PHYSICS NOTES

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1. REFLECTION OF LIGHT AT CURVED SURFACES

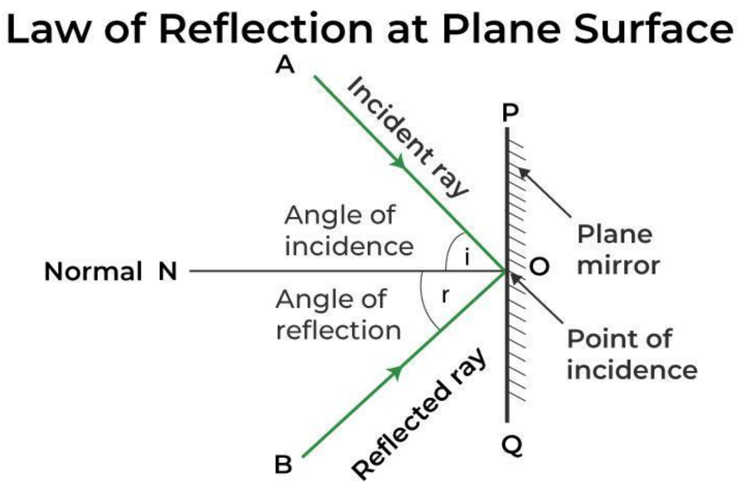
INTRODUCTION

Mirrors can be found in various situations and places in our day-to-day life. They are some of the phenomena which make our life more simple and easier. In this chapter, we are going to learn about the uses, working and construction of curved mirrors. The behaviour of light rays when they interact with curved mirrors is interesting to learn. So, we are going to learn about types of mirrors and their uses in this chapter.

LAWS OF REFLECTION:

There are three laws of reflection when dealing with the behaviour of light rays. They are-

1. The first law of reflection states that the incident ray, the reflected ray, and the normal to the surface of the mirror, all lie in the same plane.
2. The second law of reflection states that the angle of reflection is equal to the angle of incidence. Both angles are measured with respect to the normal to the mirror.
3. Light chooses the shortest path to travel.



$$i = r$$

SOME BASIC TERMS RELATED TO LIGHT:

SOURCE OF LIGHT:

A body which emits light in all directions is said to be the source of light. The source can be a point source one or an extended one. The sources of light are of two types:

(i) Luminous source: Any object which by itself emits light is called as a luminous source. e.g. Sun and Stars (natural Luminous sources), Electric lamps, Candles and Lanterns (artificial luminous sources).

(ii) Non-luminous source: Those objects which do not emit light but become visible when light from luminous objects falls on them and they reflect it back. They are called non-luminous. e.g. Moon, Planets (natural non-luminous sources), Wood, Table (artificial non-luminous sources).

TYPES OF MEDIUM:

When light falls on a medium, it can be treated in three ways.

A medium is a substance through which light propagates or tries to do so. Based on this interaction mediums are classified into three categories.
(A) Transparent: The medium which allows most of the light to pass through it is called a transparent medium. e.g. Air, Water, Glass etc.
(B) Translucent: The medium which allows only a part of the light to pass through it is called a translucent medium. e.g. Paper, Ground glass etc.
(C) Opaque: The medium which does not allow any light to pass through it is called opaque medium. e.g. Wood, Bricks, Metals etc.

RAY:

A ray of light is the straight line path along which the light travels. It is represented by an arrow head on a straight linelight. The direction of arrow gives the direction of propagation of light.

ANGLE OF INCIDENCE:

The angle formed between the normal and the incident ray at the point of incidence is called the angle of incidence.

ANGLE OF REFLECTION:

The angle formed between the normal and the reflected ray at the point of incidence is called the angle of reflection.

ACTIVITY 1: FINDING THE NORMAL TO A CURVED SURFACE

AIM: To find the normal of curved surface

APPARATUS: Rubber foam, iron nails

PROCEDURE:

1. Take a small piece of thin foam or rubber (like the sole of a slipper).
2. Put some pins in a straight line on the foam. All these pins are perpendicular to the plane of foam.
3. If the foam is considered as a mirror, each pin would represent the normal at that point.
4. Any ray incident at the point where the pin makes contact with the surface will reflect at the same angle as the incident ray made with the pin-normal.
5. If we bend the foam piece inwards, we will notice that all the pins tend to converge at a point.
6. If we bend the foam piece outwards, the pins seem to move away from each other or they diverge.

OBSERVATIONS:

1. A concave mirror will be like the rubber sole bent inwards (fig. b) where all the normals converge at center of curvature.
2. A convex mirror will be like the rubber sole bent outwards (fig. c) where all the normals appear to diverge from the center of curvature.

CONCLUSION

By this activity, we can find the normals of a curved surface / mirror.

NOTE: Tangent of a circle from any point will be perpendicular to the radius drawn to that point.

TERMS RELATED TO MIRRORS:

NORMAL: The line drawn from center of curvature to any point on the mirror gives the normal at that point.

POLE: The mid point (Geometrical centre) of the mirror is called pole (P) of the mirror.

PRINCIPAL AXIS: The horizontal line shown in the figures which passes through the centre of curvature and pole is called principal axis of the mirror.

RADIUS OF CURVATURE: The radius of the sphere from which the spherical mirror is made from is called the radius of curvature(R).

ACTIVITY: LIGHT RAYS COMING FROM FAR DISTANCE ARE PARALLEL TO EACH OTHER

AIM: To prove that ight rays coming from far distance are parallel to each other.

APPARATUS: thermocole blocks, pins, candle, matchsticks

PROCEDURE:

1. Take a thermocole block and place it on a plane surface.
2. Stick two pins on the thermocole block parallel to each other.
3. Take a candle and light it using matchsticks.
4. Bring the candle close to the pins and observe their shadows.
5. Move the candle far away from the pins and observe the shadows.

OBSERVATIONS

1. When we place the candle, close to the pins, the shadows look diverging.
2. As we move the source away from the pins, the angle of divergence gets reduced.
3. But, when we place the source of light far away, intensity of shadows reduces.

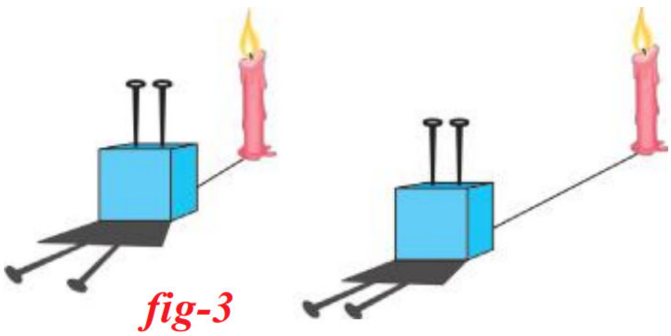


fig-3

CONCLUSION

Therefore, we can find that the light rays from far distances are parallel to each other.

ACTIVITY 2 : FINDING THE FOCAL POINT OF A CONCAVE MIRROR

PROCEDURE:

1. Hold a concave mirror such that sunlight falls on it.
2. Take a small paper and slowly move it in front of the mirror.
3. Find out the point where you get the smallest and brightest spot, which will be the image of the sun.
4. See to it that paper is small so that it does not obstruct the incoming sun rays.

OBSERVATION:

1. The rays coming from the sun parallel to the principal axis of concave mirror converge to a point called Focus or focal point (F) of the concave mirror.
2. Measure the distance of this spot from the pole of the mirror. This distance is the focal length (f) of the mirror. The radius of curvature will be twice this distance (R=2f).

CONCLUSION

Hence, we can find the focus of a concave mirror.

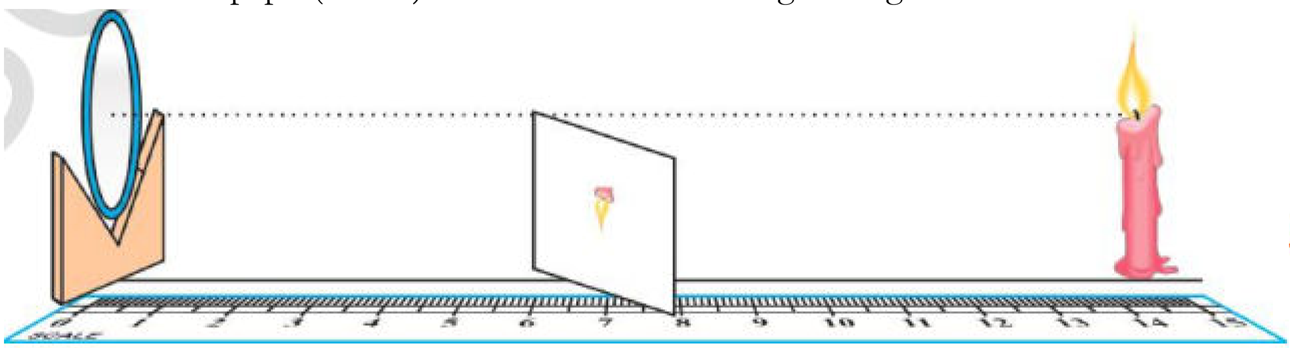
ACTIVITY: FINDING THE TYPES OF IMAGES FORMED BY CONCAVE MIRROR

AIM: Observing the types of images and measuring the object distance and image distance from the mirror.

MATERIAL REQUIRED: A candle, paper, concave mirror (known focal length), V-stand, measuring tape or meter scale.

PROCEDURE:

1. Place the concave mirror on V-stand, arrange a candle and meter scale.
2. Keep the candle at different distances from the mirror (10cm to 80cm) along the axis.
3. Move the paper(screen) such that a clear and bright image is formed on it.



4. Calculate the distance between candle and mirror(object distance), the distance betwee mirror and paper(image distance) and note them in a table.
5. Observe the orientation, size of the images formed. Note them in the table.

OBSERVATION

SL. NO.	OBJECT DISTANCE (U)	IMAGE DISTANCE (V)	ENLARGED/DIMINISHED	INVERTED OR ERECT
1.				
2.				
3.				
4.				

PRECAUTIONS:

1) The concave mirrors should be fixed in the vertical plane.

2) The base of the concave mirror stand and the screen should be parallel to the meter scale.
3) Record the position of screen only when defined, inverted and diminished image of the object is formed on the screen.

RESULT:

1) The rays of light coming from a distant object e.g. sun or a distant building can be considered to be parallel to each other. When these parallel rays of light fall on a concave mirror along its axis, reflect and meet at a point in front of the mirror, which is called as focus of the mirror.
2) A real, inverted and very small image size is formed at the focus of the mirror.
3) The distance between the pole of the concave mirror and the focus is know as the focal length of the concave mirror.

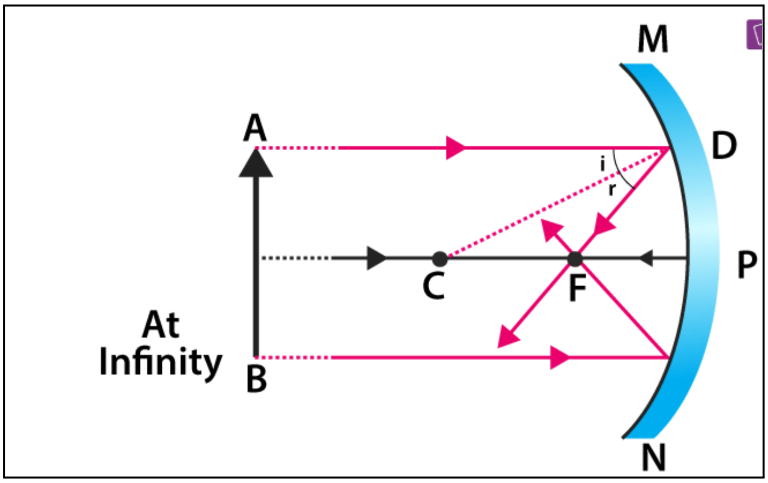
RAY DIAGRAMS FOR CONCAVE MIRROR:

S. NO	POSITION OF OBJECT	POSITION OF IMAGE	SIZE OF IMAGE	NATURE OF IMAGE
1.	At infinity	At the focus F	Highly Diminished	Real and Inverted
2.	Beyond the centre of curvature C	Between F and C	Diminished	Real and Inverted
3.	At the centre of curvature C	At the centre of curvature C	Same Sized	Real and Inverted
4.	Between C and F	Beyond C	Enlarged	Real and Inverted
5.	At focus F	At Infinity	Highly Enlarged	Real and Inverted
6.	Between P and F	Behind the mirror	Enlarged	Virtual and Erect

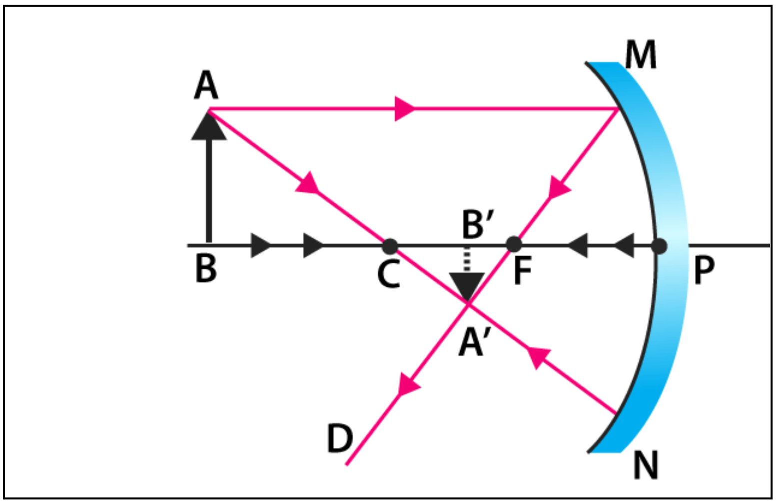
By changing the position of the object from the concave mirror, different types of images can be formed. Different types of images are formed when the object is placed:

1. At the infinity
2. Beyond the centre of curvature
3. At the centre of curvature
4. Between the centre of curvature and principal focus
5. At the principal focus
6. Between the principal focus and pole

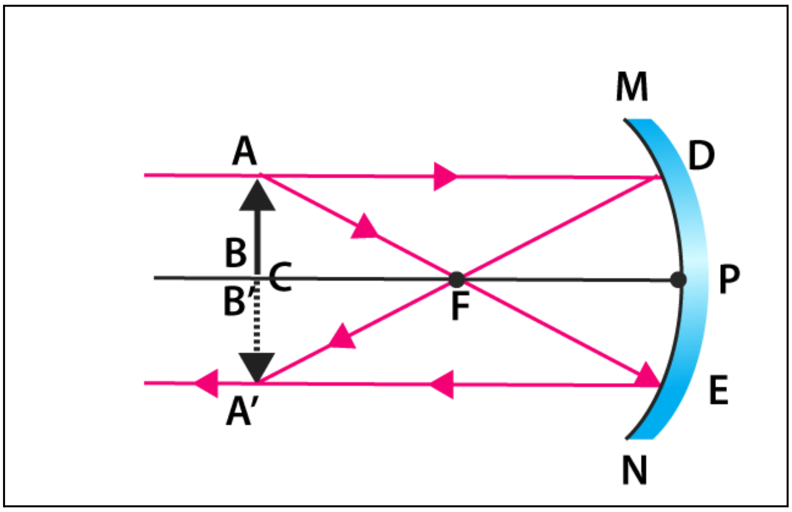
Concave Mirror Ray Diagram lets us understand that, when an object is placed at infinity, a real and inverted image is formed at the focus. The size of the image is much smaller compared to that of the object.



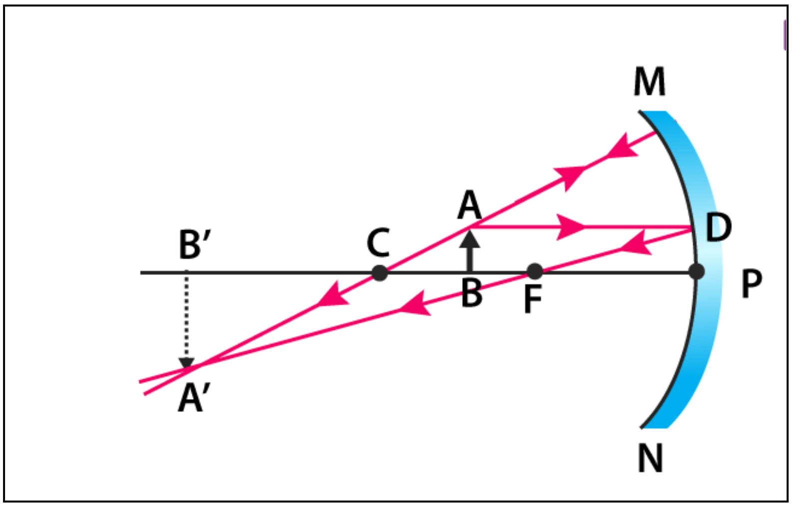
- When an object is placed behind the centre of curvature, a real image is formed between the centre of curvature and focus. The size of the image is smaller than compared to that of the object.



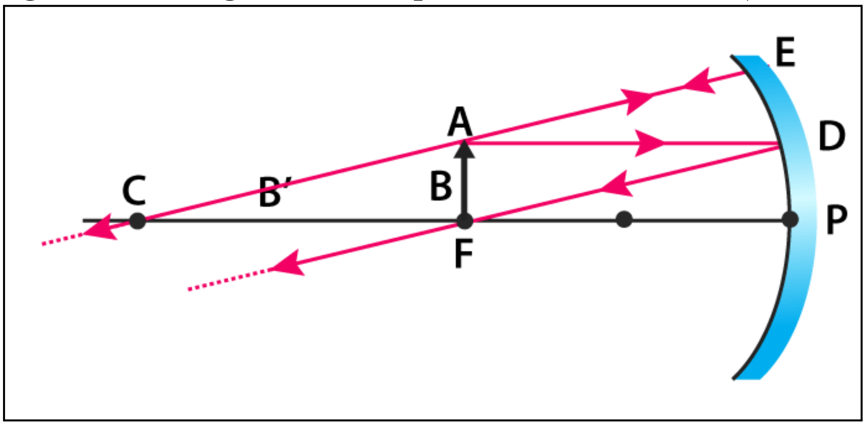
- When an object is placed at the centre of curvature and focus, the real image is formed at the centre of curvature. The size of the image is the same as compared to that of the object.



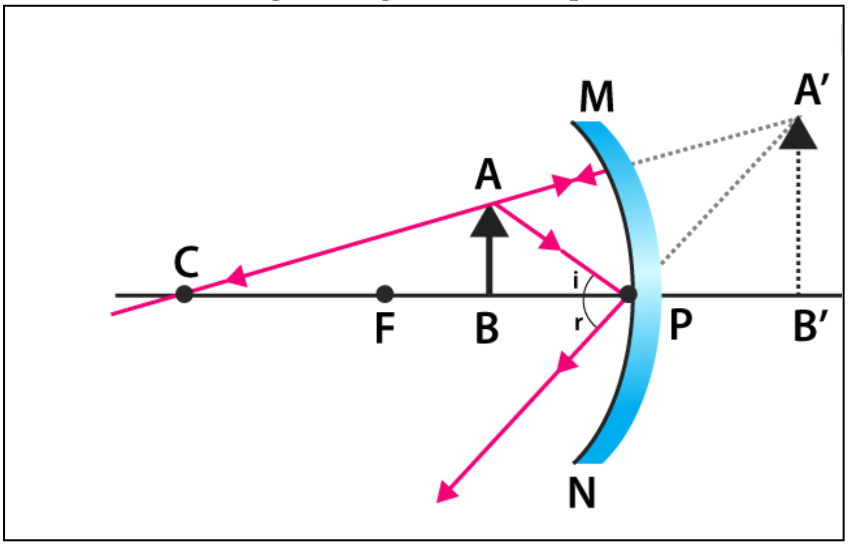
- When an object is placed in between the centre of curvature and focus, the real image is formed behind the centre of curvature. The size of the image is larger than compared to that of the object.



- When an object is placed at the focus, the real image is formed at infinity. The size of the image is much larger than compared to that of the object.



- When an object is placed in between focus and pole, a virtual and erect image is formed. The size of the image is larger than compared to that of the object.

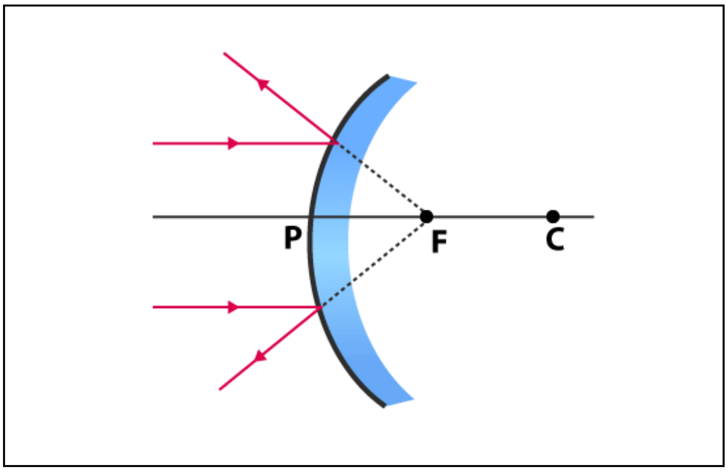


RAY DIAGRAMS FOR CONVEX MIRRORS

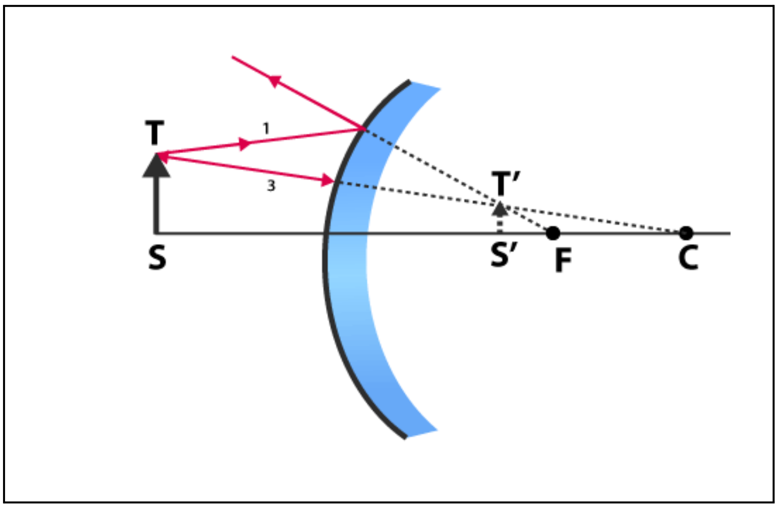
SL. NO.	POSITION OF OBJECT	POSITION OF IMAGE	SIZE OF IMAGE	NATURE OF IMAGE
1	At Infinity	At the focus F, behind the mirror	Highly diminished	Virtual and Erect
2	Between Infinity and the Pole	Between P and F, behind the mirror	Diminished	Virtual and Erect

The image formed in a convex mirror is always virtual and erect, whatever be the position of the object. In this section, let us look at the types of images formed by a convex mirror.

- When an object is placed at infinity, a virtual image is formed at the focus. The size of the image is much smaller than compared to that of the object.



- When an object is placed at a finite distance from the mirror, a virtual image is formed between the pole and the focus of the convex mirror. The size of the image is smaller than compared to that of the object.



MIRROR'S FORMULA:

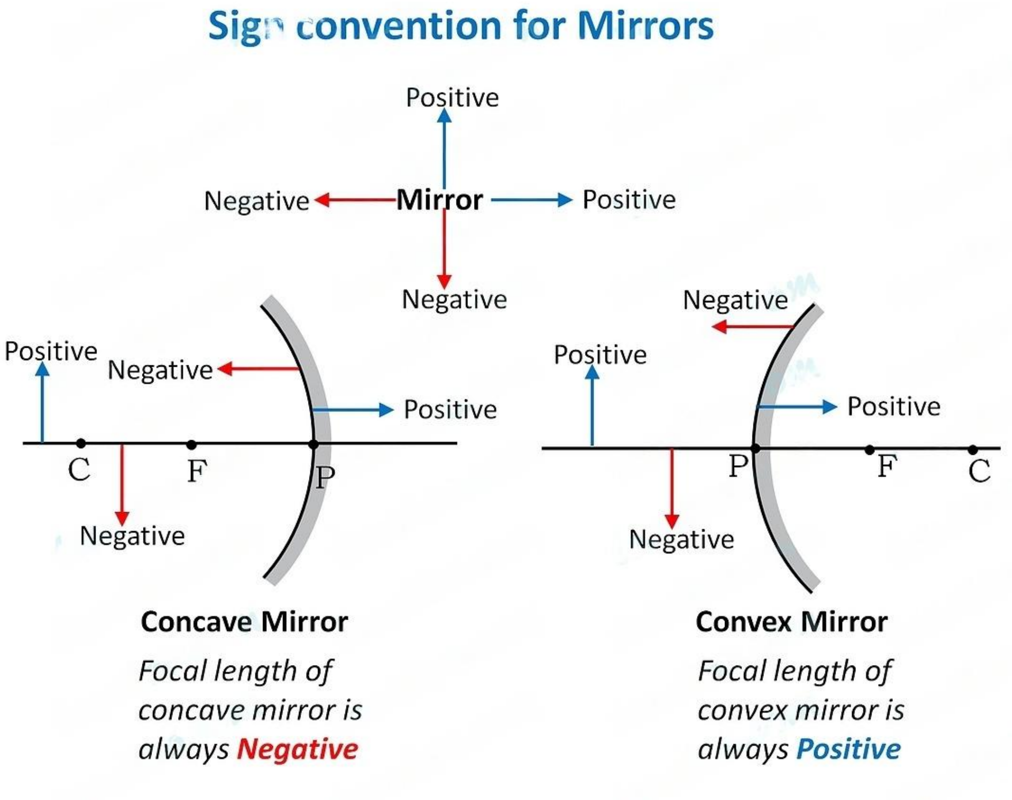
Mirrors formula is given by the following equation:

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

Where,

- u is the Object distance
- v is the Image distance
- f is the Focal Length given by
- $f = \frac{R}{2}$
- R is the radius of curvature of the spherical mirror

SIGN CONVENTION FOR SPHERICAL MIRRORS



The Sign convention rules for spherical mirrors are:

1. All distances should be measured from the pole.
2. The distances measured in the direction of incident light, to be taken positive and those measured in the direction opposite to incident light to be taken negative.
3. Height of object (h_o) and height of image (h_i) are positive if measured upwards from the axis and negative if measured downwards.

MAGNIFICATION FOR SPHERICAL MIRRORS

1. Magnification is the increase in the image size produced by spherical mirrors with respect to the object size.
2. It is the ratio of the height of the image to the height of the object and is denoted as m.

3. The magnification, m produced by a spherical mirror can be expressed as

$$\text{Magnification } \mathbf{m} = \frac{h_i}{h_o} = \frac{-v}{u}$$

We define the magnification,

m = height of image(h_i)/ height of object (h_0)

In all cases it can be shown that

m = – image distance (v)/ object distance (u)

ACTIVITY: MAKING A SOLAR COOKER

AIM: To prepare a solar cooker

APPARATUS: TV Dish Antenna, Acrylic sheet,

PROCEDURE:

1. Take a TV Dish antenna, collect some acrylic sheet and cut it in the form of isosceles triangles such that the height of triangle is equal to radius of dish antenna.
2. Place the acrylic sheet on dish antenna and face it towards the sun.
3. Now, observe where a bright spot is formed.
4. Place the container containing food at that point.
5. After sometime, open the vessel and observe

OBSERVATION

After sometime, food in the vessel will be cooked due to solar energy form the sun.

CONCLUSION

Hence, we can prepare solar cooker.

USES OF CONCAVE MIRRORS

CONCAVE MIRROR USES IN THE OPHTHALMOSCOPE

Concave mirrors are used in optical instruments such as Ophthalmoscope. Ophthalmoscope consists of a concave mirror with a hole in the centre. The doctor focuses through the small hole from behind the concave mirror while a light beam is directed into the pupil of the patient's eye. This makes the retina visible and makes it easy for doctors to check.

USES OF CONCAVE MIRROR IN ASTRONOMICAL TELESCOPES

Concave mirrors are also used in making astronomical telescopes. In an astronomical telescope, a concave mirror of a diameter of 5 meters or more is used as the objective.

CONCAVE MIRRORS USED IN HEADLIGHTS

Concave mirrors are widely used in automobiles and motor vehicles headlights, torchlights, railway engines, etc. as reflectors. The light source is placed at the focus of the mirror, so after reflecting the light rays travel over a huge distance as parallel light beams of high intensity.

USED IN SOLAR FURNACES

Large concave mirrors are used to focus sunlight to produce heat in the solar furnace. They are also used in solar ovens to collect a large amount of solar energy in the focus of the concave mirror for heating, cooking, melting metals, etc.

These were some common uses of the concave mirror in daily life. Concave mirrors are also used in satellite dishes, electronic microscopes, visual bomb detectors, etc.

USES OF CONVEX MIRRORS

CONVEX MIRRORS USED INSIDE BUILDINGS

Large offices, stores, and hospitals use a convex mirror to let people see around the corner so that they can avoid running into each other and prevent any collision.

CONVEX MIRRORS USED IN VEHICLES

Convex mirrors are widely used as rear-view mirrors in automobiles and vehicles because they can diverge light beams and make virtual images.

USES OF THE CONVEX MIRROR IN A MAGNIFYING GLASS

Convex mirrors are widely used for making magnifying glasses. In order to make a magnifying glass, two convex mirrors are placed back to back.

CONVEX MIRRORS USED FOR SECURITY PURPOSES

Convex mirrors are also used for security purposes in various places. They are placed near ATMs so that bank customers can check if someone is behind them.

These are some of the common convex mirrors used in the practical world. Convex mirrors are also used in various other places, like street light reflectors, as they can spread light over bigger areas. They are also used to make telescopes and ceiling dome mirrors.

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4. REFRACTION OF LIGHT AT CURVED SURFACES

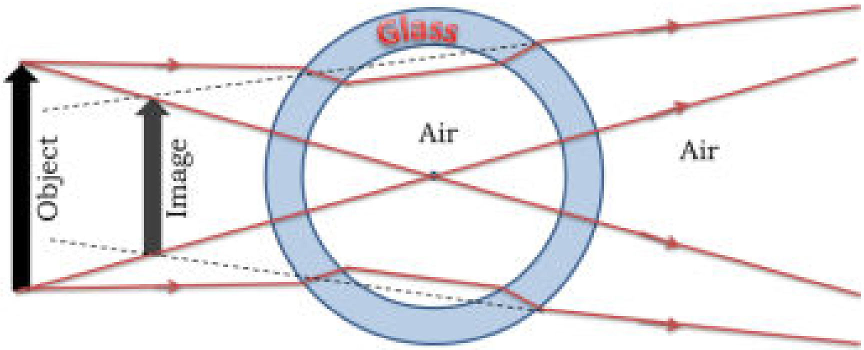
Lenses exist in a variety of fields around us, from the human eye to cinema projectors. Converging lenses focus light to a specific point called the focus. Cameras utilise converging lenses not only to focus but also to magnify the image. Microscopes also converging lenses used to magnify images. Opticians use convex and concave lenses to correct near-sightedness (Myopia) and far-sightedness(hypermetropia) respectively. Binoculars and telescopes utilise lenses to make the images closer and magnify. In security devices like door viewer we use convex and concave lenses to view the objects outside the door. Concave lenses also use flashlights.

1. It is a common observation that some people use spectacles for reading.
2. The watch repairer uses a small magnifying glass to see tiny parts of a watch.

