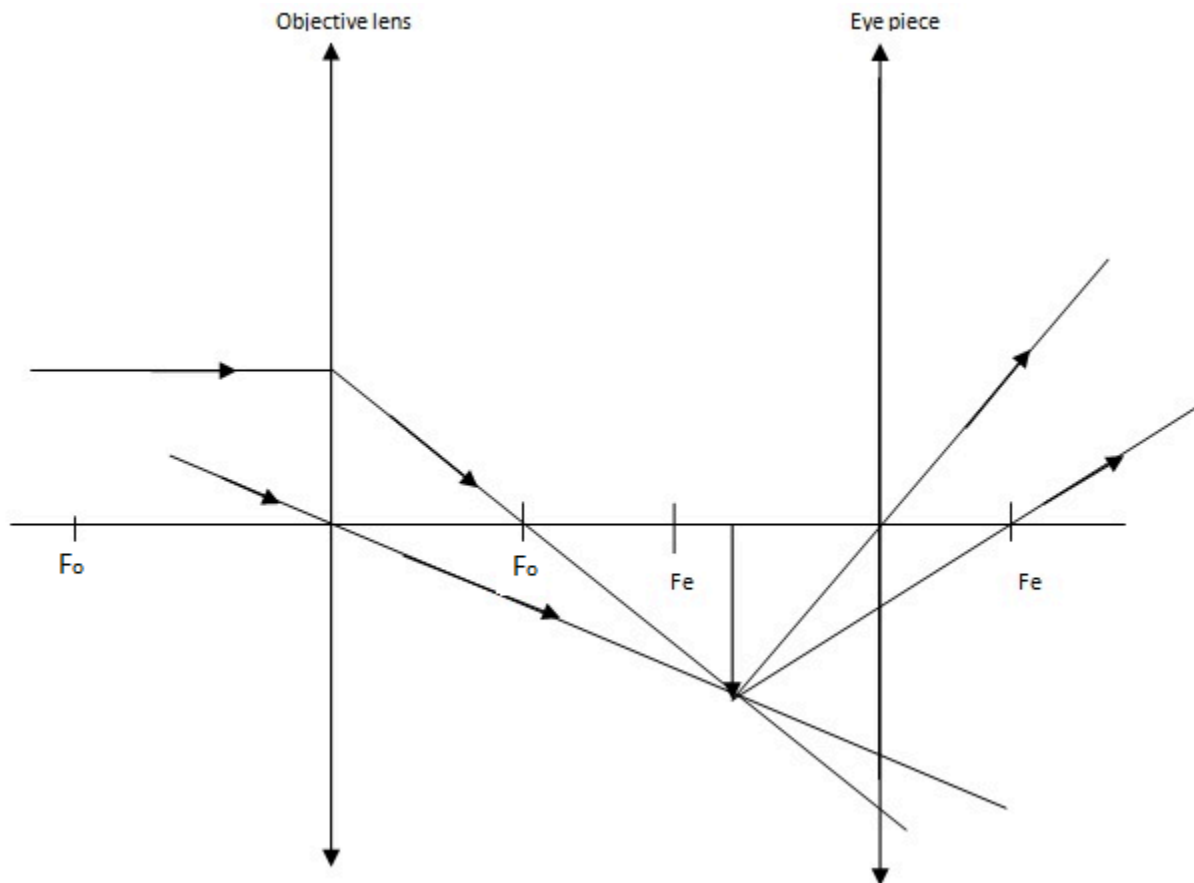
(b). What is the relationship between f_o and f_e ?

___ $f_o > f_e$

3. TELESCOPE

A telescope is an optical instrument which is used to view distant object(far object). It uses two convex lenses,the same as compound microscope but it has a large focal length on the objective lens and short focal length on the eyepiece lens.

Constructions



- The image I is virtual
- The image I is magnified
- A looks larger close to the observers' eye
- The image I is inverted

Magnification

Magnification of telescope is the ratio of the focal length of objective lens to focal length of the eye piece lens.

$$M = \frac{\text{Focal length of objective lens}}{\text{focal length of eye piece}}$$

$$\therefore M = \frac{f_o}{f_e}$$

Note: If L is the distance of separation between the objective and eyepiece lens for normal adjustment is equal to $f_o + f_e$

$$L = f_o + f_e$$

Applications of telescope

1. They are used to view distant objects example stars and other heavenly bodies in the sky
2. They are used in military bases to see enemies

Example: A telescope is consisting of two converging lens of lens at focal length 25 and 4 respectively. The final image is found at distinct vision that is 25 cm in front of the eyepiece lens. Find the position of the first image from the eyepiece.

Solution

$$\frac{1}{f_e} = \frac{1}{u_e} + \frac{1}{v_e}$$

$$\frac{1}{4} = \frac{1}{u_e} - \frac{1}{25}$$

$$\frac{1}{u_e} = \frac{1}{4} + \frac{1}{25}$$

$$\frac{1}{u_e} = \frac{29}{100}$$

$$u_e = \frac{100}{29}$$

$$= 3.4\text{cm}$$

Example: An astronomer telescope has its 2 lens 78 cm apart. If the objective lens has a focal length of 75.5 cm, what is the magnification produced by the telescope under normal vision.

Solution

$$L = f_o + f_e$$

$$78 = 75.5 + f_e$$

$$f_e = 2.5$$

$$M = \frac{f_o}{f_e}$$

$$M = \frac{75.5}{5.5}$$

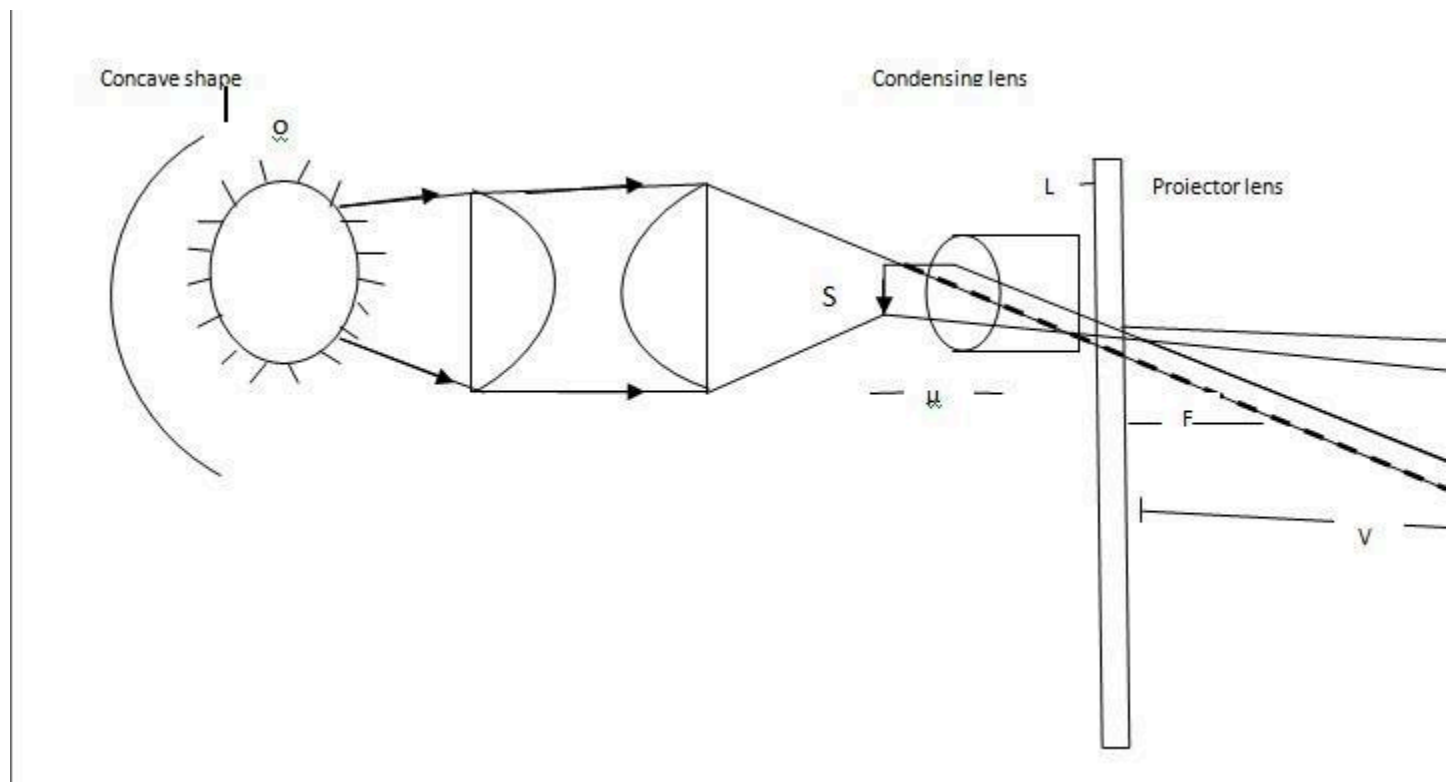
$$M = 30.2$$

∴ The magnification is 30.2

4. PROJECTORS (PROJECTION LANTERNS)

A projector is an optical instrument which is used to display large images on the screen with a slide projector. This consists of a powerful small source of light (O). It also consists of condensing lens (2 Plano convex lenses to collect the light from (O) and send it through the slide S which is then illuminated powerfully). It has a converging projection lens. A also has a distant wide screen.

CONSTRUCTION



Where :

u = distance from slides (object) to lens L

V = distance from lens L to the distance white screen A

f = Focal length of the lens L

- The image I is highly magnified
- The image I is real
- The image I erect

Note: The thin lens formula is applicable

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

MAGNIFICATION

The magnification produced by the projector is given by the ratio of the image distance to the object distance.

$$M = \frac{v}{u} \quad \text{Linear magnification}$$

or

-The magnification produced by the projector is given by the ratio of the image height to the object height.

$$M = \frac{H_i}{H_o} \quad \text{Lateral magnification}$$

Applications of projectors

1. They are used to project films, slides and transparency
2. They are used in the projection of opaque objects
3. Projections are used in search lights
4. They are used in projector apparatus in industries for gauge and screw thread testing
5. They are used in the projection of spectrum and interference
6. They are used in the projection of minute objects
7. The projectors are used in the projection microscope

Example: The lantern projector uses a slide of 2 cm by 2 cm, 2x2 to produce a picture 1 m by 1 m on a screen 12 cm from the projection lens. How far from the lens must the slide be?

Find the approximate focal length of the projection lens.

Solution:

$$M = \frac{H_i}{H_o}$$

$$M = \frac{100\text{cm}}{2\text{cm}}$$

$$M = 50$$

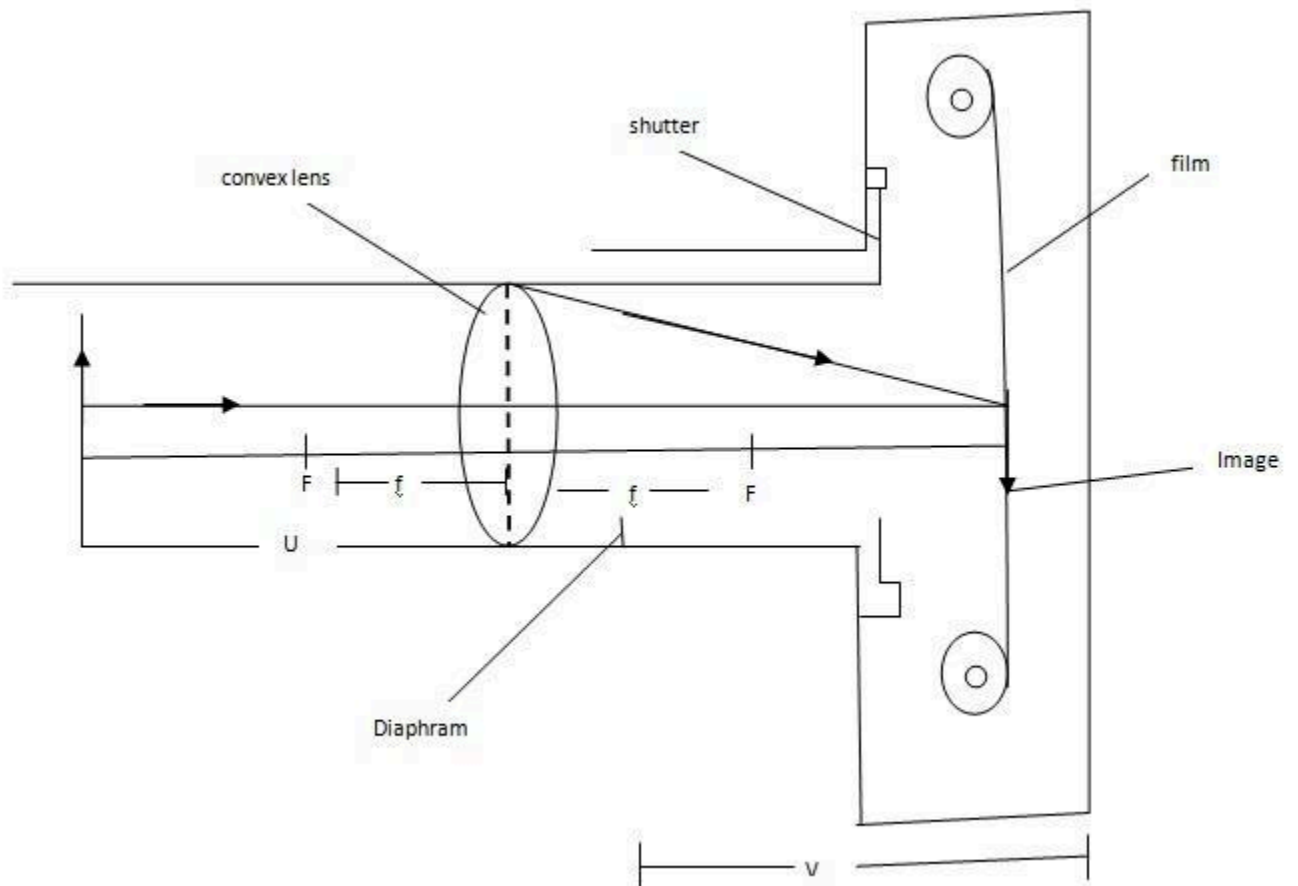
$$M = \frac{v}{u}$$

$$50 = \frac{12\text{m}}{u}$$

$$u = 240\text{m}$$

5. LENS CAMERA

This instrument has a convex lens, diaphragm, shutter and a mounting base for the film. (A light sensitive film)



- The image forms on the film.
- The image is diminished.
- The image is inverted.
- The object is focused by moving the lens.
- The amount of light entering the lens is controlled by the diameter of the diaphragm or stop and by the speed of the shutter which is pre-set for the particular lighting conditions.

The Magnification

The magnification produced by a lens of camera is always less than one which is given by the ratio of the image distance to the object distance that is;

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

Or it is given by the ratio of image height and object height;

$$M = \frac{H_i}{H_o}$$

From the formula

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$v = \frac{fu}{u-f}$$

$$\text{But } M = \frac{v}{u}$$

$$\text{Hence: } M = \left(\frac{fu}{u-f} \right) \frac{1}{u}$$

$$M = \frac{f}{u-f}$$

Example: Given that an object 2m high is placed 2010cm in front of the lens camera of focal length 10cm. calculate the minimum size of the film frame.

Solution:

$$u = 20.1\text{m} = 2010\text{cm}$$

$$f=10\text{cm}$$

$$H_o=200\text{cm}$$

$$M = \frac{10}{2010-10}$$

$$M = \frac{10}{2000}$$

$$M = 0.0005$$

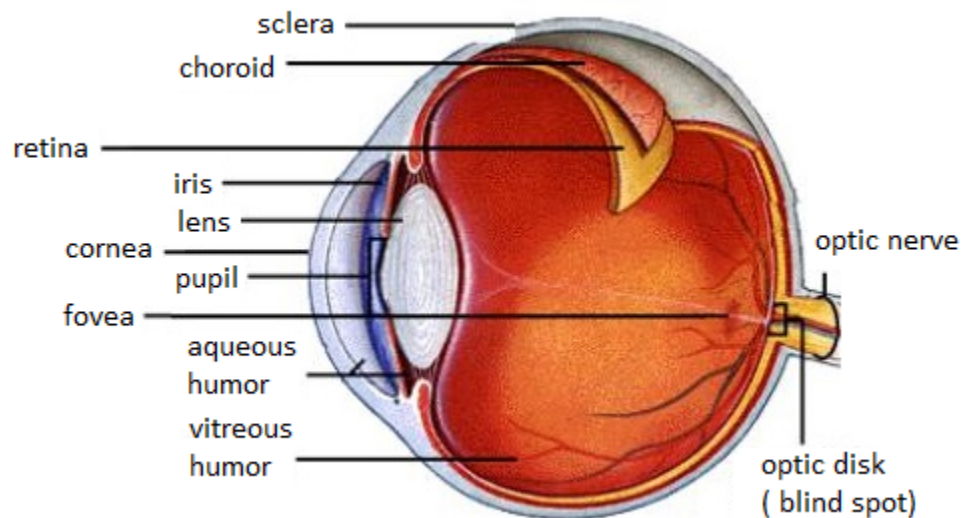
Applications of lens camera

- To take photographs
- Video camera are used to take motion pictures
- High speed cameras are used to record movements of pictures
- CCTV cameras are used for high security instruments, banks and other places
- Digital cameras are used to capture images that can be fed into computers.

6. THE HUMAN EYE

A human eye is sensitive to white light (ROYGBIV).It can detect colors of different objects.

STRUCTURE OF THE HUMAN EYE



The human eye has the following main parts

1. Crystalline flexible convex lens (surrounded by liquid) all aqueous humour and V.H/Vitreous humour.
2. It has iris (coloured and surrounding the lens)
3. Pupil (hole in the middle of the night) contracting by day and widening by night to control the amount of light entering the eye.
4. It has ciliary muscles to control the focal length of the eye lens by altering the radii of curvature of surfaces.(When the lens stretches the focal length increases)
5. Retina (light sensitive layer of cells at the rear of the eye) Rear means backside
6. Fovea (yellow spot)
-It is the most sensitive part of the retina

Note:

- **V.H (Vitreous Humour)**
- The vitreous humour is used to prevent the eye from collapsing due to change in atmospheric pressure. It focuses the images clearly on the retina (by maintaining refraction)
- **A.H (Aqueous Humour)**
- It is a watery fluid. When we blink our eyes, a tiny drop of the eye, it washes the eye and keeps the cornea moist in order to avoid opaque.

ACTION OF THE EYE

- The process whereby the eye can alter its focal length in order to form images at different distances is called accommodation.
- The process which the ciliary muscles alter the focal length of the crystalline flexible convex lens so as to focus near or far-off objects clearly on the retina.

SIMILARITIES BETWEEN THE HUMAN EYE AND THE LENS-CAMERA

1. Both human eye and lens-camera have convex lenses which form diminished, real and inverted images
2. Both human eye and the lens-camera are blackened inside in order to prevent total internal reflection.
3. In the human eye the pupil controls the amount of light while in lens camera a diaphragm controls the amount of light.
4. In the human eye the image is formed on the retina while in lens on the lens-camera the image is formed on the photographic film.

5. The human eye can adjust the focal length of its lens by contraction and relaxation of ciliary muscles in order to focus different objects at different distances, in lens-camera the objects can be focused by moving the lens forwards and backwards.