REFRACTION OF LIGHT AT CURVED SURFACE ACTIVITIES:

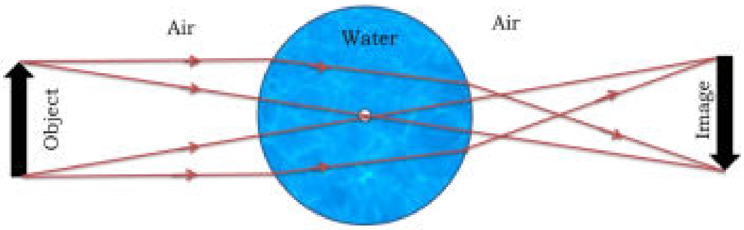
ACTIVITY 1

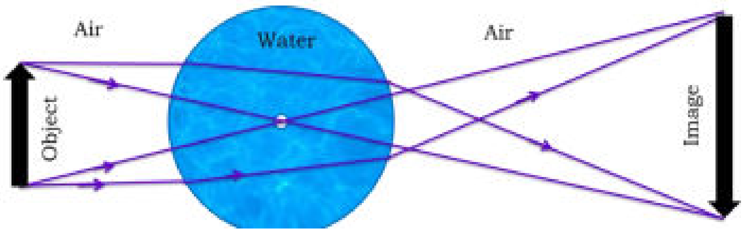
1. Draw an arrow of length 4 cm using a black sketch pen on a thick sheet of paper.
2. Take an empty cylindrical-shaped transparent vessel such as a glass tumbler and keep it on the table.
3. Ask your friend to bring the sheet of paper on which the arrow was drawn behind the vessel while you look at it from the other side (The arrow mark should be in a horizontal position).



4. We will see a diminished (small-sized) image of the arrow.
5. Ask your friend to fill the vessel with water. Look at the figure of arrow from the same position as before.
.
6. In the first case, when the vessel is empty, light from the arrow refracts at the curved interface, moves through the glass and enters into air then it again undergoes refraction on the opposite curved surface of the vessel (at the other end from where we are looking) and comes out into the air.
7. In this way light travels through two media and comes out of the vessel and forms a diminished image.
8. In the second case, light enters the curved surface, moves through water, comes out of the glass and forms an inverted image.
9. When the vessel is filled with water, there is a curved interface between two different media (air and water).

10. (Assume that the refractive indices of both water and glass are the same, they really are not equal. This setup of air and water separated by a curved surface is shown in the figure.)



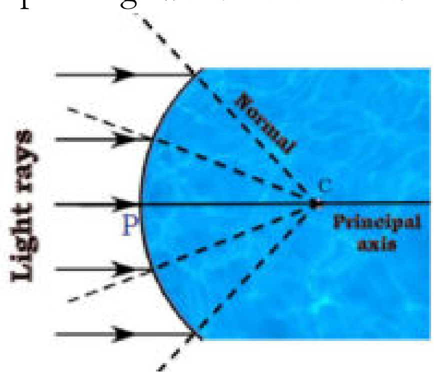


EXPLANATION

To explain this, you must think about the glass of water as if it is a magnifying glass. When light goes through a magnifying glass the light bends toward the center. Where the light all comes together is called the focal point, but beyond the focal point the image appears to reverse because the light rays that were bent pass each other and the light that was on the right side is now on the left and the left on the right, which makes the arrow appear to be reversed.

UNDERSTANDING OF CURVED SURFACES AND IMPORTANT DEFINITIONS FOR CURVED SURFACE:

1. Consider a curved surface separating two different media as shown in the figure.



2.

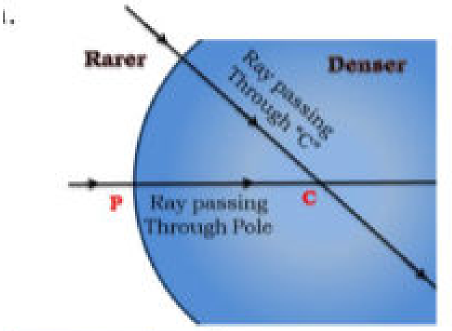
3. The centre of the sphere, of which curved surface is a part, is called as centre of curvature. It is denoted by letter 'C'.
4. Any line drawn from the centre of curvature to a point on the curved surface becomes normal to the curved surface at that point. (This was explained in the Lesson Reflection of light in the different surfaces).
5. The direction of the normal changes from one point to another point on the curved surface.
6. The centre of the curved surface is called the Pole (P) of the curved surface.
7. The line that joins the centre of curvature and the pole is called Principal axis.

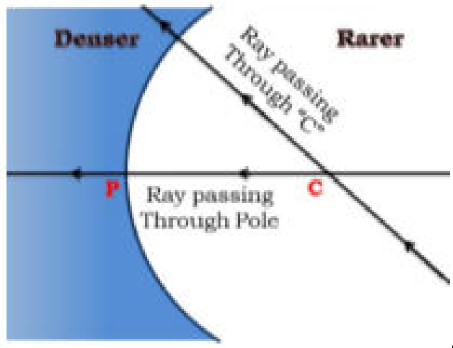
RULES TO DRAW RAY DIAGRAMS FOR CURVED SURFACES IN AN EASY WAY:

As in the case of plane surfaces, a ray will bend towards the normal if it travels from a rarer to denser medium and it bends away from the normal if it travels from a denser to a rarer medium.

RULE 1: A RAY THAT TRAVELS ALONG THE PRINCIPAL AXIS AND A RAY THAT TRAVELS THROUGH THE CENTRE OF CURVATURE:

According to Snell's law the ray which travels along the normal and through the centre of curvature drawn to the surface does not deviate from its path. And also the ray travelling along the principal axis (which also travels along the normal and through the centre of curvature) does not deviate from its path.



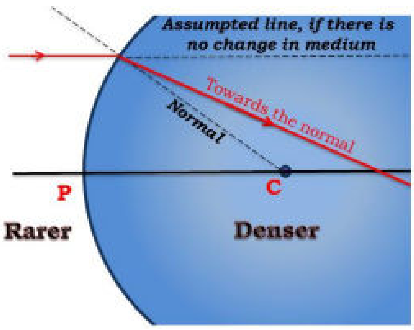


A ray that is parallel to the principal axis: Here we have two situations.

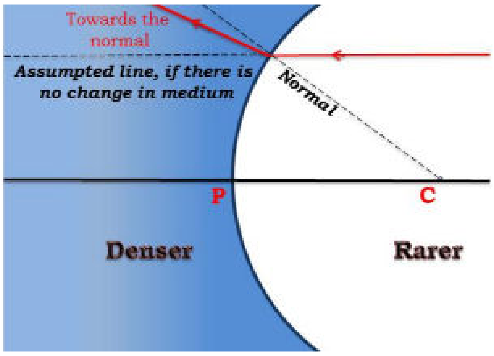
SITUATION 1	SITUATION 2
When a ray that is parallel to the principal axis, travel from rarer medium to denser medium.	When a ray that is parallel to the principal axis, travel from denser medium to rarer medium.
Strikes the curved surface and bends towards the normal. (Ray travels between assumpted line and normal)	Strikes the curved surface and bends away from the normal. (Ray travels above the assumpted line or with respect to the assumpted line, opposite side of centre of curvature)

In situation-1 we have two cases.

Case1/Situation-1: When a ray travelling parallel to the principal axis strikes a convex surface and passes from a rarer medium to denser medium, it bends towards the normal.

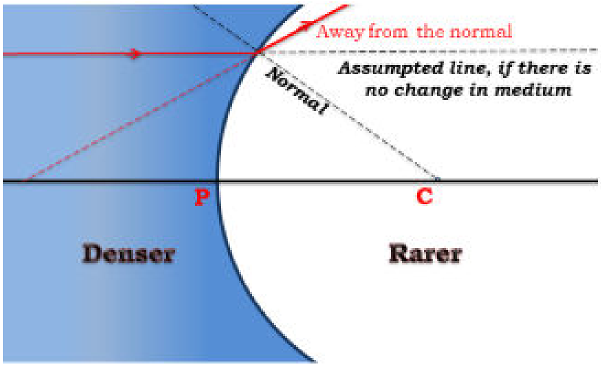


Case2/Situation-1: When a ray travelling parallel to the principal axis strikes a concave surface and passes from a rarer medium to denser medium, it bends towards the normal.

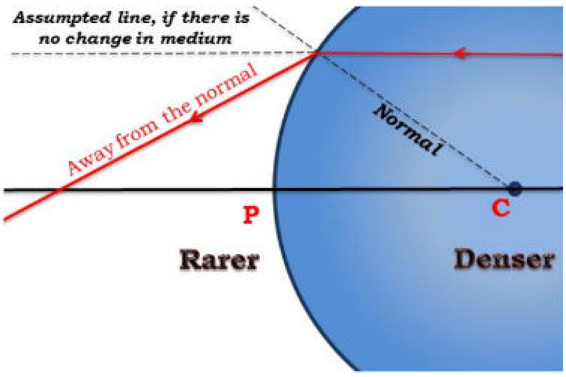


In situation-2 we have two cases.

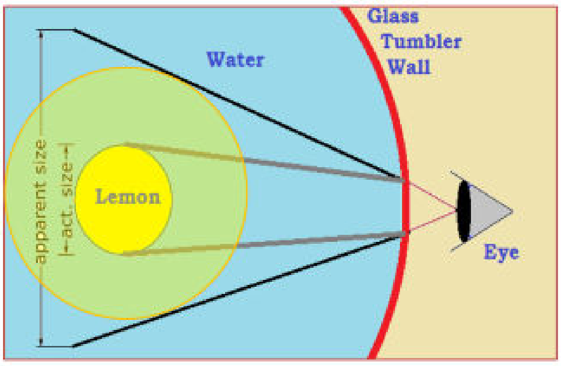
Case1/Situation-2: When a ray travelling parallel to the principal axis strikes a convex surface and passes from a denser medium to rarer medium, it bends away from the normal.



Case2/Situation-2: When a ray travelling parallel to the principal axis strikes a concave surface and passes from a denser medium to rarer medium, it bends away from the normal.



1. We noticed that in figures Case1/Situation-1 and Case2/Situation-2 the refracted ray reaches a particular point on the principal axis.
2. In figures Case2/Situation-1 and Case1/Situation-2 the refracted ray moves away from the principal axis.
3. When you extend the refracted ray backwards along the ray as shown in Case2/Situation-1 and Case1/Situation-2, the extended ray intersects the principal axis at some point.
4. The point where refracted ray intersects the axis in all the above cases is called the focal point (F).
5. We observed that a lemon in a glass of water appears bigger than its actual size, when viewed from the sides of tumbler.



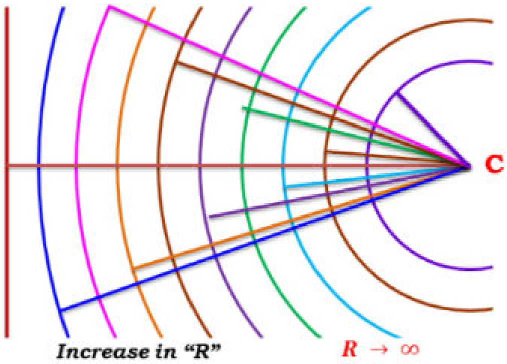
CURVED SURFACE FORMULA AND ITS TERMS:

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

Here,
n1 = Refractive index of I medium.
n2 = Refractive index of II medium.
u = Object distance
v = Image distance
R = Radius of curvature

PLANE SURFACE FORMULA:

1. Curved surface formula can also be used for plane surfaces.
2. In the case of plane surface, the radius of curvature (R) approaches to infinity.
3. Hence 1/R becomes zero.



$$R \to \infty \ then \ \frac{1}{R} = \frac{1}{\infty} = 0$$

$$Then, \quad \frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R} = (n_2 - n_1)(0) = 0$$

$$\frac{n_2}{v} = \frac{n_1}{u}$$

Here,
n1 = Refractive index of I medium.

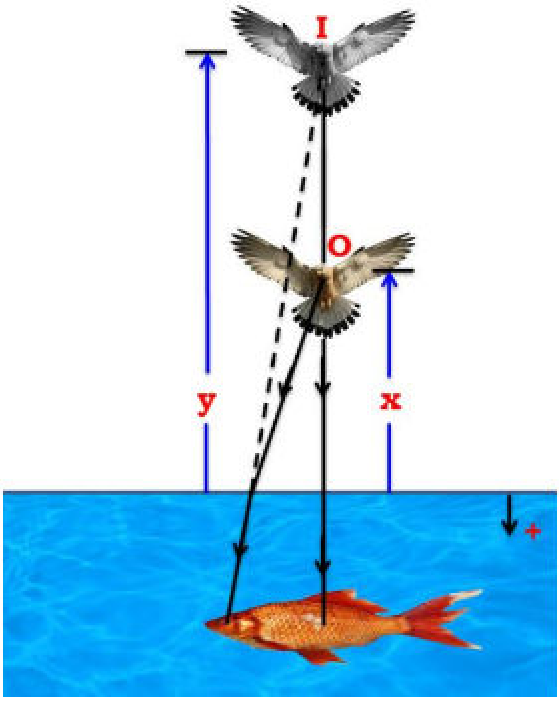
n2 = Refractive index of II medium.
u = Object distance
v = Image distance
The distances u and v are measured from the
plane interface.

PROBLEM-1:

A bird is flying down vertically towards the surface of water in a pond with constant speed. There is a fish inside the water. If that fish is exactly vertically below the bird, then the bird will appear to the fish to be:

a) farther away than its actual distance.
b) closer than its actual distance.
c) moving faster than its actual speed.
d) moving slower than its actual speed.

Which of the four options are true? How can you prove it?



Solution:

1. This is the case of refraction at plane surface. So, we use the formula of refraction at a plane surface,

$$\frac{n_2}{v} = \frac{n_1}{u}$$ —--------------------------(1)

2. In this situation the fish observes the bird. Therefore the light rays come from the bird and incident on the fish's eye.
3. Hence we take air as first medium and water as second medium.
4. Let x be the height of the bird above the water surface at an instant (object distance), y be the height of the apparent image of the bird above the water surface at an instant (image distance) and n (=n2) be the refractive index of water (second medium) and n1 be the refractive index of air (first medium).

5. Then, n1 = 1, n2 = n, u = -x (according to the sign convection object distance measured from interface and it is opposite direction of the light ray) and v = -y (according to the sign convection image distance measured from interface and it is opposite direction of the light ray)

On substituting these values in equation (1) we get,

$$\frac{n}{(-y)} = \frac{1}{(-x)}$$

$$\frac{n}{y} = \frac{1}{x}$$

$$y = nx$$

6. In the above equation, we know that n is greater than 1. Hence y is greater than x. (n > 1 then y > x)
7. Thus the bird appears to the fish to be farther away than its actual distance.

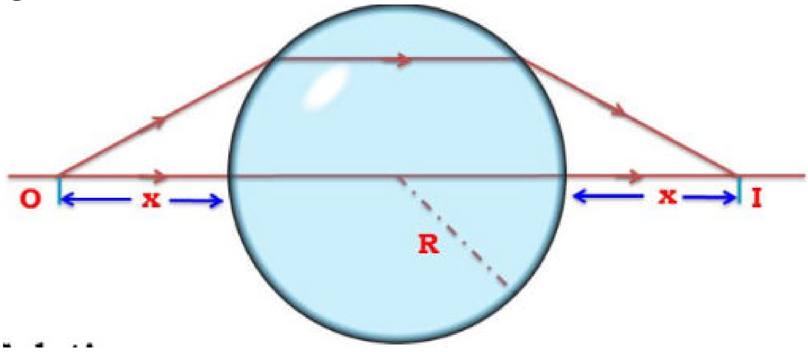
8. We have assumed that bird is flying vertically down with constant speed. For the observer on the ground, bird appears that it has covered 'x' distance for certain time (t). But for fish, it appears that bird has covered a distance 'y' in the same time (t).

9. As y is greater than x and speed = distance / time, For the observer on the ground, speed (SO) = x / t For the fish inside the water, speed (SF) = y / t

10.Then, we can conclude that the speed of the bird, observed by the fish, is greater than its actual speed. Because y > x then Speed of observed by fish (SF) > The actual (SO). So, options (a) and (c) are correct.

PROBLEM 2:

A transparent sphere of radius R and refractive index n is kept in air. At what distance from the surface of the sphere should a point object be placed on the principal axis so as to form a real image at the same distance from the second surface of the sphere?



Solution:
1. From the symmetry of figure, the rays must pass through the sphere parallel to the principal axis.
2. As refracted ray is parallel to the optical axis after refraction at first surface, u = -x, v= ∞, n1 =1 and n2 = n, (where n1 is refractive index of air)
3. Using Curved surface formula,

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

$$\frac{n}{\infty} - \frac{1}{-x} = \frac{(n-1)}{R}$$

$$\frac{1}{x} = \frac{(n-1)}{R}$$

$$x = \frac{R}{(n-1)}$$

4. Object distance from the first surface of the sphere must be equal to R/(n-1) so as to form a real image at the same distance from the second surface of the sphere.

PROBLEM-3:

A transparent (glass) sphere has a small, opaque dot at its centre. Does the apparent position of the dot appear to be the same as its actual position when observed from outside?

Solution:

1. Let refractive index of glass n1 = n

refractive index of air n2 = 1

Object distance u = –R (radius of sphere)

Image distance v = v

Radius of curvature R = –R

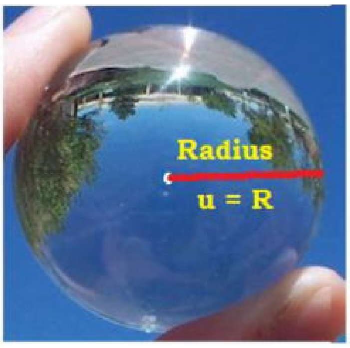
2. By using Curved Surface formula

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$$

$$\frac{1}{v} - \frac{n}{-R} = \frac{(1-n)}{-R}$$

$$\frac{1}{v} + \frac{n}{R} = \frac{(n-1)}{R}$$

$$\frac{1}{v} = \frac{(n-1)}{R} - \frac{n}{R} = \frac{-1}{R}$$



We get, Image distance v = –R

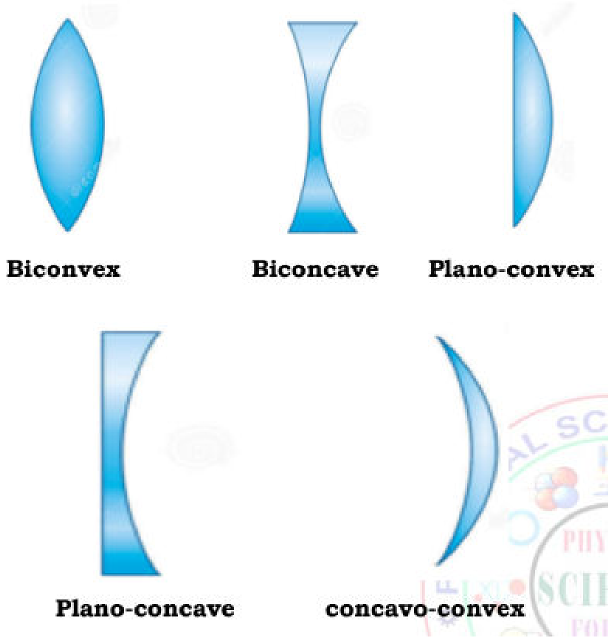
3. Thus we can say, (i) The image distance and object distance are equal, (ii) The apparent position of dot is the same as its actual position and (iii) It is independent of the refractive index of the material of the sphere.

LENSES

LENS (DEF):

A lens is formed when a transparent material is bounded by two surfaces of which one (or) both surfaces are spherical.

1. A lens is bounded by at least one curved surface.
2. Lenses can be of various types



DOUBLE CONVEX LENS OR BICONVEX LENS:

1. A lens may have two spherical surfaces bulging outwards is called Double convex lens or Biconvex lens.
2. It is thick at the middle as compared to edges.

DOUBLE CONCAVE LENS OR BICONCAVE LENS:

1. A lens may have two spherical surfaces curved inwards is called Double concave lens or Biconcave lens.
2. It is thin at the middle and thicker at the edges.

PLANO-CONVEX LENS:

1. A lens may have one plane surface and one spherical surface bulging outwards is called Plano-convex lens.
2. It is thick at the middle as compared to edges.

PLANO-CONCAVE LENS:

1. A lens may have one plane surface and one spherical surface curved inwards is called Plano-concave lens.
2. It is thin at the middle and thicker at the edges. (Here we are concerned only with thin lenses i.e. the thickness of the lens is negligible.)

CONCAVO-CONVEX LENS:

1. A lens may have two spherical surfaces, one is curved inwards and other is bulging outwards is called Concavo-convex lens.
2. It is thick at the middle as compared to edges.

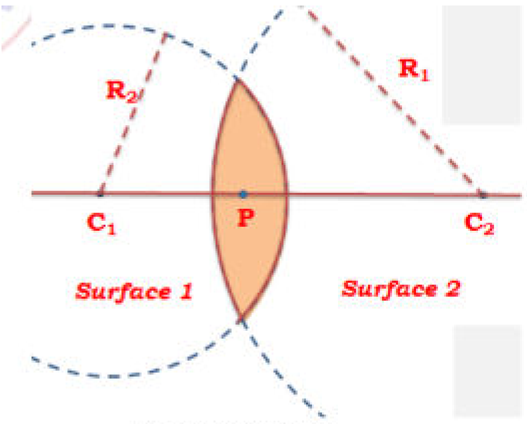
TERMINOLOGY USED IN THE CASE OF LENSES:

Each curved surface of a lens is part of a sphere.

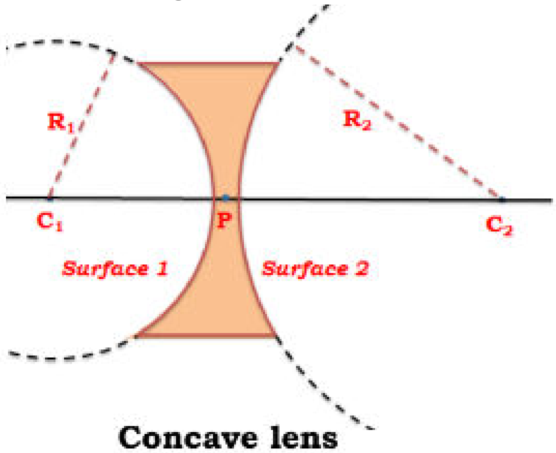
1. Centre of curvature (C): The centre of the sphere which contains the part of the curved surface is called Centre of curvature. It is denoted by a letter 'C'.
    a. If a lens contains two curved surfaces then their centre of curvatures are denoted as C1 and C2.

2. Radius of curvature (R): The distance between the centre of curvature and curved surface is called Radius of curvature (R).
    a. Radii of curvature are represented by R1 and R2 respectively.

Let us consider a double convex lens as shown in the figure below.



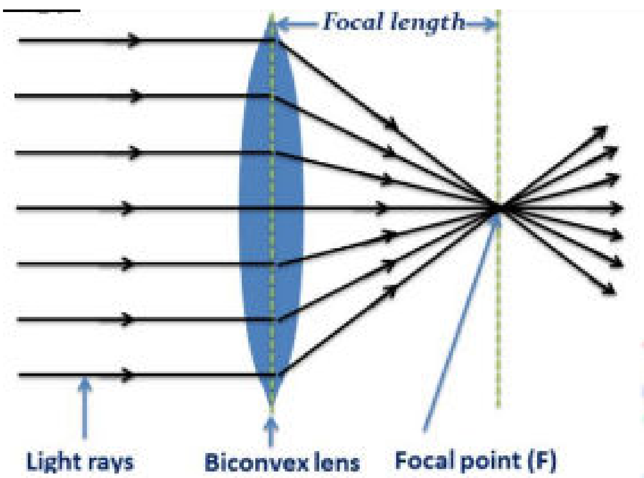
Convex lens

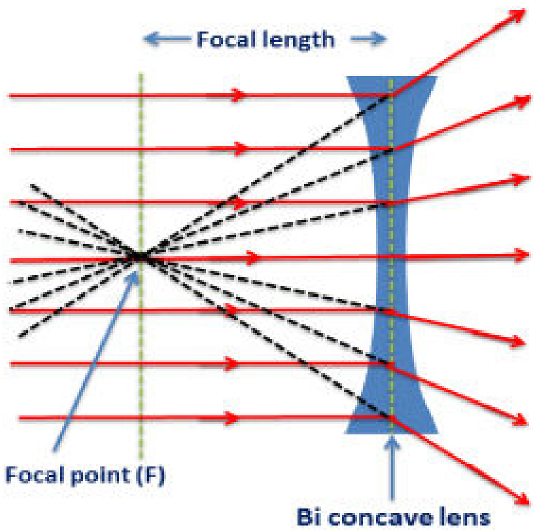


Concave lens

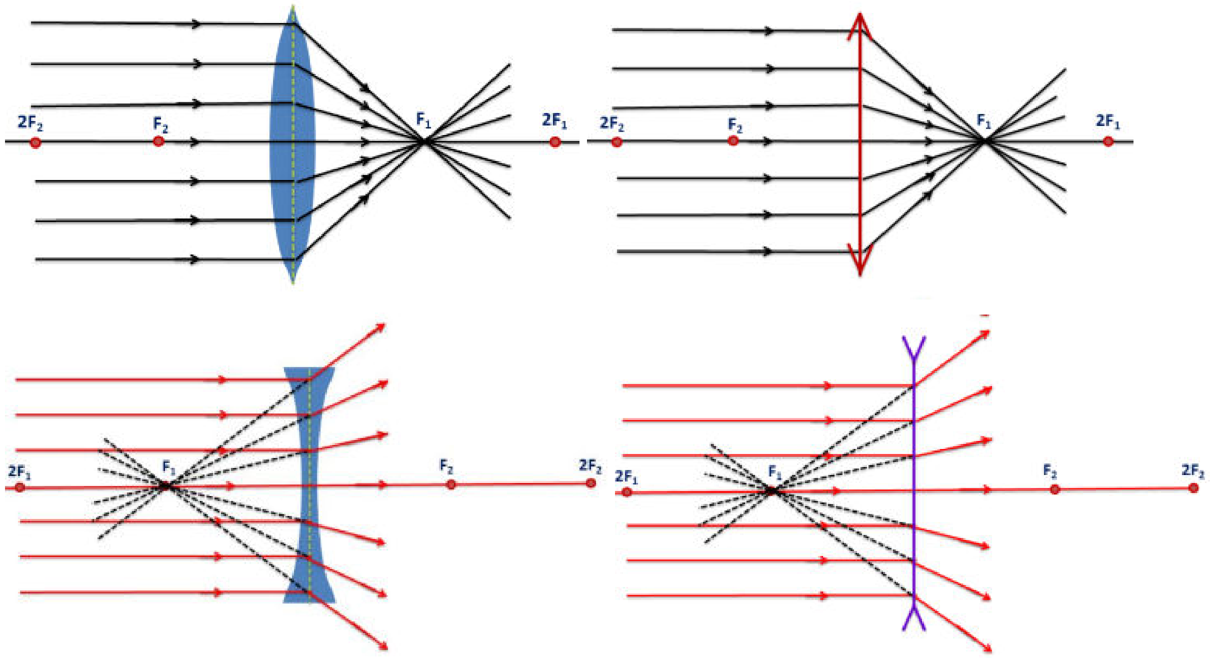
3.Principal axis: The line joining between two centre of curvatures (the points C1 and C2) is called Principal axis.
4. Optic centre of lens (P): The midpoint of a thin lens is called Optic centre of lens (P).
5. Focal point or focus (F): The point of convergence (or) the point from which rays seem to emanate on the principal axis of a lens is called focal point or focus (F).
6. Focal length (f): The distance between the focal point and optic centre is called the focal length of lens denoted by 'f'.

EXPLANATION OF FOCAL POINT (F) AND FOCAL LENGTH (F):

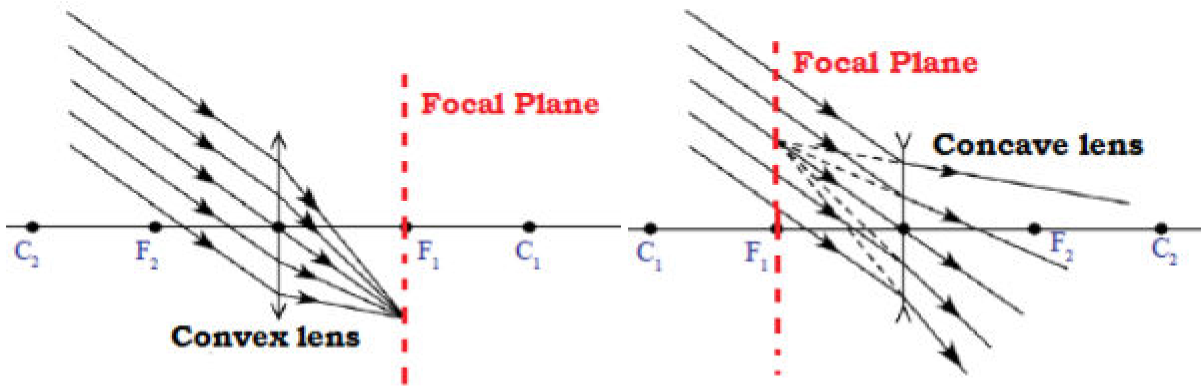




- ❖ A parallel beam of light incident on a lens converges to a point as shown in figure 1 or seems to emanate from a point on the principal axis as shown in figure 2.
- ❖ That point of convergence (or) that point from which rays seem to emanate is called focal point or focus (F).
- ❖ Every lens has two focal points. The distance between the focal point and optic centre is called the focal length of lens denoted by 'f'.
- ❖ For drawing ray diagrams related to lenses we represent convex lens with the symbol ↕ and concave lens with  .



- ❖ Focal plane: The plane perpendicular to the principal axis at the focus is called Focal plane.

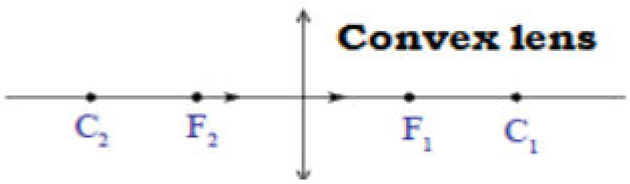


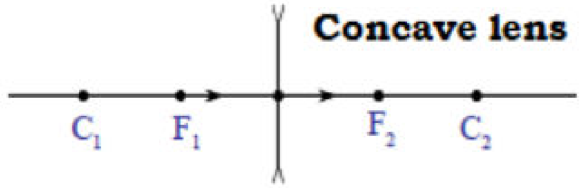
BEHAVIOUR OF CERTAIN LIGHT RAYS WHEN THEY ARE INCIDENT ON A LENS:

1. To know the formation of image by lenses, we need to know the behaviour of light rays when they meet a lens.
2. Though we know that the lens has two surfaces; while drawing ray diagrams, we can consider the lens as a single surface element because we assume that the thickness of the lens is very small and show the net refraction at only one of the surfaces, as shown in the above figures.
3. The behaviour of a light ray when it passes through a lens can be understood by observing its behaviour in the following situations:

SITUATION I- RAY PASSING ALONG THE PRINCIPAL AXIS:

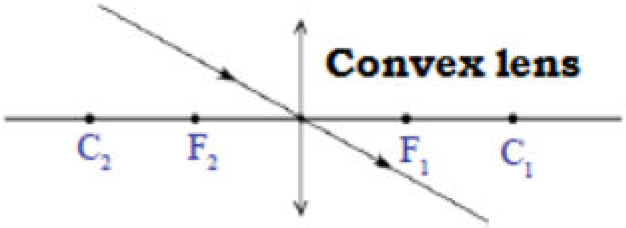
Any ray passing along the principal axis is un-deviated.

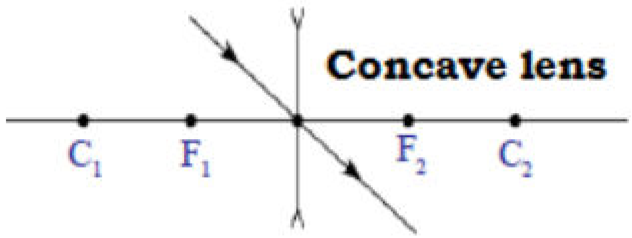




SITUATION II- RAY PASSING THROUGH THE OPTIC CENTRE:

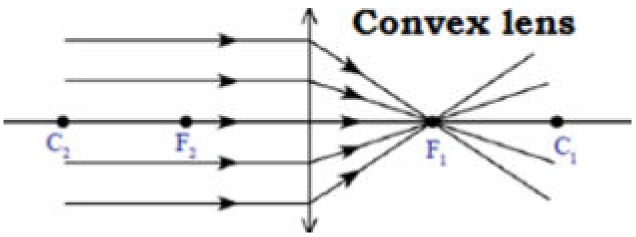
Any ray passing through the optic centre is also undeviated.

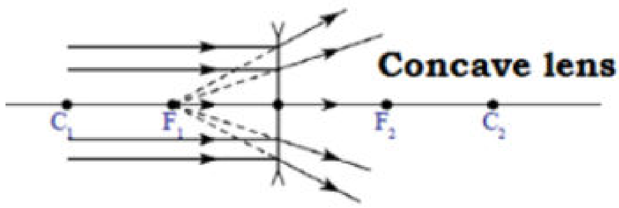




SITUATION III- RAYS TRAVELLING PARALLEL TO THE PRINCIPAL AXIS:

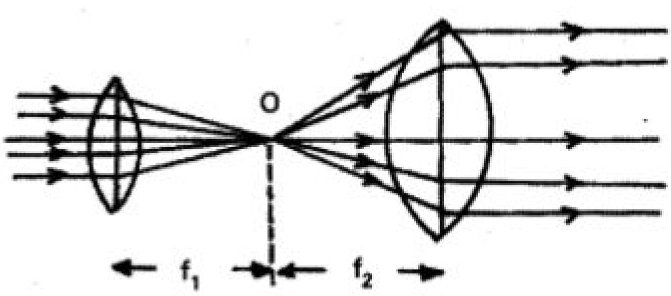
The rays passing parallel to the principal axis converge at the focus or appear to diverge from the focus.





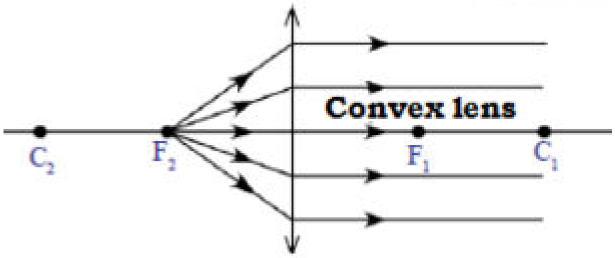
THE ARRANGEMENT OF TWO CONVERGING LENSES IS TO BE PLACED IN THE PATH OF PARALLEL RAYS SO THAT THE RAYS REMAIN PARALLEL AFTER PASSING THROUGH BOTH LENSES:

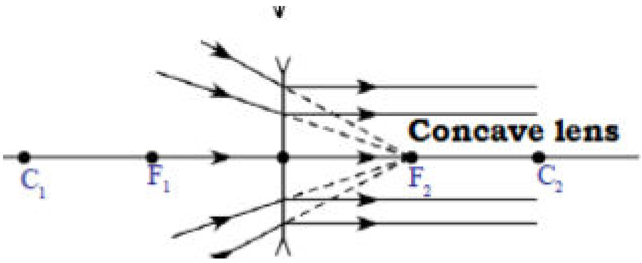
1. A parallel beam of light rays will converge on focal point of the lens after refraction.
2. Light rays passes through the focal point will parallel to principal axis after refraction.
3. So, the two lenses are arranged on a common principal axis such that their focal points coincide with each other, then the rays remain parallel after passing through both lenses.



SITUATION IV- RAY PASSING THROUGH FOCUS:

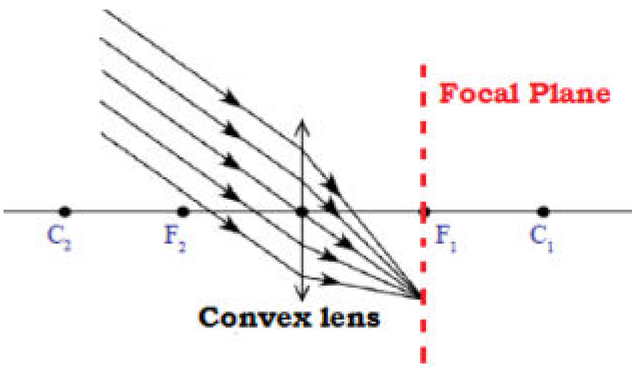
Light rays obey the principle of least time (Fermat's Principle). Hence the ray passing through the focus will take a path parallel to principal axis after refraction.

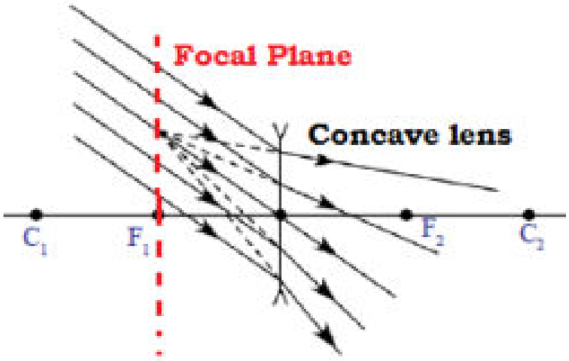




SITUATION V- PARALLEL RAYS OF LIGHT FALL ON A LENS MAKING SOME ANGLE WITH THE PRINCIPAL AXIS:

When parallel rays, making an angle with principal axis, fall on a lens, as shown in figures, the rays converge at a point or appear to diverge from a point lying on the focal plane. Focal plane is the plane perpendicular to the principal axis at the focus.



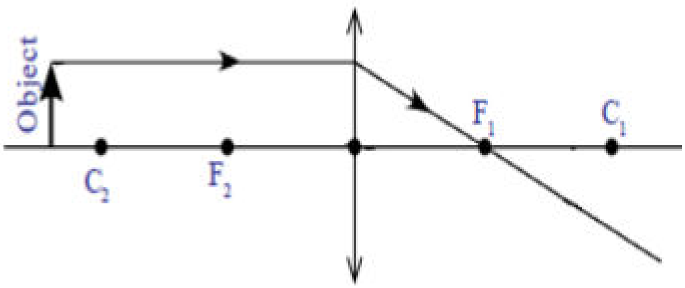


RULES TO DRAW RAY DIAGRAMS FOR IMAGE FORMATION BY LENSES (HERE WE EXPLAIN IN THE CASE OF CONVEX LENS):

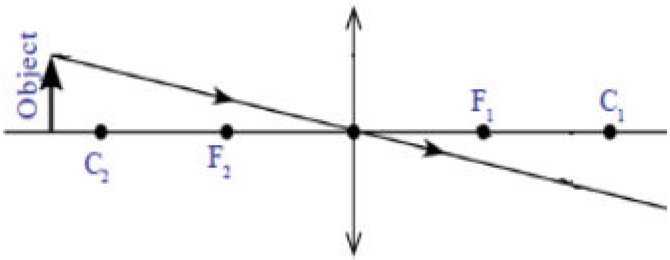
To locate position and to find the size of the image, we need two rays out of four rays that were mentioned in the situations I to IV.

STEP 1: Select the point at the top of the object (say head of the object), which is placed at a point on the principal axis.

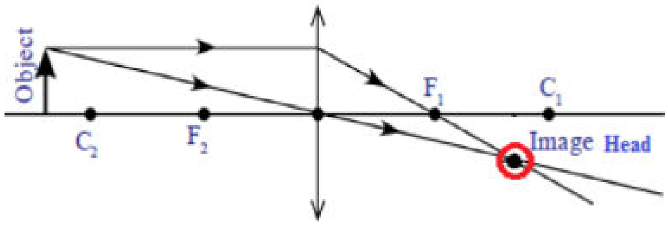
STEP 2: Draw a ray from the selected point (head of the object) which is parallel to the principal axis, it is incident on the lens passes through focus after refraction.



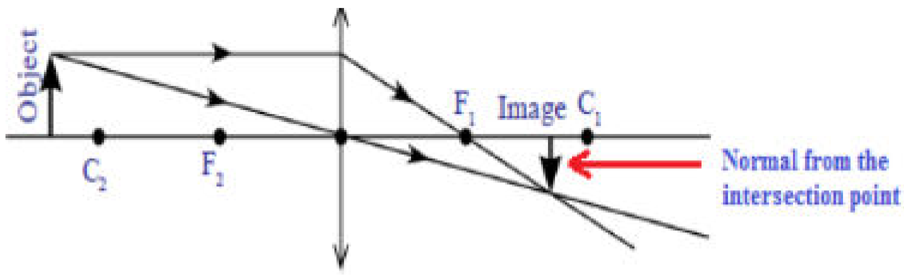
STEP 3: Draw a ray from the selected point (head of the object) which is passes through optic centre, passes without deviation and intersect at a point with the first line.



STEP 4: The intersect point gives the image of the head point of the object.



STEP 5: Draw a normal from point of intersection to the principal axis. This gives the image of the object.



NOTE: The length of this normal represents the size of the image.

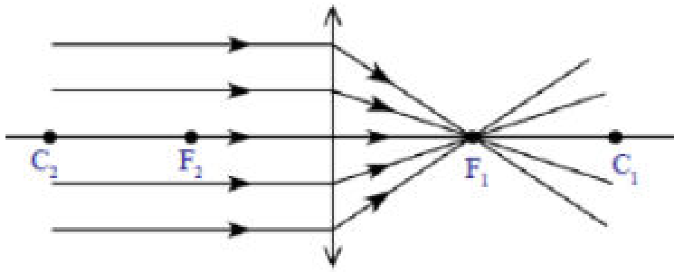
RAY DIAGRAMS FOR CONVEX LENS:

We can place the object at 5 positions of the right side of the convex lens. They are

1. At infinity,
2. Beyond the centre of curvature,
3. At the centre of curvature,
4. Between the centre of curvature and focal point and
5. At the focal point.

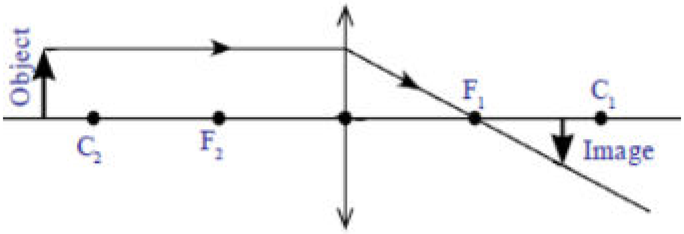
1 OBJECT AT INFINITY

1. We know that the rays falling on the lens from an object at infinity are parallel to the principal axis.
2. They converge to the focal point.
3. So, a point sized image is formed at the focal point.

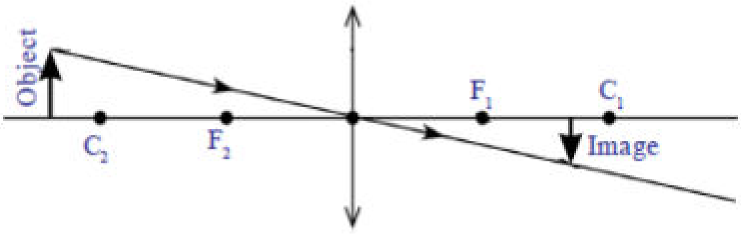


2 OBJECT PLACED BEYOND THE CENTRE OF CURVATURE ON THE PRINCIPAL AXIS

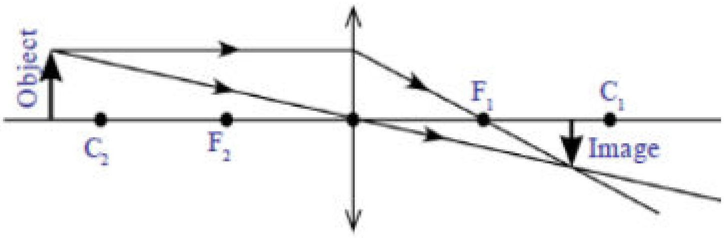
1. When object is placed beyond the centre of curvature (C2), a real, inverted and diminished image is formed on the principal axis between the points F1 and C1.
2. We have chosen two rays, one ray passing parallel to the principal axis and another ray passing through the optic centre to locate the position of the image.
3. The ray passing parallel to the principal axis passes through the focus F1 after refraction.



4) The ray passing through optic centre passes without any deviation after refraction



5) The intersecting point of the above two rays gives the head point of the image formed.

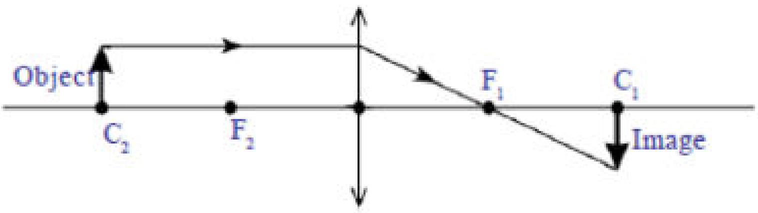


6) Now, connect this image head and principal axis as parallel line then we get complete Image.

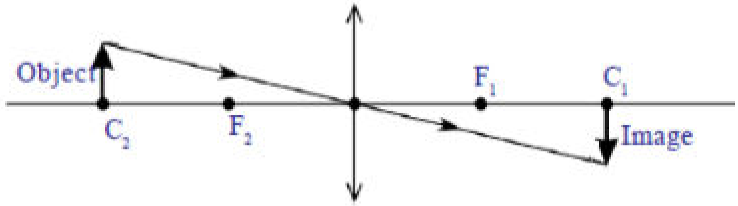
5) The intersecting point of the above two rays gives the head point of the image formed.

3 OBJECT PLACED AT THE CENTRE OF CURVATURE

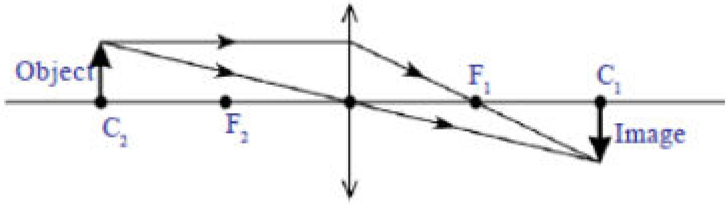
1) When an object is placed at the centre of curvature (C2) on the principal axis, a real, inverted and same size image formed at C1.
2) We have chosen two rays, one ray passing parallel to the principal axis and another ray passing through the optic centre to locate the position of the image.
3) The ray passing parallel to the principal axis passes through the focus F1 after refraction.



4) The ray passing through optic centre passes without any deviation after refraction.



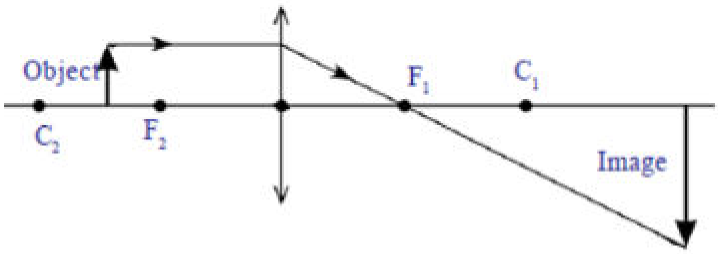
5) The intersecting point of the above two rays gives the head point of the image formed.



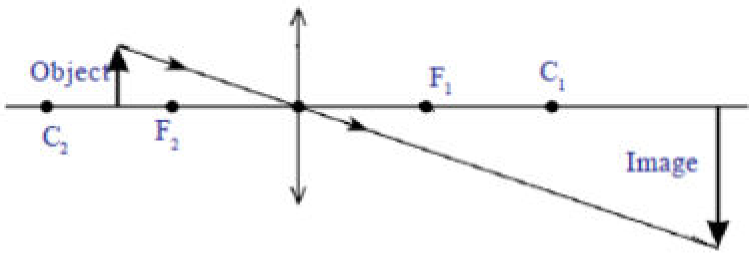
6) Now, connect this image head and principal axis as parallel line then we get complete image.

4 OBJECT PLACED BETWEEN THE CENTRE OF CURVATURE AND FOCAL POINT

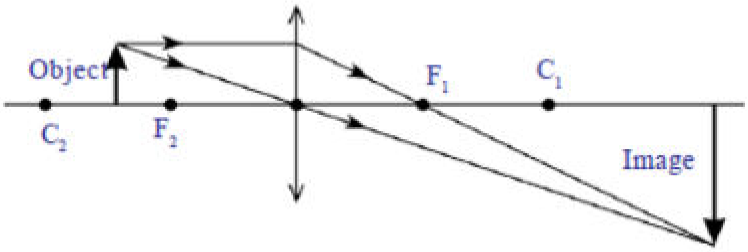
1) When an object is placed between centre of curvature (C2) and focus (F2), a real, inverted and magnified image is formed beyond C1.
2) We have chosen two rays, one ray passing parallel to the principal axis and another ray passing through the optic centre to locate the position of the image.
3) The ray passing parallel to the principal axis passes through the focus F1 after refraction.



4) The ray passing through optic centre passes without any deviation after refraction.



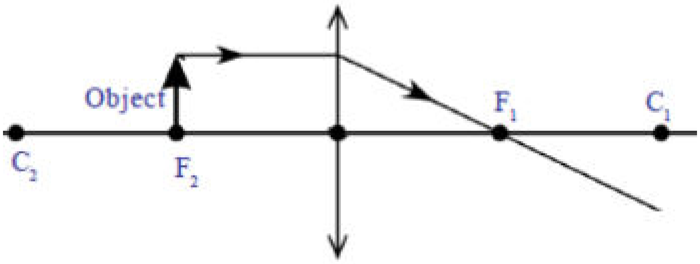
5) The intersecting point of the above two rays gives the head point of the image formed.



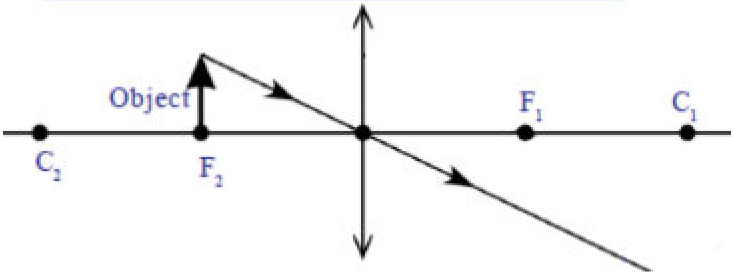
6) Now, connect this image head and principal axis as parallel line then we get complete image.

5 OBJECT LOCATED AT THE FOCAL POINT

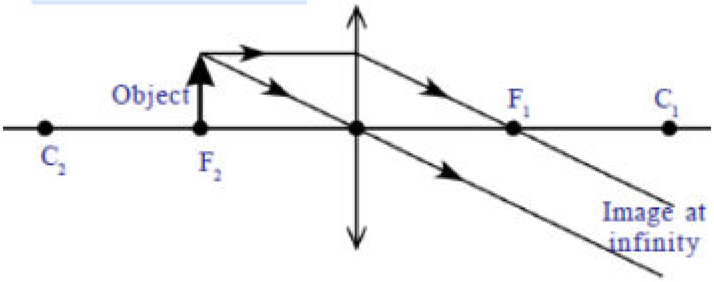
1) When an object is placed at focus (F2), an image is formed at infinity.
2) We have chosen two rays, one ray passing parallel to the principal axis and another ray passing through the optic centre to locate the position of the image.
3) The ray passing parallel to the principal axis passes through the focus F1 after refraction.



4) The ray passing through optic centre passes without any deviation after refraction.

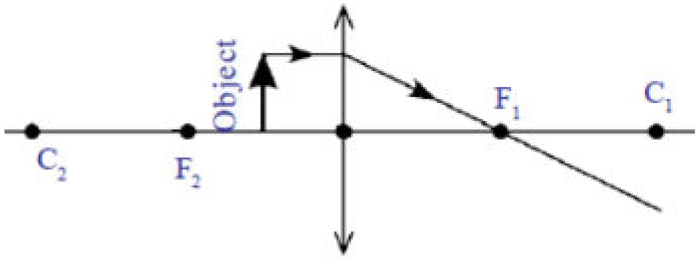


5) These two rays are parallel to each other; therefore these two rays cannot intersect each other. So, we assume that the image formed at infinity.

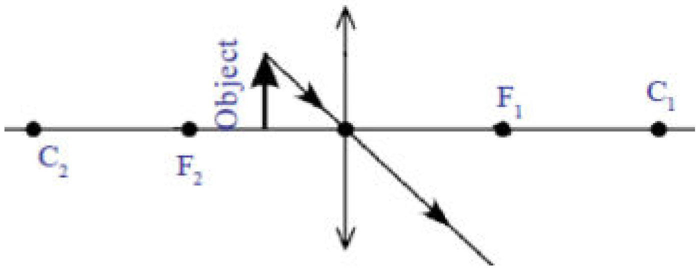


6 OBJECT PLACED BETWEEN FOCAL POINT AND OPTIC CENTRE

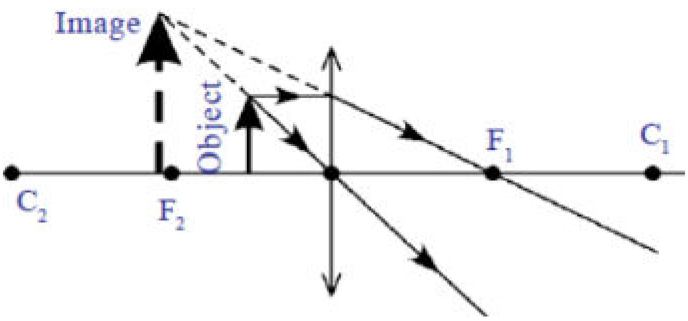
1)When an object is placed between focus (F2) and optic centre (O), a virtual, erect and magnified image is formed on the same side of the lens where the object is placed.
2)We have chosen two rays, one ray passing parallel to the principal axis and another ray passing through the optic centre to locate the position of the image.
3)The ray passing parallel to the principal axis passes through the focus F1 after refraction.



4) The ray passing through optic centre passes without any deviation after refraction.



5) Now, extend these rays to the backside, then we get a point of intersection, i.e., the head point of image.



6) Draw a perpendicular from this head point to the principal axis and then we get the complete image. It is a magnified image.

CONCLUSIONS BY THE ABOVE CONVEX LENS RAY DIAGRAMS:

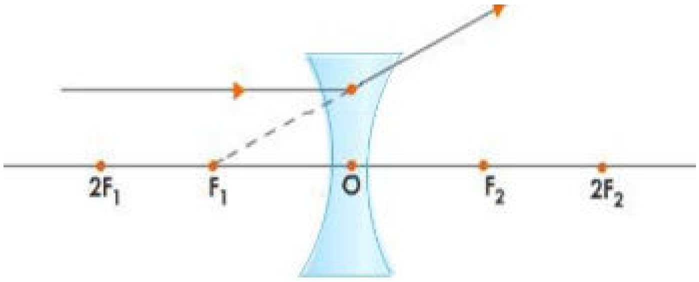
1. In all cases the image is real which we can't see with our eyes but can be viewed if the image is captured on a screen. But in the last case, as the image formed is virtual, we can see it with our eyes.
2. A magnified virtual image is formed on the same side of the lens, when the object is placed between focus (F2) and optic centre (O).
3. Therefore, the image we are seeing through a lens is not real, it is a virtual image of the object. This particular behaviour of convex lens helps to construct a microscope, which gives a magnified image.
4. We might remember that the magnification of the virtual image is possible only when the object is at the distance less than the focal length of the lens.

RULES TO DRAW RAY DIAGRAMS FOR IMAGE FORMATION BY CONCAVE LENS:

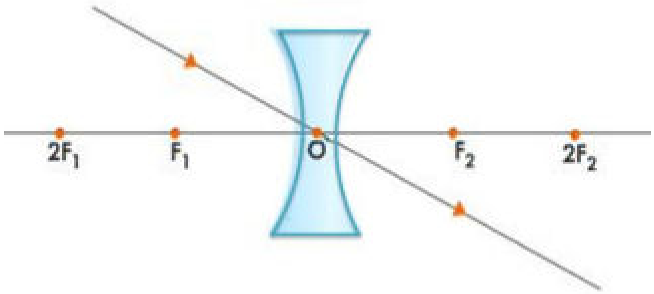
To locate position and to find the size of image, we need two rays.

STEP 1: Select the point at the top of the object (say head of the object), which is placed at a point on the principal axis.

STEP 2: Draw a ray from the selected point (head of the object) which is parallel to the principal axis, it appears to come from its focus after refraction.



STEP 3: Draw a ray from the selected point (head of the object) which is passes through optic centre, passes without deviation and intersect at a point with the first line.

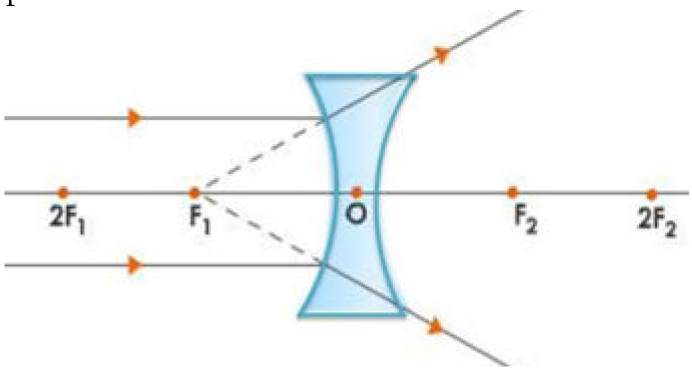


RAY DIAGRAMS FOR VARIOUS POSITIONS OF OBJECT PLACED ON PRINCIPAL AXIS USING CONVEX LENS:

Now draw ray diagrams to show the position of the images when the object is placed
(1) At infinity,
(2) Between O and F1 and
(3) Any position between infinity and O.

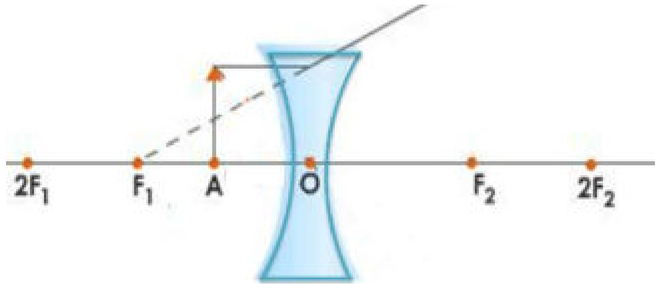
1 OBJECT IS AT INFINITY:

1. When the object is placed at infinity, erected, virtual and diminished image is formed at F1.
2. The light rays coming from the distant object are parallel and fall on the concave lens and diverge as they appear to come from the focus.

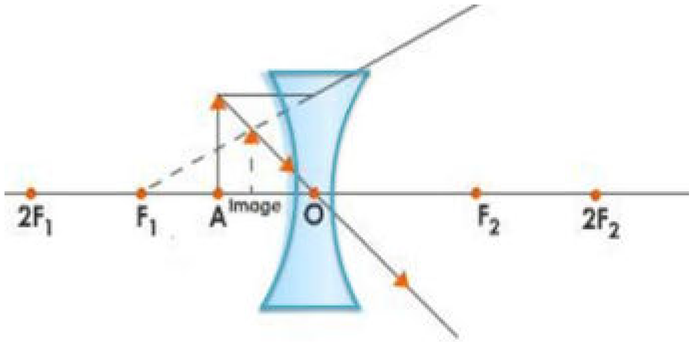


2 OBJECT PLACED BETWEEN O AND F1:

1. When the object is placed between O and F1, erected, virtual and diminished image is formed between O and F1.
2. The light ray parallel to the principal axis, coming from the object fall on the concave lens and diverge as it appears to come from the focus after refraction.



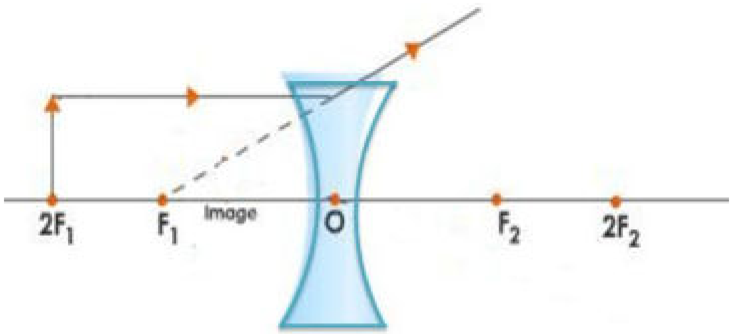
3. Draw the second ray from the head of the object, which is passes through optic centre, passes without deviation and intersect at a point with the extended line of the first ray.



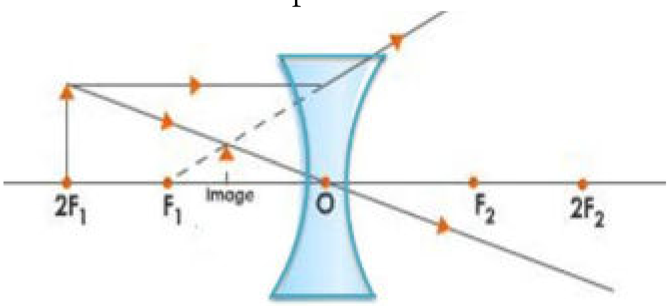
4. Now, connect the intersecting point and principal axis as normal, then we get a complete image.

3 ANY POSITION BETWEEN INFINITY AND O:

1. When the object is placed between infinity and O, erected, virtual and diminished image is formed between O and F1.
2. The light ray parallel to the principal axis, coming from the object fall on the concave lens and diverge as it appears to come from the focus after refraction.



3. Draw the second ray from the head of the object, which is passes through optic centre, passes without deviation and intersect at a point with the extended line of the first ray.



4. Now, connect the intersecting point and principal axis as normal, then we get a complete image.

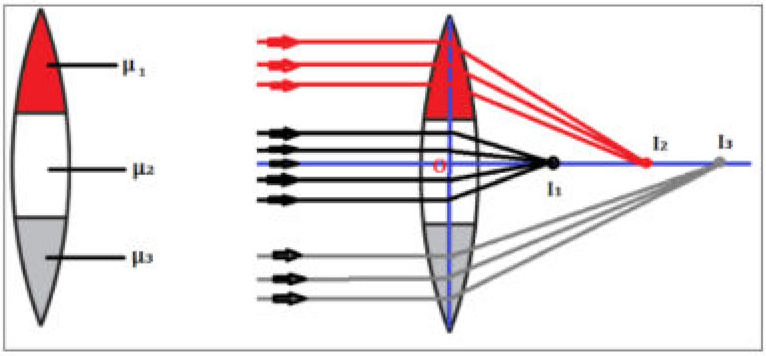
CONCLUSIONS BY THE ABOVE CONVEX LENS RAY DIAGRAMS:

1. On verifying our ray diagram with the ray diagram we have drawn for a convex lens, we will notice that irrespective of the position of the object, on the principal axis, we will get an erect, virtual image, diminished in size in between the focal point and optic centre for concave lens.
2. A concave lens always gives a virtual, erect and diminished image whatever may be the position of the object.

NOTE: A convex lens forms the number of images equal to the number of materials used to make it. This means a convex lens is made up of 'n' different materials as shown in the figure forms 'n' images. Because it has 'n' focal lengths and focal points.

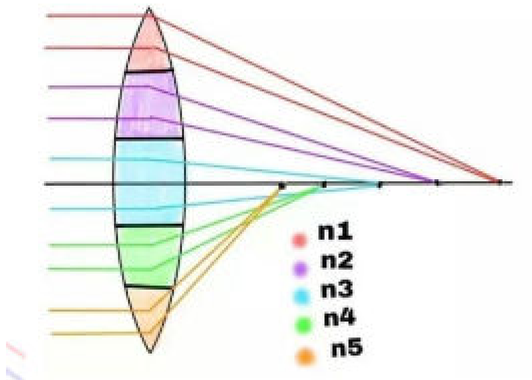
EX 1:

If the given convex is made up of three different materials. It has three refractive indices. So, it forms three images as shown in the figure.