DIFFERENCES BETWEEN THE EYE AND LENS-CAMERA

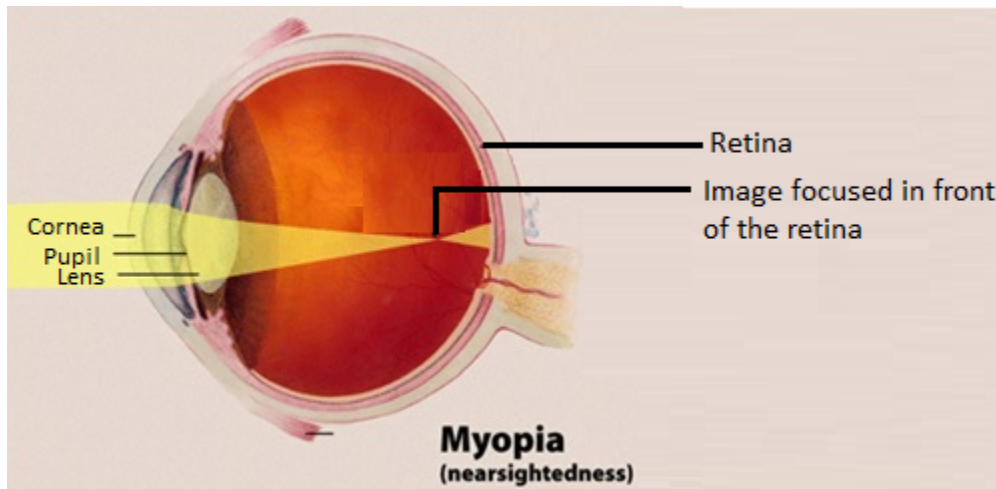
1. The human eye can alter its focal length by using ciliary muscles while the focal length of a lens-camera is fixed.
2. The eye has a fluid inside which assists for refraction while a lens-camera has air inside
3. Light is refracted by the cornea, lens and fluid in the eye but it is refracted by the lens only in the lens-camera
4. Focusing is done in the eye by changing the shape of the lens but it is obtained in the lens-camera by adjusting the focal length relative to the film.

DEFECTS OF VISION AND THEIR CORRECTION

1. SHORT-SIGHTEDNESS (MYOPIA)

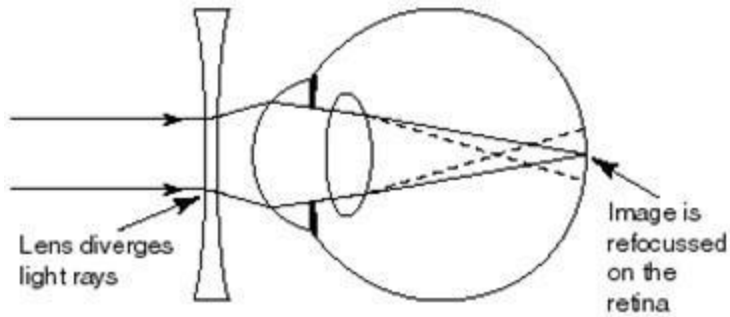
For normal vision, the objects a long way off cannot be seen clearly with the short sighted person can see the objects more clearly at shorter distances. This problem is caused by the following

1. Too long eye ball
2. Too powerful eye-lens



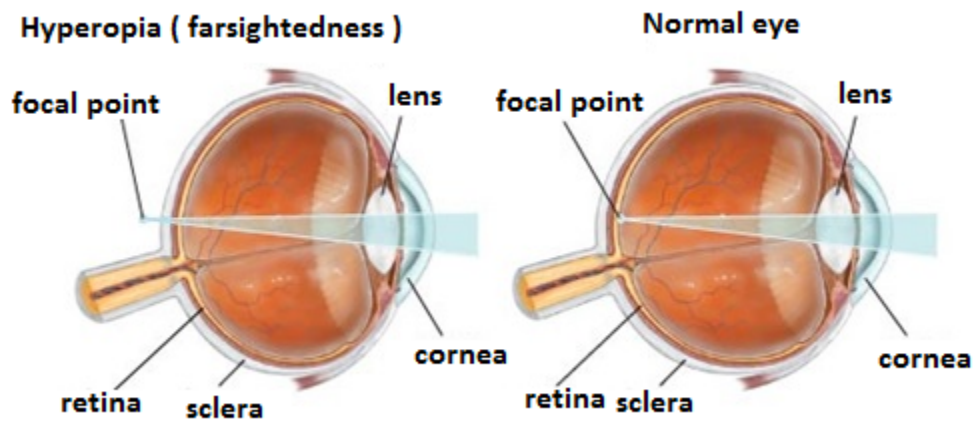
CORRECTION

A short sighted person is provided with a diverging lens (concave lens) to correct his/her sight.



2. LONG-SIGHTEDNESS (HYPERMETROPIA)

For normal vision, far objects away can be seen clearly. A person with long-sightedness cannot see near objects clearly. Objects at longer distances can be seen more clearly due to the following possible causes:

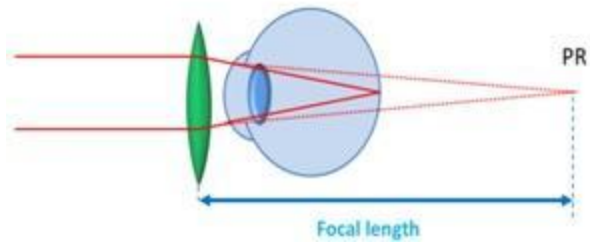


- a) Too short eyeball
- b) Less powerful eye lens

CORRECTION

Long sightedness person is provided with convex lens to correct its sight

Correction of Hypermetropia



THERMAL EXPANSION

EXPANSION OF METAL WHEN HEATED

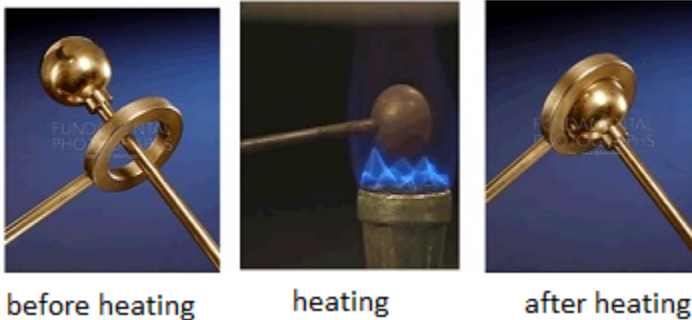
Expansion is the increase in dimension of a solid when heated.

Contraction is the decrease in dimension when a solid cooled.

Thermal expansion is the changes of size of matter when the temperature of matter change.

DEMONSTRATION

1. The ball and ring experiment



RESULT

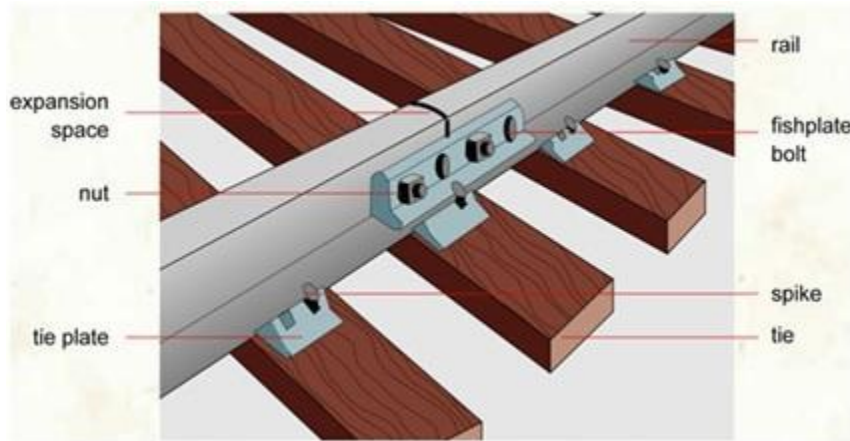
A metal ball just slips through a metal ring before heating. This shows that diameter of the metal ball is slightly smaller than that of a metal ring. After heating the metal ball it does not slip through the metal ring. This shows that the diameter of the metal ball increases when heated (the diameter of the ball is slightly larger than that of the metal ring)

NOTE:

Due to kinetic theory of energy, all matter is made of small particles that are in state of random motion. Hence when a solid metal is heated, it tends to expand due to that random motion of such particles.

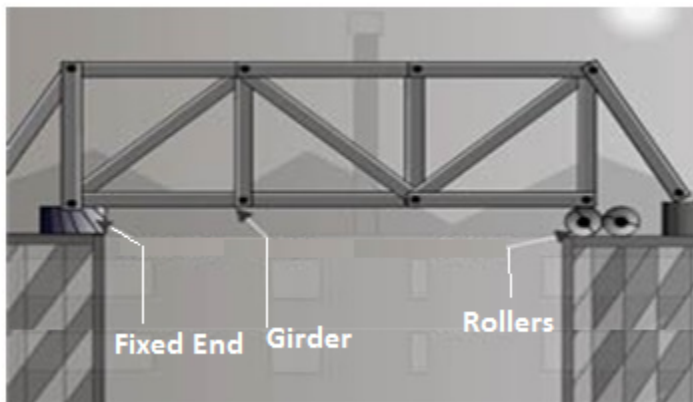
DISADVANTAGES

1. When the solid is expanded/ contracted large forces are created to resist either expansion / contraction respectively. that is why the railway lines are laid in such a way that a gap left at the junction of two rail bars.



Note: The slits through which the nuts pass are rectangular in shapes so that when the rail bar expands/ contracts the slight movement is free otherwise the rail bars are likely to cause accidents.

2. In steel bridges and roofs of both sides are fixed, the bridge or roof would elongate and hence buckle during expansion and crack during contraction.

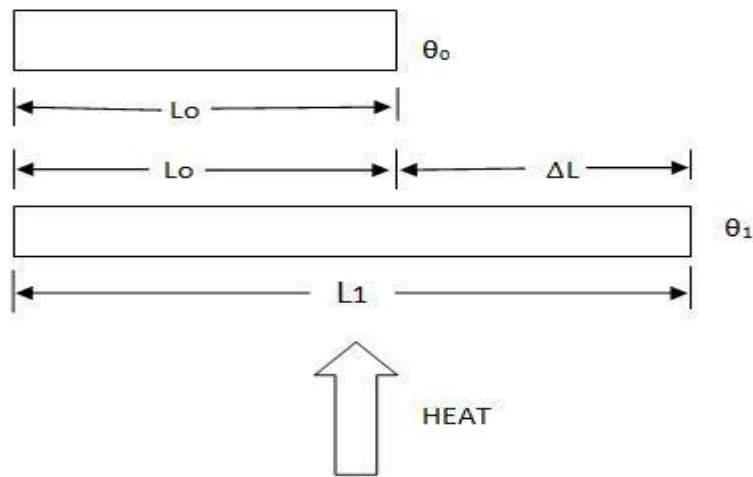


NOTE; To avoid these situations, one side of the bridge or roof is fixed while the other side's rests on roles so that movement of bridges or roofs is allowed during expansion and contraction.

3. Glass ware breaks easily by expansion e.g. Bottle contained cold liquids cracks if placed near or strong heat.

THE COEFFICIENT OF LINEAR EXPANSION OR LINEAR EXPANSIVITY OF SOLID SUBSTANCE

Consider the original length L_0 of the solid substance placed at initial temperature θ_0 (at room temperature) when a solid substance is subjected under heat energy, the new length of the solid substance is L_1 at final temperature θ_1



Where ΔL represents the amount of increase in length after the expansion

Note: The amount of increase in length, ΔL depend on the following factors:

1. The amount of increase in length of the solid substance depends on the original length

i.e. $\Delta L \propto L_0$ (i)

2. The amount of increase in length depends on the temperature rise i.e. $\Delta L \propto \Delta\theta$ (ii)

3. The amount of increase in length depends very much on the nature of the substance

Using expressions (i) and (ii) above

$$L \propto L_0$$

$$\Delta L = \alpha L_0 \Delta\theta$$

Where α = linear expansivity of the solid substance

= coefficient of linear expansion

$$\alpha = \frac{\Delta L}{L_0 \Delta \theta}$$

The linear expansivity is the fractional increase in length per degree temperature rise

Or

The linear expansivity is the fractional increase in length per degree temperature rise.

The SI units are ($^{\circ}\text{C}^{-1}$) and (K^{-1})

Note: Some linearly expansive solid metal substances are:

SOLID SUBSTANCE	LINEAR EXPANSIVITY ($^{\circ}\text{C}^{-1}$)
Aluminum	0.000026
Brass	0.000019
Copper	0.000017
Iron	0.000012
Concrete	0.000011
Glass	0.0000085
Invar	0.000001

NB: The higher the linear expansivity of the substance the larger the amount of the expansion and the lower the linear expansivity the smaller the amount of expansion.

EXAMPLE: 1

1. Copper rod has a length of 40cm on a day when the temperature of the room is 22.3°C. What will its length become on a day when the temperature of the room is 30°C?

Take the linear expansivity of copper 0.000017

Solution

$$L_0 = 40\text{cm}$$

$$\theta_0 = 22.3^\circ\text{C}$$

$$\theta_1 = 30^\circ\text{C}$$

$$L_1 = ?$$

$$0.000017 = \frac{L_1 - L_0}{40(\theta - \theta_0)}$$

$$0.000017 = \frac{L_1 - L_0}{40(30 - 22.3)}$$

$$0.000017 = \frac{L_1 - 40}{40 \times 7.7}$$

$$0.000017 = \frac{L_1 - 40}{308}$$

$$L_1 - 40 = 0.000017 \times 308$$

$$L_1 = 0.000017 \times 308 + 40$$

$$L_1 = 0.005236 + 40$$

$$L_1 = 40.005236\text{cm}$$

2. A block of concrete 5.0m expands to 5.00412m. When heated from 25°C to 100°C.

Find the linear expansivity of the concrete

Solution

$$\alpha = \frac{\Delta L}{L_0 \Delta \theta}$$

$$\alpha = ?$$

$$L_0 = 5.0 \text{ m}$$

$$\theta_0 = 25^\circ \text{C}$$

$$L_1 = 5.00412 \text{ m}$$

$$\theta_1 = 100^\circ \text{C}$$

$$\alpha = \frac{5.00412 - 5.0}{5.0 (100 - 25)}$$

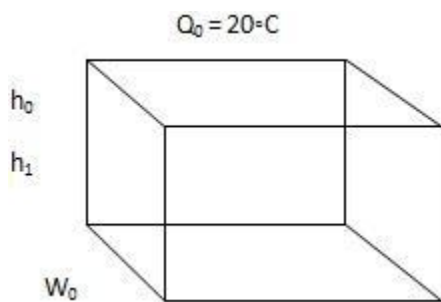
$$\alpha = \frac{0.00412}{5.0 (75)}$$

$$\alpha = \frac{0.00412}{37.5}$$

$$= 0.000170$$

3. A brick 30cm x 18cm x 10 cm is at 20°C. If it is heated to a temperature of 50°C, what will be its new dimension (the coefficient of linear expansion of concrete is $1.2 \times 10^{-5} \text{ K}^{-1}$)

Solution:



CASE I

New length L

$$\alpha = \frac{L_1 - L_0}{L_0 (\theta_1 - \theta_0)}$$

$$L_1 = L_0 [1 + \alpha(\theta_1 - \theta_0)]$$

$$= 30 [1 + 0.000012 (50 - 20)]$$

$$= 30 [1 + 0.000012 \times 30]$$

$$= 30 [1 + 0.00036]$$

$$= 30 \times 1.00036$$

$$\therefore L_1 = 30.0108\text{cm}$$

CASE II

New width, w_1

$$\begin{aligned} w_1 &= w_0 [1 + \alpha(\theta_1 - \theta_0)] \\ &= 18 [1 + 0.000017 \times 30] \\ &= 18 [1 + 0.00036] \\ &= 18 \times 1.00036 \\ \therefore w_1 &= 18.00648\text{cm} \end{aligned}$$

CASE III

New height, h

$$\begin{aligned} h_1 &= h_0 [1 + \alpha(\theta_1 - \theta_0)] \\ &= 10[1 + 0.000012 (30)] \\ &= 10(1 + 0.00036) \\ &= 10 \times 1.00036 \\ \therefore h_1 &= 10.0036\text{cm} \end{aligned}$$

4. An iron plate at 20°C as a whole of radius 8.92mm in the centre. An iron rivet with the radius of 8.95mm at 20°C is to be inserted into the hole. To what temperature must the plate will be heated for the rivet to fit into the whole (linear expansivity of iron is $1.24 \times 10^{-5} \text{ K}^{-1}$)

Solution

$$\alpha = \frac{R_1 - R_0}{R_0 (\theta_1 - \theta_0)}$$

$$\alpha R_0 (\theta_1 - \theta_0) = (R_1 - R_0)$$

$$\theta_1 - \theta_0 = \frac{R_1 - R_0}{\alpha R_0}$$

$$\theta_1 = \theta_0 + \frac{R_1 - R_0}{\alpha R_0}$$

$$\theta_1 = \frac{20 + (8.95 - 8.927)}{0.0000124 (8.92)}$$

$$\theta_1 = \frac{20 + 0.003}{0.0000124 \times 8.92}$$

$$\theta_1 = \frac{20 + 0.003}{0.0000124 \times 8.92}$$

$$\theta_1 = \frac{20 + 0.03}{0.00110608}$$

$$2.568 \times 101 = 25.68$$

$$\therefore \theta_1 = 20 + 25.68$$

$$\theta_1 = 45.68$$

5. A brass plate has a hole whose radius is too small for an iron rivet to fit into explain 2 different ways the rivet can be made to fit in the hole.

Answer

1. By expanding the brass plate to a certain diameter that could make the iron rivet to fit into.
2. By contracting the iron rivet to a certain diameter which could fit into the brass plate.

Modification

2. The brass plate will be heated, the radius of the whole will increase and iron rivet can be fitted easily. When the brass plate cools the contraction of the whole will secure the rivet.
3. An iron rivet is kept at the cool place for it to contract (decrease in diameter) such that the diameter of the iron rivet is slightly smaller than the diameter of the hole.

6. Aluminium and ordinary glass jar fits so tightly so that it cannot be unscrewed should the jar and the lid be immersed in hot water or cold water? To loosen the lid?

Answer - Hot water

Explanation

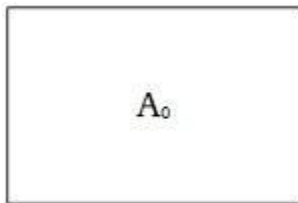
The aluminium expands more than the glass when heated though the same temperature change, so aluminium and glass expands by different amounts.

THE COEFFICIENT OF AREAL AND CUBICAL VOLUMETRIC EXPANSION

When a cubic solid is heated all its dimension changes, its surface area and volume change too.