EX:2

If a lens made by 5 different materials then it forms 5 images.

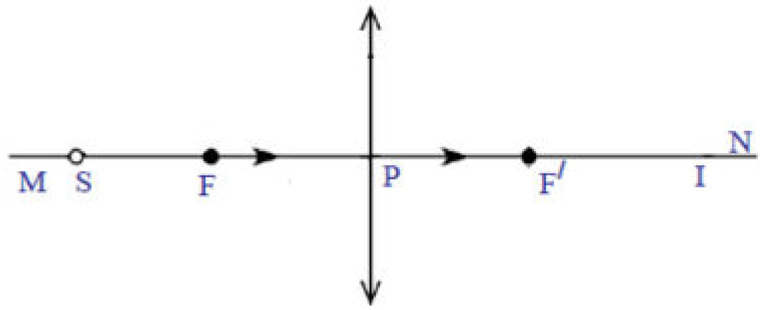


EXPLANATION ON A MAN GET A WHITE DONKEY, WHILE HE PHOTOGRAPHED A WHITE DONKEY AFTER FITTING A GLASS WITH BLACK STRIPES ON TO THE LENS OF HIS CAMERA:

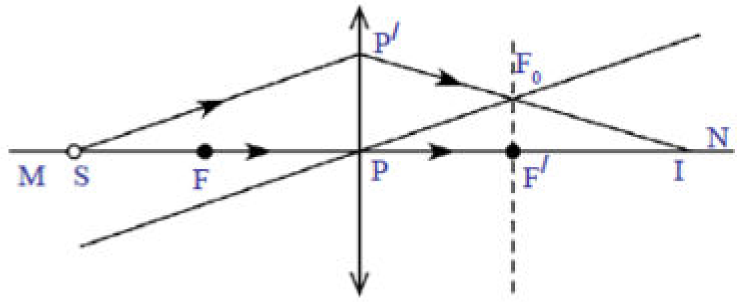
Every part of a lens forms an image with less intensity.

PROBLEM-4:

Draw a ray diagram to locate the position of image when a point source (S) is placed on optical axis MN of a convex lens, in such a way that it is beyond focal point (F).



SOLUTION:



2. Draw a ray from point source (S) in any direction to meet lens at point (PI).
3. Now, draw another line parallel to the ray drawn from the point source (S) such that it passes through the optic centre (P); this line intersects the normal at point FO.
4. Now draw a line passing from point PI to pass through the point FO such that it meets principal axis at a point say (I).
5. 'I' is the image point for the point source (S).

PROBLEM-5: Complete the ray diagram to show the paths of the rays after refraction through the lenses shown in the figures 1 & 2.1. Draw a perpendicular line to principal axis passing through the focus (FI).

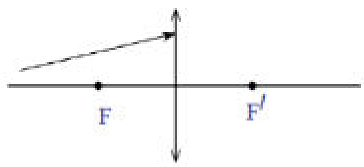


Fig-1

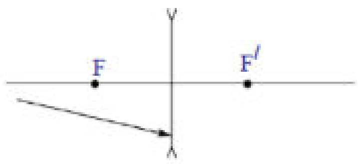


Fig-2

SOLUTION:

1. Draw a perpendicular line to principal axis passing through the focus (FI).
2. Now, draw another line parallel to the ray given in the figure-1 such that it passes through the optic centre (P); this line intersects the normal at point FO.
3. Now draw a line passing from point PI to pass through the point FO such that it meets principal axis at a point say (I).
4. 'I' is the image point for the point source (S).

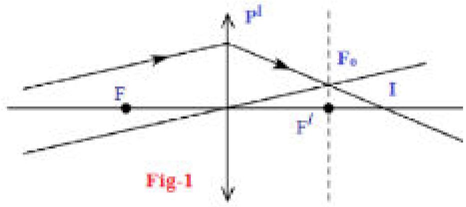


Fig-1

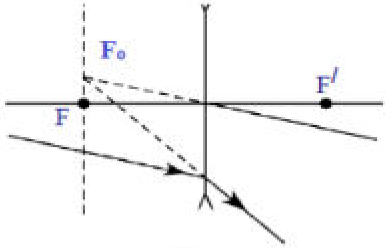


Fig-2

FINDING THE FOCAL LENGTH OF A LENS (CONVEX LENS) (ACTIVITY): AIM: TO FIND THE FOCAL LENGTH OF A CONVEX LENS.

APPARATUS: 'V'- stand, convex lens, candle, match box, screen and meter scale, etc.

PROCEDURE:

1. Take a v-stand, place it on a long table at the middle and place a convex lens on the vstand.
2. Imagine the principal axis of the lens.
3. Light a candle and ask your friend to take the candle far away from the lens along the principal axis.
4. Adjust a screen (a sheet of white paper placed perpendicular to the axis) which is on other side of the lens until we get an image on it.
5. Measure the distance of the image from the v-stand of lens and also measure the distance between the candle and stand of lens.
6. Record the values in the below table.
7. Now place the candle at a distance of 60 cm from the lens, such that the flame of the candle lies on the principal axis of the lens.
8. Try to get an image of the candle flame on the other side on a screen.
9. Adjust the screen till you get a clear image.
10. Measure the image distance (v) from lens and record the values of 'u' and 'v' in table.

SL. NO.	OBJECT DISTANCE (U)	IMAGE DISTANCE (V)	FOCAL LENGTH (F)
1			
2			
3			
4			

11. Repeat this for various object distances like 50 cm, 40 cm, 30 cm, etc. Measure image distances in all the cases and note them in table.

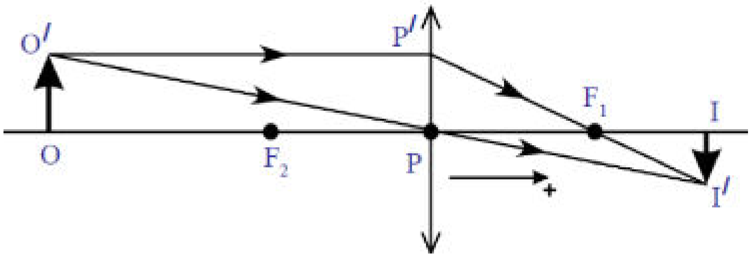
12. When we do not get an image on the screen, try to see the image with our eye directly from the place of the screen.
13. We will see a magnified image on the same side where we kept the object.
14. This is a virtual image of the object which we cannot capture on the screen.
15. In table, you got different values of 'v' for various position of candle (u).

FORMULA:

$\frac{1}{f} = \frac{1}{v} + \frac{1}{v}$ On substituting u and v values we get focal length (f) of convex lens.

ESTABLISHING THE RELATION BETWEEN 'U', 'V' AND 'F':

Consider an object OO^I placed on the principal axis in front of a convex lens as shown in figure. Let II^I be the real image formed by the lens on the other side of it. Observe the following figure.



LENS FORMULA AND ITS TERMS:

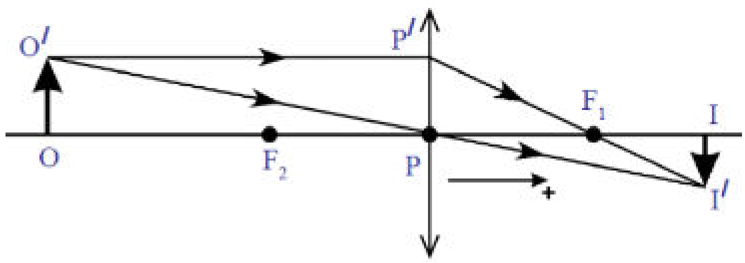
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

In this, f = focal length
u = object distance and
v = image distance

DERIVATION:

EXPLANATION:

1. The ray, starting at O^I and moving parallel to the principal axis and which falls on the lens, should pass through the focal point F1 as shown in figure.

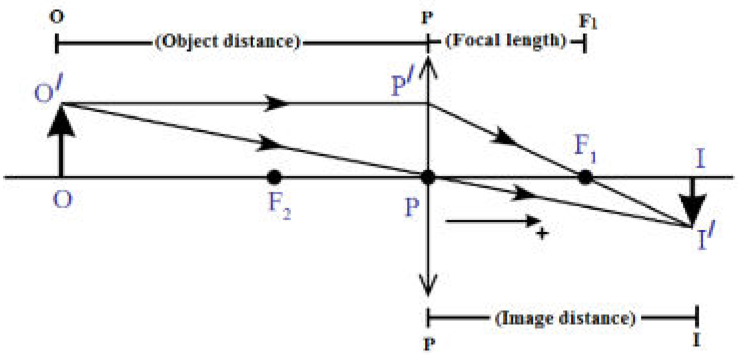


2. To locate the point of image (II) for the object point (OI), consider another ray that passes through the optic centre P.
3. We know that any ray passing through the optic centre P will not deviate.
4. The ray starting from OI and passing through optic centre P, will meet the refracted ray (first ray) at the point II.
5. This point is the image of the point OI of the object.

6. Similarly, the image of the point O on the principal axis is formed at point I on the principal axis.

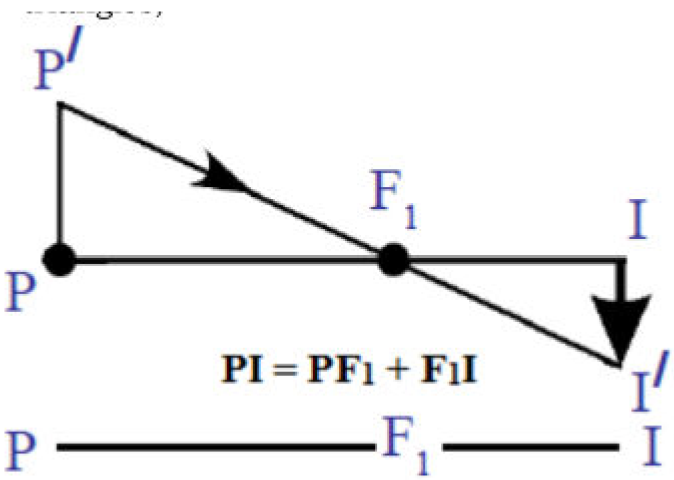
7. We get the inverted image III of object OOI.

LENS FORMULA DERIVATION:



1. PO, PI and PF1 are the object distance, image distance and focal length respectively.

2. From the figure, ΔPPIF1 and ΔF1I II are similar triangles,



3. Therefore,

$$\frac{PP'}{II'} = \frac{PF_1}{F_1I} \quad \text{................ (1)}$$

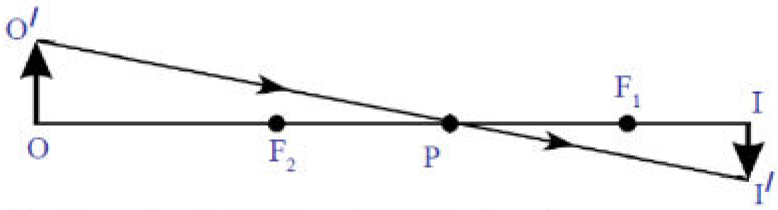
4. But from the figure, $PI = PF_1 + F_1I$

$F_1I = PI - PF_1$

5. On substituting F_1I in equation (1) above, we get

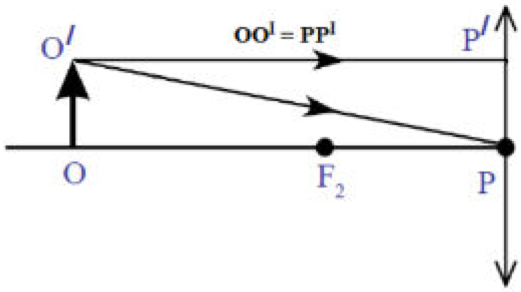
$$\frac{PP'}{II'} = \frac{PF_1}{(PI - PF_1)} \quad \text{................. (2)}$$

6. We have another set of similar triangles OOIP and PIII.



7. From the ΔOO^{I}P and ΔPII^{I}, triangles we get,

$$\frac{OO'}{II'} = \frac{PO}{PI}$$



8. But from figure, OO^{I} = PP^{I}, hence we have

$$\frac{PP'}{II'} = \frac{PO}{PI} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

From (2) and (3), we get

$$\frac{PO}{PI} = \frac{PF_1}{(PI - PF_1)}$$

$$\frac{PI}{PO} = \frac{(PI - PF_1)}{PF_1}$$

$$\frac{PI}{PO} = \frac{PI}{PF_1} - 1$$

On dividing the equation by PI, we get

$$\frac{1}{PO} = \frac{1}{PF_1} - \frac{1}{PI}$$

$$\frac{1}{PO} + \frac{1}{PI} = \frac{1}{PF_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

9. The above equation is derived for a particular case of the object while using a convex lens.

10. To convert this into a general equation, we need to use the sign convention.

11. According to the sign convention PO = -u; PI = v; PF1 = f Substituting these values in equation 4, we get

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

This equation is called lens formula.

12. It can be used for any lens. But remember to use the sign convention while using this equation.

(We have 'u' and 'v' values in the above table that were measured during activity–2. Find focal length of the lens from the values of the table for each set of values of 'u' and 'v'.)

NOTE: We might have noticed that irrespective of object distance and image distance, we will get same focal length. If you do not get the same value of focal length, there may be some experimental error while doing the experiment.

In such a case, find the average of all the values. This will be equal to the focal length of the lens.

PROBLEM:

The focal length of a converging lens is 20cm. An object is 60cm from the lens. Where will the image be formed and what kind of image is it?

Focal length of the converging lens (f) = 20 cm.
Object distance (u) = - 60 cm.
(Distance measured opposite to the direction of light)
Image distance (v) = ?
According to the lens formula,

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

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{(-60)} = \frac{1}{20} - \frac{1}{60}$$

$$\frac{1}{v} = \frac{2}{60} = \frac{1}{30}$$

v = 30 cm.

The image distance (v) = 30 cm.

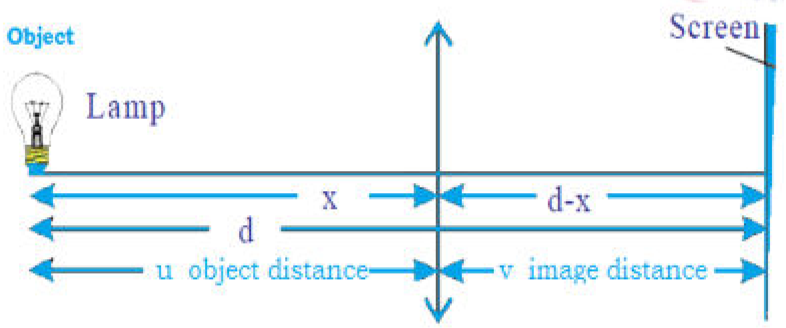
IMAGE CHARACTERISTICS:

1. Real image (u > 2f, means the object placed between F & C)
2. Diminished image (m = -v/u = -30/(-60) = 30/60 = 1⁄2 <1)
3. Inverted image (image forms other side as inverted)

EXAMPLE 6

An electric lamp and a screen are placed on the table, in a line at a distance of 1m. In what positions of convex lens of focal length of f = 21 cm will the image of lamp be sharp?

Solution



1. Let 'd' be distance between the lamp and screen and 'x' be the distance between lamp and lens.
2. From figure, we have u = -x and v = (d-x) By substituting these in lens formula, We get

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

$$\frac{1}{f} = \frac{1}{(d-x)} - \frac{1}{(-x)}$$

$$\frac{1}{f} = \frac{1}{(d-x)} + \frac{1}{x} \quad , \quad \frac{1}{f} = \frac{x+(d-x)}{(d-x)x}$$

It is a quadratic equation.
Hence we get two solutions.
The solutions of the above equation are

$$x = \frac{-(-d) \pm \sqrt{d^2-4(1)(fd)}}{2}$$

$$x = \frac{d \pm \sqrt{d^2-4fd}}{2} \qquad \text{.................(1)}$$

Given that f = 21cm and d= 1m =100cm.

On substituting these values in equation 1, we get

$$x = \frac{100 \pm \sqrt{100^2-4(21)(100)}}{2}$$

$$x = \frac{100 \pm \sqrt{10000-8400}}{2}$$

$$x = \frac{100 \pm \sqrt{1600}}{2}$$

$$x = \frac{100 \pm 40}{2}$$

$$x_1 = \frac{100+40}{2} \quad , \quad x_2 = \frac{100-40}{2}$$

$$x_1 = \frac{140}{2} \quad , \quad x_2 = \frac{60}{2}$$

Therefore, x_1 = 70cm and x_2 = 30cm.

NOTE: Image of the lamp can be sharp only when 'f' is less than or equal to 25cm.

ACTIVITY TO SHOW FOCAL LENGTH OF A LENS DEPENDS UPON THE SURROUNDING MEDIUM (OR) EXPERIMENTAL VERIFICATION THAT THE FOCAL LENGTH OF A CONVEX LENS IS INCREASED WHEN IT IS KEPT IN WATER:

AIM: To know the focal length of a convex lens depends upon the surrounding medium. (or) To prove that the focal length of a convex lens is increased when it is kept in water.

APPARATUS: Glass tumbler, black stone, water, convex lens (f=10cm) and scale.

PROCEDURE:

1. Take a convex lens and note the focal length.

2. Take cylindrical a glass tumbler, which has the height greater than the focal length of the lens (the glass tumbler has a depth nearly equal to four times of the focal length of the lens).

3. Keep a black stone inside the vessel at its bottom and use the circular lens holder to see the stone inside the tumbler.

4. Set the distance of the lens and stone which is less than to the focal length of the lens i.e., $f<10$cm).

5. We can see the image of the stone if the distance between lens and stone is less than the focal length of the lens in the air.

6. Now pour water into the vessel up to a height such that the height of the water level from the top of the stone is greater than focal length of lens.

7. Now dip the lens horizontally using a circular lens holder as shown in the figure above the stone.

8. Set the distance between stone and lens that is equal to or less than focal length of lens.

9. We can see the image of the stone.

10. Now increase the distance between lens and stone until you cannot see the image of the stone.

11. That means, as we have dipped the lens to a certain height which is greater than the focal length of the lens in the air ($f<10$cm) we can see the stone.

12. Measure the distance from the stone and the lens. It is 40cm.

OBSERVATIONS:

Focal length of the lens in air = 10 cm.

Focal length of the lens in water = 40 cm.

Focal length of lens has increased in water.

RESULT ANALYSIS:

The focal length of a thin lens is given by the lens maker's equation

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Here n1 is the refractive index of the medium and n2 is the refractive index of the material R1 and R2 are the radii of curvature of the two faces.

The refractive index of glass = 3/2
The refractive index of air is = 1
The refractive index of water = 4/3
Focal length of lens in air = fa = 10cm.

$$\frac{1}{f_a} = \frac{1}{10} = \left(\frac{\left(\frac{3}{2}\right)}{1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Focal length of lens in water =

$$\frac{1}{f_w} = \left(\frac{\left(\frac{3}{2}\right)}{\left(\frac{4}{3}\right)} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

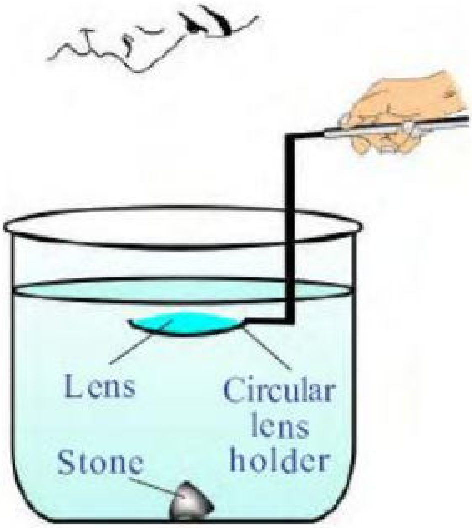
Taking the ratio we get:

$$\frac{f_w}{10} = \frac{\left(\frac{3}{2} - 1\right)}{\left(\frac{9}{8} - 1\right)} \quad \Rightarrow \quad \frac{f_w}{10} = 4$$

Focal length in water = 40 cm

RESULT: The focal length of lens depends upon the surrounding medium in which it is kept. The focal length of the lens has increased in water.

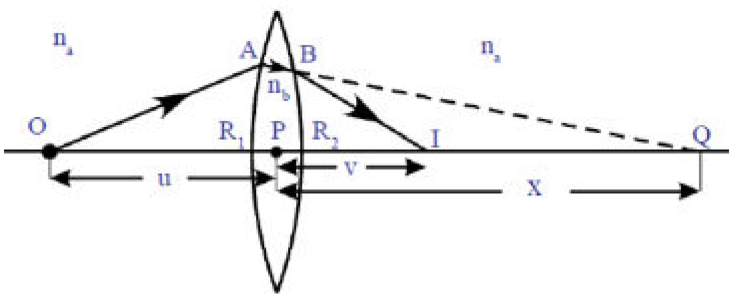
PRECAUTIONS: We require the tumbler which has length (depth) nearly equal to four times of the focal length of the lens.



DERIVATION OF LENS MAKER'S FORMULA:

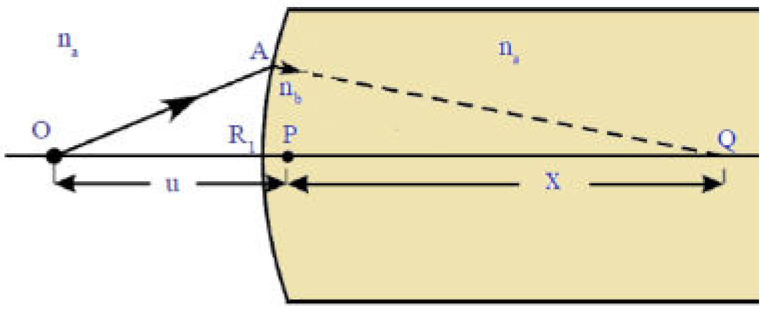
1. Imagine a point object 'O' placed on the principal axis of the thin lens as shown in the figure.

2. Let this lens be placed in a medium of refractive index na and let refractive index of lens medium be nb.



3. Consider a ray, from 'O' which is incident on the convex surface of the lens with radius of curvature R1 at A as shown in the figure.

4. The incident ray refracts at A. Let us assume that, it forms image at Q, if there were no concave surface.



From the figure,

Object distance PO = –u;

Image distance v = PQ = x

Radius of curvature R = R_1

$n_1 = n_a$ and $n_2 = n_b$

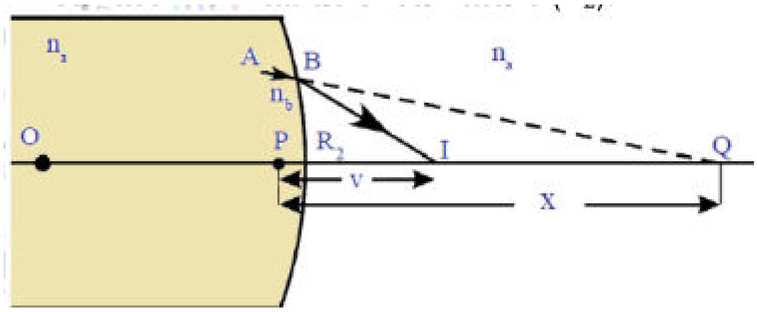
Substitute the above values in the equation,

$$\left(\frac{n_2}{v} - \frac{n_1}{u}\right) = \frac{(n_2 - n_1)}{R}$$

$$\left(\frac{n_b}{x} - \frac{n_a}{(-u)}\right) = \frac{(n_b - n_a)}{R_1}$$

$$\left(\frac{n_b}{x} + \frac{n_a}{u}\right) = \frac{(n_b - n_a)}{R_1} \quad \text{.................. (1)}$$

5. But the ray that has refracted at 'A' suffers another refraction at 'B' on the concave surface with radius of curvature (R2).



6. At B the ray is refracted and reaches I on the principal axis.

7. The image Q of the object due to the convex surface is taken as object for the concave surface.

8. So, we can say that I is the image of Q for concave surface.

Object distance u = PQ = x (Distance measured along the direction of light) Image distance PI = v (Distance measured along the direction of light)

Radius of curvature R = –R2 (Distance measured along the opposite direction of light)

9. For refraction, the concave surface of the lens is considered as medium-1 and surrounding medium is considered as medium2.

10. Hence the suffixes of refractive indices interchange. Then we get, n1 = nb and n2 = na. On substituting the above values in equation

$$\left(\frac{n_2}{v}-\frac{n_1}{u}\right)=\frac{(n_2-n_1)}{R}$$

$$\left(\frac{n_a}{v}-\frac{n_b}{x}\right)=\frac{(n_a-n_b)}{(-R_2)} \qquad \text{.................... (2)}$$

By adding (1) and (2) we get,

$$\left(\frac{n_b}{x}+\frac{n_a}{u}\right)+\left(\frac{n_a}{v}-\frac{n_b}{x}\right)=\frac{(n_b-n_a)}{R_1}+\frac{(n_a-n_b)}{(-R_2)}$$

$$\frac{n_a}{u}+\frac{n_a}{v}=\frac{(n_b-n_a)}{R_1}+\frac{(n_b-n_a)}{R_2}$$

$$\frac{n_a}{u}+\frac{n_a}{v}=(n_b-n_a)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

Dividing both sides by n_a, We get

$$\frac{1}{u}+\frac{1}{v}=(\frac{n_b-n_a}{n_a})\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

$$\frac{1}{u}+\frac{1}{v}=\left(\frac{n_b}{n_a}-\frac{n_a}{n_a}\right)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

$$\frac{1}{v}+\frac{1}{u}=\left(\frac{n_b}{n_a}-1\right)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

11. We know n_b / n_a = n_{ba} called refractive index of lens with respect to surrounding medium.

$$\frac{1}{v}+\frac{1}{u}=(n_{ba}-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

12. This is derived for specific case for the convex lens. So, we need to generalize this relation by use sign convention.

13. Applying sign convention to this specific case we get,

$$\frac{1}{v}-\frac{1}{u}=(n_{ba}-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

We know that,

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

So, we get,

$$\frac{1}{f} = (n_{ba} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{..............(3)}$$

14. If the surrounding medium is air, then the relative refractive index could be absolute refractive index of the lens.

$$\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...................(4)}$$

15. This can be used only when the lens is kept in air. Where n is absolute refractive index and this equation is called lens maker's formula.

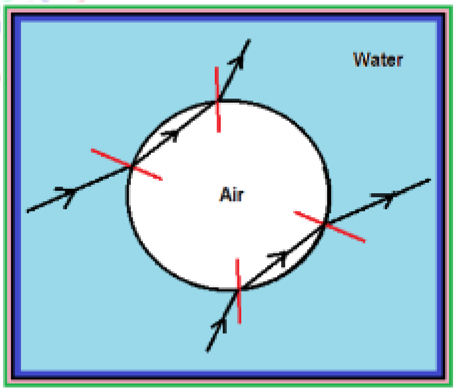
NOTE-1: Always use sign convention while using any formula derived in this chapter and the above formula can be used for any thin lens.

NOTE-2: The convex lens behaves as a converging lens, if it is kept in a medium with refractive index less than the refractive index of the lens.

NOTE-3: The convex lens behaves like a diverging lens when it is kept in a transparent medium with greater refractive index than that of the lens.

EXAMPLE:

An air bubble in water behaves like a diverging lens.

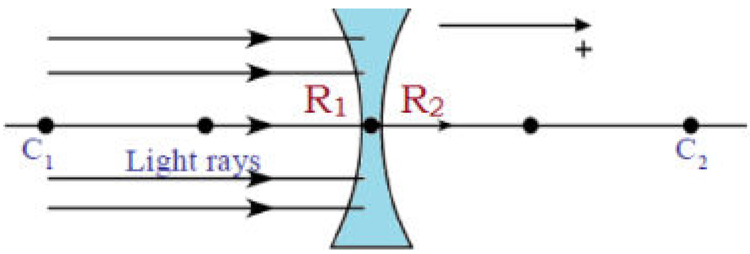


EXAMPLES FOR LENS MAKER FORMULA:

EXAMPLE 7

What is the focal length of double concave lens kept in air with two spherical surfaces of radii R1 = 30cm and R2 =60cm. Take refractive index of lens as n = 1.5.

SOLUTION:



From the figure, using sign convention we get, R1 = -30cm (distance R1 measured opposite to the light direction) R2 = 60cm (distance R2 measured in the direction of light) n = 1.5 (given)

$$\text{Using } \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{-30} - \frac{1}{60}\right) = (0.5)\left(\frac{-2-1}{60}\right)$$

$$\frac{1}{f} = \left(\frac{1}{2}\right)\left(\frac{-3}{60}\right) = \left(\frac{1}{2}\right)\left(\frac{-1}{20}\right) = \frac{-1}{40}$$

f = -40cm

Therefore, Focal length of double convex lens kept in air (f) = -40cm.

Here minus indicates that the lens is divergent.

PROBLEM: A double convex lens has two surfaces of equal radii 'R' and refractive index n = 1.5. Find the focal length 'f'.

Radius of curvature R1 = R and R2 = -R (sign convention)(given)

Refractive index (n) = 15 Focal length (f) = ?

According to Lens maker's formula:

$$\text{Using } \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{R} - \frac{1}{-R}\right) = (0.5)\left(\frac{1}{R} + \frac{1}{R}\right)$$

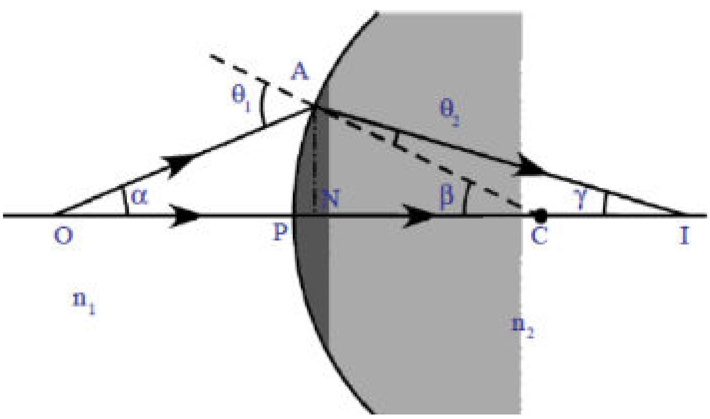
$$\frac{1}{f} = \left(\frac{1}{2}\right)\left(\frac{2}{R}\right) = \frac{1}{R}$$

F = R

Means the focal length (f) is equal to the radius of curvature (R).

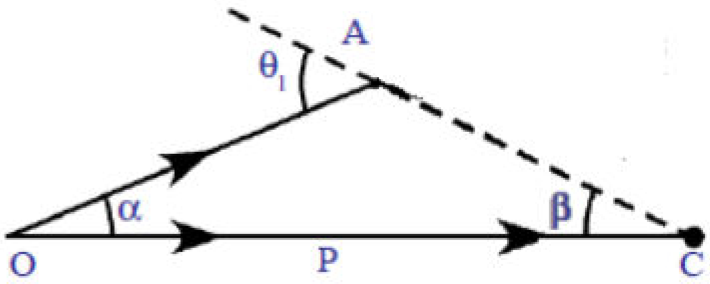
CURVED SURFACE FORMULA DERIVATION:

1. Consider a curved surface separating two media of refractive indices n1 and n2.
2. A point object is placed on the principal axis at point O.