AREAL CO EFFICIENCY EXPANSION OR SUPERFICIAL EXPANSIVELY

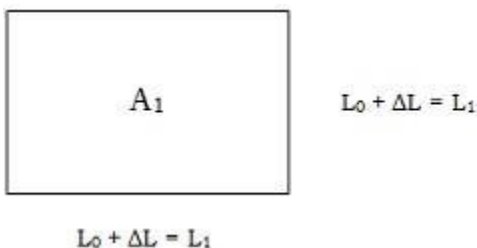
It is amount by which a unit surface area of a solid expands for a unit temperature increase.



$$A_0 = L_0 \times L_0$$

$$A_0 = L_0^2$$

When the surface area is subjected under heat energy, the dimensions change



$$\begin{aligned} A_1 &= (L_0 + \Delta L) (L_0 + \Delta L) \\ &= L_0(L_0 + \Delta L) + \Delta L (L_0 + \Delta L) \\ &= L_0^2 + \Delta L L_0 + \Delta L L_0 + \Delta L^2 \end{aligned}$$

$$= L_0^2 + 2L_0\Delta L + \Delta L^2$$

$$\text{But; } \Delta L = L_0\Delta\theta$$

$$A_1 = L_0^2 + 2L_0(\alpha L_0\Delta\theta) + \alpha^2 L_0^2 (\Delta\theta)^2$$

$$A_1 = L_0^2 + 2L_0^2 \alpha \Delta\theta + \alpha^2 L_0^2 (\Delta\theta)^2$$

REMEMBER: α is very small then $\alpha^2 = 0$

$$\therefore A_1 = L_0^2 + 2L_0^2 \Delta\theta + 0$$

$$\text{i.e. } A_1 = L_0^2 + 2L_0^2 \Delta\theta$$

$$A_1 = L_0^2 + L_0^2 (2) \Delta\beta$$

β = areal expansivity

$$A_1 = L_0 + L_0^2 \beta \Delta\theta$$

$$A_1 = A_0 + A_0 \beta \Delta\theta$$

$$\beta = \frac{A_1 - A_0}{A_0 \Delta\theta}$$

$$\beta = \frac{\Delta A}{A_0 \Delta\theta}$$

$$\beta = \frac{A_1 - A_0}{A_0 (\theta_1 - \theta_0)}$$

Examples

1. A steel plate has an area of 0.4m^2 when at a temperature of 30°C by how much should its temperature be raised so that its area may increase by 0.5% . take the linear expansivity of steel to be $0.00002^\circ\text{C}^{-1}$

Data:

$$A_0 = 0.4 \text{ m}^2$$

$$\theta_0 = 30^\circ\text{C}$$

$$\Delta A = \frac{0.5}{100} \times 0.4 \text{ m}^2$$

$$\Delta \theta = \frac{1}{5}$$

$$\Delta A = 0.002$$

$$\theta_1 = ?$$

But

$$\theta = \frac{\Delta \theta}{\theta_0 \Delta \theta}$$

$$2 \propto \frac{\theta_1 - \theta_0}{\theta_0 (\theta_1 - \theta_0)}$$

$$2 \propto \frac{A_0 (\theta_1 - \theta_0)}{2 \propto A_0} = \frac{A_1 - A_0}{2 \propto A_0}$$

$$\theta_1 - \theta_0 = \left(\frac{\theta_1 - \theta_0}{2 \propto \theta_0} \right)$$

$$\theta_1 = \left(\frac{A_1 - A_0}{2 \propto A_0} \right) + \theta_0$$

$$\theta_1 = \frac{0.002 - 0.4}{2 \times 0.000012 \times 0.4}$$

$$\theta_1 = 208.3 + 30$$

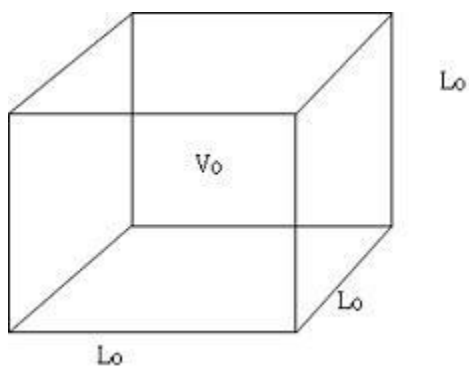
$$\theta_1 = 238.3^\circ\text{C}$$

$$\therefore 238.3^\circ\text{C} - 30^\circ\text{C} = 208.3^\circ\text{C}$$

$\therefore$ By 208.3°C the temperature may be raised

VOLUMETRIC/ CUBIC EXPANSIVITY

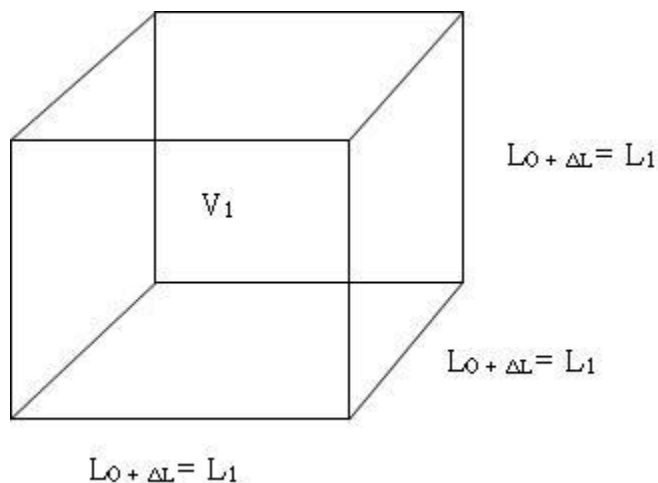
Consider a cube



$$V_0 = L_0 \times L_0 \times L_0$$

$$V_0 = L_0^3 \dots\dots\dots (i)$$

When a cube is heated to temperature



$$V_1 = (L_0 + \Delta L) (L_0 + \Delta L) (L_0 + \Delta L)$$

$$V_1 = [L_0^2 + 2L_0 \Delta L + (\Delta L)^2] L_1$$

$$V_1 = L_0^3 + 2L_0^2 \Delta L + 3L_0 (\Delta L)^2 + (\Delta L)^3$$

$$V_1 = L_0^3 + 3L_0^2 \Delta L + 3L_0 (\Delta L)^2 + (\Delta L)^3$$

But; $\Delta L = L_0 \Delta \alpha$

$$V_1 = L_0^3 + 3L_0^2 (L_0 \Delta \alpha) + 3L_0^2 (L_0^2 (\Delta \alpha)^2) + L_0^3 (\Delta \alpha)^3$$

$$V_1 = L_0^3 + 3L_0^2 L_0 \Delta \alpha + 3L_0^2 L_0^2 (\Delta \alpha)^2 + L_0^3 (\Delta \alpha)^3$$

Remember α is very small

$$\therefore \alpha^2 = 0, \alpha^3 = 0 \text{ etc.}$$

$$\therefore V_1 = L_0^3 + 3L_0^2 L_0 \Delta \alpha + 3L_0^2 L_0^2 (\Delta \alpha)^2 + 0$$

$$V_1 = L_0^3 + 3L_0^2 L_0 \Delta \alpha + 3L_0^2 L_0^2 (\Delta \alpha)^2$$

$$V_1 = L_0^3 + L_0^2 (3 \alpha / 1) L_0 \Delta \alpha + L_0 (3 \alpha / 1)^2 L_0^2 (\Delta \alpha)^2$$

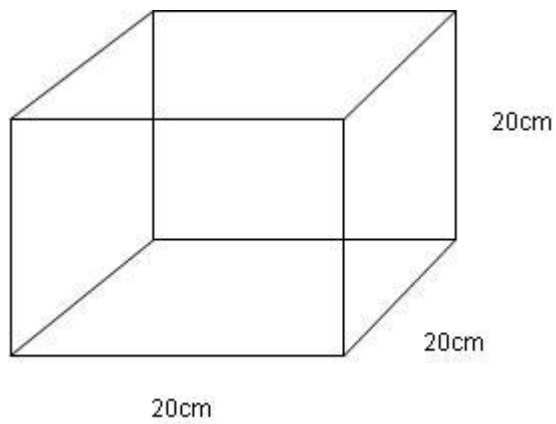
$$\therefore V_1 = L_0^3 + L_0^2 L_0 \Delta \alpha + L_0^2 L_0^2 (\Delta \alpha)^2$$

EXAMPLES:

1. A solid cube has dimensions 20 cm at 20°C. To what temperature must the cube be heated for its volume to become 800.0 cm³?

(Take linear expansivity of solid cube to be $1.1 \times 10^{-5} \text{ K}^{-1}$)

Solution



Data: -

$$V_0 = L_0^3$$

$$V_0 = 20 \times 20 \times 20$$

$$V_0 = 8000.02 \text{ cm}^3$$

$$\theta_1 = 20^\circ \text{C}$$

$$V_1 = 8000.02 \text{ cm}^3$$

$$\theta = ?$$

$$\gamma = 3\alpha$$

$$= 3 \times 1.1 \times 10^{-5} \text{ K}^{-1}$$

$$= 3.3 \times 10^{-5} \text{ K}^{-1}$$

From

From $\alpha = \frac{\Delta V}{V_0 \Delta \theta}$

$$3.3 \times 10^{-5} = \frac{V_1 - V_0}{V_0 (\theta_1 - \theta_0)}$$

$$3.3 \times 10^{-5} = \frac{8000.02 - 8000.02}{8000 (\theta_1 - 20)}$$

$$3.3 \times 10^{-5} = \frac{0.02}{8000 (\theta_1 - 20)}$$

$$\theta_1 - 20 = \frac{0.02}{8000 \times 3.3 \times 10^{-5}}$$

$$\theta_1 = 20 + 0.00758$$

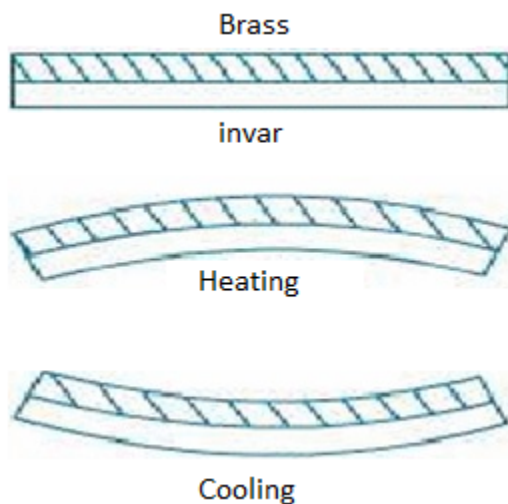
$$= 20.0756^\circ$$

$\therefore$ The answer is 20.00756°C

APPLICATIONS OF THE THERMAL EXPANSION IN SOLIDS

Some solids expand more than other due to the fact that so different solids have different linear expansiveness.

BIMETALLIC STRIP



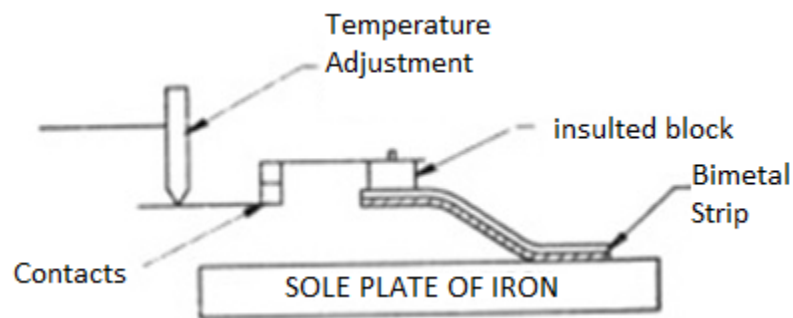
A Bimetallic strip consists of two (2) dissimilar metal strips e.g. Brass and iron welded together. At room temperature the compound bar is straight, when it is heated to a higher temperature than

the room temperature, brass expand longer than iron this cause the strip to bend to wards the sides of iron.

When bimetallic strip is cooled brass will contract more and the strip will bend towards the side of brass.

The uses of Bimetallic strip

- Is used in electric circuit of pressing which is completed by a metal strip. The maximum temperature is adjusted by a knob. When the temperature is maximum, the bimetallic strip bends sufficiently to break the circuit at the contact and the break point, the current is then switched off and the heating process stops. The temperature then flows Stanley infill the bimetallic strip straightens and re- makes. The current then flows again and the hearing process occur again



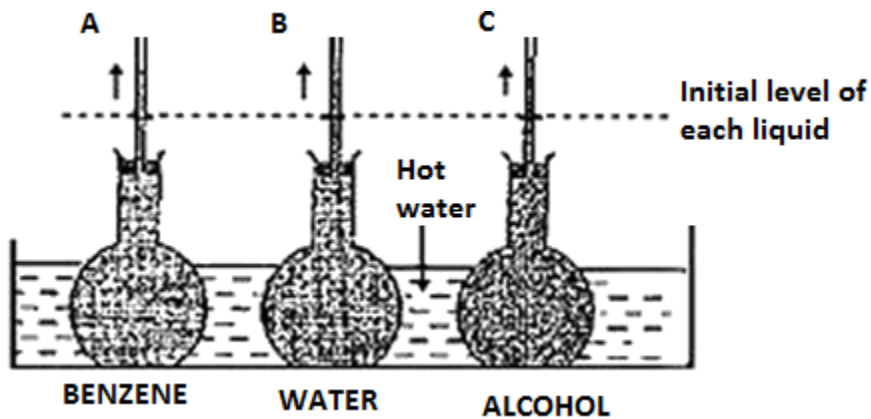
- Is used in manufacturing the thermostats. It is found in hot water storage tanks and refrigerators.
- Is used in the traffic light circuits
- Is used as bi-metallic thermometers to record temperature of in accessible structures such as the engines of vehicles, marine ships

EXPANSIONS IN LIQUIDS

Liquids do expand when heated. Different liquids have different thermal expansions.

Demonstration

Consider the glass bulbs A, B and C filled to a short distance above the bulb with various liquids as shown below in order to make fair comparison.



The liquids in the stems will rise by different amounts when heated at the same environment. Since the liquids have no shapes, they take the shapes of the vessels. Therefore they don't have linear and areal expansiveness. They have only volume and expansiveness. When the liquids are heated, their volume does increase.

THE CO-EFFICIENCY OF VOLUME EXPANSION OF LIQUIDS

The coefficient of volume expansion is the fractional increase in volume per temperature rise. It is sometimes called apparent volume expansivity

$$\gamma_{ap} = \frac{\Delta V}{V_0 \Delta \theta}$$

NB: absolute volume expansivity of a liquid is the sum of the apparent with volume expansivity and for the volume expansivity material of the containing vent i.e. $\gamma_{ab} = \gamma_{ap} + \gamma_{material}$

Example:

The volume of liquid 20°C and 70°C are $4 \times 10^{-5} \text{ m}^3$ and $4.1 \times 10^{-5} \text{ m}^3$ respectively. Calculate the apparent volume expansivity of the liquid

Data:

$$r_{ap} = \frac{v_1 - v_0}{v_0(\theta_1 - \theta_0)}$$

$$r_{ap} = \frac{4.1 \times 10^{-5} - 4.0 \times 10^{-5}}{4 \times 10^{-5}(70 - 20)}$$

$$r_{ap} = \frac{0.1 \times 10^{-5}}{4 \times 10^{-5} \times 50}$$

$$r_{ap} = \frac{0.1 \times 10}{200}$$

$$r_{ap} = \frac{1}{200}$$

$$r_{ap} = 0.005^\circ\text{C}^{-1}$$

THE DENSITY OF LIQUID WITH TEMPERATURE

- When the liquid is heated, its volume increases while its density decreases and its mass remains constant

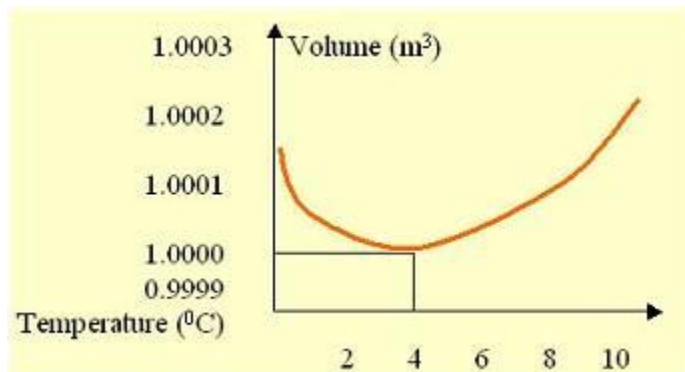
$$\text{From: } \rho = \frac{m}{v}$$

- When volume, V increases; (density decreases). Hence the more volume of the liquid the lower is the density of the liquid and vice versa.

The unusual expansion of water

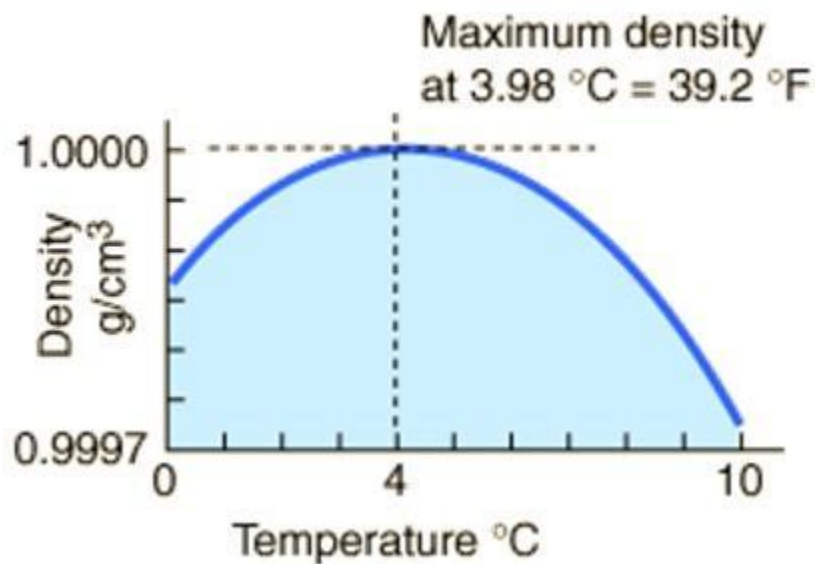
When water is heated from 0 °C to 4 °C it contract instead of expanding . This unusual behavior is called anomalous expansion of water . Below 0 °C and above 4 °C water behave just like any other liquid.

THE VARIATION OF VOLUME OF WATER WITH TEMPERATURE



Volume of water is minimum at 4°C

THE VARIATION OF DENSITY OF WATER WITH TEMPERATURE

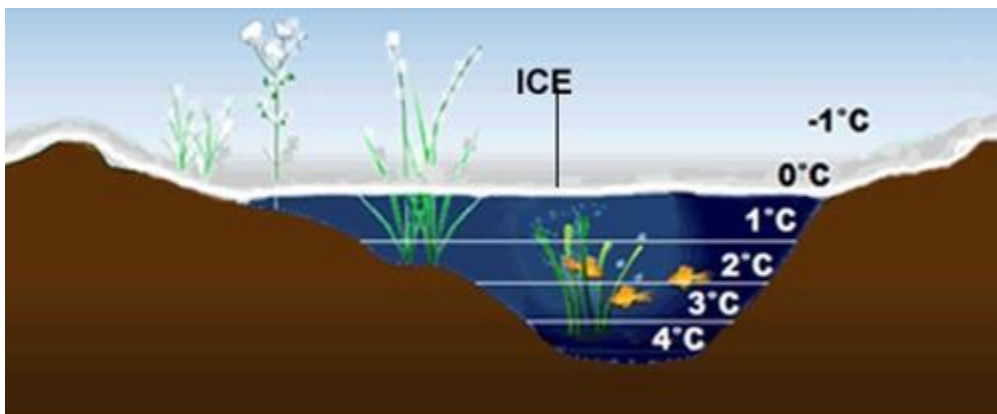


Note; the density of water is maximum 4°C

BIOLOGICAL IMPORTANCE OF ANOMALOUS EXPANSION OF WATER

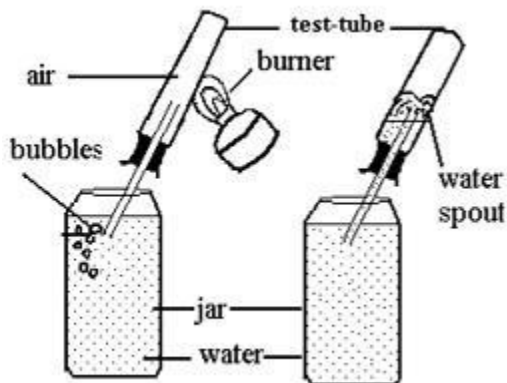
The anomalous expansion of water has an important use on the preservation of the aquatic life during very cold weather.

As the temperature of a pond or lake falls, the water contracts it becomes denser and it sinks. A circulation is thus setup until all the water reaches its maximum temperature. If further cooling occurs, any water below 4°C will stay at the top due to its lighter density. as a result ice forms on top of water and after this, the lower layers of water at 4°C can lose heat only by conduction. Shallow water is this liable to freeze solid. In deeper water, there will be water beneath the ice in which fish and other creatures can live and survive



THERMAL EXPANSION IN GASES

The gas takes the shape of the container. When the gas is heated, the volume of the gas increases, gases are sensitive to pressure changes as well



When the flask containing air is heated, gas (air) it expanded that is bubbles come out of the tube through the water.

The bubbles are the escaping gases

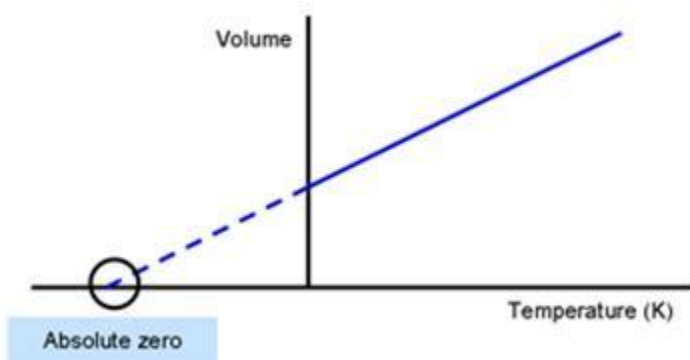
THE PRESSURE OF A GAS IN A CONTAINER

When the gas is heated the molecules acquire thermal energy which increases their kinetic energy. The molecules collide themselves and heat on the wall equal to the rate of change of momentum of the molecules, hence force acting normally per unit area simply pressure of a gas.

EXPANSION OF AIR AT A CONSTANT PRESSURE

When air is heated, the volume varies proportional to the temperature rise.

THE GRAPH OF VOLUME OF AIR AGAINST TEMPERATURE



Note:

Air expands uniformly with temperature at constant pressure

ABSOLUTE SCALE OF TEMPERATURE

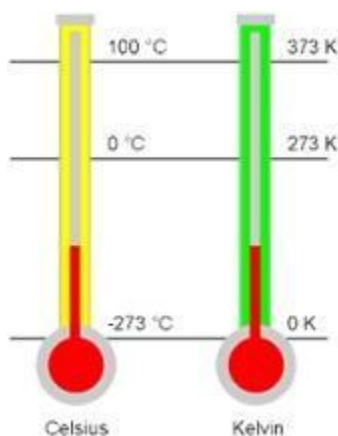
In the graph above, when the line is extended to left it cuts the temperature axis at -273°C

Theoretically; this means that the volume of air becomes 0 when the temperature is -273°C

Practically; air will have liquefied before it reaches this temperature.

Suppose that the 2 axis of volume and temperature were to intersect at this temperature -273°C .

Then a new scale of temperature is at -273°C



The temperature -273°C or 0 K is called absolute. This was proposed by Lord Kelvin, thus the scale is known as Kelvin's scale consider to be the temperature on Celsius scale and T to be the temperature on Kelvin scale then

$$0 - (-273) = 273 - 0$$

$$0 + 273 = 273 - 0$$

$$273 = 273$$

$$\text{Hence } \theta - 0 = T - 273$$

$$\boxed{\theta = T - 273}$$

E.g. the temperature of the gas is 65°C . What is the value of this temperature for absolute value?

Solution

$$T = \theta + 273$$

$$= 65 + 273$$

$$=338 \text{ K}$$

Note: From the graph above the volume of the gas is directly proportional to the absolute temperature i.e. $V \propto T$.

- This relation was proposed by a French scientist called *Jacques Charles* and hence called **Charles Law**.

Charles law states that “*The volume of a fixed mass of a gas at constant pressure is directly proportional to the absolute temperature*”

i.e.

$$\begin{aligned} V &\propto T \\ V &= KT \\ K &= \frac{V}{T} \\ \frac{V_1}{T_1} &= \frac{V_2}{T_2} = \frac{V_3}{T_3} = \frac{V_4}{T_4} \end{aligned}$$

Thus: $\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$ pressure is kept constant

Example1. The volume of the fixed mass of the gas is 290cm^3 at 20°C

At what temperature will it's volume be 340 cm^3 . If it's pressure is kept constant.

Solution;

$$\begin{aligned} \frac{V_1}{T_1} &= \frac{V_2}{T_2} \\ \frac{290}{293} &= \frac{340}{T_2} \\ T_2 &= \frac{340 \times 293}{290} \end{aligned}$$

$$T_2 = 343.5 \text{ K}$$

$$T_2 = 70.5^\circ\text{C}$$

BOYLE’S LAW states that: “*The volume of a fixed mass of a gas at constant temperature is inversely proportional to the pressure*”

$$V \propto \frac{1}{P}$$

$$V = \frac{K}{P}$$

$$K = VP$$

$$V_1P_1 = V_2P_2 = V_nP_n$$

Example;

The volume of a given mass of a gas is 550cm³. When the pressure is 79cm of mercury, what will be its volume when the pressure is 76cm of mercury? If the temperature remains constant

Solution

$$V_1 = 550\text{cm}$$

$$P_1 = 79\text{cmHg}$$

$$P_2 = 76\text{cm Hg}$$

$$V_2 = ?$$

Using

$$V_1P_1 = V_2P_2$$

$$550 \times 79 = V_2 \times 76$$

$$V_2 = 57.7\text{m}^3$$

PRESSURE LAW

The pressure law states that the pressure of a fixed mass of a gas at constant volume is directly proportional to absolute temperature.

i.e. $P \propto T$

$$P = KT$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \frac{P_3}{T_3} = \frac{P_4}{T_4}$$

EXAMPLE: The pressure of a fixed mass of a gas at 20°C is 78 m of mercury, find the pressure of gas at 0°C if constant volume.

Solution

$$T_1 = 20^\circ\text{C} = 293 \text{ K}$$

$$T_2 = 0^\circ\text{C} = 273 \text{ K}$$

$$P_1 = 78 \text{ mmHg}$$

$$P_2 = ?$$

From

$$\frac{78}{293} = \frac{P_2}{273}$$

$$P_2 = \frac{273 \times 78}{293}$$

$$P_2 = 72.7 \text{ mmHg}$$

GENERAL GAS EQUATION

The combination of the 3 gas laws that is Charles's, Boyle's and pressure law. Give the gas equation divided by using only 2 of them

$$V \propto T \quad \text{(i) Charles's law}$$

$$P \propto \frac{1}{V} \quad \text{(ii) Boyle's law}$$

$$\therefore V \propto \frac{1}{P} \propto T$$

Which is the same as

$$\frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2} = \frac{V_3 P_3}{T_3} \dots \dots \dots \text{etc}$$

$$\text{Hence } \boxed{\frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2}} \text{ Gas Equation}$$

CASES

1. At constant temperature

$$T_1 = T_2$$

$$\text{Hence } V_1 P_1 = V_2 P_2 \quad \text{Boyle's law}$$

2. At constant pressure

$$P_1 = P_2$$

Hence

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Charles's law

3. At constant volume

$$V_1 = V_2$$

Hence

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

pressure law

Note: at S.T.P temperature is 0°C or 273 K

Question1: At a temperature of 30°C and a pressure of 740 mmHg the volume of a gas 30cm³.

Calculate the volume of the gas at S.T.P

Data:

$$T_1 = 30^\circ\text{C} (+273^\circ) = 303^\circ$$

$$P_1 = 740\text{mm}$$

$$V_1 = 300\text{cm}$$

FROM

$$\frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2}$$

$$\frac{300 \times 740}{303} = \frac{V_2 \times 760}{273}$$

$$300 \times 740 \times 303 = V_2 \times 760 \times 300$$

$$V_2 = \frac{67266000}{228000}$$

$$V_2 = 295.026\text{cm}^3$$

Question2: Sample of oxygen gas has a volume of 0.11m³ at a temperature of 12°C and a pressure of 8.1 x 10⁴ Pascal while a sample of Nitrogen gas has a volume 0.18m³ at a temperature of 22°C and pressure 1.03 x 10⁵Pa which gas will have a large volume at S.T.P

Solution

Q₂

N₂

$$V_1 = 0.11$$

$$V_2 = 0.18$$

$$T_1 = 12^\circ\text{C}$$

$$T_2 = 22^\circ\text{C}$$

$$P_1 = 8.1 \times 10^4$$

$$P_2 = 1.03 \times 10^5$$

$$\frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2}$$

$$\frac{0.11 \times 8.1 \times 10^4}{285} = \frac{V_2 \times 0.76}{295}$$

$$V_2 \times 0.76 \times 285 = 295 \times 0.11 \times 8.1 \times 10^4$$

$$V_2 = \frac{262.845 \times 10^4}{216.6}$$

∴ The large volume is $1.2 \times 10^4 \text{m}^3$

THE TRANSFER OF THERMAL ENERGY

Heat is a form of energy which flows as a result of temperature difference. Consider objects A and B.

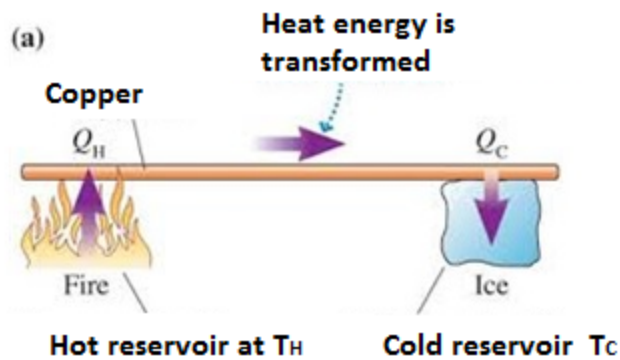


Let θ_1 to be the temperature of object A and θ_2 to be the temperature of object B such that θ_A is greater than θ_B i.e. $\theta_A > \theta_B$. Then the heat energy therefore flows from object A toward object B.

There are three ways in which heat energy can be transferred these include **conduction**, **convection** and **Radiation**.

1. BY CONDUCTION

Conduction is the transfer of heat through matter (solids) from a region of high temperature to the region of low temperature. The movement of energy from one atom to another without the movement of the matter itself. The atom is bonded to neighboring atoms, when heat is supplied to a part of solid matter, the atom is vibrating, and the vibration is passed on to the neighboring atom through the bonds. This process spreads the heat throughout the solid matter.



THE CONDUCTORS AND INSULATORS OF HEAT

All material which allow heat to flow through them easily are called good conductor of heat such as most of the metal (copper , silver , iron , aluminium , brass ,lead and etc) but the rate of conduction differ from one another .

When the metal is heated the electrons which move around the lattice structure carry thermal energy from a region of high temperature to region of low temperature.

Insulator is all material that they don't conduct heat e.g. glass, plastic, clothes, rubber and wood

THE SIMPLE EXPERIMENT TO INVESTIGATE THE CONDUCTION OF HEAT BY METAL

SIMPLE EXPERIMENT

Simple experiment to show that water is bad conductor of heat.

Apparatus:

- Test tube
- Water
- Ice
- Wire gauze
- A pair of tongs
- Source of heat

Procedure:

1-Fill the test tube about 2/3 of water

2-Holding a test tube with a pair of tongs, heat it slightly and heat it over a Bunsen burner as shown below.

OBSERVATION:

The water near the opened end , the test tube boils but the ice at the bottom of test of test tube does not melt. This shows that water does not conduct heat (hence water is the poor conductor of heat)

THE FACTOR AFFECTING THE RATE OF CONDUCTION OF HEAT

1. The rate of conduction of heat is inversely proportional to the length of material. The longer the material, the lower is production of heat. The longer is the material the more the time it takes to conduct heat and vice versa.
2. The rate of conduction of heat is inversely proportional to the cross sectional area of the material perpendicular to the heat flow. The larger is the cross section area the faster is the rate of conduction of heat.
3. The rate of conduction is directly proportional to the difference in temperature between the two ends of the material. The higher the temperature difference the higher the rate of conduction of heat and vice versa
4. The rate of conduction depends on the thermal conducting of the material (nature). The thermal conductivity is the measure of the rate at which a material conducts heat the higher the thermal conducting of the material, the higher is the rate of conduction of heat vice versa.

HOW TO MINIMIZE THE LOSS OF HEAT BY CONDUCTION

1. In a system where heat needs to be conserved the heat losses by conduction can be minimized by thermal insulation. Thermal insulation involves the use of poor or bad conductors of heat – thermal insulation is used in the boilers. Hot water pipes.
2. In a house insulating against heat loss is achieved by using double glazed window, carpets, curtains etc.

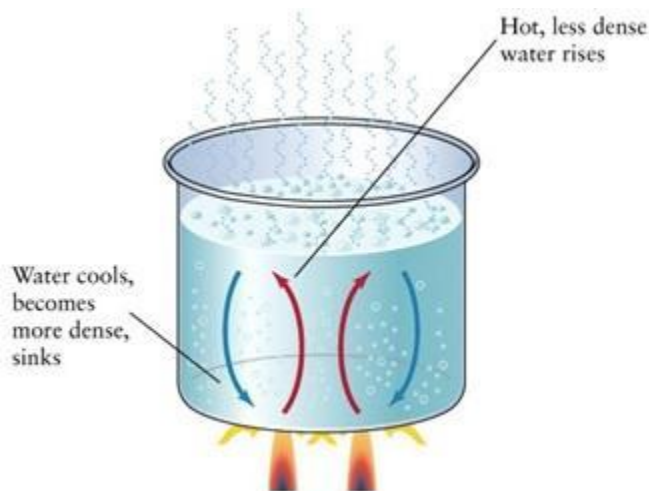
APPLICATION OF CONDUCTION OF HEAT

1. The cooking materials are made up of metal to efficiently transfer heat to the food being prepared. The vessels have wooden material or plastic handles that stay cold.
2. In elect devices i.e. computers some components are likely to be damaged by high temperature. To protect such component the **heat sinks** are attached to the device. The heat ink is a material with high thermal conducting i.e. copper that can conduct heat away.
3. Aluminum is used in making motor engines, piston and cylinders because of its low density and high thermal conduct.
4. Bad conductors are used for insulation purposes, the clothes we wear are insulators hence poor conductors of heat which insulates us chains loss of heat by conduction e.g. in hot region people wear light clothes and vice versa.

5. The bottoms cooking pots need periodic clean to remove layers of heat which improve the flow of heat.
6. The fibre glass is used under roofs of buildings to prevent heat loss in cold areas.
7. Saw dust which is a poor conductor of heat is used for making hot water pipes.

2. BY CONVECTION

This is the transfer of heat in fluids by currents. When the fluid at the bottom is heated it expands, as it expands the volume increases. The density decreases as the volume increases. Therefore the warmer fluid becomes less dense and thus rises to the top. The cooler fluid at the top becomes denser and thus it sinks. This sets up a convectional current.



NB. The convection involves mass movement of the fluid.

HOW TO MINIMIZE HEAT LOSS BY CONVECTION

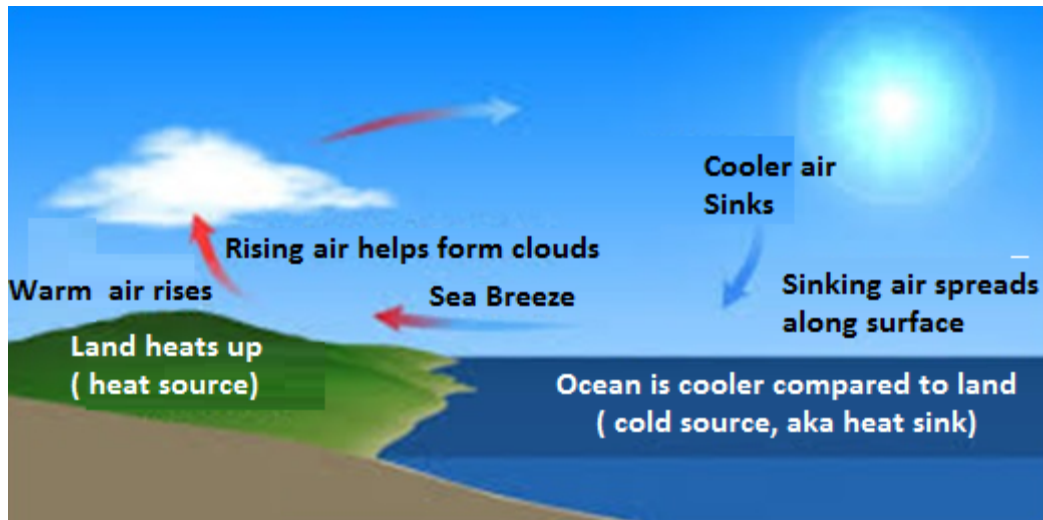
1. The losses of heat can be minimized by removing any fluid medium within which convectional current move. This principle is used in making of the vacuum flask.
2. The losses of heat can be minimized filling hair cavity with insulating materials.

APPLICATIONS OF CONVECTION OF HEAT

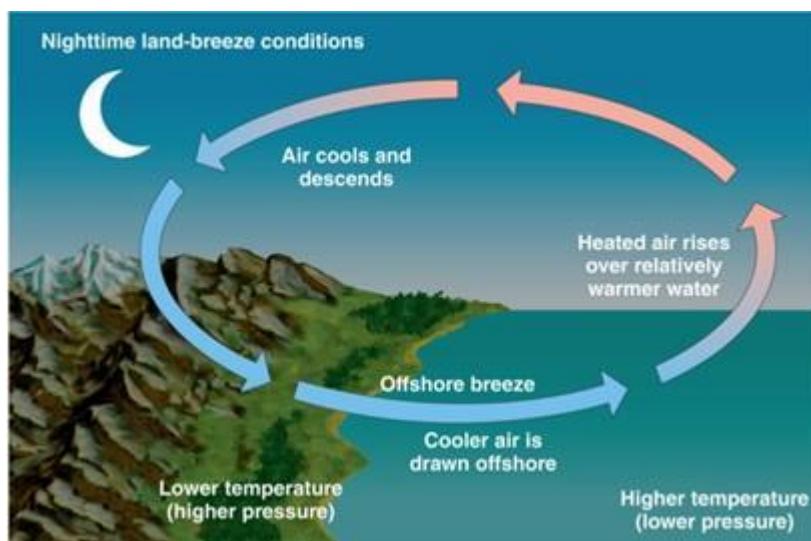
1. Land breeze and sea breeze

These are a result of expansion of air caused by unequal heating and cooling of adjacent sea and land surfaces.

- During the day time the land is warmer than the sea thus the air over the land surface becomes less dense and it rises. The space left is occupied by cooler air from above the sea surface.



- During the night time the sea is hotter than the land thus the air over the sea becomes less dense it rises.



2. Domestic hot water supply system.

Hot water moves from the boiler to where it is used under convection current. Inside the boiler water is heated making it less dense, water rises and flow into the hot water reserve where it is stored until needed for use main water supply.

3. Air conditioning systems relied on convectional currently to heat or cool a room. When it is hot, cool air is blown into the room from the air conditioner. This sinks to the bottom of the room taking place of the less dense warmer air (warmer air rises and is lead out to be cooled the recirculated).

When it is cold, the heater is turned on heating the surrounding air. The heated air rises up and cold air moves

down to take the place of the rising warm air. This forms convectional current which continues to circulate until the air in the room is at the desired temperature.