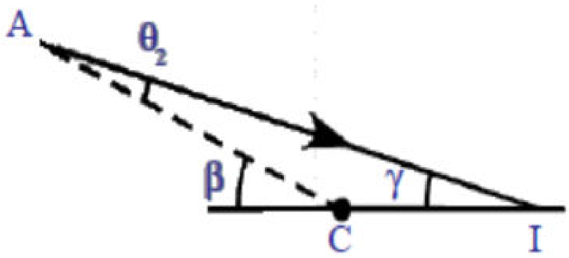
3. The ray, which travels along the principal axis passes through the pole undeviated.
4. The second ray, which forms an angle α with principal axis, meets the interface (surface) at A.
5. The angle of incidence is θ1.
6. The ray bends and passes through the second medium along the line AI.
7. The angle of refraction is θ2.
8. The two refracted rays meet at I and the image is formed there.
9. Let the angle made by the second refracted ray with principal axis be γ and the angle between the normal and principal axis be β.
(see figure)
10. In figure, PO is the object distance (u), PI is image distance (v) and PC is radius of curvature (R).
11. n1, n2 are refractive indices of two media.

In the triangle ACO,



$$\theta_1 = \alpha + \beta$$

(Since in a triangle sum of interior angles equal to exterior angle. Interior angles α, β and exterior angle θ1)
and in the triangle ACI,



$$\beta = \theta_2 + \gamma$$

[As the same above but here, interior angles γ, θ2 and exterior angle β] Implies

$$\beta - \gamma = \theta_2$$

12. According to Snell's law, we know

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

On substituting the values of θ_1 and θ_2, we get,

$$n_1 \sin(\alpha + \beta) = n_2 \sin(\beta - \gamma) \quad .... (1)$$

13. If the rays move very close to the principal axis, the rays can be treated as parallel and are called paraxial rays.

14. Then the angles α, β and γ become very small. This approximation is called paraxial approximation.Then,

$$\sin(\alpha+\beta)=\alpha+\beta \text{ and } \sin(\beta-\gamma)=\beta-\gamma$$

Substituting in equation (1)

$$n_1(\alpha+\beta)=n_2(\beta-\gamma)$$

Implies

$$n_1\alpha+n_1\beta=n_2\beta-n_2\gamma \text{ .... (2)}$$

Since all angles are small, we can write

$$\tan\alpha=\frac{AN}{NO}=\alpha$$
$$\tan\beta=\frac{AN}{NC}=\beta$$
$$\tan\gamma=\frac{AN}{NI}=\gamma$$

Substitute these in equation (2), we get,

$$n_1\left(\frac{AN}{NO}\right)+n_1\left(\frac{AN}{NC}\right)=n_2\left(\frac{AN}{NC}\right)-n_2\left(\frac{AN}{NI}\right)$$

$$AN\left(\frac{n_1}{NO}+\frac{n_1}{NC}\right)=AN\left(\frac{n_2}{NC}-\frac{n_2}{NI}\right)$$

$$\frac{n_1}{NO}+\frac{n_1}{NC}=\frac{n_2}{NC}-\frac{n_2}{NI} \text{ ... ... (3)}$$

15. As the rays move very close to the principal axis, the point N coincides with pole of the interface (P).

16. Therefore NI, NO and NC can be replaced by PI, PO and PC respectively.

NI = PI,

NO = PO,

NC = PC

After substituting these values in equation (3), we get,

$$\frac{n_1}{PO}+\frac{n_1}{PC}=\frac{n_2}{PC}-\frac{n_2}{PI}$$

$$\frac{n_1}{PO}+\frac{n_2}{PI}=\frac{n_2}{PC}-\frac{n_1}{PC}$$

$$\frac{n_1}{PO}+\frac{n_2}{PI}=\frac{n_2-n_1}{PC} \text{ .... (4)}$$

Equation (4) shows the relation between refractive indices of two media, object distance, image distance and radius of curvature and is true for the case we considered.

17. We can generalize equation (4) if we use the following sign convention.

18. For all purposes of applications of refraction at curved surfaces and through lenses following conventions are used.

a) All distances are measured from the pole (or optic centre).

b) Distances measured along the direction of the incident light ray are taken as positive

c) Distances measured opposite to the direction of the incident light ray are taken as negative

d) The heights measured vertically above from the points on axis are taken as positive

e) The heights measured vertically down from points on axis are taken as negative.

19. Here PO is called the object distance (u), PI is called the image distance (v) and PC is called radius of curvature (R).

20. According to sign convention mentioned above, we have

PO = -u (object distance measured in the opposite direction of the light ray) PI = v (image distance measured in the same direction of the light ray) PC = R (radius of curvature measured in the same direction of the light ray) Substituting these values in equation (4) we get,

Substituting these values in equation (4) we get,

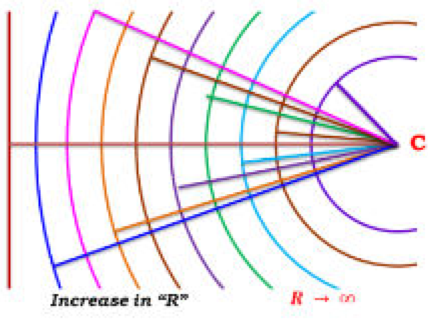
$$\frac{n_1}{(-u)} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$$

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

This is called curved surface formula.

FOR PLANE SURFACES:

In the case of a plane surface, radius of curvature (R) approaches infinity.



Hence 1/R becomes zero.

Substituting this in equation 5, we get formula for the plane surfaces.

$$\frac{n_2}{v} - \frac{n_1}{u} = 0 \Rightarrow \frac{n_2}{v} = \frac{n_1}{u}$$

NOTE: The distances u and v are measured from the plane interface.

IMPORTANT TOPICS

TOPIC-1: PHOTOGRAPH OF VIRTUAL IMAGE

A virtual image can be photographed. A plane mirror forms a virtual image; we can take photograph of that image formed in the plane mirror.

TOPIC-2: APPRECIATION OF THE COINCIDENCE OF THE EXPERIMENTAL FACTS WITH THE RESULTS OBTAINED BY A RAY DIAGRAM IN TERMS OF BEHAVIOUR OF IMAGES FORMED BY LENSES:

1) Ray diagrams are very useful in optics.
2) By draw the ray diagram we can easily find out the values of object distance, image distance, focal length and radius of curvature without doing experiments.
3) If you want to find out the above values for a lens, we spend more time and it requires lab equipment also.
4) Ray diagrams also useful in constructing optical instruments like telescopes, microscopes, projectors, cameras, etc.
5) So, I appreciate the coincidence of the experimental facts with the results obtained by a ray diagram in terms of behaviour of images formed by lenses.

TOPIC-3: REASON FOR YOUR FRIEND APPEARS TO BE TALLER WHEN YOU ARE INSIDE THE WATER IN THE SWIMMING POOL NEAR AN EDGE; YOUR FRIEND IS STANDING ON THE EDGE:

Because the light travelling from denser to rarer, the rays bend away from the normal. And you see the apparent image of your friend due to refraction.

TOPIC-4: FOCAL LENGTH OF THE SYSTEM(A) WHEN TWO LENSES TOUCH EACH OTHER.(B) WHEN THEY ARE SEPARATED BY A DISTANCE 'D' WITH COMMON PRINCIPAL AXIS:

Let the focal lengths of two lenses are f1 and f2.
a) When two lenses touching each other than the focal length of the system,

$$f = \frac{f_1\ f_2}{(f_1 + f_2)}$$

b) When they are separated by a distance 'd' with common principal axis then the focal length of the system (f) is related with f1 and f2 as given below,

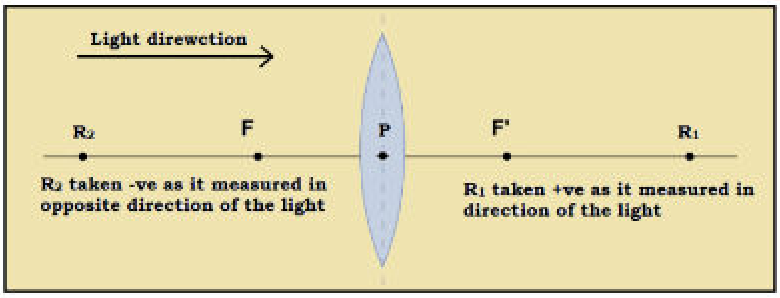
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1\, f_2}$$

PROBLEMS GIVEN IN THE TEXT BOOK:

1) Find the refractive index of the glass which is a symmetrical convergent lens if its focal length is equal to the radius of curvature of its surface.

SOLUTION:

In the problem he gives symmetrical convergent lens, means two radius of curvatures are same.
Let it be R.
Therefore R1 = R = f and R2 = (-R) = (-f)



According to the Lens maker's formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{f} - \frac{1}{(-f)}\right)$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{f} + \frac{1}{f}\right)$$

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

1 = (n-1)2 = 2n – 2

2n = 1 + 2 =3

n = 3/2 = 1.5

Therefore Refractive index of glass = 1.5

2) Find the radii of curvature of a convexo – concave convergent lens made of glass with refractive index n=1.5 having focal length of 24cm. One of the radii of curvature is double the other.

SOLUTION:

In the problem given, Refractive index = n = 1.5 Focal length = f = 24 cm.

Let one of the radius of curvature is R then other is 2R.

Therefore R1 = R and R2 = 2R [Two radiuses of curvatures are same side so these are taken as +Ve]

According to the Lens maker's formula,

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{24} = (1.5-1)\left(\frac{1}{R} - \frac{1}{2R}\right)$$

$$\frac{1}{24} = (0.5)\left(\frac{2-1}{2R}\right)$$

$$\frac{1}{24} = (0.5)\left(\frac{1}{2R}\right)$$

2R = (0.5) x 24

$$R = \frac{(0.5X\ 24)}{2}$$

R = 12/2 = 6 cm.

Therefore R_1 = 6 cm. and R_2 = 12 cm.

5. HUMAN EYE AND COLOURFUL WORLD

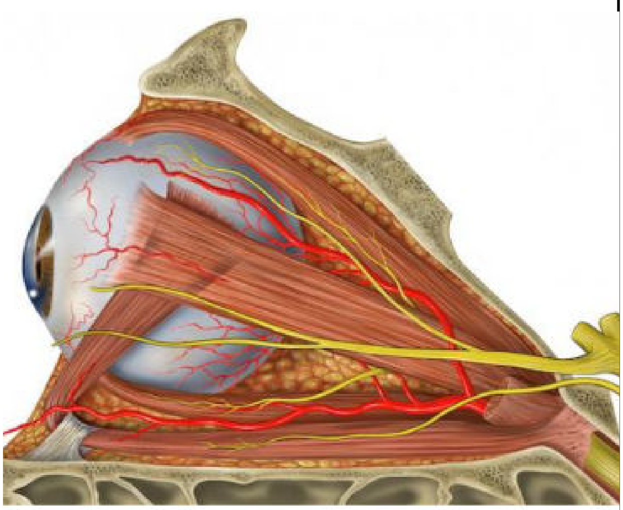
INTRODUCTION

Eyes are our most important sense organs. We able to see many colourful and beautiful things around us like 7 colour rainbow, colourful mountains like Himalayas, dal lake, colourful animals, forest, flowers and so on with our eye. We have to take care about our eyes. Eyes some time get defect of vision. Vision defects are Myopia, Hypermetropia and Presbyopia. To correct myopia we use concave lens, for hypermetropia convex lens and for Presbyopia bifocal lens.

Both eyes play major role in our vision. One eye is having a field of vision of about 150 degrees. Both the eyes enable us to see up to a field of 180 degrees. As two different images get juxtaposed in the brain, so we are able to see a three dimensional view of the world. To see objects we required light and eyes. No light, no sight.

The phenomenon of dispersion of light was first discovered by Newton. Rainbows formed due to dispersion of sunlight. From an airplane, a rainbow may view as a complete circle. In the rainbow we observe 7 colours VIBGYOR.

Sky appears blue due to the molecules N_2 and O_2. The sizes of these molecules are comparable to the wavelength of blue light. According to the Raman Effect, the frequency of scattered light by the liquids is greater than the frequency of incident light. The sun appears red in colour during sunrise and sunset due to scattering of light.



Human eye and orbital anatomy

1. In class IX, 6th chapter on Sense Organs in Biological Science text book, explained the structure of the human eye.
2. The human eye functions on the principle of sensation of vision.
3. We see objects because the light scattered from them falls on the eye.
4. The eye has a lens in its structure.
5. In the previous chapter, we learned that the focal length of lens and object distance determine the nature, position and size of image.

ACTIVITIES TO KNOW ABOUT SOME INTERESTING FACTS ABOUT OUR VISION:

I. Activity to find the least distance of distinct vision (25 cm.),
II. Activity to find the angle of vision (60°)

I. ACTIVITY TO FIND THE LEAST DISTANCE OF DISTINCT VISION (25 CM.):

1) Take a text book and hold it with your hands in front of you at a certain distance.
2) Now try to read the contents on the page and slowly move the book towards your eye till it is very close to your eyes.
3) You may see that printed letters on the page of the text book appear blurred or you feel strain in the eye.
4) Now slowly move the book backwards to a position where you can see clear printed letters without straining your eye.
5) Ask your friend to measure the distance between your eye and text book at this position and note down its value.
6) Repeat the activity with other friends and note down the distances for distinct vision in each case.
7) Find the average of all these distances of clear vision.
8) From this activity we will come to know that to see an object comfortably and distinctly, you must hold it at a distance about 25 cm. from your eyes. This distance is called least distance of distinct vision.

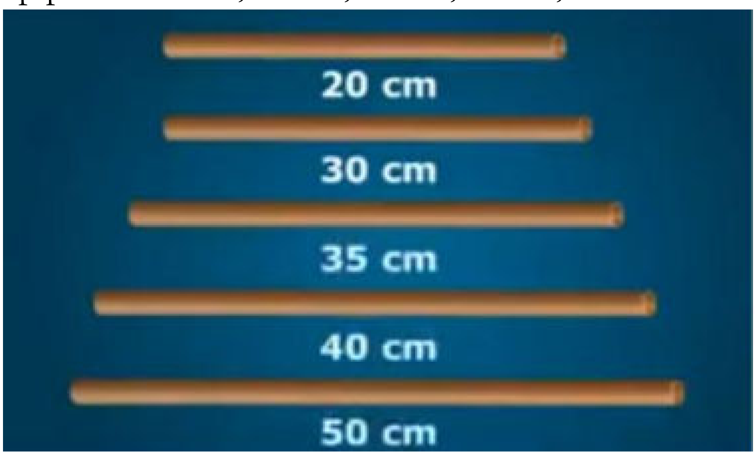
Least distance of distinct vision = 25 cm.

EXPLANATION FOR LEAST DISTANCE OF DISTINCT VISION:

1) Least distance of distinct vision is varies from person to person and with age.
2) At a young age (say below 10 years) the muscles around the eye are strong and flexible and can bear more strain therefore the least distance of distinct vision at this age is as close as 7 to 8 cm.
3) In old age the muscles cannot sustain more strain hence the least distance of distinct vision shifts to a larger value and is about 1 to 2 m or even more.

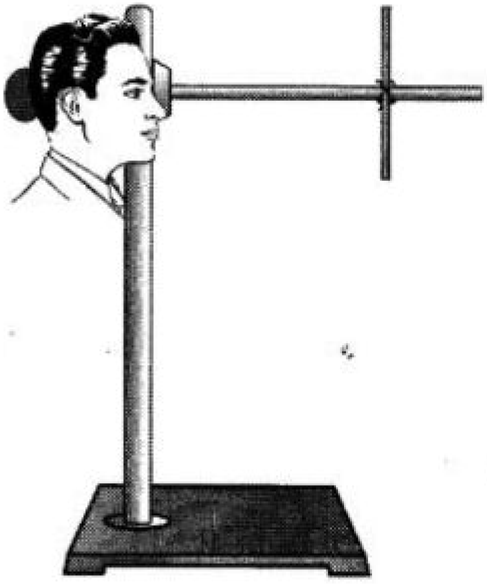
II. ACTIVITY TO FIND THE ANGLE OF VISION (60):

1) Collect a few wooden sticks used in cloth roller in clothes store (or) collect waste PVC pipes that are used for electric wiring.
2) Prepare sticks or pipes of 20 cm, 30 cm, 35 cm, 40 cm, 50 cm from them.

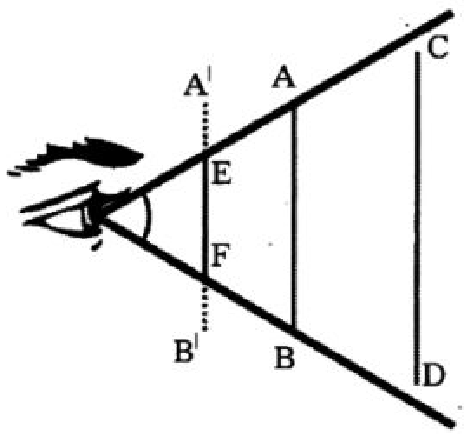


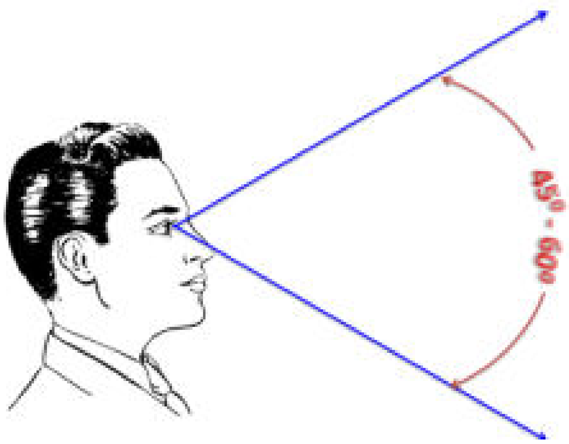
3) Place a retort stand on a table and stand near the table such that your head is beside the vertical stand (see fig).
4) Adjust the clamp on the horizontal rod and fix it at a distance of 25 cm. from your eyes.
5) Ask one of your friends to fix a wooden stick of 30 cm height to the clamp in a vertical position as shown in fig above.

6) Now keeping your vision parallel to horizontal rod of the stand, try to see the top and bottom of wooden stick kept in vertical position.



7) If you are not able to see both end of the stick at this distance (25 cm), adjust the vertical stick on the horizontal rod till you are able to see both ends of the stick at the smallest possible distance from your eye.





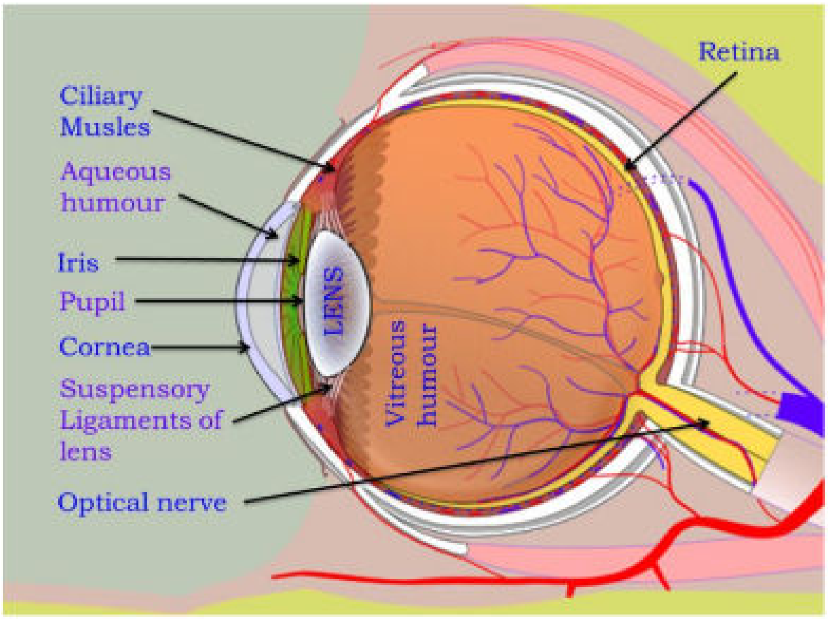
8) Fix the vertical stick at this position with the help of the clamp.
9) Without changing the position of the clamp on the horizontal rod, replace this stick of 30 cm length with other sticks of various lengths one by one and try to see the top and bottom of the stick simultaneously without any change in the position of eye either upwards downwards or sideways.
10) From the figure above, you can see the whole object AB which is at a distance of 25 cm (least distance of distinct vision) because the rays coming from the ends A and B of the object AB will enter the eye.
11) Similarly you can also see whole object CD with eye as explained above.
12) Let us assume that AB moves closer to the eye to a position AI BI as shown in figure.
13) From the figure, you notice that you will be able to see only the part (EF) of the object AI BI because the rays coming from E and F only enter your eye.
14) The rays coming from AI and BI cannot enter your eye.
15) The rays coming from the extreme ends of an object form an angle at the eye.
16) If this angle is below 60, then we can see the whole object.

17) If this angle is above 60, then we can see only the part of the object.
18) This maximum angle, at which we are able to see the whole object is called angle of vision.
19) The angle of vision for a healthy human being is about 60.
20) It varies from person to person and with age.

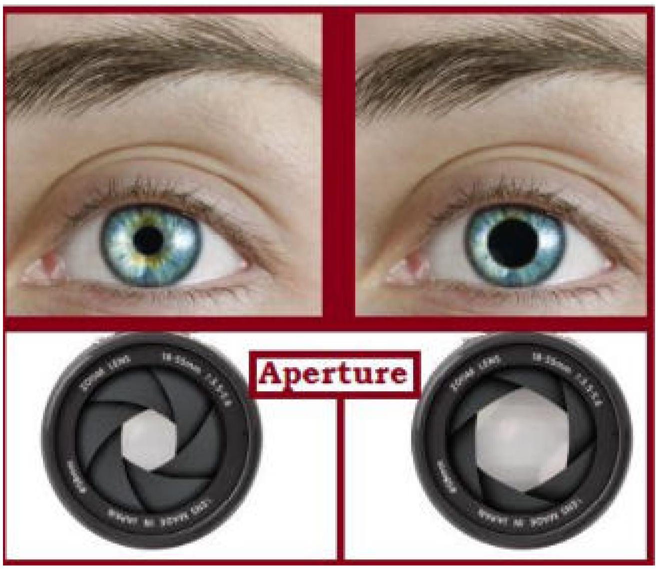
The angle of vision for a healthy human being is about 60

STRUCTURE OF HUMAN EYE:

1) The human eye is one of the most important sense organs and it enables us to see the object and colours around us.
2) Figure shows schematically the basic components of human eye.
3) The eyeball is nearly spherical in shape.

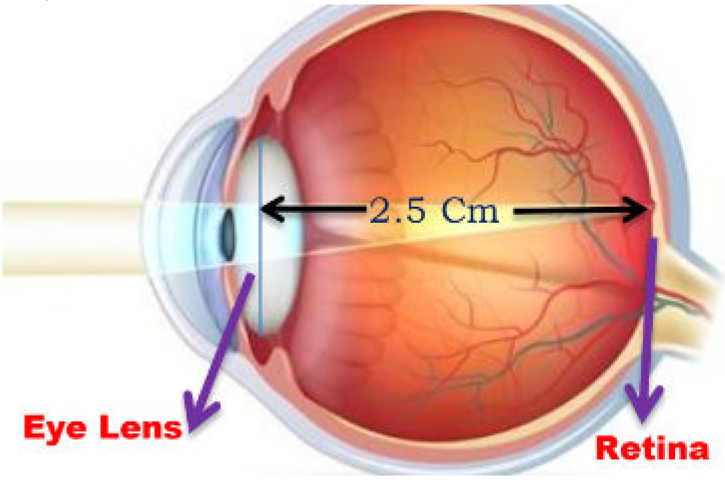


4) The front portion is more sharply curved and is covered by a transparent protective membrane called the “cornea”, which is visible from outside.
5) Behind the cornea, there is place filled with a liquid called aqueous humor and behind this a crystalline lens which is responsible for the image formation.
6) Between the aqueous humor and the lens, we have a muscular diaphragm called “iris” which has a small hole in it called pupil.
7) Iris is the coloured part that we see in an eye.
8) The pupil appears black because any light falling on it goes into the eye and there is almost no chance of light coming back to the outside.
9) Iris helps in controlling the amount of light entering the eye through “pupil”.
10) In low light condition, the iris makes the pupil to expand so that more light is allowed to go in and in the case of bright (or) excess light condition; it makes the pupil contract and there by prevent the excess light not to go into eye.
11) Thus "iris" enables pupil to act as a “variable aperture” for entry of light into the eye.
12) The lens is hard in the middle and gradually becomes soft towards the outer edge.

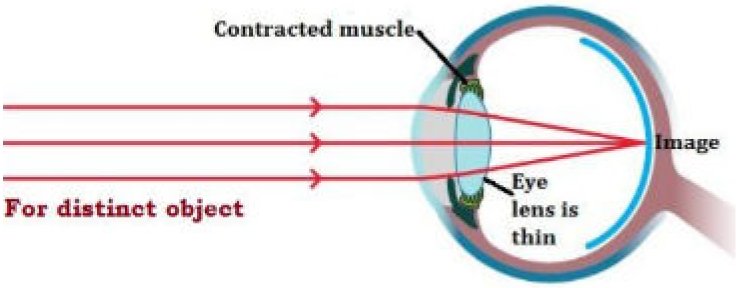


13) The light that enters the eye forms an image on the retina. (It covers the rear part of eyeball).
14) The distance between the lens and retina is about 2.5 cm.
15) Means, for any position of object in front of the eye the image distance is fixed and about 2.5 cm.

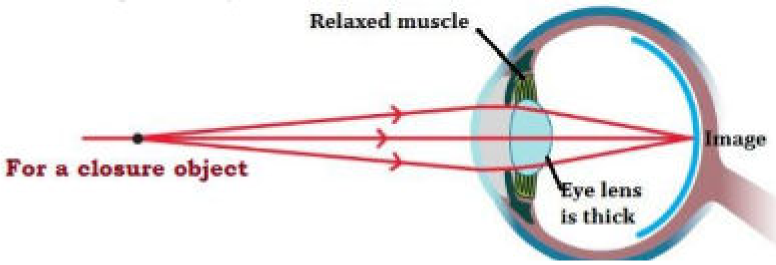
- ❖ The distance between the lens and retina is about 2.5 cm. for any position of object in front of the eye.



16) For different positions of object, the image distance remains constant only when there is a change in focal length of lens also the focal length of a lens depends on the material by which it has been made and radii of curvature of lens.
17) We need to change focal length of eye lens to get same image distance for various positions of object in front of the eye. This is only possible when the eye lens is able to change its shape.
18) The ciliary muscle to which eye lens is attached helps the eye lens to change its focal length by changing the radii of curvature of the eye lens.
19) When the eye is focused on a distant object, the ciliary muscles are relaxed so that the focal length of eye lens has its maximum value which is equal to its distance from the retina.



20) The parallel rays coming into the eye are then focused on to the retina and we see the object clearly.
21) When the eye is focused on a closer object, the ciliary muscles are strained and focal length of eye-lens decreases.



22) The ciliary muscles adjust the focal length in such a way that the image is formed on retina and we see the object clearly.
23) This process of adjusting focal length is called "accommodation".

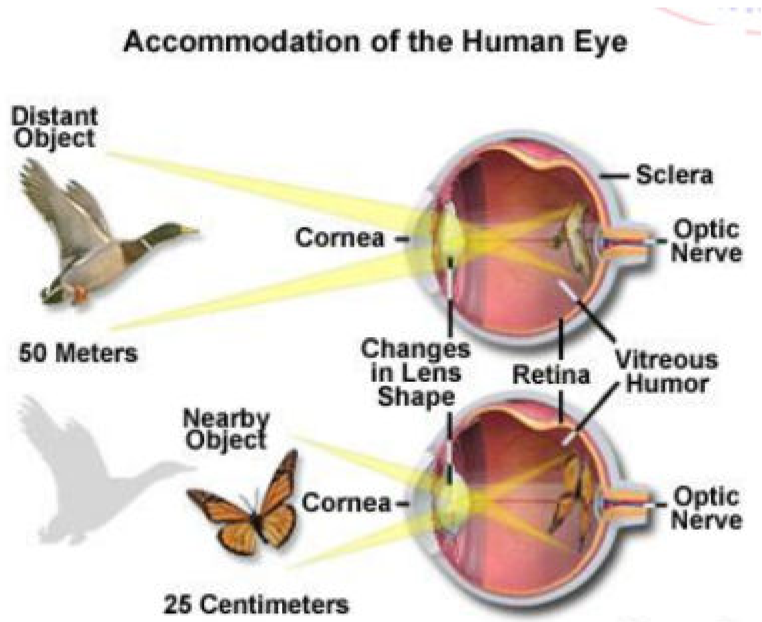
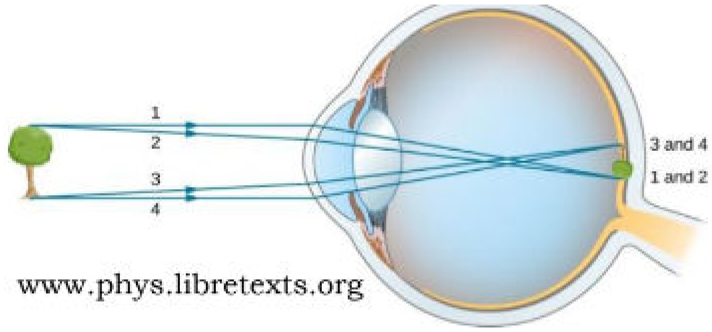


Figure 2

24) However these muscles cannot strain beyond a limit and hence if the object is brought too close to eyes, the focal length cannot be adjusted to form an image on the retina.
25) Thus there is a minimum distance for distinct vision of an object which is roughly equal to 25 cm as we have learned.



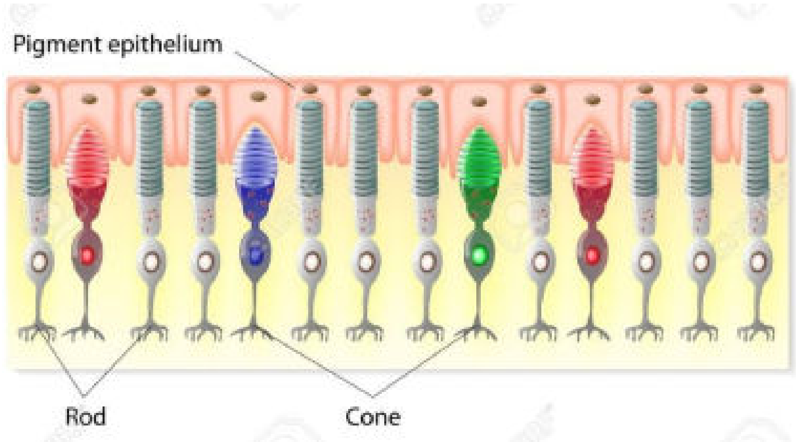
26) The eye

-lens forms a real and inverted image of an object on the retina.
27) The retina is a delicate membrane, which contains about 125 million receptors called "rods" and "cones" which receive the light signal (rods- identify the intensity of light cones-identify the colour).

RODS: intensity of light **CONES:** colour

28) These signals are transmitted to the brain through about 1 million optic-nerve fibres.
29) The brain interprets these signals and finally processes the information so that we perceive the object in terms of its shape, size and colour.

STRUCTURE OF RETINA:



31) In our previous discussion, you have learnt that eye-lens itself changes its focal length in accordance with distance of the object with the help of ciliary muscles.

APPRECIATION ON THE WORKING OF CILIARY MUSCLES IN THE EYE:

1) The ciliary muscle to which eye lens is attached helps the eye lens to change its focal length by changing the radii of curvature of the eye lens.
2) When the eye is focused on a distant object, the ciliary muscles are relaxed so that the focal length of eye lens has its maximum value which is equal to its distance from the retina.
3) The parallel rays coming into the eye are then focused on to the retina and we see the object clearly.
4) When the eye is focused on a closer object, the ciliary muscles are strained and focal length of eye-lens decreases.

5) The ciliary muscles adjust the focal length in such a way that the image is formed on retina and we see the object clearly.