3. RADIATION OF HEAT

Radiation is the transfer of heat between two bodies by means of electromagnetic waves that arise due to the temperature of a body in the form of infrared radiation. The transfer of heat by radiation does not require material medium. It takes place in vacuums. All bodies at a temperature above absolute 0°C emit some radiant energy. The heat from the sun reaches the earth through radiation. The region between the sun and the earth's atmosphere is a vacuum. The heat energy from the sun cannot reach the earth by conduction or convection, it reaches by radiation.

NB: Radiation heat travels with the speed of light and hence can be reflected absorbed or transmitted.

ABSORBERS, EMITTERS AND REFLECTORS OF RADIANT HEAT

Dark or black surfaces are good absorbers and emitters of radiant heat. A surface that absorbs all radiant heat energy is called black body. A polished or shiny surface on the other hand is good reflector of radiant energy but a poor emitter.

EXPERIMENT TO INVESTIGATE THE ABSORPTION AND EMISSION OF RADIANT HEAT

Apparatus

: Two containers (shiny and black) surfaces.

: Two thermometers A and B

: Water

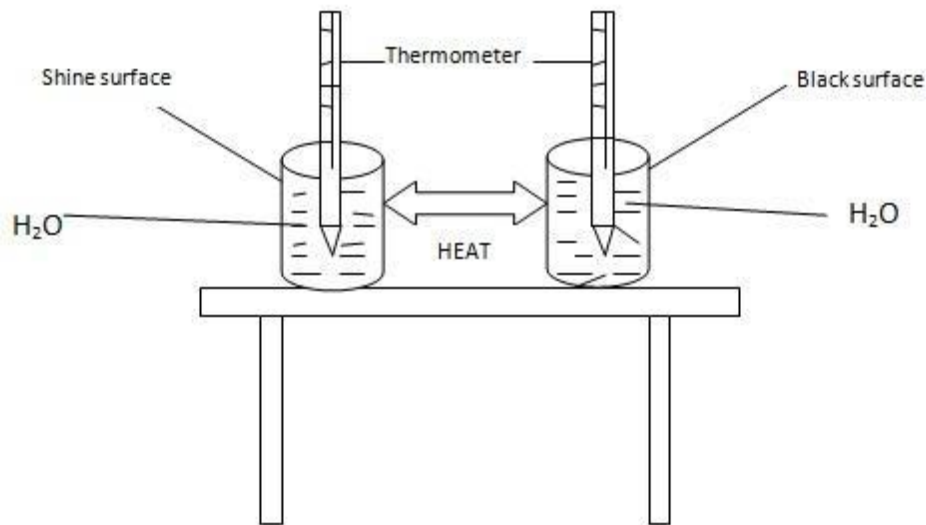
: Heat source

Procedure

: Fill the containers with water to about $\frac{2}{3}$ full.

: Place the containers close to the heat source

: Insert thermometers A and B into water contained in the shiny and black surface respectively.



Observations:

Thermometer B records high temperature than thermometer A because the black surface absorbs heat faster than the shine surface.

When the heat source is removed, thermometer B record lower temperature than thermometer A because a good absorber of heat is a good emitter of heat. This means that black surfaces absorb and radiant heat energy better than shinny surfaces

HOW TO MINIMIZE HEAT LOSSES BY RADIATION

1. The mechanism of thermos flask to hold hot or cold liquid for a long time. It is designs to minimize the losses of heat by radiation, conduction and convection. It consists of double walled glass containers with a vacuum between the walls. The inner wall is coated with silver. It has a stopper made up of cork or other insulating materials and insulated materials to keep the inner glass container away from touching the outer container.



Both conduction and convection are minimized by vacuum between the glass walls insulated stoppers and the separators. The silvered walls effectively reflect heat thus preventing heat loss by radiation.

MEASUREMENTS OF THERMAL ENERGY

Thermal energy refers to type of energy that relates to the heat or caused by heat. When one boil a utensil of water, thermal energy is applied at the bottom of the utensil then transferred to the water inside the utensil causing the water molecule to move faster and get hot.

Measurement of thermal energy involves indirect measurement of molecule kinetic energy which in total makes the heat content of an object.

We have already seen that heat is a form of energy transferred between bodies due to difference in temperature between them.

The heat required to raise the temperature of 1Kg of water through one degree is approximately 4.2 Joule.

The energy is possessed by the body due to its temperature is called **internal thermal energy or heat content**.

The heat content of a substance of an object due to random motion of the particles make up an object.

THE HEAT CONTENT OF A SUBSTANCE

The following are the factors which affect the amount of heat supplied to or taken away from a body.

1. **The mass**

The amount of heat is directly proportional the mass of a body.

$$Q \propto M$$

$$Q = kM$$

2. **Temperature different**

The amount of heat is directly proportional to the temperature change.

$$Q \propto \theta$$

3. **Thermal property**

The amount of heat depends on the thermal property of the body.

Note: when a quantity of heat is supplied to different bodies of equal masses, it will not cause the same temperature rise, this shows that each body has its own thermal property i.e. heat capacity.

HEAT CAPACITY

Is the amount of heat required or needed by a body to raise its temperature by one 1K.

The SI Unit of heat capacity is J/ K.

The amount of heat required to raise the temperature of a unity mass by 1K , is called **Specific Heat Capacity** (a unit mass =1Kg)

HEAT EQUATION

Using the factors affecting the amount of heat supplied to or taken away from a body is discussed above, $Q \propto M\Delta\theta$

$$Q \propto M\theta$$

$$Q = kM\theta$$

But, k is a constant known as specific heat capacity, C

Therefore;

$$Q = CM\theta$$

$$Q = MC\theta \rightarrow \text{Heat formula / equation}$$

Whereby:

Q → Quantity of heat applied or lost

M → Mass of a substance

C → Specific heat capacity of a substance

$\theta \rightarrow$ Temperature change ($\theta_2 - \theta_1$).

The SI unit of specific heat capacity

$$C = \frac{Q(i)}{M\Delta\theta(KgK)}$$

∴ The SI unit is J/KgK.

Specific Heat Capacities of a new Substances

Substance	J/kgK	J/gK
Water	4200	4.2
Alcohol	2500	2.5
Ice	2100	2.1

Steel	460	0.46
Mercury	130	0.13
Copper	390	0.39
Brass	320	0.32

Example

1. Water of mass 3kg is heated from 26°C to 96°C. Find the amount of heat supplied to water. Given that the specific capacity of water is 4200 J/kg°C

DATA GIVEN

$$M = 3 \text{ Kg}$$

$$\Delta\theta = 96^\circ\text{C} - 26^\circ\text{C}$$

$$= 70^\circ\text{C}$$

$$C = 4200$$

$$Q = Mc\Delta\theta$$

$$Q = 3 \times 4200 \times 70$$

$$Q = 882000 \text{ J}$$

∴ The amount of heat supplied is 882000J or 882KJ

2. How much heat is required to raise the temperature of sample of mercury from 20°C to 30°C. Take the specific heat capacity of mercury as 1395 J/KgK.

$$Q = Mc\Delta\theta$$

$$Q = 25 \times 1395 \times (30^\circ\text{C} - 20^\circ\text{C})$$

$$Q = 25 \times 1395 \times 10^\circ\text{C}$$

$$Q = 348750 \text{ J}$$

∴ The heat required is 348750 J

EXPERIMENT:I

Determination of the specific heat capacity of a solid substance by mixture method

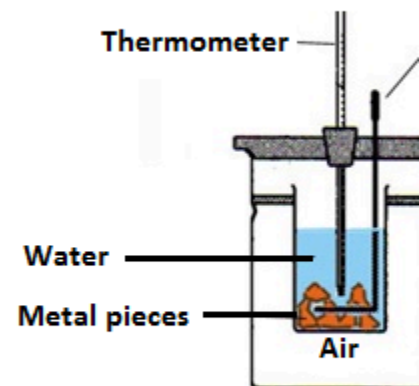
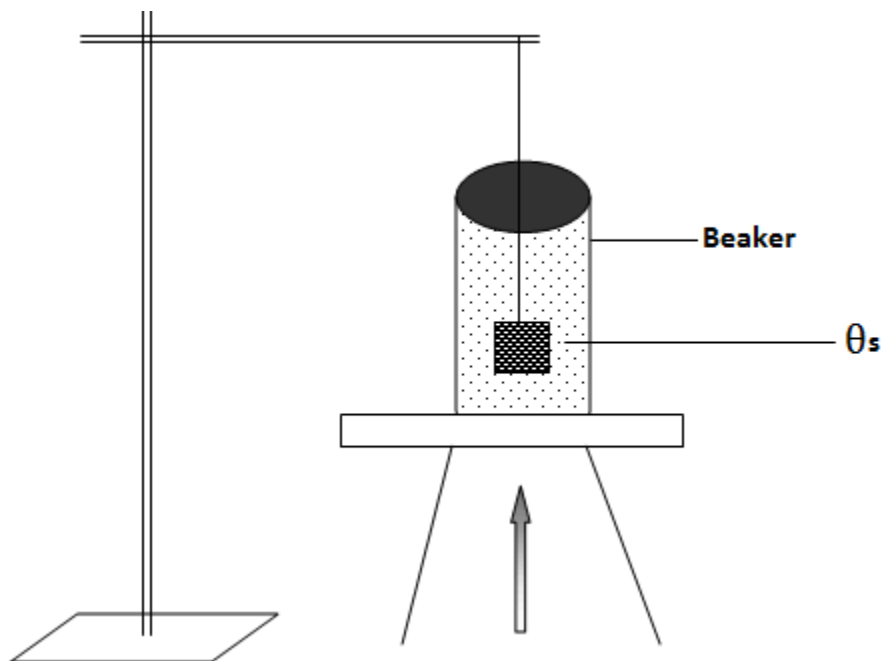
Requirements;

- Calorimeter (made of copper and Aluminum)
- An insulating cover

- Thermometer
- Stirrer (same nature as the calorimeter)
- Solid substance
- Beam balance
- Heat source and beaker

Procedure

1. Measure and record the mass of the calorimeter and the stirrers (M_c).
2. Put water into the calorimeter and then put it in its jacket and cover.
3. Record the temperature of the water (θ_i).
4. Boil water in a beaker.
5. Tie a solid substance of known mass (M_s) with a thin thread and place it in hot water in the beaker for a certain length of time .
6. Remove the solid quickly and wipe it with a dry cloth and place it in a calorimeter.
7. Replace the cover and stir gently until the temperature is steady.
8. Read and record thus steady temperature (θ_f).



Heat loss by the solid substance = heat gained by water + heat gained by calorimeter

LET; Q_s = heat loss by the solid

$$\therefore Q_s = Q_w + Q_c$$

Where; Q_w = heat gained by water

Q_c = heat gained by calorimeter

Given that

$$Q_s = M_s C_s \Delta\theta_s$$

$$\therefore Q_s = M_s C_s (\theta_s - \theta_f)$$

$$Q_w = M_w C_w \Delta\theta_w$$

Where; Q_w = heat gained by water

M_w = mass of water

$\Delta\theta_w$ = change in temperature of calorimeter

$$\therefore Q_w = M_w C_w (\theta_f - \theta_i)$$

$$Q_c = M_c C_c \Delta\theta_c$$

Where; Q_c = heat gained by calorimeter

M_c = mass of calorimeter

$\Delta\theta_c$ = change in temperature of calorimeter

$$\therefore Q_c = M_c C_c (\theta_f - \theta_i)$$

$$\therefore M_s C_s (\theta_s - \theta_f) = M_w C_w (\theta_f - \theta_i) + M_c C_c (\theta_f - \theta_i)$$

$$C_w = \frac{M_s C_s (\theta_s - \theta_f) - M_c C_c (\theta_f - \theta_i)}{M_w (\theta_f - \theta_i)}$$

Note: The solid should be transferred quickly in order to minimize heat losses to the environment.

EXPERIMENT: II

Determination of specific heat capacity liquid by mixture

Like in the experiment above, but instead of water we have another liquid. The specific heat capacity can be calculated as follows.

Heat loss by substance = heat gained by liquid + heat gained by liquid calorimeter

Given That;

$$Q_s = M_s C_s \Delta\theta_s$$

$$\therefore Q_s = M_s C_s (\theta_s - \theta_f)$$

$$Q_L = M_L C_L \Delta\theta_L$$

$$\therefore Q_L = M_L C_L (\theta_f - \theta_i)$$

$$Q_c = M_c C_c \Delta \theta_c$$

$$\therefore Q_c = M_c C_c (\theta_f - \theta_i)$$

Therefore;

$$C_1 = \frac{M_S C_S (\theta_S - \theta_F) - M_C C_C (\theta_F - \theta_I)}{M_I (\theta_F - \theta_I)}$$

CHANGE OF STATES

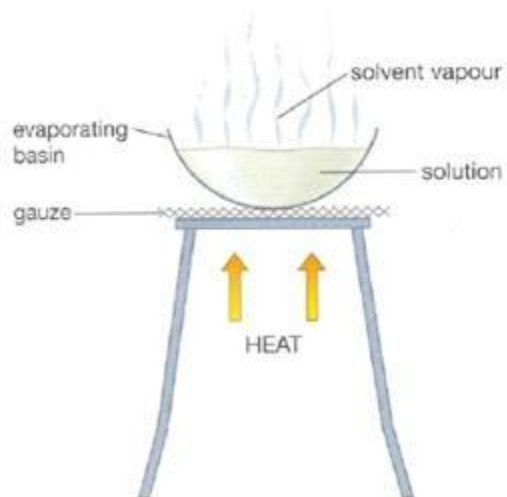
When heat is applied to a substance, a change of state may take place. The reverse change of state takes place on cooling.

The change of state from solid to liquid takes place at a constant temperature known as **melting point**.

Boiling and **evaporation** are terms used to describe the change from liquid to vapour (gas)

Evaporation

This is a slow process which occurs at all temperature and takes place only at the surface of the liquid.



Boiling Point

This is the temperature at which all of a liquid changes into gas. This takes place when the bubbles of vapour. The temperature at which boiling takes place is called as **Boiling point**.

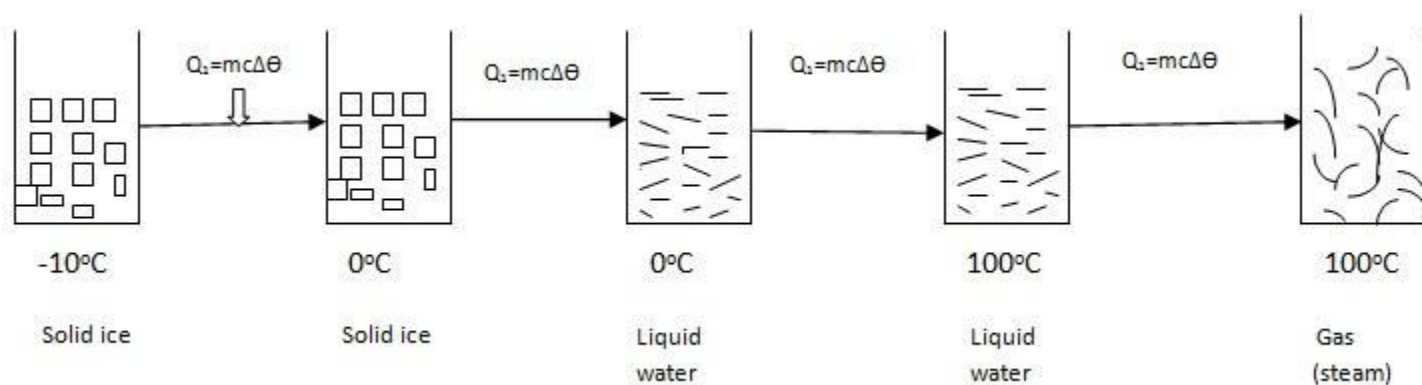
Freezing point

This is the temperature at which a liquid changes into a solid without change in temperature. The freezing point of a substance is the same as its **melting point**.

LATENT HEAT

Consider a block of ice which is cooled by a freezing mixture to -10°C and then heated steady: at first the ice which has a specific heat capacity of $2100\text{J/kg}^{\circ}\text{C}$ rises in temperature to 0°C , it then changes into water (liquid) at the temperature 0°C . Since the temperature is not changing and the state is changing the heat needed to change a solid ice to a liquid water is called **LATENT HEAT**

When the water formed from ice is heated further its temperature rises until it reaches about 100°C . Here it begins to change into vapour or gas at constant temperature 100°C the heat needed is again **latent heat** (hidden).



NOTE:

1. Latent heat of a substance

This is the quantity of heat needed by a given mass of a substance to change the state without change in Temperature.

2. Specific latent heat of a substance

This is the quantity of heat needed to change a state of a unit mass without change in temperature, it is denoted by L .

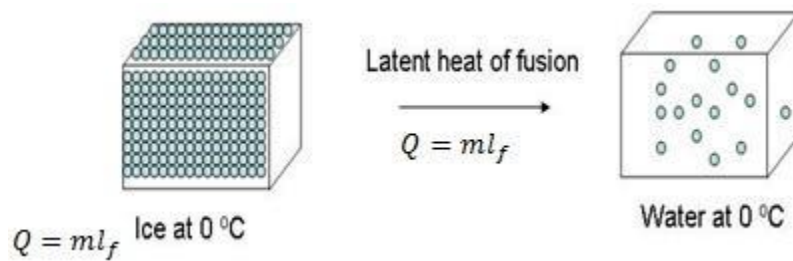
$$L = Q/M$$

$$Q = ML$$

Its SI Unit is **J/Kg**

3. Specific latent heat of fusion

This is the quantity of heat needed to change the state of a unit mass of solid to liquid without change in temperature.



4. Specific latent heat of vaporization.

This is the quantity of heat needed to change the state of count mass of liquid to vapour without change in temperature.

Specific latent heat of solidification.

This is the quantity of heat needed to change the state of a unit mass of liquid to solid without change in temperature. $Q = ML_v$

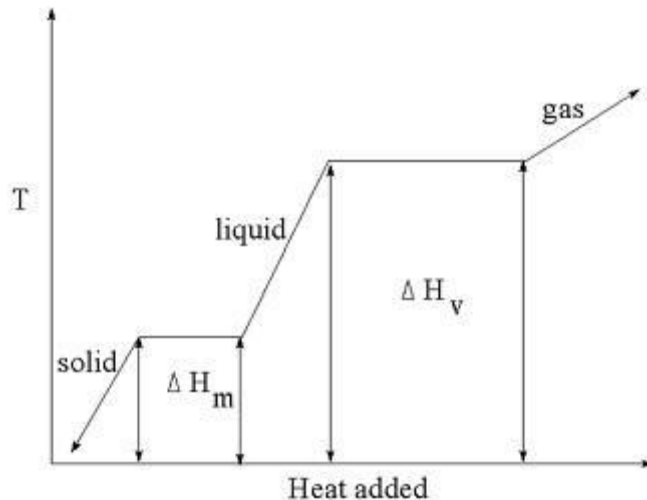


5. Specific latent heat of liquidifications

This is the quantity of heat needed to change the state of a unit mass from to liquid without temperature change.

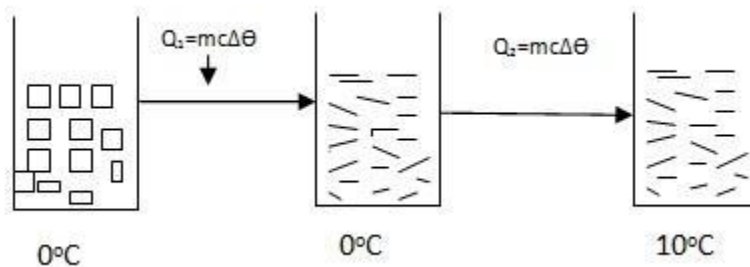


GRAPHICAL REPRESENTATION OF CHANGE OF STATE



Example

1. 8g of ice at 0°C is heated so that it forms water at 10°C. Calculate the total quantity of heat required to do so given that the Specific Heat Capacity of water 4200 J/KgK. The specific latent heat of fusion of ice is 334000J/KgK.



$$Q_T = Q_1 + Q_2$$

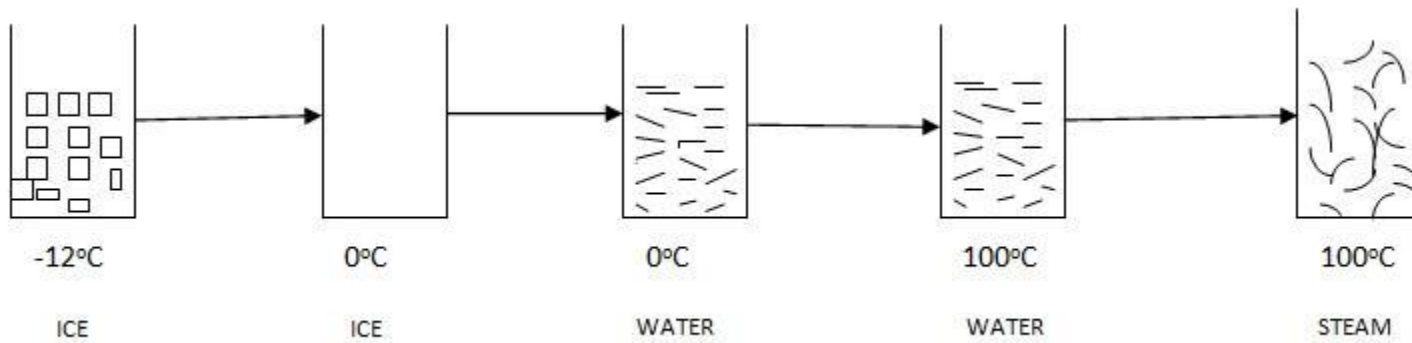
$$Q_T = ml_f + mc\Delta\theta$$

$$Q_T = 0.008 \text{ Kg} \times 334000 + 0.008 \times 4200 \times 10$$

$$Q_T = 3008$$

∴ the energy required to so is 3008 joule

2. The Specific Latent Heat of vaporization of liquid is 2260000J/kg, Specific Latent Heat of fusion of ice is 334000J/kg, the Specific Heat Capacity of ice is 2100J/kgK, Specific Heat Capacity of water 4200J/kgK, calculate the heat required to convert 2kg of ice at -12°C to steam at 100°C.



$$Q_T = Q_1 + Q_2 + Q_3 + Q_4$$

$$Q_T = MC\theta + ML_f + MC\theta + ML_v$$

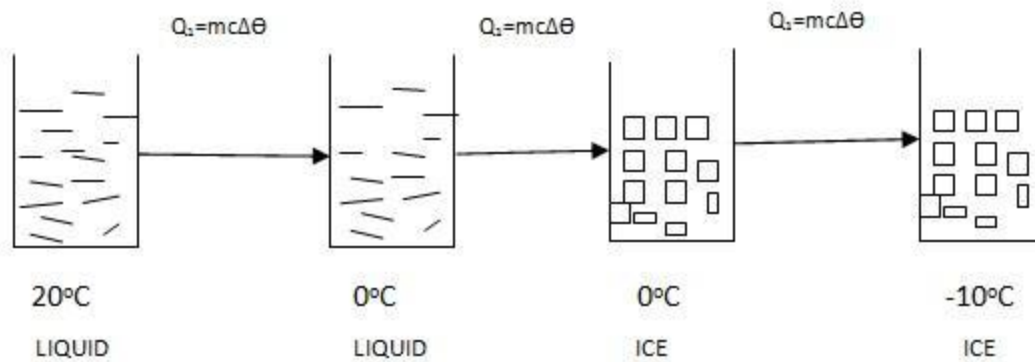
$$Q_T = (2 \times 2100 \times 12) + (2 \times 33400) + (2 \times 4200 \times 100) + (2 \times 2260000)$$

$$Q_T = 50400 + 66800 + 840000 + 4520000$$

$$Q_T = 5477200\text{J}$$

Therefore; the heat required to convert 2kg of ice to steam is 5477200J

3. A refrigerator can convert 400g of water at 20°C to ice at -10°C in 3hrs. Find the average rate of heat extraction from water in J/sec given that the Specific Heat Capacity is 4200J/kgK . The Specific Heat Capacity of fusion of ice is 336000J/kg . The Specific Heat Capacity of ice is 2100J/kgK .



$$Q_T = Q_1 + Q_2 + Q_3$$

$$Q_T = mc\Delta\theta + ml_f + mc\Delta\theta$$

$$Q_T = 0.4 \times 4200 \times 20 + 0.4 \times 336000 + 0.4 \times 2100 \times 10$$

$$Q_T = 33600 + 134400 + 8400$$

$$Q_T = 176400 \text{ joule}$$

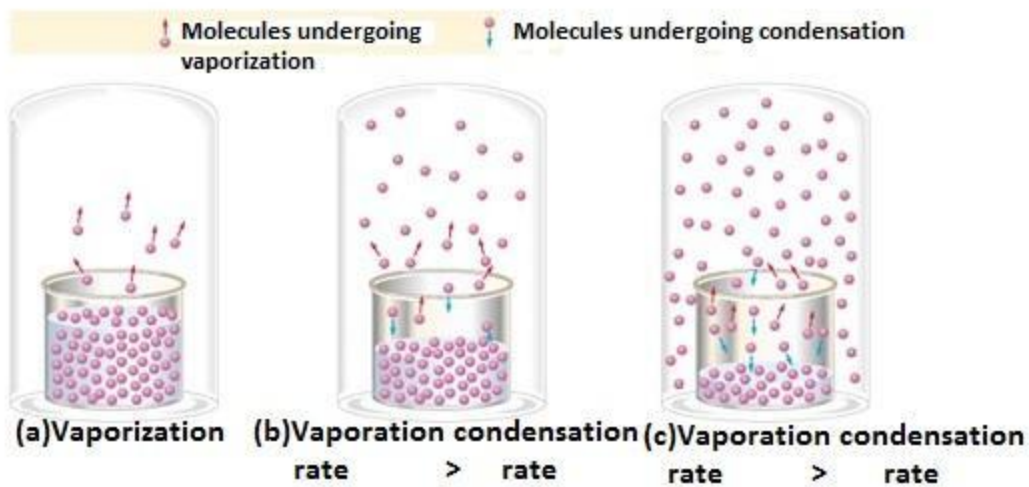
$$\text{power} = \frac{\text{energy}}{\text{time}}$$

$$\text{power} = \frac{176400}{10800}$$

$$\text{power} = 16.3 \text{ watt}$$

∴ The average rate of heat extraction is 16.3 watt

VAPOUR AND HUMIDITY



Content

- Evaporation
- Factors affecting evaporation
- Saturated vapor
- Humidity
- Rotation humidity (R. H)
- Measuring Rotation humidity (R. H)
- Dew point
- Factors influence dew formulation
- Application of evaporation

EVAPORATION

This is a gradual change of state from liquid to gas that occurring on surface of liquid.

According to kinetic theory of matter, when molecules of liquid gain heat they consequently gain kinetic energy .

As result of the random speed of the molecules increases. When the molecules at the surface gain large amount of energy they escape to the surrounding environment. This process is known as evaporation.

The molecules that have strong bonding force evaporate hardly. eg, evaporation of water , diesel etc. The molecules that have weak bonding force evaporate easily, eg , Methylated spirit , petrol.

Factor affecting evaporation

- Temperature
- Surface area

- Concentration
- Rate of air flow

1. TEMPERATURE

An increase in temperature increases the rate of evaporation. At high temperature the molecules are able to break out of the surface of the liquid and evaporate because they possess high kinetic energy (K.E). E.g. wet clothes hung on a line dry quickly on a warm day.

2. SURFACE AREA

We said that evaporation occurs on a surface of a liquid. So when a surface area of a liquid is large, also the rate of evaporation will be high because more molecules are escaping the surface of the liquid.

3. CONCENTRATION

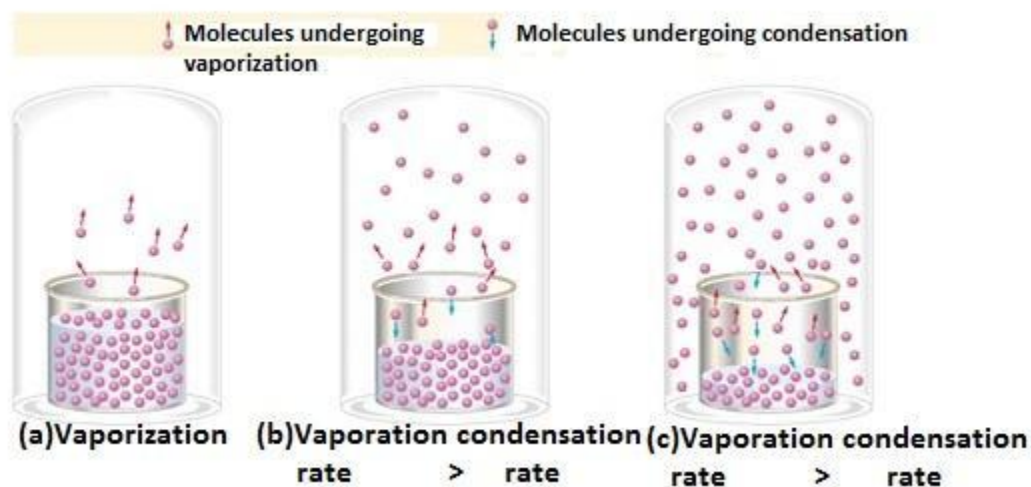
The concentration of the evaporating liquid in the surrounding air will determine the rate of its evaporation. When the concentration of the evaporating liquid in air is high, the evaporation will be low and vice versa.

4. Rate of flow of air

Rate of flow of air determines the evaporation of liquid. In a wind environment the molecules will be carried away when arriving soon on the surface of liquid; hence there is a high rate of evaporation.

Saturated vapour pressure

Vapour pressure is the pressure created by the vapour of a substance that forms above a liquid of the same substance.

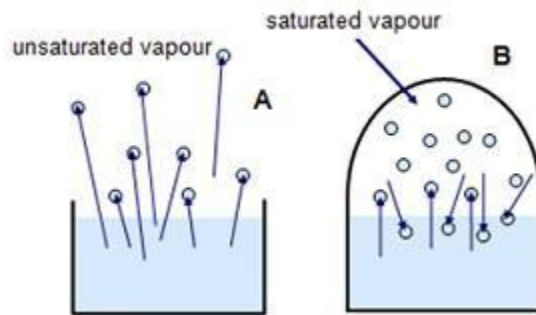


When the molecule gain K.E are able to escape from liquid. This is due to that temperature favour in raising the speed of molecules so when temperature increases also the rate of escaping molecule increase. These create more **vapour pressure**.

We said that as temperature increase also the rate of escaping molecule increase but other molecule return on it. So at any instant molecule are lowering the liquid and thus are returning to it. When the unsaturated more molecule leave the liquid than return to it per second and so the liquid evaporate until it all change into vapour.

Also when the spaces above the liquid become saturated i.e. some liquids present the number of molecule leaving the liquid per second equal to the number returning to it. The space above the liquid now has the maximum possible number of molecule at particular temperature;

- Saturated vapour pressure (SVP) if is in equilibrium
- Unsaturated vapour pressure does not in equilibrium because if pressure is less than saturated vapour pressure S. V. P raising with him



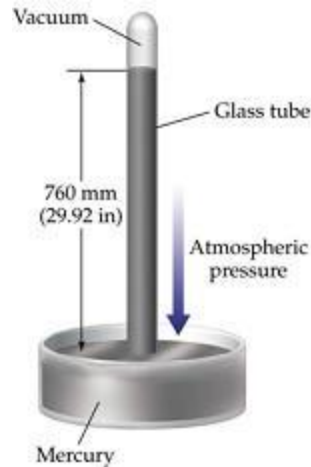
AMBIENT PRESSURE

Other gases that may be present beside the evaporating liquid also introduce pressure these are called ambient pressure e.g. atmospheric pressure.

Measuring saturated vapour pressure

Saturated vapour pressure is measured when vapour pressure is equal to atmospheric air by using **Mercury Barometer**.

- A standard mercury barometer has tube with height about 76 cm closed at one and with an open mercury filled receiver at the base.



The mercury in the tube adjusts until the weight of mercury column balance at atmospheric pressure (A.P) exerted on reservoirs.

High A.P exerts more force on the reservoir forcing the mercury in higher column. Lower pressures allow the mercury to drop to lower level in the column by lowering the reservoir.

At a pressure of $1 \text{ atm} = 760 \text{ mm}$ height of mercury. When you squirt a few drop of a liquid into mercury will form layers. Some of these liquid will evaporate at some time will condense and form saturated vapor pressure which force the mercury level down. This gives S.V.P the level of mercury has been forced down.

EFFECT OF TEMPERATURE ON S. V. P

If the temperature of the liquid/ solid increase the rate of evaporation and condensation increase and this leads to increase in vapor pressure.

NOTE: Liquid boils when vapor pressure is equal ambient pressure

HUMIDITY

This is the water vapor in the atmosphere. Water vapor enters in the atmosphere by evaporation from different source of water like river, ocean etc. Also transpiration form humidity.

Water vapor condenses to form dew, frost and clouds. The amounts of water vapor depend on the temperature of place so cause the water vapor varies from location and location. Also the level of saturation depends on *temperature* and *availability of water*.

RELATIVE HUMIDITY

We have seen that saturated vapor pressure increase as the temperature increases. This means that the high temperature there is some more vapor in situated air than at lower temperature.

Also the density of water vapor in saturated air is called **Absolute humidity (AH)**

But the air not always saturated at any temperature e.g. if vapor is less than saturated vapor pressure at the temperature. So **dew point** is the temperature at which vapor would become saturated.

Relative humidity is the measure of water vapor in a mass of air compared to the amount of water vapor that would be in air if was saturated.

$$R.H = \frac{S.V.P \text{ at dew point}}{S.V.P \text{ at current air temperature} \times 100\%}$$

Also can expressed as follow

$$R. H = \frac{\text{actual vapor}}{\text{Saturated vapour} \times 100\%}$$

Note: Density of water in Air = absolute humidity

MEASUREMENT OF RELATIVE HUMIDITY

Relative humidity is measured by device know as **hygrometer**

There are two types of hygrometer

1. Wet and dry hygrometer
2. Regnault hygrometer

1. WET AND DRY HYGROMETER

Wet and dry bulb hygrometer are the most simple and common way of measuring humidity. This type of hygrometer uses two basic mercury thermometers, one with a wet bulb one with a dry bulb. Evaporation from the water on the wet bulb causes its temperature reading to drop, causing it to show a lower temperature than the dry bulb.

2. REGNAULT HYGROMETER

A type of hygrometer in which the silvered bottom of a vessel contains ethoxy-ethane, through which air is bubbled to cool it, Regnault's hygrometer consists of a brightly polished thimble of very thin silver, forming the continuation of a short glass tube to which the silver thimble is attached by plaster of Paris or some other cement not acted upon by ether. Through a cork fitting tightly into the top of the glass tube pass two narrow tubes of glass, one (A) going to the bottom of the thimble, the other (B) opening at the top of the vessel just below the cork; also a sensitive thermometer so placed that when the cork is in position, the bulb (which should be a small one) is close to the bottom of the thimble.

If, then, ether be poured into the thimble until it more than covers the thermometer bulb, air can be made to bubble through the liquid either by blowing into the tube (A) or sucking air through (B) by means of an aspirating pump of any sort.

The passage of the air through the ether causes it to evaporate and the temperature of the liquid to fall in consequence, while the bubbling ensures the mixing of the different layers of liquid, and therefore very approximately, at any rate, a uniform temperature of silver, ether, and thermometer. The passage of air is continued until a deposit of dew is seen on the silver, which shows that the temperature of the silver is below the dew-point. The thermometer is then read, and the temperature of the apparatus allowed to rise until the deposit of moisture has completely disappeared, when the thermometer is again read. The temperature is now above that of the dew-point, and the mean of the two readings so obtained may be taken as the temperature of the dew-point, provided that there is no more difference than two or three tenths of a degree centigrade between them.



DEW AND DEW POINT

Dew is liquid moisture on the ground that is seen in the morning. It can be confused with rain but the moisture does not result from rain. At night the ground will cool. If there is enough moisture in the air and the cooling is great enough then condensation will occur on the ground. The formation of the condensation is the same process that occurs when you leave a glass of ice water out when there is moisture in the air. You will see condensation forming on the outside of the glass. This is because the glass is cold (ground is cold) and there is enough moisture in the air that the dew point is reached. Vegetation and animals can get moisture from the dew forming process even when there is no moisture available from rain.

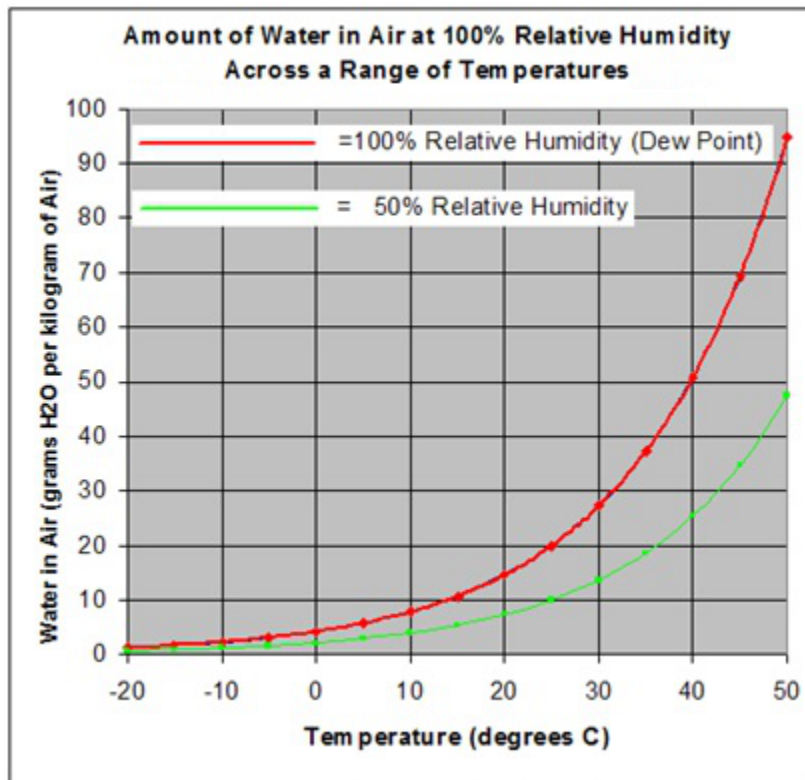


The dew point is the temperature at which the water vapor in air at constant barometric pressure condenses into liquid water at the same rate at which it evaporates. At temperatures below the dew point, water will leave the air. The condensed water is called dew when it forms on a solid surface.

FACTORS AFFECTING DEW POINT

There are two factors influence a dew formation which are the temperature of the object can cause condensation of the water vapor on the object. The dew point is a water-to-air saturation temperature.

The dew point is associated with relative humidity. A high relative humidity indicates that the dew point is closer to the current air temperature. Relative humidity of 100% indicates the dew point is equal to the current temperature and that the air is maximally saturated with water. When the moisture content remains constant and temperature increases, relative humidity decreases.