6) This process of adjusting focal length is called “accommodation”.

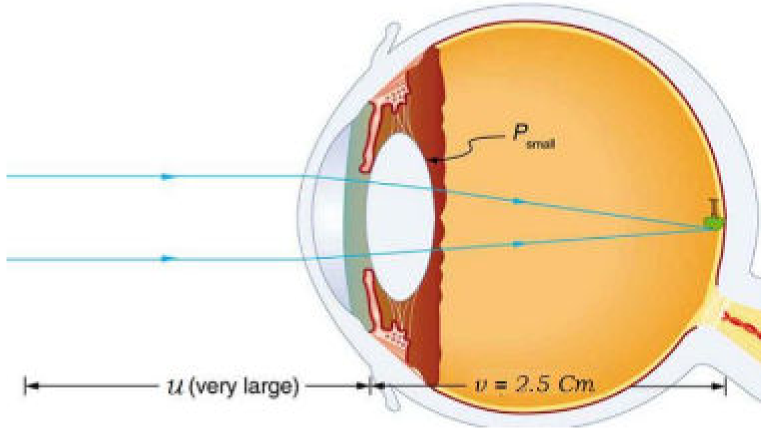
7) By this way ciliary muscles are useful to see distinct and closure objects clearly by adjusting focal length.

8) So, I appreciate the working of ciliary muscles in the eye.

CALCULATE THE MAXIMUM AND MINIMUM OF FOCAL LENGTHS OF EYE LENS:

CASE-I: WHEN THE OBJECT IS AT INFINITY:

1) When the object is at infinity, the parallel rays from the object falling on the eye lens are refracted and they form a point sized image on retina (see fig).



2) In this situation, eye-lens has a maximum focal length.

3) When the object is at infinity, u= - ∞; v = 2.5 cm (Image distance which is equal to distance between eye-lens and retina)

Formula: $$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{f_{max}} = \frac{1}{2.5} + \frac{1}{\infty}$$

$$\frac{1}{f_{max}} = \frac{1}{2.5}$$

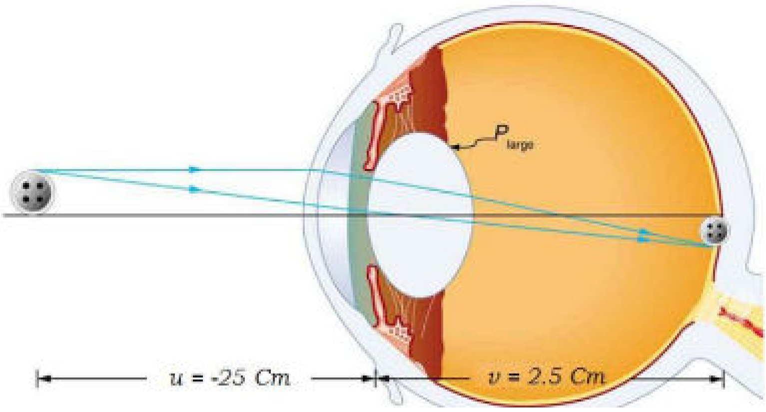
$$f_{max} = 2.5\ Cm$$

Maximum focal length of eye lens =

f_{max} = 2.5 cm

CASE-II: WHEN THE OBJECT IS PLACED AT DISTANCE OF 25 CM:

1) When the object is placed at distance of 25 cm from our eye, then the eye has minimum focal length.



2. Here,

u = - 25 cm;

v = 2.5 cm

Formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\frac{1}{f\,min} = \frac{1}{2.5} - \frac{1}{-25}$$

$$\frac{1}{f\,min} = \frac{1}{2.5} + \frac{1}{25}$$

$$\frac{1}{min} = \frac{10+1}{25} = \frac{11}{25}$$

$$f_{min} = \frac{25}{11} = 2.27\ Cm$$

Minimum focal length of eye lens =

f_{min} = 2.27 cm

ACCOMMODATION OF LENS: If the position of an objectis between infinity and the point of least distance of distinct vision, then the eye lens adjusts its focal length in between 2.5 cm to 2.27 cm to form a clear image on the retina. The ability of eye-lens to change its focal length is called "accommodation of lens".

EYE DEFECTS:

1) Sometimes the eye may gradually lose its ability for accommodation.
2) In such conditions the person cannot see an object clearly and comfortably.
3) The vision becomes blurred due to defects of the eye lens.
4) There are mainly three common defects of vision. They are:
   i) Myopia (or) near sightedness
   ii) Hypermetropia (or) Far sightedness
   iii) Presbyopia.

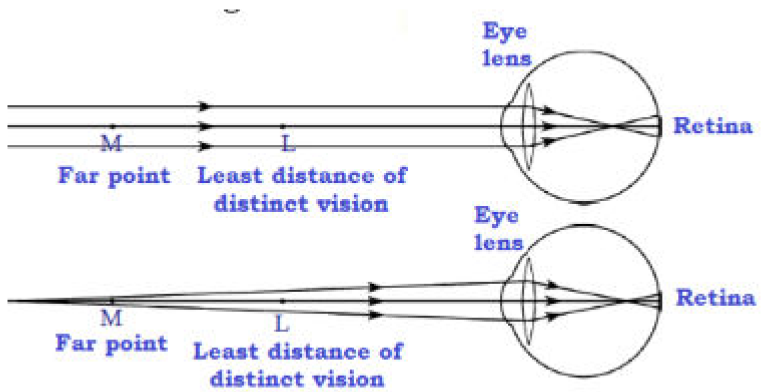
MYOPIA (OR) NEAR-SIGHTEDNESS:

The defect, in which people cannot see objects beyond far point is called "Myopia".

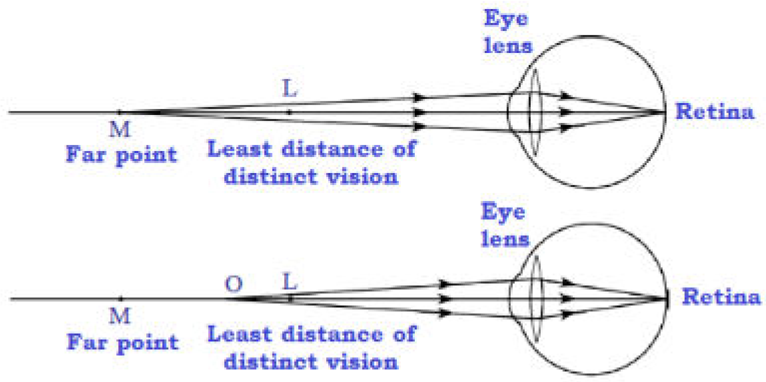
EXPLANATION:

1) Some people cannot see objects at long distances but can see nearby objects clearly. This type of defect in vision is called "Myopia".

2) It is also called "near sightedness".
3) For these people the maximum focal length is less than 2.5 cm.
4) In such cases the rays coming from distant objects, after refraction through the eye lens, form an image before the retina as shown in the below figures



5) A healthy person can see objects at all distances more than 25 cm clearly but a person with myopia can see objects clearly up to a certain distance.
6) Let the extreme point from where an object appears clearly to a person with myopia be "M" (shown in figure).



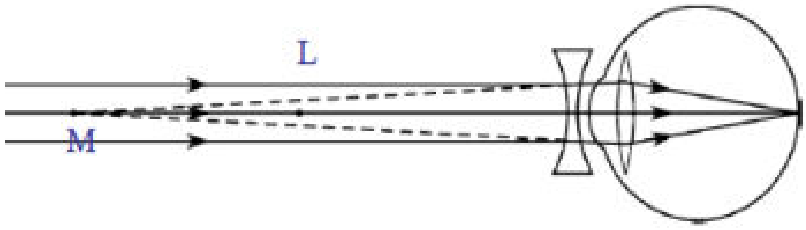
7) If the object is at M or in between M and point of least distance of distinct vision (L), the eye lens can form an image on the retina (see the above figures). This point M is called "far point".

FAR POINT (DEFINITION): The point of maximum distance at which the eye lens can form an image on the retina is called "far point".

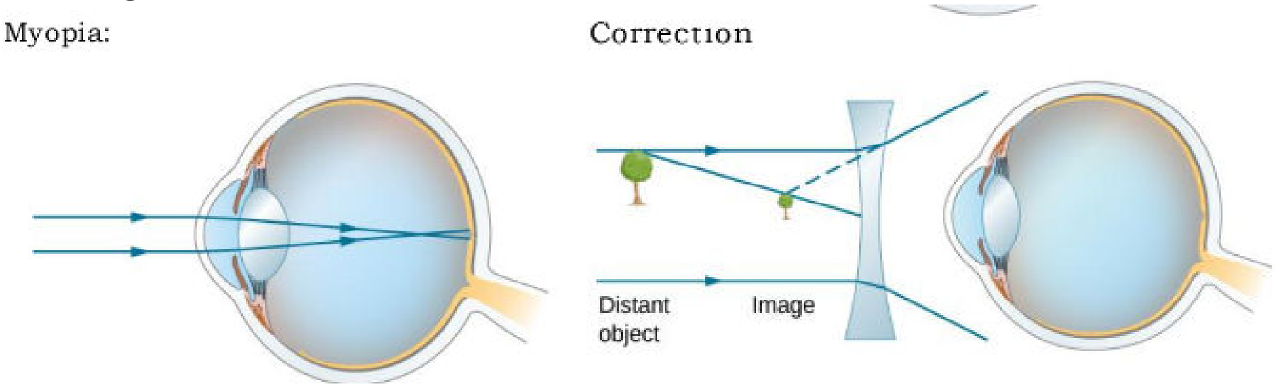
8) The eye lens can form clear image on the retina, when an object is placed between far point and point of least distance of distinct vision.
9) If we are able to bring the image of the object kept beyond far point, between the far point and the point of least distance of distinct vision using a lens, this image acts as an object for the eye lens.
10) This can be made possible only when a concave lens is used (recollect image formation by refraction through a concave lens).

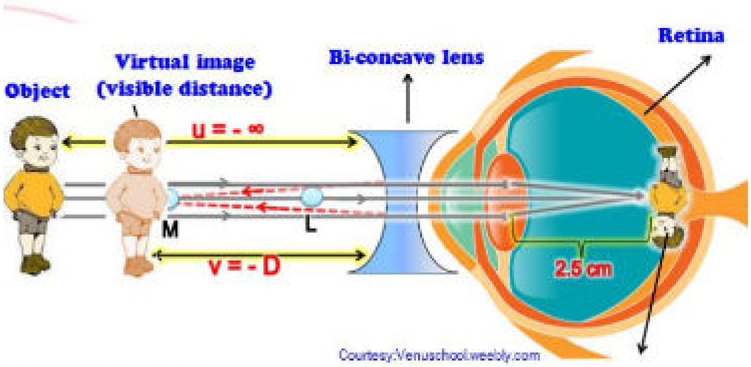
CORRECTION OF MYOPIA:

1) To correct one"s Myopia, we need to select a lens which forms an image at the far point for an object at infinity.
2) We need to select bi-concave lens to achieve this.

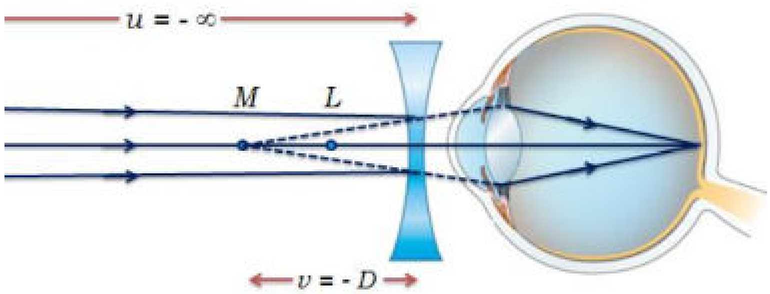


3) This image (which forms at the far point) acts like an object for the eye lens and the final image is formed on the retina.





FINDING THE FOCAL LENGTH OF THIS BI-CONCAVE LENS:



1) Here object distance (u) is infinity and image distance (v) is equal to distance of far point.

$$u = -\infty;$$
$$v = \text{distance of far point} = -D$$

2) Let "f" be the focal length of bi-concave lens.

$$\text{Lens formula: } \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{(-D)} - \frac{1}{(-\infty)}$$

$$\frac{1}{f} = \frac{1}{(-D)} \Rightarrow f = -D$$

3) Here "f" is negative showing that it is a concave lens

.HYPERMETROPIA (OR) FAR SIGHTEDNESS:

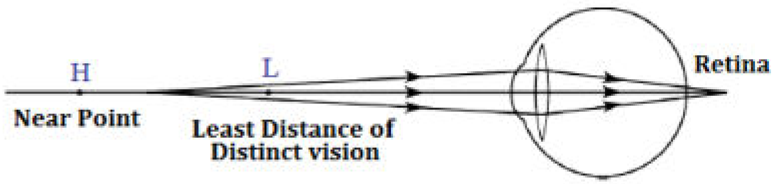
The defect, in which people can see distant objects clearly but cannot see objects at near distances is called "Hypermetropia".

EXPLANATION:

1) Hypermetropia is also known as "farsightedness".

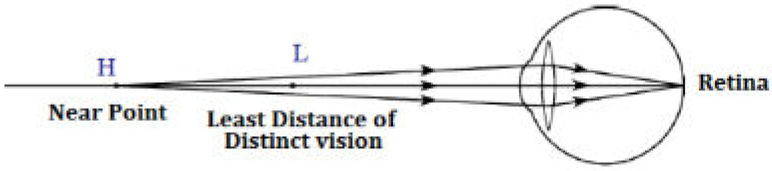
2) A person with hypermetropia can see distant objects clearly but cannot see objects at near distances, because the minimum focal length of eye lens for the person of hypermetropia is greater than 2.27 cm.

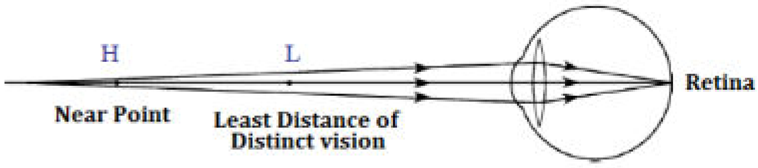
3) In such cases, the rays coming from a nearby object, after refraction at eye lens, forms an image beyond the retina as shown in figure.



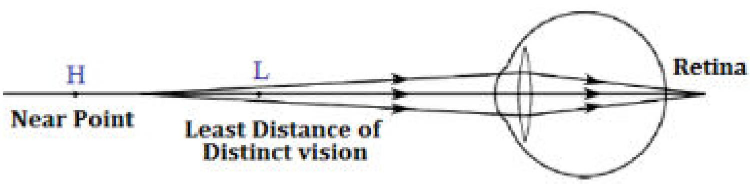
4) Let the point of least distance at which the eye lens forms a clear image on the retina for a person with hypermetropia be "H".

5) If an object is at H or beyond H, the eye can form its image on retina (see figures).





6) If the object is between H and point of least distance of distinct vision (L) then it cannot form an image. See figure.

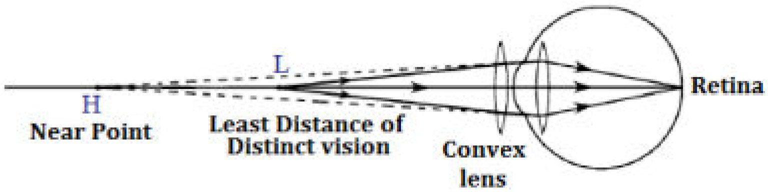


7) The people with defect of hypermetropia cannot see objects placed between near point (H) and point of least distance of distinct vision (L).

NEAR POINT (H): The point of minimum distance at which the eye lens can form an image on the retina is called near point (H).
8) Eye lens can form a clear image on the retina when any object is placed beyond near point (H).

CORRECTION OF HYPERMETROPIA:

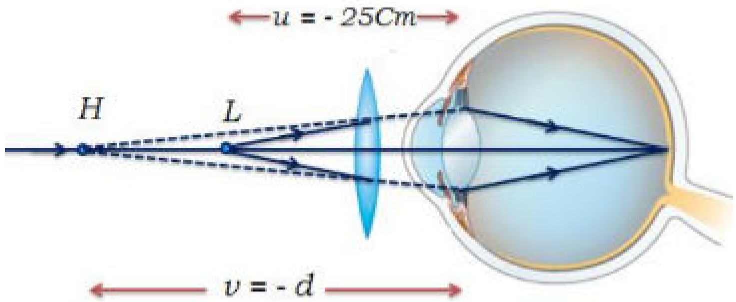
1) To correct the defect of hypermetropia, we need to use a lens which forms an image of an object beyond near point (H), when the object is between near point (H) and least distance of distinct vision (L).
2) This is possible only when a double convex lens is used.



3) This image [which forms beyond near point (H)] acts like an object for the eye lens and the final image is formed on the retina.

FINDING THE FOCAL LENGTH OF THIS BI-CONVEX LENS:

1) To find the focal length of lens, let us consider that the object is at point of least distance of distinct vision (L).
2) Hypermetropia is corrected when the image of the object at L is formed at the near point (H) by using a bi-convex lens as shown in figure.



3) This image [w hich was formed at the near point (H)] acts like an object for the eye lens.
4) Hence final image due to eye is formed at retina (see above figure)

Here object distance (u) = -25 cm
(opposite to the light ray)
Image distance (v) = distance of near point
= -d (opposite to the light ray)
Let 'f' be the focal length of bi-convex lens.

Lens formula: $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{(-d)} - \frac{1}{(-25)}$

$$\frac{1}{f} = \frac{1}{(-d)} + \frac{1}{25}$$

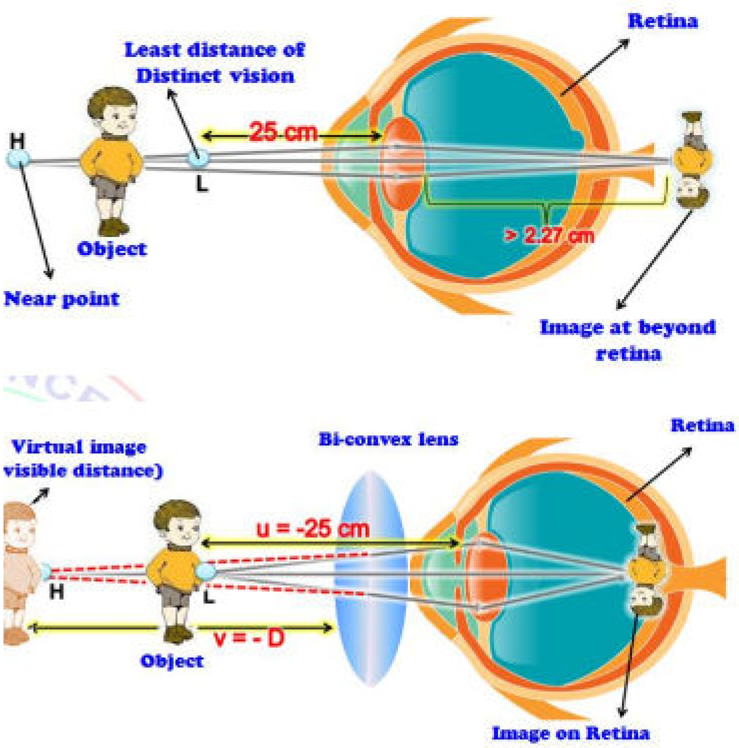
$$\frac{1}{f} = \frac{d-25}{25d}$$

$$f = \frac{25d}{d-25} \quad \text{(f is measured in centimeters)}$$

We know that if d > 25cm, then 'f' becomes +ve

We know that if d > 25cm, then "f" becomes Ve i.e., we need to use biconvex lens to correct defect of hypermetropia.

Hypermetropia correction:



PROBLEM: The focal length of a lens suggested to a person with Hypermetropia is 100cm. Find the distance of near point and power of the lens?

SOLUTION:

Given, Focal length of the lens, f = 100cm.

Image distance (v) = Distance of near point = -d

Object distance (u) = -25 cm

Lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \frac{1}{100} = \frac{1}{d} - \frac{1}{(-25)}$$

$$\Rightarrow \frac{1}{d} = \frac{1}{25} - \frac{1}{100}$$

$$\Rightarrow \frac{1}{d} = \frac{4-1}{100}$$

$$\Rightarrow \frac{1}{d} = \frac{3}{100}$$

$$\Rightarrow d = \frac{100}{3} = 33.33\text{cm.}$$

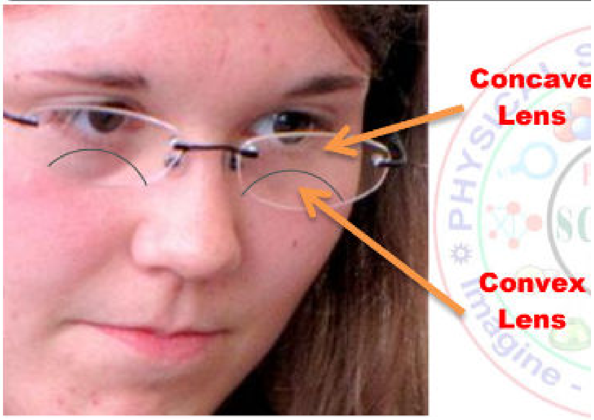
Power of lens, $p = \frac{100}{f} = \frac{100}{100} = 1$ D.

PRESBYOPIA (DEFINITION):

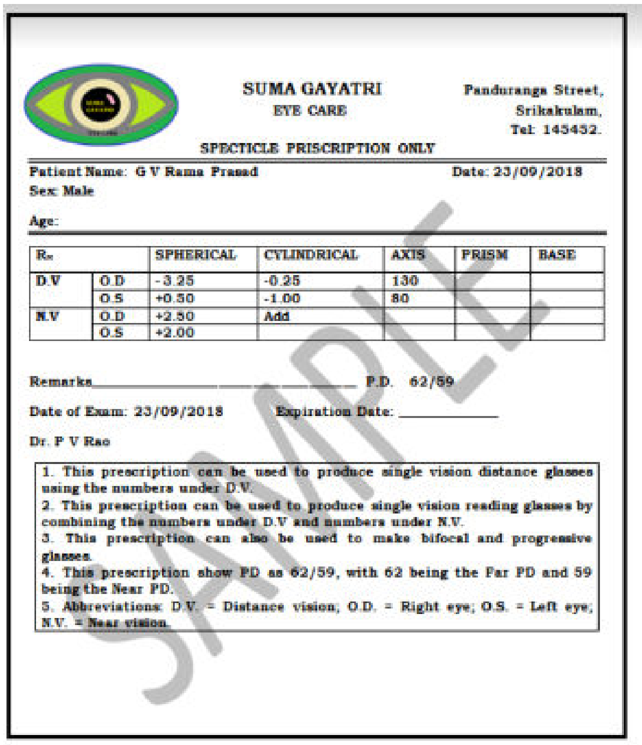
Presbyopia is vision defect when the ability of accommodation of the eye usually decreases with ageing.

EXPLANATION:

1) For most people the near point gradually recedes away.
2) They find it difficult to see nearby objects clearly and distinctly.
3) This happens due to gradual weakening of ciliary muscles and diminishing flexibility of the eye lens. This effect can be seen in aged people.
4) Sometimes a person may suffer from both myopia and hypermetropia with ageing.



5) To correct this type of defect of vision we need bi-f ocal lenses which are formed using both concave and convex lenses.
6) Its upper portion consists of the concave lens and lower portion consists of the convex lens.
7) If you go to an eye hospital to get tested for vision defects, the doctor gives you a prescription that contains some information regarding type of lens to be used to correct vision



SUMA GAYATRI
EYE CARE

Pandurangа Street,
Srikakulam,
Tel: 145452.

SPECTICLE PRISCRIPTION ONLY

Patient Name: G V Rama Prasad   Date: 23/09/2018
Sex: Male
Age:

Rx		SPHERICAL	CYLINDRICAL	AXIS	PRISM	BASE
D.V	O.D	-3.25	-0.25	130		
	O.S	+0.50	-1.00	80		
N.V	O.D	+2.50	Add			
	O.S	+2.00				

Remarks______________ P.D. 62/59

Date of Exam: 23/09/2018   Expiration Date: ________

Dr. P V Rao

1. This prescription can be used to produce single vision distance glasses using the numbers under D.V.
2. This prescription can be used to produce single vision reading glasses by combining the numbers under D.V and numbers under N.V.
3. This prescription can also be used to make bifocal and progressive glasses.
4. This prescription show PD as 62/59, with 62 being the Far PD and 59 being the Near PD.
5. Abbreviations: D.V. = Distance vision; O.D. = Right eye; O.S. = Left eye; N.V. = Near vision.

SAMPLE

Eye sight prescription

8) You might have heard people saying "my sight is increased or decreased".
9) Usually doctors, after testing for defects of vision, prescribe corrective lenses indicating their power which determines the type of lens to be used and its focal length.

POWER OF LENS (DEFINITION):

The reciprocal of focal length is called Power of lens.

EXPLANATION:

1) The degree of convergence or divergence of light rays that can be achieved by a lens is expressed in terms of its power.
2) Let "f" be the focal length of lens.

$$Power\ of\ lens = \frac{1}{Focal\ length} = \frac{1}{f\ (in\ metres)}$$

$$Power\ of\ lens = \frac{100}{f\ (in\ Cms)}$$

UNIT OF POWER OF LENS: The unit of power is dioptre.
It is denoted by the letter "D".

PROBLEM:

Doctor advised to use 2D lens. What is its focal length?

SOLUTION: Given, Power of lens P = 2D, Using,

$$Power\ of\ lens\ (P) = \frac{100}{f\ (in\ Cms)}$$

$$2 = \frac{100}{f}$$

Therefore f = , f = 100/2 = 50 cm.

The lens has focal length, f = 50 cm.

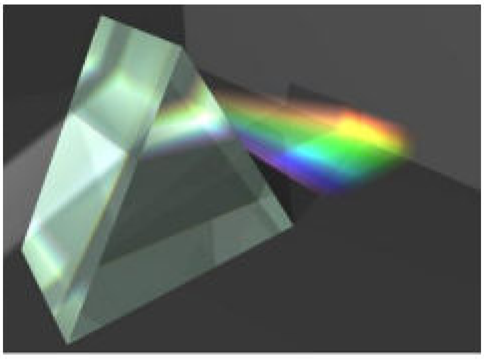
DISPERSION AND SCATTERING OF LIGHT:

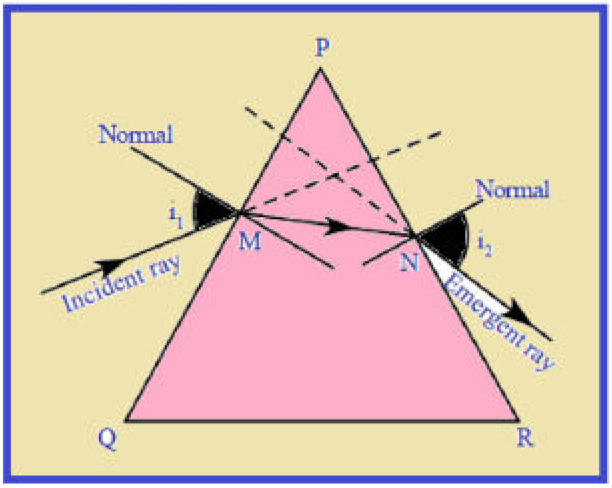
I. DISPERSION OF LIGHT:

1) We might have seen a rainbow form in the sky just after a rain shower.
2) It must have fascinated us with spectacular colours appearing as a semi-circular band of colours.

PRISM AND CERTAIN TERMS ASSOCIATED WITH PRISMS:

1) PRISM: A prism is a transparent medium separated from the surrounding medium by at least two plane surfaces which are inclined at a certain angle in such a way that, light incident on one of the plane surfaces emerges from the other plane surface.

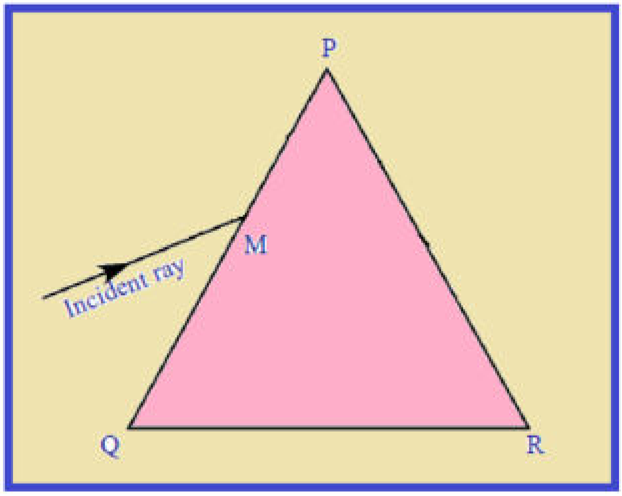




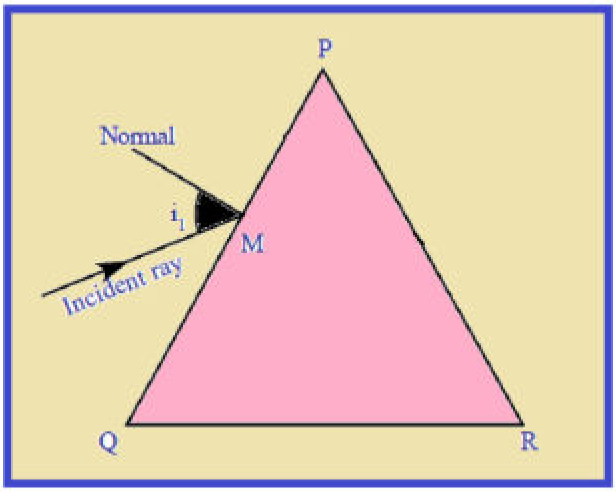
2) A triangular glass prism contains two triangular bases and three rectangular plane lateral surfaces, which are inclined to each other.

3) Let us consider that triangle PQR represents outline of the prism where it rests on its triangular base.

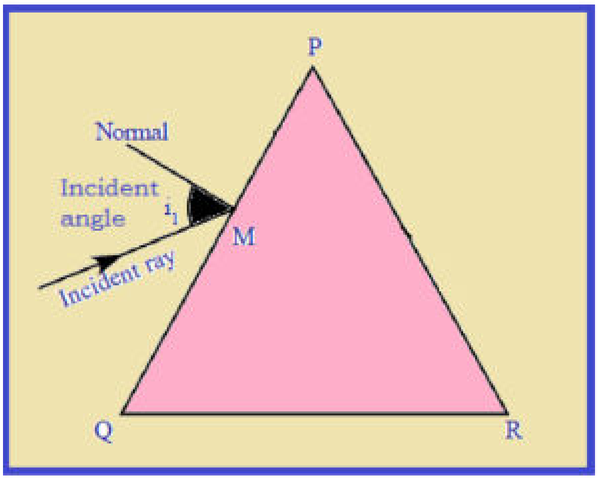
4) Let us assume that a light ray is incident on the plane surface PQ of a prism at M as shown in figure.



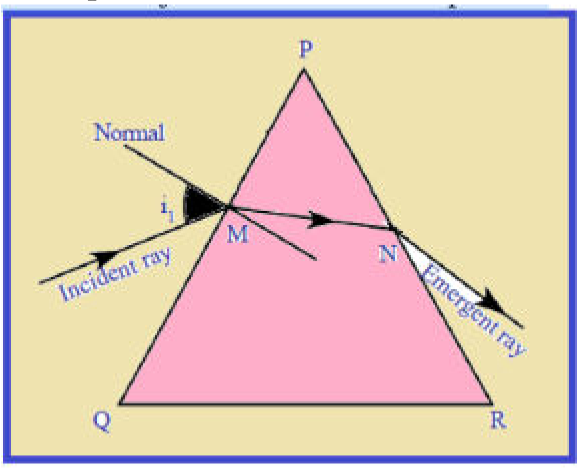
5) Draw a perpendicular to the surface at M, then it becomes a normal to that surface.