APPLICATION OF EVAPORATION

1. Evaporation of perspiration cools our bodies.
2. Evaporation of water from the earth keeps the air moist and provides the moisture for clouds. Thus evaporation has an important influence on weather and climate.
3. It is important also in air conditioning, refrigeration, and distilling. Substances are evaporated in a partial vacuum to speed evaporation or to prevent deterioration by heat. Instant coffee and frozen orange juice is evaporated in this way, and so are blood plasma, vaccines, and antibiotics such as penicillin. Camphor is purified by sublimation.
4. In industry, the principles of evaporation and refrigeration are used to great extent in the treatment, separation, handling and storage of materials in any of the three states of matter - Solid, Liquid or Gas. Distillation concerns the separation of liquid mixtures by evaporation processes.
5. Evaporation of sea water to produce salt
6. Evaporation ponds are used to prevent pesticides, fertilizers and salts from agricultural waste water from contaminating the water bodies they would flow into.

BONUS --> Some of our power plants work by evaporation. The evaporation is the final step of water cycling driving small turbines before it is fed back into the primary pool.

CURRENT ELECTRICITY

Introduction

Current electricity is the study of flow of charge through a conductor.

- A charge particle which flow can be positive or negative.
- A push called voltage is needed to enable the charge to flow. The charge move from high electric potential to low electric potential.
- For an electric current to flow, two things are necessary, a source and a closed path.

POTENTIAL DIFFERENCE AND ELECTROMOTIVE FORCE

Electric potential difference (pd) – is the work done per unit charge in moving electric charge from one point to another.

$$\text{potential difference} = \frac{\text{work done (W)}}{\text{charge moved (Q)}}$$

- The SI unit for Pd is **Volt**. One volt is equivalent to **one joule per coulomb**
- Potential difference is measured by **Voltmeter**
- The electromotive force Emf of a cell is potential difference across the terminal when there is no current flowing through it.
- Emf is not a force but a process whereby a device such as cell or generator convert chemical or mechanical energy into electrical energy.
- It can be thought of as an electrical potential energy that is converted into the kinetic energy of charge moving in on electric circuit.

Thus the cell provides an electromotive force which sets up (Pd) across various circuit components, there by driving current through them.

When a cell is connected to an external device such as lamp, electric current flow through the device and some electric energy is converted into other form like heat and light.

- The amount of converted energy per unit charge is the potential difference Pd across the device. The potential difference is also called a **voltage**.
- When several cells have been joined together they form a **battery**. This voltage cause the flow of charge (electron)
- Every cell has a voltage across the terminal. This voltage causes the flow of charge (electron) in a circuit. A dry cell has a voltage 1.5 V normally marked on a cell.
- Voltage is measured by using a voltmeter, and the SI unit of a voltage is VOLT (V).
- If 1 coulomb of charge given 1 Joule of potential difference energy, then the Pd across terminal of a battery is 1 volt.

ELECTRIC CURRENT AND CONDUCTOR

An electric current is composed of moving electric charge. In solid partially metals the current is made up of moving negative charged electronic.

In case of liquid solution the charge can be carried by electron and positively charged ions (atom from which one or more electron has been removed).

Electric current (I) is defined as the tube at which electric charge (Q) passes through in a given point and is measure in Ampere (A).

Hence; $I=Q/t$

An electric circuit is a closed path around which electric charge moves. A circuit contain device that either supply electric energy and cause the charge to move or convert electric energy to other form such as heat, light, sound or mechanical energy, also wires made of metal are used to connect various components.

Just as water flow freely through a pipe if there is pressure difference. Electric charge also flow through a wire where there is difference in electric potential. As friction in the pipe opposes the flow of water, electrical resistance in the circuit opposes the flow of electric current. This results to energy losses.

OHM'S LAW

When a source of Pd (cell) is connected across the end of a conductor (eg. metal – wire) current flows.

Ohm's Law States that "The current flowing through a conductor is directly proportion to the potential difference across its ends whereby other factors remain constant"

This law can be expressed as:-

$$V \propto I \text{ or } V/I=\text{constant}$$

The constant of proportional is called resistance (R) of the conductor

FACTORS THAT AFFECT THE RESISTANCE OF A CONDUCTOR

The resistance of a conductor is determined by the temperature, length, cross – sectional area and type of a material.

1. Temperature

The resistance of all substance changes with temperature. For most metal and metal alloys the resistance increases with increase in temperature.

However for same metal alloys the temperature change has little effect on their resistance.

2. Length of a conductor

When the length of a conductor is increased while the other factors are held constant the resistance of a conductor also increases. It can be shown as resistance (R) is directly proportional to the length (L) of the conductor that is $R \propto L$

3. Cross - Sectional area

When the cross – sectional area of a conductor is increased while the other factors are held constant, the resistance of a conductor decreases.

This means that the resistance (R) of a conductor is inversely proportional to the cross – sectional area of the conductor that is:

$$R \propto \frac{1}{A} \dots \dots (i)$$

4. Material of conductor

Resistance also depends on the material making the conductor. For example a steel wire will have higher resistance than copper wire of identical dimension at the same temperature.

NB: Combination of expression 1 and 2 assuming constant temperature, the resistance of a conductor is given

$$R \propto \frac{L}{A}$$

Therefore

$$R = \rho \frac{L}{A}$$

ρ is a constant term of proportional and called Resistivity of the conductor.

$$\rho = \frac{RA}{L}$$

The SI unit of a resistance is Ohm – meter (**Ωm**)

Resistivity it defined as the ability of a material to oppose the flow of an electric current.

RESISTOR

Resistor is used to control the magnitude of current and voltage in a circuit in accordance with Ohms law.

They are designed to have either a *fixed* or *valuable resistor*

The most common type of resistor is wire wound and carbon resistor.

1. WIRE WOUND RESISTOR

Wire wound resistor is made up by winding made up of certain metal alloy into spool.

-The material have used usually in high resistance to the flow of an electric current.

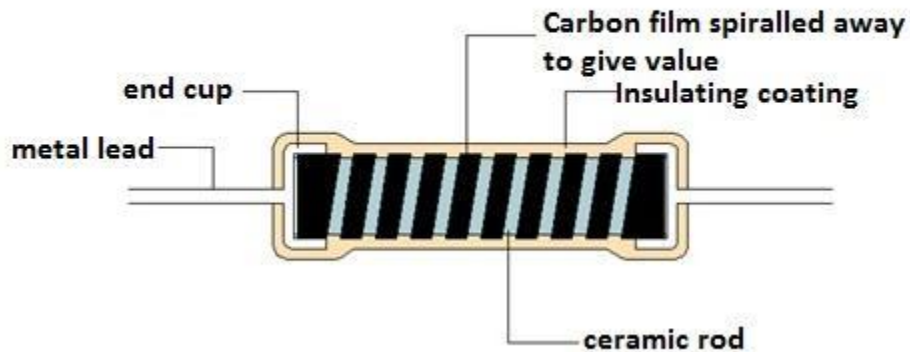
- The spool can be used in circuit to provide fixed or variable resistance. Wire wound resistor can pass large current without overheating and are used in power supplies and other high current recruit.

- The rheostat is an example of a wire would resistor.

2. CARBON RESISTOR

Carbon resistor is made by mixing carbon granule with varying amount of clay and rounding them into cylinder. This cylinder has fixed resistance.

Carbon resistor is useful in election circuit.



Carbon resistors are also known as **electronic resistor**. They usually have very large values of resistor.

3. METAL FILM RESISTOR

Metal film resistor are usually made up of a stable ceramic core coated with metal alloy such as Nickel – Chromium.

Metal film have higher accuracy than carbon resistor, however metal film resistor are most expensive than carbon film resistor.

4. METAL OXIDE FILM RESISTOR

Metal oxide resistor is made up of a ceramic core coated with metal oxide such as tin oxide.

FIXED AND VARIABLE RESISTOR

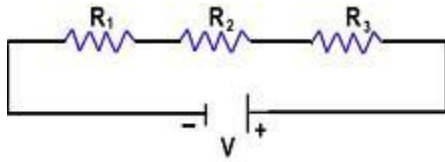
Resistors can be classified into fixed resistors and Variable resistors. Fixed resistors has a resistor value which cannot be changed. Most of carbon resistors are fixed resistors. In variable resistors, the resistor value can be adjusted. Example of variable resistor includes potentiometer, thermostat, and photo resistor. The rheostat is also a variable resistor.

COMBINING RESISTORS

Resistors can be combined in series or in parallel.

1. SERIES RESISTOR

This is the single loop combination of resistor and battery as shown in figure below.



In this circuit, the current flowing is the same at all point .The sum of potential difference in external circuit is equal the to the potential difference across the battery.

Therefore

$$V = V_1 + V_2 + V_3$$

From ohm's law the current in the circuit (I) given by

$$I = \frac{V}{R_{total}}$$

Where R_{total} is the combined resistance

$$\text{Thus } V = IR_{total}$$

But

$$V = V_1 + V_2 + V_3$$

Also $V_1 = IR_1$, $V_2 = IR_2$, and $V_3 = IR_3$

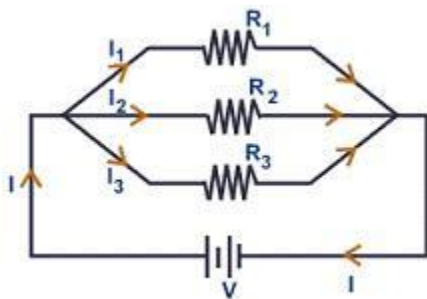
Therefore $V = IR_{total} = IR_1 + IR_2 + IR_3$

$$R_{total} = R_1 + R_2 + R_3$$

The total resistance for resistor in series the same of individual resistor

2. PARALLEL COMBINATION

A parallel circuit on which two or more resistor are connected across the common points. For example terminal of a battery provide separate conducting path for a current. A parallel circuit with three resistors below



When component are connected in parallel the voltage across each is the same. Ohm's law can be applied for each of the branch.

Through the voltage is the same at all branches, the current in different branches not be equal. To find difference current one considers the current junction.

$$I = I_1 + I_2 + I_3$$

From ohm's law, the current I in the circuit is given by

$$I = \frac{V}{R_{\text{total}}}$$

Where by R_{total} equivalent resistance

$$\text{But } I = I_1 + I_2 + I_3$$

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$$

THEREFORE

$$\frac{V}{R_{\text{total}}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

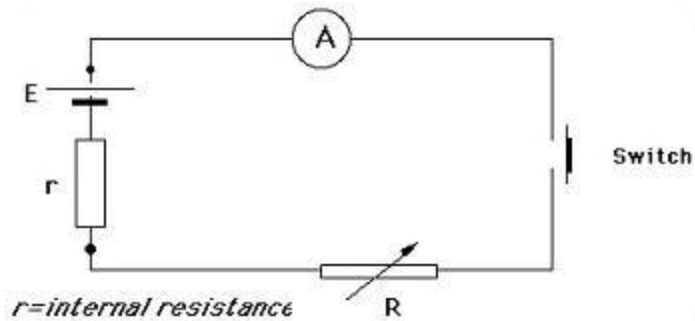
When resistor is in parallel the reciprocal of the total resistance is the sum of the reciprocal of the individual resistance.

It should be noted that when resistor are combined in series the total resistance is higher than that of individual. However for the resistor in parallel the total resistance is lower than that of individual resistor.

INTERNAL RESISTANCE OF A CELL

Cell have internal resistance that opposes the flow of current through them and hence through the circuit to which they are connected. The internal resistance of a cell act as if it is connected in series with the cell that when current flow through the cell, there is a potential drop across this resistance.

Consider a cell of emf (E) and internal resistance (r) connected across an internal resistance (R) as shown in figure below.



Suppose the switch is closed so that current (I) flow through the circuit. From ohm's law the (p.d) (V) across the resistor (R) is given by

$$V = IR$$

The potential drop (V_1) is caused by the cell internal resistance given by

$$V_1 = Ir$$

The total voltage across the circuit (E) is sum of potential drop due to the cell internal resistance and that resistor R .

$$\text{i.e. } E = Ir + IR = I(r + R)$$

$$\text{Therefore; } E = Ir + V$$

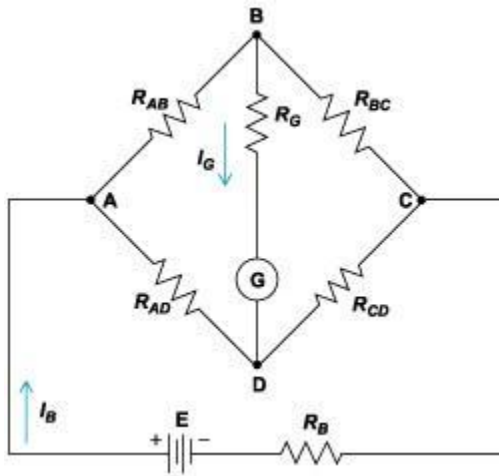
This equation can be used to determine the internal resistance of a cell.

When current $I = 0$ then $V = E$

WHEAT STONE BRIDGE

The wheat stone bridge is an electrical bridge circuit used to measure the resistance of a conductor.

It consist source of electrical current such as battery and a galvanometer which connect two parallel branches of containing four resistors, three of them which have known resistance.



By adjusting one of the known resistor usually resistor (Q) we can reach at the value of the which the galvanometers shown no direction reading. The bridge is then said to be balanced.

The Voltage across AB is the same as voltage across AD and the Voltage across BC is the same as voltage across CD.

Mathematically; $V_{AB} = V_{AD}$ and $V_{BC} = V_{CD}$

$$\frac{V_{AD}}{V_{DC}} = \frac{V_{AB}}{V_{CB}}$$

From; $V = IR$

$$\frac{I_1 R_{AD}}{I_1 R_{DC}} = \frac{I_2 R_{AB}}{I_2 R_{CB}}$$

$$\frac{R_{AD}}{R_{DC}} = \frac{R_{AB}}{R_{CB}}$$

Therefore; If the value of any of the three resistors is unknown we can use the others three resistor with known value to determine the unknown value.

HEATING EFFECT OF AN ELECTRIC CURRENT

- Current flow is accompanied by conversion of electric energy into other form of energy. Some of this form is light, sound and heat.
- In all the case, party of electric energy is converted to heat due to resistance of the circuit component. In fact bulb lights because the filament get heated.

- The heating effect of an electric current is observed in electric kettles, electric iron and electric fire among others.

Factors that affect the quantity of heat generated by an electric current

The quantity of heat generated in a conductor by an electric current depends on

- The resistance of a conductor, Magnitude of the current and the length of time current passes through the conductor.

JOULE'S LAW

The relationship between the resistance of a conductor, the current passing through it and the heat quantity generated. Can be summarized by using Joule's law

Joule's law states that *"when an electric current passes through a conductor the heat evolved in a given time is directly proportional to the resistance of the conductor in Ohm's multiplied by the square of the current in ampere"*.

Consider a conductor through which current (I) flows for a time driven by potential difference (V) maintained at its ends.

The quantity of charge Q that flows in that time is given by

$$Q = It$$

Since potential difference is work per unit charge, the work done (w) on charge is given by

$$W = QV$$

$$W = ItV$$

This work that is converted to heat (H) developed in a conductor is given by.

$$H = ItV$$

Applying Ohm's law $I = V/R$ or $V = IR$

Therefore;

$$H = IRIt \text{ or } H = I^2Rt$$

The current (I) in the expression can be replaced by $I = V/R$

$$\text{Therefore, } H = \frac{V^2}{R^2} RT \text{ or } H = \frac{V^2}{R} t$$

Therefore the three expressions for the heat energy generated in a conductor by an electric current are following

- (i) $H = ItV$
- (ii) $H = (I^2)Rt$
- (iii) $H = (V^2)/R t$

ELECTRICAL POWER

Power is the rate of doing work rate at which energy is dissipated. Electric power can be obtained from the expression of electrical energy can be deduced as follow.

$$Power = \frac{Work}{time}$$

$$\text{Electrical energy} = ItV$$

$$Electric\ power = \frac{ItV}{t}$$

$$P=IV$$

Since

$$V = IR$$

$$P = IR \times I$$

$$P = I^2R$$

$$\text{Also } I = V/R$$

$$\text{Therefore } P = V \times \frac{V}{R} = \frac{V^2}{R}$$

Expression of power

- $P = IV$
- $P = I^2R$
- $P = \frac{V^2}{R}$

The SI unit of power joule per Second or WATT

Since the SI unit of energy is joule. The SI unit of power is joule per second or watt (w)

$$1W = 1J/S \text{ or } 1 \text{ JS}^{-1}$$

Other common units used are kilowatt (KW), megawatt (MW) and Gig watt (GW)

$$1KW = 1000W$$

$$1MW = 1000000W$$

$$1GW = 1000000000W$$

ELECTRICAL APPLIANCES

Electrical appliances make use of heating element to produce heat. Nichromes wire which has high melting point is suitable making such heat element.

The rate at which the appliance disperse energy called a **rating of the appliance** and usually is **marked on the appliance**

For example appliance marked on 3000W, 240V disperse the energy of rate of 3000 joule per second when connected to 240 volt.

Common electric appliance includes heaters, electric iron, kettles, cooker and fridge, television and air condition.

It should be noted that if the main supply fall below 240 V the rating of appliance would drop. Suppose for example supply reduced to 230 V due to fault an electrical heater heated 2000 W would reduce rating as follow down.

$$\text{Power (P)} = \frac{V^2}{R} = 2000 \text{ W}$$

$$R = \frac{V^2}{P} = \frac{240^2}{2000}$$

$$\begin{aligned} \text{New power} &= \frac{V^2}{R} = \frac{230^2}{\frac{240^2}{2000}} \\ &= 1836.8 \text{ W} \end{aligned}$$

N.B: If power supply rises the rating would rise. However this would be due to overheating.

MEASUREMENT OF ELECTRICAL POWER

When we pay for electricity we pay for the electrical energy we have used. The power company use power bills for the energy we have used.

Power companies usually measure the electrical energy in used in kilowatt-hours (KWH).

One kilowatt hour is energy consumed by an appliance rated 1 KW in hour.

$$\begin{aligned} 1\text{Kwh} &= (1000 \times 60 \times 60) \text{ J} \\ &= 36000000 \text{ J or } 3600 \text{ Kj} \end{aligned}$$

ELECTRICAL INSTALLATION OF A HOUSE

Domestic electrical supplied by two cables: the live cable (L) which colored brown or red and the Neutral cable (N) which usually colored blue or black.

The live cable is 240V relations to be neutral. The current in neutral cable is alternates to times a second (60 HZ)

The neutral cable is earthed (connected to ground) at the power station. This ensures that even through current flow through this cable it remains at zero potential. In this position it cannot give an electric shock on touching.

To provide extrasafety especially in electrical appliance, a third cable called the earth (E) and colored yellow or green is also provided and is earthed by connecting it to water pipe. This cable connector the metal body of an electrical appliance to the ground

The three pin plug

The three cables are connected to the three pins of three pin plug and fuse connected to the neutral cable. However if a fault develop and the fuse blows the body of the appliance remain live and therefore, could give electric shock to a user.

The earth pin is usually longer than the other two. This enables it to open the device covering and open of socket. It also ensure that appliance is earthed before be connected to power.

When connecting a three pin plug the colour code mentioned **must** be strictly here **to** avoid electric shock. Also the switch should be in the off position when pushing into the socket.

Two pin plug

A two pin plug does not have a *fuse* and *earth pin*. Thus an appliance using a two pin plug does not have body connected to earth. The connection for this plug follow at the same colour code as tree pin plug

When using plug always check the plug is correct wired that is:-

- All connection are tight with no loose strands of wire
- The cable firmly clamped without damage to the insulation
- Fuse of the correct rating for the appliance rating.
- The individual wire supposed to be cat to such a long that is if the cable is pulled out of the plug the live come out before the earth and the neutral.

FUSES

A fuse is a safety device used protects an electric – circuit against excess current. A fuse consist of an element, usually a piece of copper or tin lead alloy wire which melt when current through if exceed a specific determined value. This element is contained in a suitable casing.

It is placed in series with the circuit to be protected and automatically breaks the circuit when over loaded.

A fuse provides protection by destroying itself. It must be replaced before a circuit work again.

TYPES OF FUSE

There are several types of fuse in use. These include rewritable and cartridge fuses.

1. REWIRIABLE FUSES

In this type of fuses the fuses element is carried in removable fuse link. This fuse link may be made by porcelain or other suitable insulating material. This ensures that there is no danger to operator when removing the fuse link.



2. Cartridge fuses

- Cartridge fuses consist with of a porcelain to be caps to which the fuse element with metal and caps to which the fuse element is attached.
- The fuse element passes through the tube from cap to cap and is welded or soldered to the inside of the cap.
- In installation and fitted in distribution board.



MODE OF ACTION

Fuse blowing (melting) occurs mainly when the circuit is over loaded or when a short circuit occurs.

A short circuit fault is unwanted connection which allow current to flow a long path (or path) which is not part of the circuit design. The now path will re-route some or all of the current from the designed path.

Short circuit fault can be identified by the fact that the current leading to fuse blowing. The potential difference between point joined by a short circuit is zero or much lower than expected.

CIRCUIT – BREAKERS

A circuit – breakers is a type of a switch that cuts off the flow of current when the current exceeds a specific value. The circuit breaker operator by opening in the event of excess current unlike a fuse, a circuit breaker can be reset once the current in the circuit has returned to normal.

However just like the fuse, the circuit breaker is connected in series with the circuit it control.

In a circuit – breaker, the switch contact are hold closed by a latch mechanism that releases the contact quickly to open the circuit. This happens whenever there is excess current in the circuit.



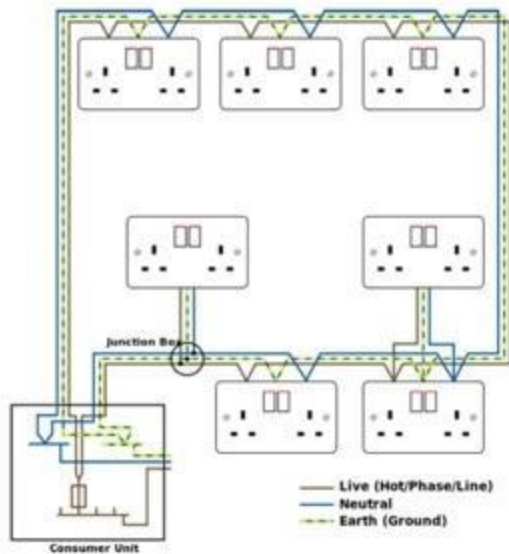
Common circuit breakers are either **thermal** or **magnetic** device the incorporate a **bimetallic strip** or **electromagnetic** to open and close the switch respectively.

Magnetic circuit use an electromagnetic which pulling force increase with current. When current increase beyond the rating of a circuit breaker the electromagnetic pull release the ratch which allow the switch to open by spring mechanism

DOMESTIC WIRING

The power company connect power to the house up to the consumer unit where house start. Consumer unity is the place where the main switch, main fuse and distribution board are placed in single box or unit.

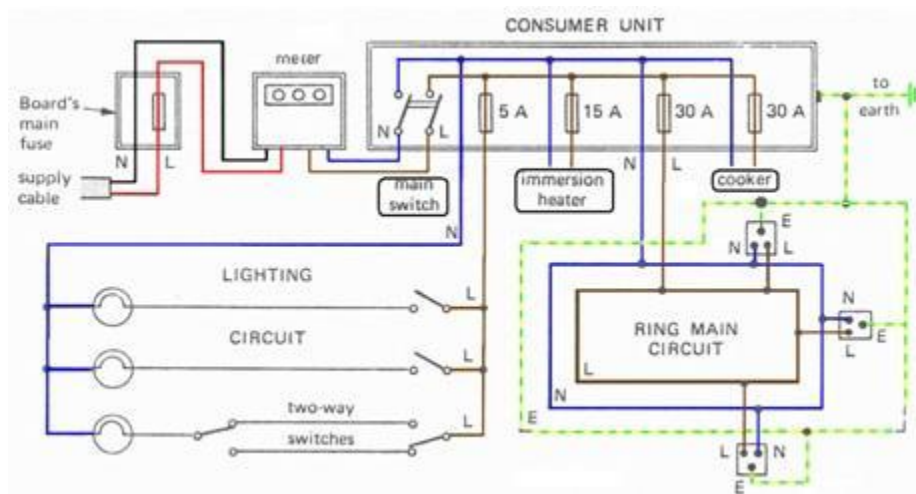
From the consume unit, the cable branch into several parallel circuit which carry current to the various part of the house.



RING MAIN

In many houses the main socket are connected to any main. This cable which begins and ends of the consumer unit, it has live neutral and earth wire each forming a ring around the house.

In this circuit, the current has two parts so that thinner cable can be used. The sockets usually have a 30 A fuses at the consumer unit.



LIGHTNING CIRCUIT

Lighting circuit is used in controlling the lighting fixture in the house. Unlike the ring circuit, the lighting circuit does not form a loop returning to the consumer unit.

Instead the consumer unit is normally connected to the first lamp which in turn is connected to the second lamp and soon.

There are two type of lightning circuit. These are

1. loop in lightning circuit
2. junction box lightning circuit
1. Loop in lightning circuit

In this type of lightning circuit, the live, neutral, and the earth cable run from consumer unit to each of the ceiling rose's one after the other. From each rose another set of cable run to switch which operate the light

2. Junction box lightning circuit

In this type of circuit, the neutral and the earth cable run to one junction box after another. From junction box one cable run to the light and the other runs to the switch for that light.

REPAIRING FAULT IN ELECTRICAL APPLIANCE

Two devices are important when checking electrical appliance for fault. These are multimeter and the live mains lead indicator.

1. The multimeter

The multimeter is a single meter that measure current (both dc and ac) voltage and resistance. Multimeter also have a range switch so that practice reading can be taken. There are moving coil and digital multimeter. The moving coil type is more difficult to use due the various setting involved The digital one have no moving part it is easy to use and reading are displayed on a screen.



Moving coil multimeter



Digital multimeter

2. Live main indicator

The live main lead indicator is made up of a form of a screw driver with a hollow insulating handle containing a tiny neon discharge tube.

One electrode of the neon tube is usually in contact with the metal probe of a driver

The other is connected to a metal cup of the handle through high carbon resistor. When one insert the metal probe into a live socket and touch the touches the metal cup with fingers, current leak to earth the body and neon tube glowing to the high resistance, the metal is little and so there is no risk of electric shock.

Most of the fault occur in electrical appliance are simple and can be easily .If for example an electric kettle fails to works.

1. Check if there is power in the socket. This is done by using live main lead indicator.
 2. Check the cable from the socket to the appliance.
 3. If there is no default the plug should be opened and fuse checked.
 4. Also check each cable for continuity using a voltmeter milometer
-
- If there are in good condition then the next place to check for fault is element .This can be checked by a short circuit using a multimeter.
 - If element have fault, then it must be replaced as may not be possible.
 - If element is not fault, then look for loose connection. These should be made firm and cleaned rust and other dirt.
 - Repair in electrical appliance should be limited to connection to power supply only. Beyond that technician should be involved a care should be taken to avoid electrical shock during such a repair.
 - Simple repair on electrical connection in the banish system can also carried out.
 - When a fuse blow it is very likely to be due to fault in an appliance.
 - If the fault is determined or connected, then the fuse can replace or (the circuit breaker switch on
 - Other fault occurs due to wire cutting or joining, socket get dirty and switched off.
 - When replacing switches and socket, the colour code mentioned earlier should be followed strictly.

CELLS

A cell is a set up to cause flow of electric current in a conductor.

The flow of current is caused by reaction, releasing and accepting electron at the different end of a conductor.

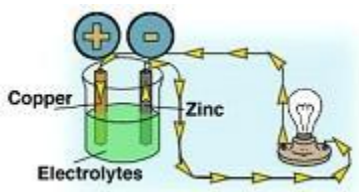
There are two main common type of electrochemical cell which are

1. primary cell

2. secondary cell

1. PRIMARY CELL

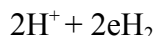
Primary cell is also known as voltaic cell. A primary cell is formed by dipping two different metals at conducting solution. The two metals are called electrodes while solution is referred to as the electrolyte. In primary cell the reactant are used up after sometime and must be replaced.



The electrodes of the simple cell are made up of copper (positive) and zinc (negative) while the electrolyte is dilute sulphuric acid.

The following are the process that occurs when cell is in operation.

- The dilute sulphuric acid separate into ions(SO_4^{-2}) and hydrogen ions (H^+)
$$\text{H}_2\text{SO}_4 \rightarrow 2\text{H}^+ + \text{SO}_4^{-2}$$
- Zinc also goes into solution as zinc ion (Zn^{2+}) releasing two electrons which travel along the wire (external circuit) to the copper.
- Zinc ion joins to sulphate ions to form Zinc sulphate (ZnSO_4). At the same time the Zinc ion go into a solution an equivalent number of hydrogen ions move to copper electrode where they gain electron and liberated as hydrogen gas (bubbles).



DEFECT OF A SIMPLE CELL

When the simple cell is in operation, the current drop to a very small value after sometime, this occurs because of two reasons. These are two defects which are

(i). LOCAL ACTION

The formation of bubbles of hydrogen on Zinc plate usually is referred to a local action. This caused by impurities in Zinc which react with acid. Local action can be reduced by pure Zinc or by rubbing with mercury on Zinc plate to form an **amalgam**. The Zinc **amalgam is pure**.

(ii). POLARISATION

The second reason is polarisation. Bubbles of hydrogen formed on copper plate. Those bubbles from another cell with the zinc which oppose the zinc copper cell, thus reducing the current

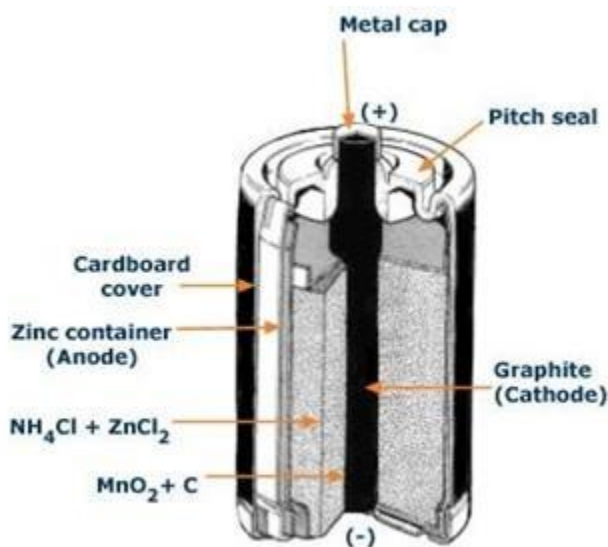
The hydrogen also insulates the copper plate thus increasing the resistance of the cell. This lowers the current.

Polarizations is reduced by adding a depolarizer, for example potassium dichromate which oxides the hydrogen to water.

NB; the simple cell is no longer used as the source of electric current

2. Leclanche cell

The leclanche cell consists of carbon (positive electrode) and a Zink (negative electrode). The electrolyte in this cell was an ammonium chloride (NH_4Cl) solution.



There is no local action in this cell. Polarization is reduced by manganese dioxide (MnO_2) which oxides hydrogen to water. The manganese dioxide with carbon is put in porous pit around the carbon electrode.

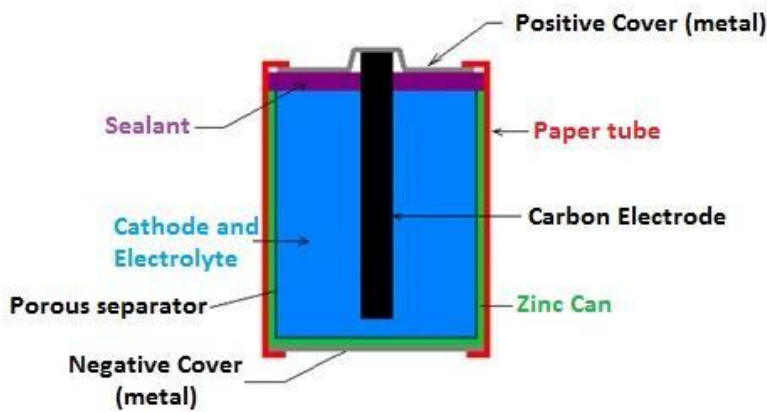
However manganese dioxide is slow down depolarizer. When the large current is drawn from the cell polarization take place causing reduction in the voltage of the cell.

It allowed resting briefly, however the cell soon recovers.

THE DRY CELL

The electrolyte of a simple cell can be liquid or paste. If an electrolyte is a liquid, the cell is said to be a wet sell. The electrolyte is a wet cell.

If electrolyte is paste the cell resaved to use a dry cell. The leclanche cell exist today is dry cell.



The component of dry cell are same as those of the Leclanche cell except instead of ammonium chloride solution. The battery is filled with paste of manganese dioxide, ammonium chloride, and zinc chloride.

The two salts (ammonium chloride & zinc chloride) act as the electrolyte. The negative electrode (zinc) is the can containing the electrolyte and depolarizer.

Series and Parallel arrangement of cell

Cells are often used in combination. A **battery** is formed when two or more cells are connected together.

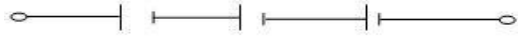
There are two ways of combining two or more cells. These are series combination and parallel combination.

1. Series Combination

When cells are placed in series, the positive terminal of one cell is connected to the negative terminal of another cell.

The current flowing through the cell is the same as for one cell. The total voltage across the equal to the sum of the voltage of the individual cells.

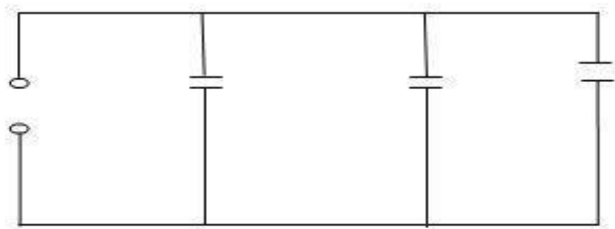
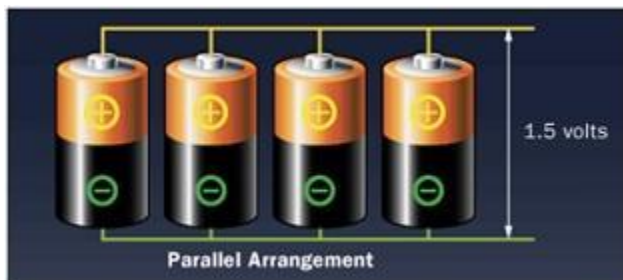




2. Parallel arrangement

When the cells are placed in parallel all the positive terminal are connected together. Any point of the positive side of the battery can serve on the positive terminal of the battery.

This is also the case on negative side of the battery. The total voltage of all cell in parallel is the same as that of a single cell. The total current across the circuit is equal to same total of the current across each cell. The parallel arrangement is use when they required current larger than that of single cell.



Uses of dry cell

Dry cells are used in operating radio's electronic calculator and other small electronic Devices.

3. SECONDARY CELL

In secondary cell the chemical reaction can revised after the cell run down. Example of a secondary cell is the lead – acid cell and the nickel ferrous cell.

Secondary cell is also called accumulator.

The lead acid accumulator

The lead acid battery consists for a number of lead – acid cell. Each cell has two group lead plate. One group is from positive terminal while the other group from the negative terminal.

All positive terminals are connected together with a connecting strap. This also case for the negative terminal. The positive and negative terminal is insulated so that they alternate. Between the plates are sheet of insulating material called separator.

Separators are made up of porous wood or fiberglass the separator prevent positive and negative plate from coming into contact and producing a short circuit.

The positive Plate is made up of lead dioxide while negative plates are made up of porous lead metal.

The two sets of plates with separator between them are placed in a container with filled with a dilute solution of sulphuric acid.

The term lead acid refers to lead Plate and sulphuric acid in a container which are the main component of the battery.

DISCHARGING OF THE LEAD – ACID BATTERY

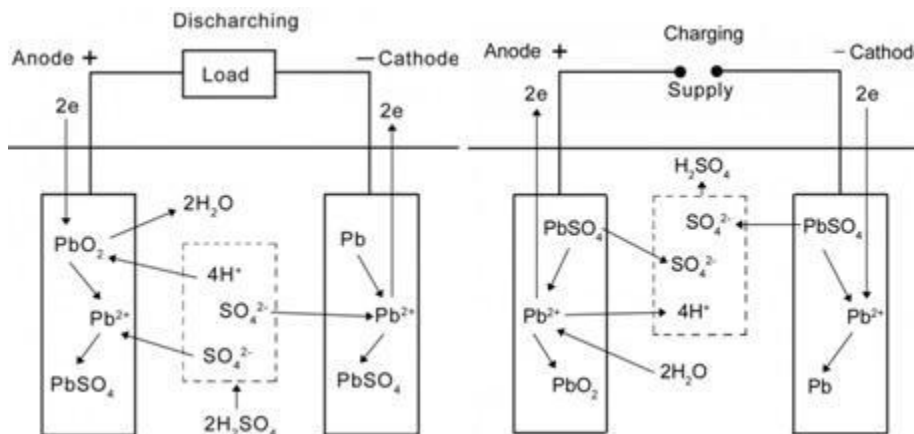
When the battery gives out energy is said to be discharging. The energy is produced when acid (electrolyte) gradually combine the active material of the electrode. This lowers the concentration of the sulphuric acid.

Charging of the lead – acid battery

The aim of charging battery is to drive all acid out of the plates and return it for the electrolyte. During charging a direct current is passed through the battery in opposite direction of that during discharge.

The negative terminal of charge connected to a positive terminal of a battery and negative terminal of a battery connected to a positive charge.

This reverse action of discharge is charging . When the battery is fully charged, the active material of appositve Plato is lead peroxide while that negative Plato is a porous lead metal. The concentration of the acid is a maximum when it's fully charged.



If the battery is only partially discharge. It can recharge using a battery charger. Lead acid batteries should never be allowed to become full discharged. The maximum recommended discharged 75% of that maximum voltage. When the battery is full discharged both electrode are completely converted function cannot be recharged.

The main advantage of lead – acid accumulator is its ability to be recharged. Its major disadvantage is its size and weight.

Taking care of accumulator

Lead – acid accumulator are commonly used as car batteries although it is recharged the accumulator does not last forever.

After sometime the plates fall from the frame and the cell can no longer be recharged. If we taken care of however lead – acid battery can last for long time. The following are some tips on can lead acid battery.

TIPS ON HOW TO CARE LEAD ACID BATTERY

1. The cell should be charged regularly and should never be left fully discharged. Cars have alternators that automatically charge the battery.
2. The acid level should be maintained by adding distilled water where necessary.
3. The terminal should be kept clean and greased.
4. Rough handling should be avoided. For example dropping battery down.
5. The cell should not be short circuited, that is allowed to drive large current or connected terminal of the battery to each other.
6. When charging the rate specified by manufacturer should not be exceed.

Use of lead - acid batteries

The following are some uses of the lead – acid batteries

1. They are used to provide power in motor vehicle
 2. They are used to provide energy to power domestic appliances such as radio, television and lighting fixture.
 3. They are used together with solar panel to convert solar energy to electrical energy.
 4. They are used to store electrical energy
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