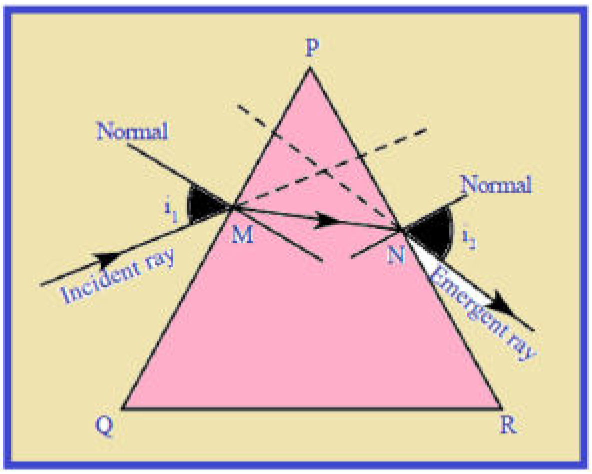
6) The angle between the incident ray and normal is called angle of incidence (i1).



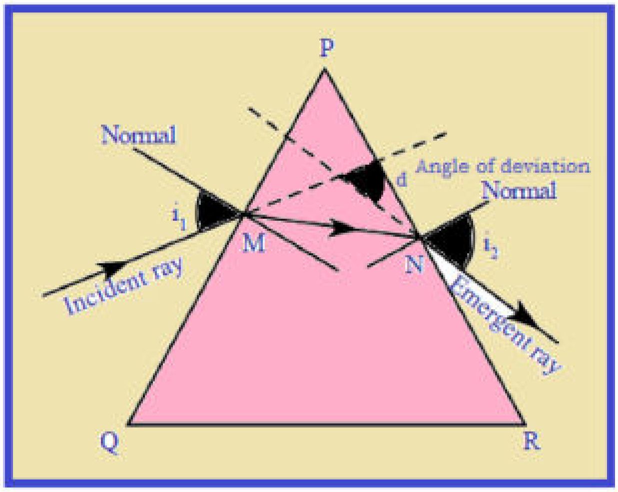
7) The ray is refracted at M and moves through prism and meets the other plane surface at N and finally comes out of the prism.



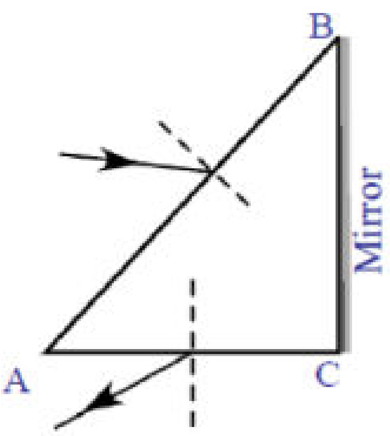
8) The ray which comes out of the surface PR at N is called emergent ray.
9) Draw a perpendicular to PR at point N. The angle between the emergent ray and normal is called angle of emergence (i2).



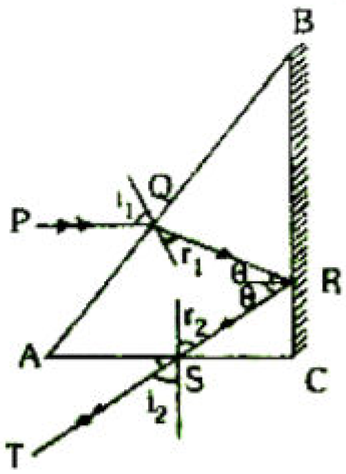
10) The angle between the plane surfaces PQ and PR is called the angle of the prism or refracting angle of prism (A) and the angle between the incident ray and emergent ray is called angle of deviation (d).



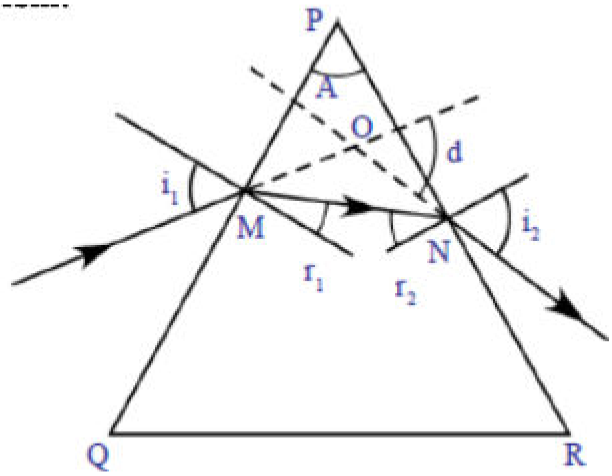
COMPLETION OF RAY DIAGRAM: Incident ray on one of the face (AB) of a prism and emergent ray from the face AC are given in figure. Complete the ray diagram.



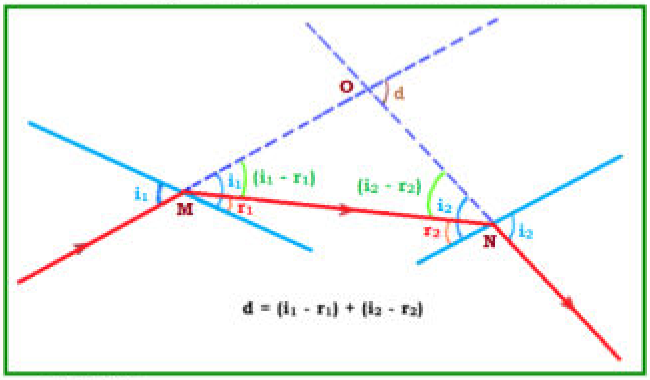
Solution:



DERIVATION OF FORMULA FOR REFRACTIVE INDEX OF A PRISM:



Observe the ray diagram in the above figure.



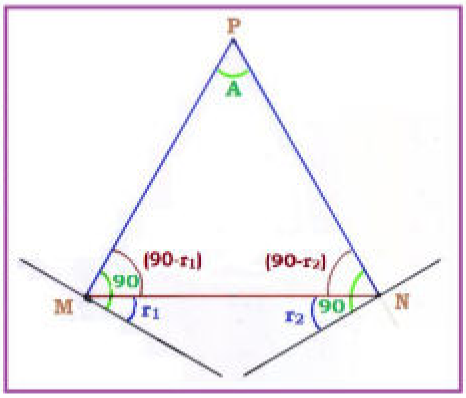
From ΔOMN,

$d = (i_1 - r_1) + (i_2 - r_2)$

[In a triangle external angle is equal to the sum of internal angles, here 'd' is external angle and $(i_1 - r_1)$, $(i_2 - r_2)$ are internal angles]

$\Rightarrow d = i_1 - r_1 + i_2 - r_2$

$\Rightarrow d = (i_1 + i_2) - (r_1 + r_2)$ ------------------------ (1)



From ΔPMN, $A + (90^0 - r_1) + (90^0 - r_2) = 180^0$

[The sum of angles in a triangle is equal to 180^0]

$\Rightarrow A + (90^0 - r_1) + (90^0 - r_2) = 180^0$

$\Rightarrow A + 90^0 - r_1 + 90^0 - r_2 = 180^0$

$\Rightarrow A + 180^0 - r_1 - r_2 = 180^0$

$\Rightarrow A + 180^0 - (r_1 + r_2) = 180^0$

$\Rightarrow A = 180^0 - 180^0 + (r_1 + r_2)$ $\Rightarrow A = r_1 + r_2$

$\Rightarrow r_1 + r_2 = A$ ---------------------------------- (2)

From (1) and (2), we get,

$d = (i_1 + i_2) - A$

$(i_1 + i_2) = A + d$ --------------------------------- (3)

According to the Snell"s law,

n1 sin i = n2 sin r

Apply Snell"s law at M and N points.

I. AT M: Boundary is PQ; here the light enters into the prism from air medium. So, the first medium is air and the second medium is prism"s material.

Let the refractive index of the prism is "n".

Therefore, at "M" of the boundary PQ,

n1 = 1 (As air is the first medium and refractive index of air = 1)

i = i1 (incident angle at M on PQ surface)

n2 = n (refractive index of the prism, we assume and required to find out)

r = r1 (Angle of refraction at PQ surface)

Therefore (1) sin i1 = n sin r1

sin i1 = n sin r1

n = sin i1/ sin r1 ------------------------- (4)

II. AT N: Boundary is PR; here the light enters into the air from the prism. So, the first medium is prism"s material and the second medium is air.

Therefore, at "N" of the boundary PR, n1 = n (Refractive index of the first medium, prism)

i = r2 (At PR surface, r2 is the incident angle of the ray MN)

n2 = 1 (Air is the second medium and its refractive index = 1)

r = i2 (At N, for PR surface i2 is the refracted angle)

Therefore n sin r2 = (1) sin i2

n = sin i2/ sin r2 -------------- (5)

At the angle of minimum deviation (D), angle of incident (i1) is equal to the angle of emergence (i2) Means, i1 = i2

And also, at the minimum deviation (D), MN is parallel to the side QR or MN is parallel to the base of the prism (figure).

When i1 = i2, angle of deviation (d) becomes angle of minimum deviation (D).

Therefore (3) ⇒ A + D = i_1 + i_1 [At the angle of minimum deviation, d = D & (i_1 + i_2)]

$$\Rightarrow A + D = 2i_1$$

$$\Rightarrow i_1 = \frac{(A+D)}{2} \text{ -------------- (6)}$$

When $i_1 = i_2$, from the figure $r_1 = r_2$

Therefore (2) ⇒ $r_1 + r_1 = A$

$$\Rightarrow 2r_1 = A$$

$$\Rightarrow r_1 = \frac{A}{2} \text{ ------------------ (7)}$$

On substituting (6) & (7) in (4), we get

$$n = \frac{Sin\left(\frac{A+D}{2}\right)}{Sin\left(\frac{A}{2}\right)}$$

This is the formula for the refractive index of the prism. By calculating the angle of minimum deviation from the lab activity (explained above), we calculate the refractive index of the prism.

AN ACTIVITY TO STUDY THE REFRACTION OF LIGHT THROUGH A TRIANGULAR PRISM (LAB ACTIVITY):

AIM: Finding the refractive index of a prism.

MATERIAL REQUIRED: Prism, piece of white chart of size 20x20 cm, pencil, pins, scale and protractor.

PROCEDURE:

1) Take a prism and place it on the white chart in such a way that the triangular base of the prism is on the chart.
2) Draw a line around the prism (boundary) using a pencil and remove the prism.
3) Name those triangle vertices as P, Q and R.[for many prisms the triangle formed are equilateral].
4) The refracting surfaces could be rectangular in shape.
5) Find the angle between PQ and PR, i.e., the angle of the prism (A).
6) Mark M on the side of triangle PQ and also draw a perpendicular to PQ at M.
7) Place the centre of the protractor at M and along the normal.
8) Mark an angle of 30° and then draw a line up to M. This line denotes the incident ray and angle is called angle of incidence. Note it in a table below.
9) Draw a small arrow on it as shown in figure.
10) Place the prism in its position (triangle) again and fix two pins vertically on the line at points A and B as shown in figure.
11) Look for the images of pins through the prism from the other side (PR) and fix another two pins at points C and D in such a way that all the four pins appear to lie along the same straight line (Do it carefully).
12) Now remove the prism, take out pins and draw a line joining the two pin-holes formed by the pins to meet surface "PR", this is the emergent ray which emerges from the surface PR at a point "N".
13) The angle between the normal at N and the emergent ray is the angle of emergence. Measure this angle and note its value in the table.

14) Now join the points M and N by a straight line.
15) The line passing through the points A, B, M, N, C and D represents the path of light when it suffers refraction through the prism.
16) Extend both incident and emergent rays till they meet at a point "O".
17) Measure the angle between these two rays.
This is the angle of deviation (d). Note it in table.
18) Repeat this procedure for various angles of incidence such as 40°,500 etc. Find the corresponding angles of deviation and angles of emergence and note them in table.

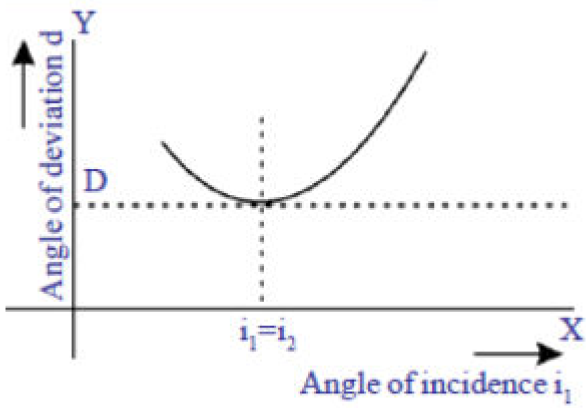
Table

Angle of incidence (i_1)	Angle of emergence (i_2)	Angle of deviation (d)

19) We will notice that the angle of deviation decreases first and then increases with increase in the angle of incidence.

GRAPH:

1) Take angle of incidence along X- axis and the angle of deviation along Y- axis.
2) Using a suitable scale, mark points on a graph paper for every pair of angles.
3) Finally join the points to obtain a graph (smooth curve).
4) Draw a tangent line to the curve, parallel to X- axis, at the lowest point of the graph.
5) The point where this line cuts the Y- axis gives the angle of minimum deviation (D).
6) Draw a parallel line to y-axis through the point where the tangent touches the graph.
7) This line meets x-axis at a point showing the angle of incidence corresponding to the minimum deviation.
8) If you do the experiment with this angle of incidence you will get an angle of emergence equal to the angle of incidence.



Formula: Refractive index of the prism =

$$n = \frac{Sin\left(\frac{A+D}{2}\right)}{Sin\left(\frac{A}{2}\right)}$$

RESULT: On substituting the values of A and D in the above equation, which we get by the above experiment, we get the refractive index of the prism material.
If we use quartz as the material of the prism then we get Refractive index between1.55 to 1.40

PROBLEM:

A prism with an angle A = 60° produces an angle of minimum deviation of 30°. Find the refractive index of material of the prism.
SOLUTION: Given that A = 60° and D = 30°.

$$\text{Using } n = \frac{Sin\left(\frac{A+D}{2}\right)}{Sin\left(\frac{A}{2}\right)}$$

$$n = \frac{Sin\left(\frac{60+30}{2}\right)}{Sin\left(\frac{60}{2}\right)}$$

$$n = \frac{Sin\left(\frac{90}{2}\right)}{Sin\ 30}$$

$$n = \frac{Sin\ 45}{Sin\ 30} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \frac{2}{\sqrt{2}} = \sqrt{2}$$

Therefore $n = \sqrt{2}$
Thus,
the refractive index of the given prism = √2

PROBLEM:

A light ray falls on one of the faces of prism at an angle 40° so that it suffers angle of minimum deviation of 30°. Find the angle of prism and angle of refraction at the given surface?

SOLUTION:

Given, Angle of incident i1 = 40°
Angle of minimum deviation, D = 30°
We know, at minimum deviation,

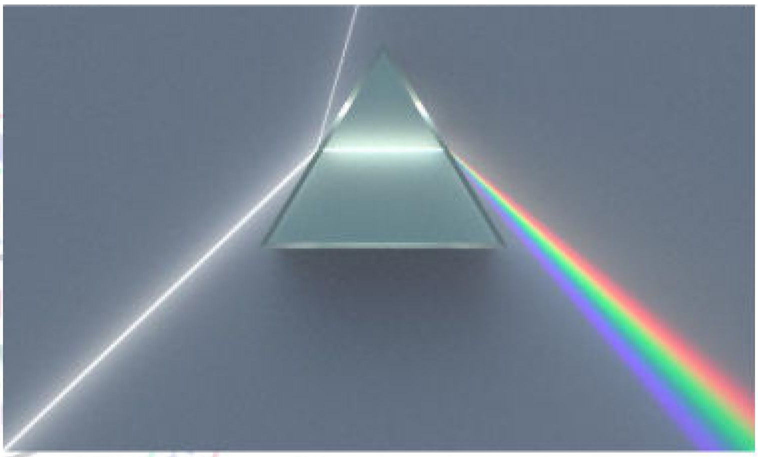
$$A+D = 2i$$
$$\Rightarrow A = 2i-D = (2x40^0) - 30^0 = 80^0 - 30^0 = 50^0$$
$$\Rightarrow A = 50^0$$
$$\text{Angle of refraction} = \frac{A}{2} = \frac{50}{2} = 25^0$$

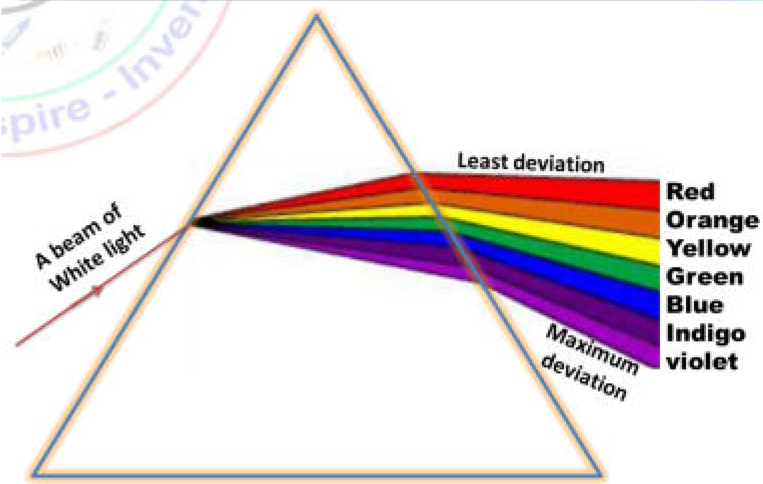
Therefore, **the angle of prism = 50^0**
angle of refraction = 25^0

DISPERSION OF WHITE LIGHT ON THE WALL BY PRISM (ACTIVITY):

1) Take a prism and place it on the table near a vertical white wall.
2) Take a thin wooden plank, make a small hole in it and fix it vertically on the table.
3) Place the prism between the wooden plank and wall and place a white light source behind the hole of the wooden plank.
4) Switch on the light.
5) The rays coming out of the hole of plank become a narrow beam of light.
6) Adjust the height of the prism such that the light falls on one of the lateral surfaces.

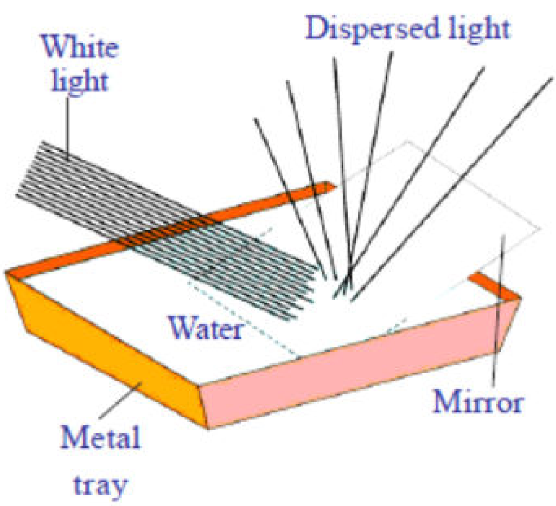
7) Observe the changes in emerged rays of the prism.
8) Adjust the prism by slightly rotating it till you get an image on the wall.
(Do this experiment in the dark room)

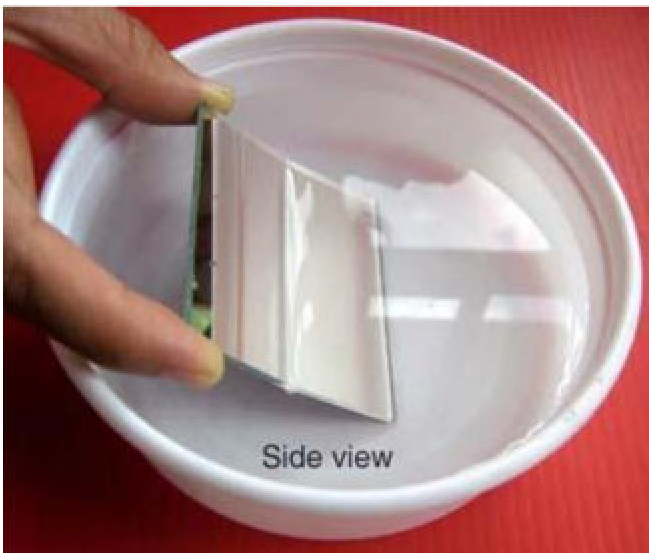


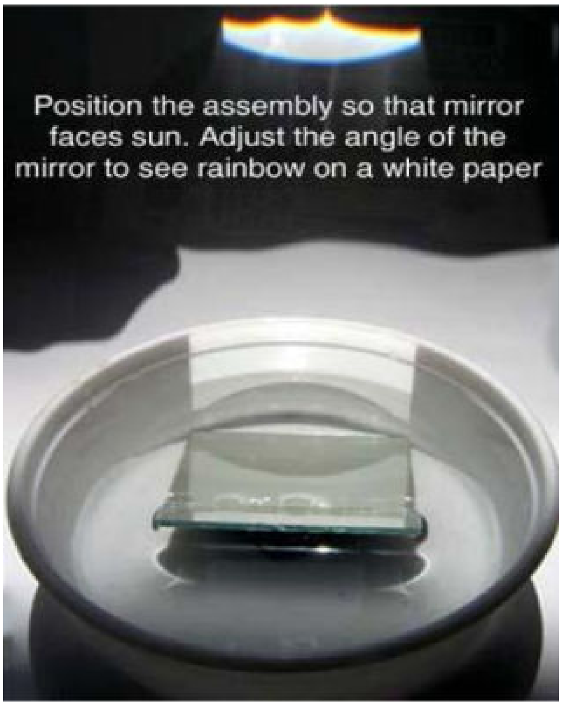


AN EXPERIMENT PRODUCES A RAINBOW IN THE CLASS ROOM:

1) Take a metal tray and fill it with water.
2) Place a mirror in the water such that it makes an angle to the water surface.
3) Now focus white light on the mirror through the water as shown in figure.
4) Try to obtain colour on a white card board sheet kept above the water surface.
5) Note the names of the colours you could see in your book.







NOTE: In above activities, we observe that white light is splitting into certain different colours.

NOTE: It is not possible to explain the splitting of white light into different colours using ray theory.

DISPERSION OF LIGHT : The splitting of white light into different colours (VIBGYOR) is called dispersion.

EXPLANATION ON DISPERSION OF LIGHT:

1) The angle of deviation is minimum for red as compared to the angles of deviation of other colours and maximum for violet.

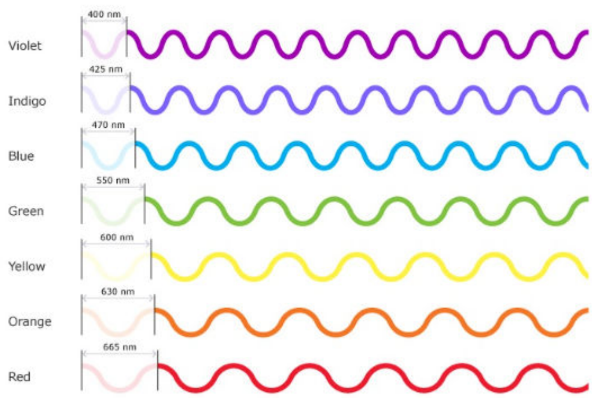
2) For a particular refractive index of prism there must be only one angle of minimum deviation and according to Fermat"s principle, light ray always chooses the path of least time.

3) But in the above activity, we noticed that light has chosen different paths.

4) The situation we witnessed in the above activities rule out ray theory of light.

5) We can consider that white light is a collection of waves with different wavelengths.

6) Violet colour is known to have the shortest wavelength while red is of the longest wavelength.



7) According to wave theory, light can be thought of a wave propagating in all directions.
8) Light is an electromagnetic wave.
9) Here no particle physically oscillates back and forth.
10)Instead, the magnitude of electric and magnetic fields, associated with the electromagnetic wave, vary periodically at every point.
11)These oscillating electric and magnetic fields propagate in all directions with the speed of light.
12)The reason lies in the fact that, while the speed of light is constant in vacuum for all colours, it depends on the wavelength of light when it passes through a medium.
13)We know that refractive index is the ratio of speeds in vacuum and in the medium.
14) Consequently, the refractive index of a medium depends on wavelength of light.
15)When white light passes through a medium, each colour selects its least time path and we have refraction of different colours to different extents.
16)This results in separation of colours, producing a spectrum on the wall and in the mirror as we saw in activities above.
17)It has been experimentally found that refractive index decreases with an increase in wavelength.
18)If we compare the wave lengths of seven colours in VIBGYOR, red colour has longest wavelength and violet colour has shortest wavelength.
19)The refractive index of red is low hence it suffers low deviation.
20)We noticed that when white light passes through a prism, it splits into seven colours.
21)Let us assume that you have sent a single colour ray through the prism.
22)We know that the frequency of light is the property of the source and it is equal to number of waves leaving the source per second.
23)This cannot be changed by any medium.
24) Hence frequency doesn"t change due to refraction.
25) Thus coloured light passing through any transparent medium retains its colour.
26) While refraction occurs at the interface, the number of waves that are incident on the interface in a second must be equal to the number of waves passing through any point taken in another medium.
27)This means that the frequency of the light wave remains unaltered while its wavelength changes depending on the medium through which it passes.
28)We know that the relation between the speed of wave (v), wavelength (λ) and frequency (f) is, $v = f\lambda$ (frequency (f) may be denoted by υ) 29)For refraction at any interface, v is proportional to λ.
30)Speed of the wave increases with increase in wavelength of light and vice versa.
31)Rainbow is a good example of dispersion of light.

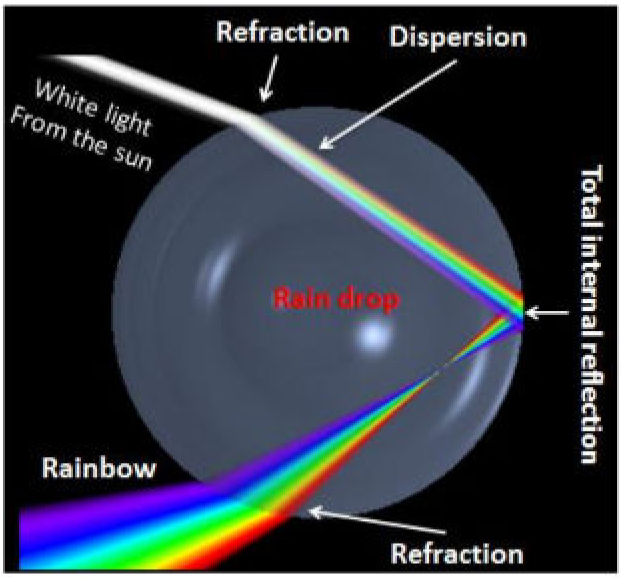
RAINBOW ON THE WHITE WALL (OR) ARTIFICIAL RAINBOW FORMATION ACTIVITY:

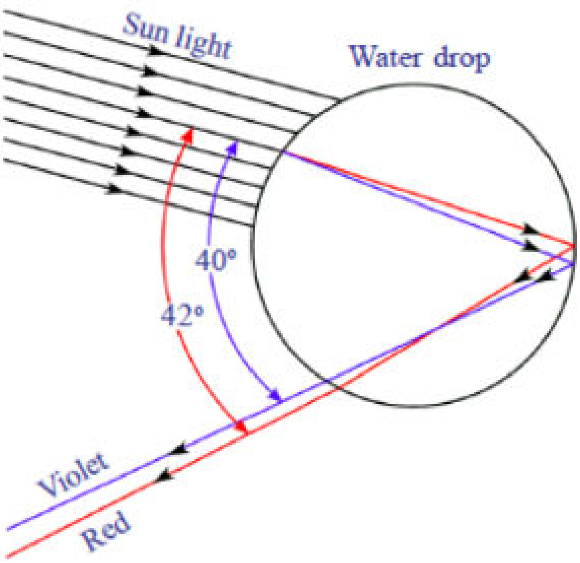
1) Select a white coloured wall on which the sun rays fall and stand in front of that wall in such a way that the sun rays fall on your back.
2) Hold a tube through which water is flowing and place your finger in the tube to obstruct the flow of water.
3) Water comes out through the small gaps between the tube and your finger like a fountain.
4) You observe the changes on the wall while the water shower is maintained.
5) You can see colours on the wall.

6) The beautiful colours of the rainbow are due to dispersion of the sunlight by millions of tiny water droplets is formed on the white wall.

EXPLANATION ON THE FORMATION OF RAINBOW:

1) Let us consider the case of an individual water drop.
2) Observe figure, the rays of sunlight enter the drop near its top surface.
3) At this first refraction, the white light is dispersed into its spectrum of colours, violet being deviated the most and red the least.

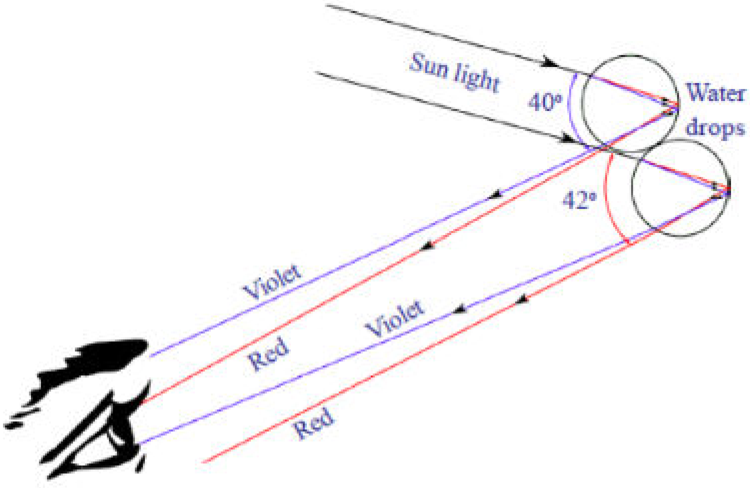




4) Reaching the opposite side of the drop, each colour is reflected back into the drop because of total internal reflection.
5) Arriving at the surface of the drop, each colour is again refracted into air.
6) At the second refraction the angle between red and violet rays further increases when compared to the angle between those at first refraction.
7) The angle between the incoming and outgoing rays can be anything between 00 and about 420.
8) We observe bright rainbow when the angle between incoming and outgoing rays is near the maximum angle of 420 (Diagrammatically it is shown in figure).
9) Although each drop disperses a full spectrum of colours, an observer is in a position to see only a single colour from any one drop depending upon its position.

10)If violet light from a single drop reaches the eye of an observer, red light from the same drop can"t reach his eye.

11)It goes elsewhere possibly downwards of the eye of the observer (see in figure).



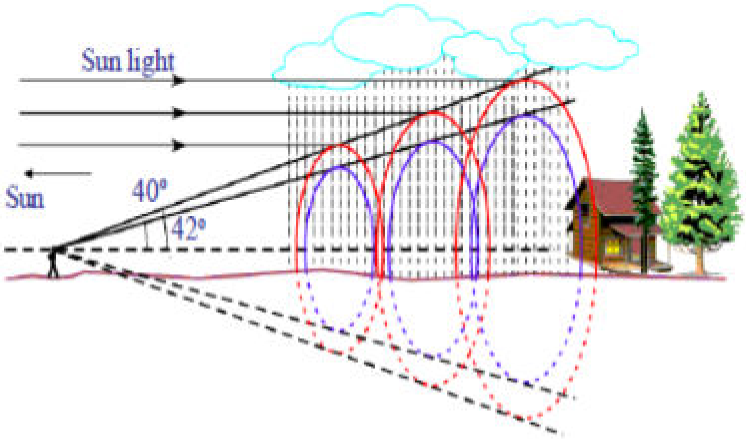
12)To see red light, one must look at the drop higher in the sky.

13)The colour red will be seen when the angle between a beam of sunlight and light sent back by a drop is 420.

14)The colour violet is seen when the angle between a sunbeam and light sent back by a drop is 40°.

15)If you look at an angle between 40° and 420, you will observe the remaining colours of VIBGYOR.

16)A rainbow is not the flat two dimensional arc as it appears to us.



17)The rainbow we see is actually a three dimensional cone with the tip at our eye as shown in figure.

18)All the drops that disperse the light towards us lie in the shape of the cone (or) a cone of different layers.

19)The drops that disperse red colour to our eye are on the outer most layer of the cone, similarly the drops that disperse orange colour to your eye are on the layer of the cone beneath the red colour cone.

20)In this way the cone responsible for yellow lies beneath orange and so on it till the violet colour cone becomes the innermost cone. (see in figure).

:he above figure shows the shape of the rainbow from the airplane.

BLUE COLOUR OF THE SKY:

1) It is our common experience that the sky appears blue in colour on a bright dry day.

SCATTERING OF LIGHT: Scattering of light is a complex phenomenon.

SCATTERING OF LIGHT (DEFINITION):

The process of re-emission of absorbed light in all directions with different intensities by atoms or molecules is called scattering of light.

EXPLANATION OF SCATTERING OF LIGHT:

1) Atoms or molecules which are exposed to light absorb light energy and emit some part of the light energy in different directions. This is the basic process happens in scattering of light.

2) The effect of light on a molecule or an atom depends on the size of atom or molecule.

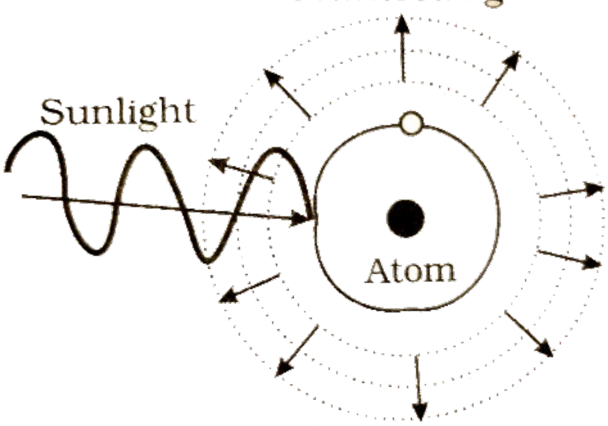
3) If the size of the particle (atom or molecule) is small, it will be affected by higher frequency (lower wave length) light and vice versa.

4) Let us consider that a certain frequency of light is incident on an atom and then the atom comes into vibration due to this light.

5) This in turn releases or re-emits light in all directions with different intensity.

6) The intensity of light is the energy of light passing through unit area of plane, taken normal to the direction of propagation of light, in one second.

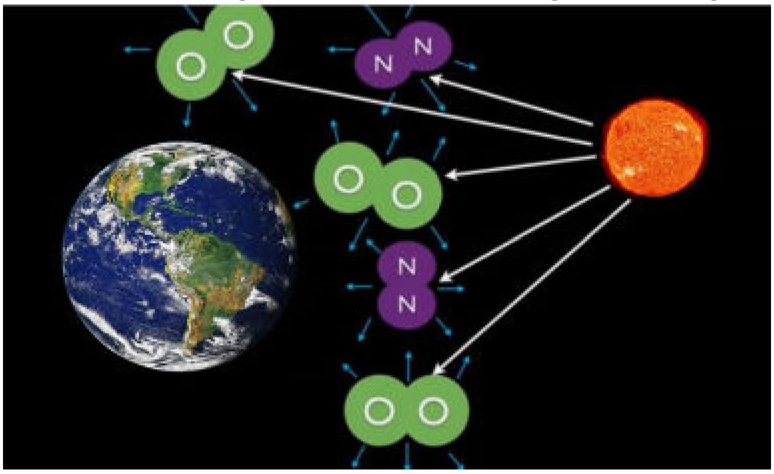
7) Let us consider that the free atom or free molecule is somewhere in space as shown in figure.



8) When light of certain frequency falls on that atom or molecule, it responds to the light whenever the size of the atom or molecule is comparable to the wave length of light.
9) If this condition is satisfied, the atom absorbs light and vibrates.
10) Due to these vibrations, the atom re-emits a certain fraction of absorbed energy in all directions with different intensities.
11)The re-emitted light is called scattered light and the process of re-emission of light in all directions with different intensity is called scattering of light and the atoms or molecules are called scattering centre.
12) Let us take the angle "θ" between the incident light and a direction in which the intensity of scattered light is observed, we call this angle as angle of scattering.
13)It is experimentally observed that the intensity of scattered light varies with angle of scattering.
14)The intensity is maximum at 900 angle of scattering.
15)This is the reason for the appearance of clear blue colour when look at the sky in a direction perpendicular to the direction of the sun rays.
16)If our angle of view is changed, the intensity of blue colour also changes.

REASON FOR THE BLUE OF THE SKY:

1) Our atmosphere contains different types of molecules and atoms.
2) The reason for blue sky is due to the molecules N2 and O2.
3) The sizes of these molecules are comparable to the wavelength of blue light.
4) These molecules act as scattering centres for scattering of blue light.



APPRECIATION ON THE ROLE OF MOLECULES IN THE ATMOSPHERE FOR THE BLUE COLOUR OF THE SKY:

1) Our atmosphere contains different types of molecules and atoms.
2) The reason for blue sky is due to the molecules N2 and O2.
3) The sizes of these molecules are comparable to the wavelength of blue light.
4) These molecules act as scattering centres for scattering of blue light.
5) So, I Appreciate the role of molecules in the atmosphere for the blue colour of the sky.

REASON FOR THE SKY APPEARS WHITE ON A HOT DAY:

1) Our atmosphere contains atoms and molecules of different sizes.
2) According to their sizes, they are able to scatter different wavelengths of light.
3) For example, the size of the water molecule is greater than the size of the N2 or O2.
4) It acts as a scattering centre for other frequencies which are lower than the frequency of blue light.

5) On a hot day, due to rise in the temperature water vapour enters into atmosphere which leads to abundant presence of water molecules in the atmosphere.
6) These water molecules scatter the colours of other frequencies (other than blue).
7) All such colours of other frequencies reach our eye and the sky appears white.

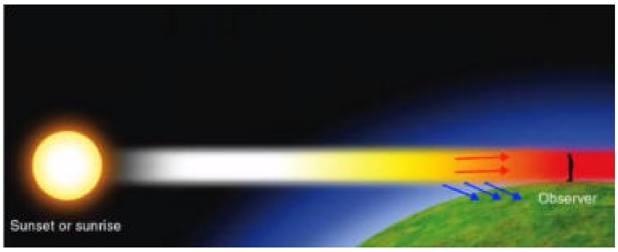
DEMONSTRATION OF SCATTERING OF LIGHT (ACTIVITY):

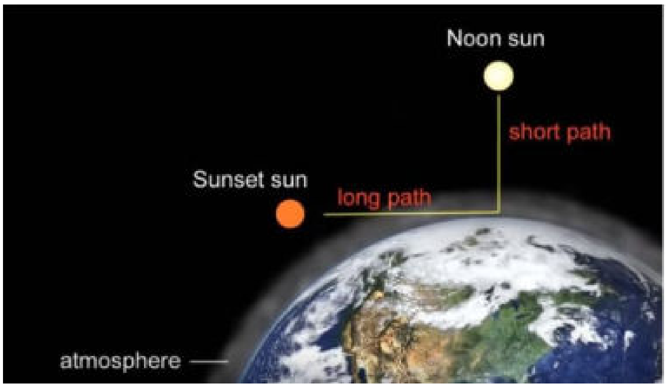
1) Take a solution of sodium-thio-sulphate (hypo) and sulphuric acid in a glass beaker and place the beaker in an open place where abundant sun light is available.
2) Watch the formation of grains of sulphur and observe changes in the beaker.
3) We will notice that sulphur precipitates as the reaction is in progress.
4) At the beginning, the grains of sulphur are smaller in size and as the reaction progresses, their size increases due to precipitation.
5) Sulphur grains appear blue in colour at the beginning and slowly their colour becomes white as their size increases.


6) The reason for this is scattering of light.
7) At the beginning, the size of grains is small and almost comparable to the wave length of blue light.
8) Hence they appear blue in the beginning.
9) As the size of grains increases, their size becomes comparable to wave lengths of other colours. As a result of this, they act as scattering canters for other colours.
10)The combination of all these colours appears as white.

REASON FOR THE SUN APPEARS RED IN COLOUR DURING SUNRISE AND SUNSET:

1) The atmosphere contains free molecules and atoms with different sizes.
2) These molecules and atoms scatter light of different wavelengths which are comparable to their size.
3) Molecules having a size that is comparable to the wavelength of red light are less in the atmosphere.
4) Hence scattering of red light is less when compared to the other colours of light.
5) The light from the sun needs to travel more distance in atmosphere during sunrise and sunset to reach our eye.
6) In morning and evening times, during sunrise and sunset, except red light all colours scatter more and vanish before they reach us.
7) Since scattering of red-light is very small, it reaches us.
8) As a result sun appears red in colour during sunrise and sunset.





THE REASON FOR THE SUN DOES NOT APPEAR RED DURING NOON HOURS (OR) THE REASON FOR THE SUN APPEARS WHITE DURING NOON HOURS:

1) During noon hours, the distance to be travelled by the sun rays in the atmosphere is less than that compared to morning and evening hours.
2) Therefore all colours reach your eye without much scattering.
3) Hence the sun appears white during noon hours.

REASON FOR THE GLASS IS KNOWN TO BE A TRANSPARENT MATERIAL, BUT GROUND GLASS IS OPAQUE AND WHITE IN COLOUR.

1) In general glass is a transparent material because it transmits most of the light incident on it.
2) When glass is ground, its surface becomes rough.
3) When light is incident on such a rough surface, it is reflected in many different directions and appears like blur.
4) Due to this reason ground glass is opaque and white in colour.

REASON FOR A WHITE SHEET OF PAPER IS STAINED WITH OIL THEN IT TURNS TRANSPARENT:

1) The refractive index of oil and refractive index of paper is same.
2) When a white sheet of paper is stained with oil then light passes from oil to paper without scattering.
3) Hence the paper becomes transparent.

REASON FOR THE OCEAN APPEARS BLUE (OR) THE WATER IN SEA APPEARS BLUE:

1) The ocean appears blue because red, orange and yellow of longer wavelength light are absorbed more strongly by water than is blue of shorter wavelength light.
2) When white light from the sun enters the ocean, it is mostly the blue that gets returned and the ocean appears blue just like the sky appears blue.

SIR C.V.RAMAN AND RAMAN EFFECT:

1) Our beloved scientist and Noble prize winner, Sir C.V.Raman explained the phenomenon of light scattering in gases and liquids.
2) He found experimentally that the frequency of scattered light by the liquids is greater than the frequency of incident light. This is called Raman Effect.
3) By using this effect scientists determine the shapes of the molecules.

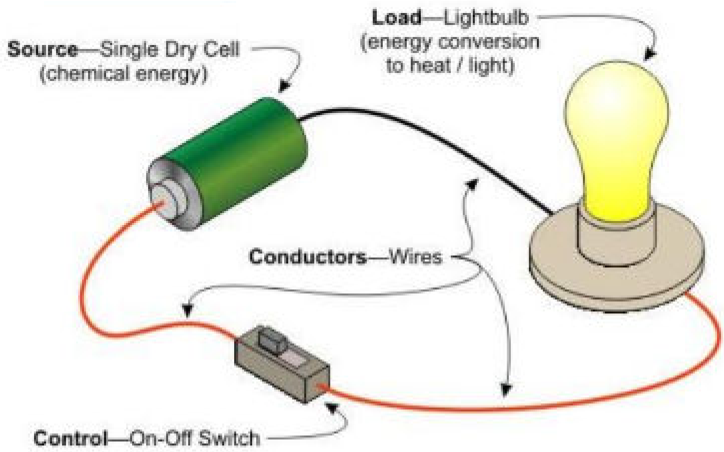
9.ELECTRIC CURRENT

INTRODUCTION

1) We had learnt about electric current, battery, electric circuit and its components in previous classes.
2) Lightning: Lightning is an electric discharge between two clouds or between cloud and earth.
3) This electric discharge through air appears to us as an electric spark or lightning.
4) Lightning is a live example which provides evidence for the motion of charge in the atmosphere.

OBSERVING THE NATURE OF THE SUBSTANCE PLAYS AN IMPORTANT ROLE IN THE TRANSFER OF ENERGY FROM BATTERY TO BULB (ACTIVITY): SITUATION 1:

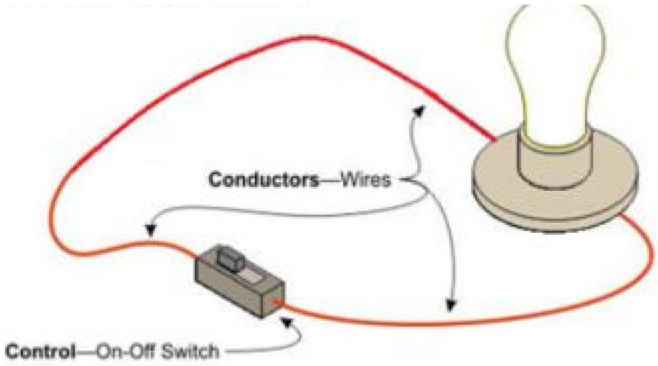
1) Take a bulb, a battery, a switch and few insulated copper wires.
2) Connect the ends of the copper wires to the terminals of the battery through the bulb and switch.



3) Now switch on the circuit and observe the bulb.

SITUATION 2:

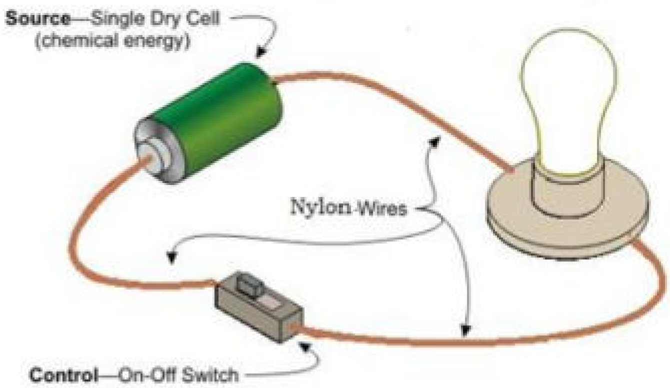
1) Remove the battery from the circuit and connect the remaining components to make a complete circuit.



2) Again switch on the circuit and observe the bulb.

SITUATION 3:

1) Replace the copper wires with nylon wires and connect the nylon wires to the terminals of the battery through a bulb and switch.



2) Now switch on the circuit and observe the bulb.]

3) After doing these activities we will notice that the bulb glows only in situation 1.

4) The battery store chemical energy and this energy converts into electric energy and makes the bulb to glow as we observed in situation 1 i.e. the battery supplies the required energy to make the bulb glow.

5) But in situation 3, though there is a battery in the circuit, the bulb does not glow because the connecting wires (nylon wires) are not able to carry the energy from source (battery) to bulb.

6) Hence, the nature of the substance plays an important role in the transfer of energy from battery to bulb.

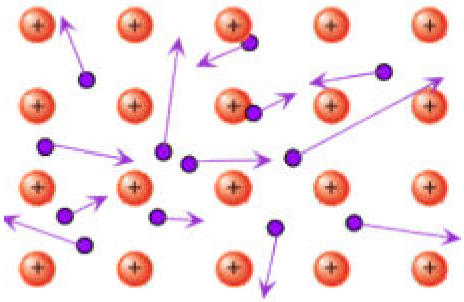
7) **CONDUCTOR:** The material which transfers energy from battery (source) to the bulb is called a conductor.

8) **NON CONDUCTOR:** The material which cannot transfer energy from battery (source) to the bulb is called a non conductor.

ELECTRIC CURRENT (OR) EXPLANATION OF, HOW ELECTRONS FLOW CAUSES ELECTRIC CURRENT WITH LORENTZ- DRUDE THEORY OF ELECTRONS:

1) Drude and Lorentz, scientists of the 19th century, proposed that conductors like metals contain a large number of free electrons while the positive ions are fixed in their locations.

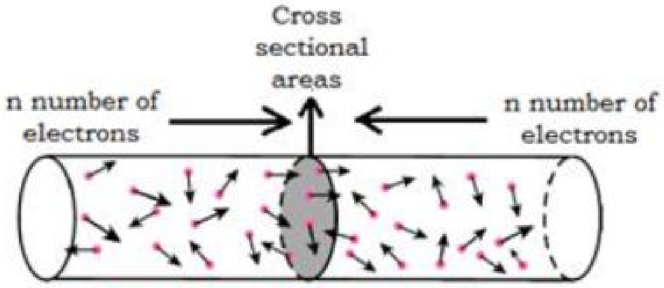
2) **LATTICE:** The arrangement of the positive ions is called lattice.



3) Assume that a conductor is an open circuit, then the electrons move randomly in lattice space of a conductor as shown in figure.

4) When the electrons are in random motion, they can move in any direction.

5) Hence, if we imagine any cross section as shown in figure, the number of electrons, crossing the cross section of a conductor from left to right in one second is equal to that of electrons passing the cross section from right to left in one second.



Random motion of electrons
(in open circuit)
Net Charge = 0

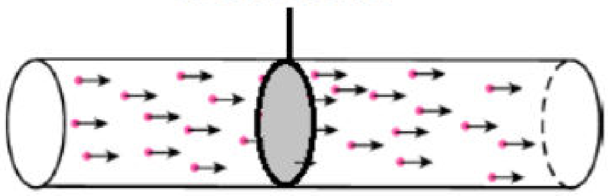
6) It means that net charge moving along a conductor through any cross section is zero when the conductor is in open circuit.

7) When the ends of the conductor are connected to the battery through a bulb, the bulb glows because energy transfer takes place from battery to the bulb.

8) The electrons are responsible for this transfer of energy.

9) If the electrons are responsible for transfer of energy from battery to bulb, they must have an ordered motion.

10) When the electrons are in ordered motion, there will be a net charge crossing through any cross section of the conductor.



Ordered motion of electrons
Net Charge ≠ 0

11) This ordered motion of electrons is called electric current.

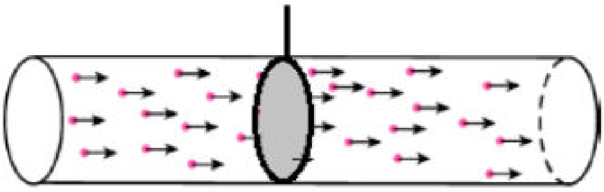
12) Thus we can say that electric current is ordered motion of charges.

ELECTRIC CURRENT (QUANTITATIVE DEFINITION):

Electric current is defined as the amount of charge crossing any cross section of the conductor in one second. (or) Electric current is expressed as the amount of charge flowing through a particular cross section area in unit time.

EXPLANATION:

1) Let Q be the charge crossing through any cross section of the conductor in a time interval t.



2) Then the amount of charge crossing through that cross section in one second is Q/t.

$$t \text{ sec} \rightarrow Q$$

$$1 \text{ sec} \rightarrow \frac{Q}{t} = I$$

3) Therefore,

$$Electric\ current\ (I) = \frac{Electric\ charge\ (Q)}{time\ interval\ (t)}$$

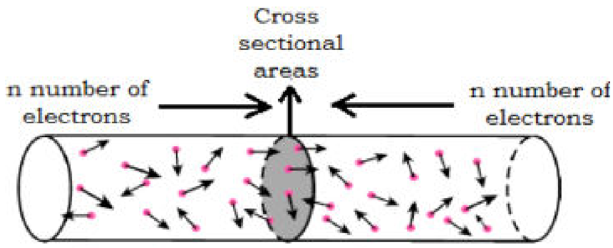
$$I = \frac{Q}{t}$$

SI unit of electric current: SI unit of electric current is ***ampere*** denoted by **A**.

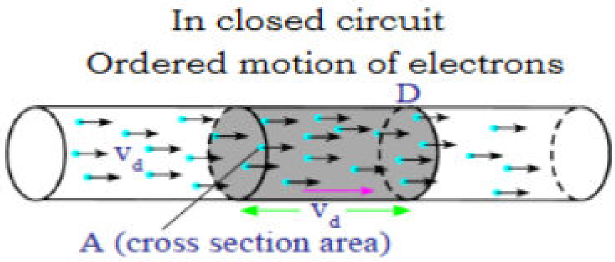
$$1\ Ampere = \frac{1\ Coulomb}{1\ second}$$

$$1\ A = \frac{1C}{1\ S}$$

4) When the conductor is not connected to the circuit through a battery, the electrons inside the conductor are in random motion but when the conductor is connected to a battery, the electrons move in a specified direction.

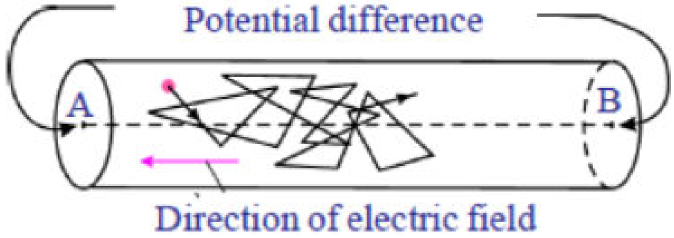


Random motion of electrons
(in open circuit)



Drift of positive charges

5) This shows that something causes the electron to move it in a specified direction.
6) When the ends of the conductor are connected to the terminals of a battery a uniform electric field is set up throughout the conductor.
7) This field makes the electrons move in a specified direction.
circuit through a battery, the electrons inside the conductor are in random motion but when the conductor is connected to a battery, the electrons move in a specified direction.
5) This shows that something causes the electron to move it in a specified direction.
6) When the ends of the conductor are connected to the terminals of a battery a uniform electric field is set up throughout the conductor.
7) This field makes the electrons move in a specified direction.
8) The free electrons in the conductor are accelerated by the electric field and move in a direction opposite to the direction of the field because they are negatively charged and the electric field direction is defined as the direction of the force on a positive charge.
9) When electrons are in motion under the influence of the field, they collide with lattice (positive) ions, lose energy and may even come to a halt at every collision.
10) They are again accelerated by the electric field and make collisions with other lattice ions.
11) In this way they continue to move along the conductor. (The motion of electron is shown in figure.)



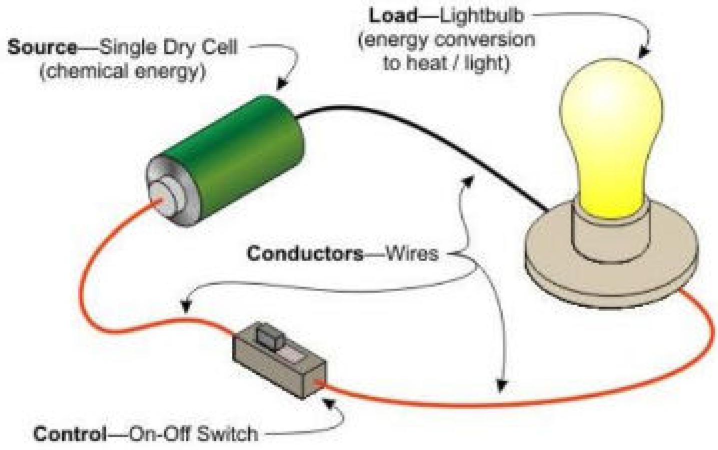
Motion of electron

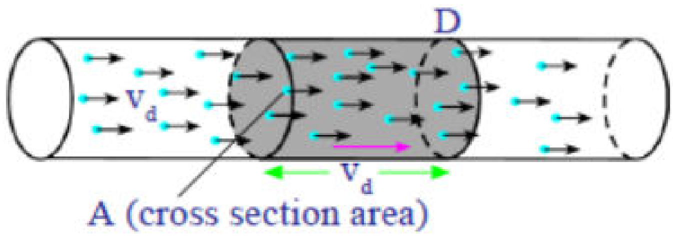
12) Hence, we assume that electrons in the conductor move with a constant average speed called as drift speed or drift velocity.

CALCULATION OF THE DRIFT SPEED OF FREE CHARGES QUANTITATIVELY:

1) Consider a conductor with cross sectional area A.

2) Assume that the ends of the conductor are connected to a battery to make the current flow through it.





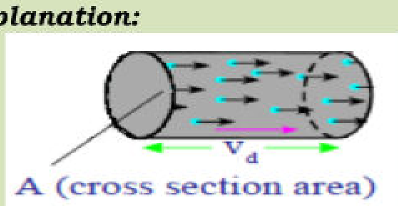
Drift of positive charges

3) Let vd be the drift speed of the charges as shown in figure and n be the number of charges present in the conductor in an unit volume (charge density).

4) The distance covered by each charge in one second is vd.

> ***Explanation:***
> ***speed*** = *distance/ time*
> → *distance = speed x time*
> → *distance covered = drift speed x time*
> → *distance covered =* v_d *x 1 sec*
> → ***distance covered*** = v_d

5) Then the volume of the conductor for this distance is equal to Avd (see figure).

> ***Explanation:***
>
> 
>
>
> *In a cylinder*
> ***volume*** *= area of cross section x height,*
> *here area of cross section = A*
> *height =* v_d.
> *Therefore,*
> ***Volume of the conductor*** =
> *Area of cross section x distance covered*
> $= A \times v_d = Av_d$

6) The number of charges contained in that volume is equal to nAvd.

Explanation:
n be the number of charges present in the conductor in an unit volume, here the volume is ***Av_d****, therefore the number of charges contained in Av_d volume*

$$= n \times Av_d = nAv_d$$

7) Let q be the charge of each carrier, then the total charge crossing the cross sectional area at position D in one second is nqAvd.

Explanation:
q is the charge of each carrier and here we have ***nAv_d*** *carriers. So, the total charge crossing the cross sectional area A*

$$= q \times nAv_d = nqAv_d$$

8) This is equal to electric current.

Explanation:
electric current = the amount of charge crossing any cross section of the conductor in one second. Here $nqAv_d$ charge crossed the area of cross section A in one second.
So, ***electric current (I) = $nqAv_d$***

9. Hence, Electric current **$I = nqAv_d$** .... (1)
10.Therefore
drift speed of the charges (electrons)

$$V_d = \frac{I}{nqA} \quad ....(2)$$

NOTE: The charge carriers in a conductor are electrons and the magnitude of electric charge 'e' is 1.602×10^{-19} C.

CALCULATE THE DRIFT SPEED OF ELECTRON IN A COPPER WIRE:

1) Let us consider a copper wire carrying a current of 1A and cross sectional area A = 10^{-6} m^2.
2) The electron density (n) of copper is $8.5\times10^{28}m^{-3}$.
3) Then, I = 1A
   n = $8.5\times10^{28}m^{-3}$
   q = electron charge = 1.602×10^{-19}C

We have, drift speed of the charges (electrons)

$$V_d = \frac{I}{nqA}$$

on substituting the above values in the equation, then we get,

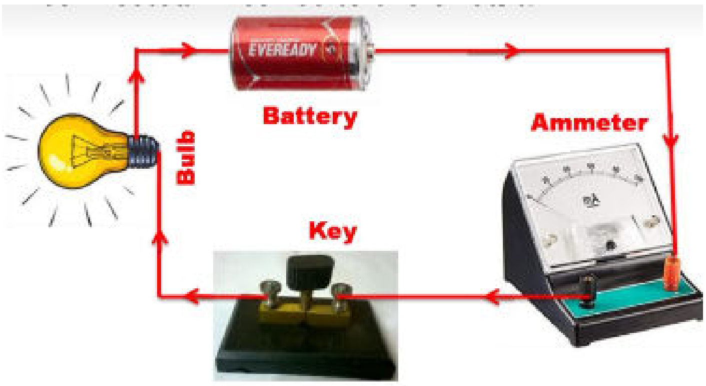
$$V_d = \frac{I}{(8.5X10^{28})X(1.602X10^{-19})X(10^{-6})}$$

$$v_d = 7x10^{-5}m/s = 0.07\ mm/s$$

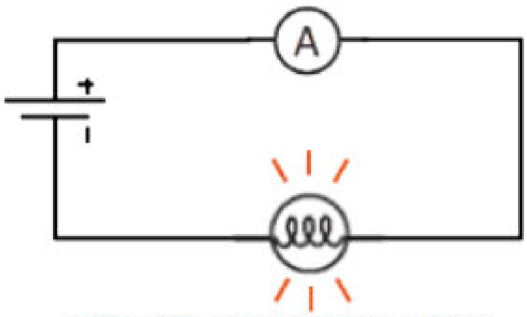
4) Means the electron moves with drift speed 0.07 mm/s. This shows that the electrons are moving very slowly.
5) When we switch on any electric circuit, irrespective of length of the connecting wire (conductor) an electric field is set up throughout the conductor instantaneously due to the potential difference of the source (battery) connected to the circuit.
6) This electric field makes all the electrons to move in a specified direction simultaneously.
7) The equation I = nqAvd Indicates that the values of n and A are positive. Because n indicates the number of charges (a positive number) and A indicates area of cross section (a positive number) and also these two are greater than zero.
8) Therefore the direction of electric current is determined by the signs of the charge q and drift speed vd.
9) For electrons (negative charges), q is negative and vd is positive (drift velocity is always positive).
10) Then the product of q and vd is negative.
(negative x positive = negative)
11) Therefore, for electrons, current I = (Positive value of n) x (Positive value of A) x (Negative value of q) x (Positive value of vd) = Negative value.
12) This negative sign shows that the direction of electric current is opposite to the flow of negative charge.
13) For positive charges the product of q and vd is positive. (positive x positive = positive) (Here vd is always positive)
14) Therefore for positive charges, current I = (Positive value of n) x (Positive value of A)x (Positive value of q) x (Positive value of vd) = Positive value.
15) Hence, the direction of electric current can be taken as the direction of flow of positive charges.

Ammeter Symbol

16) An ammeter is used to measure electric current and it is always connected in series to the circuit. A galvanometer is used to measure less electric current and it is also connected in series to the circuit.



Ammeter connected in series



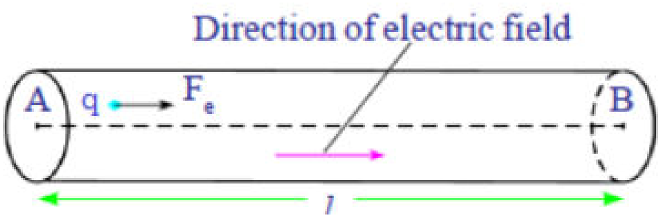
Ammeter connected in series
(Circuit diagram)

POTENTIAL DIFFERENCE (OR) VOLTAGE:

Electric potential difference between points in an electric circuit is the work done to move a unit positive charge from one point to another.

EXPLANATION:

1) When the ends of a conducting wire are connected to the terminals of a battery, an electric field is setup throughout the conductor.



2) This field exerts a force on the charge (electron).
3) Let Fe be the force exerted by the electric field on a free charge q.
4) The free charges accelerate in the direction of the electric field (If the free charges are electrons, then the direction of electric force on them is opposite to the direction of electric field).
5) It means the electric field does some work to move free charges in a specified direction.
6) Let the electric force made the charges move through a distance 'l' from A to B as shown in figure.
7) We know that, the work is the product of force and distance along the direction of force.
Work (W) = Force (F) x Distance (s)
8) Hence, work done by the electric force on a free charge q is given by

W = Fe l

(here Force (F) = Fe and distance (s) = length of the conductor from which the charge move = l)
9) Work done by the electric force on unit charge = W/q = Fe l /q 10) Work done by the electric force on unit positive charge to move it through a distance 'l' from A to B is called potential difference between those points.
11) Potential difference is denoted by a symbol V.
12) The potential difference between two points separated by a distance l in a conducting wire is given by,

$$V = W/q = Fe\, l / q$$

13)This potential difference is also called voltage.
14) The SI unit of potential difference is "Volt" and it is denoted by V.

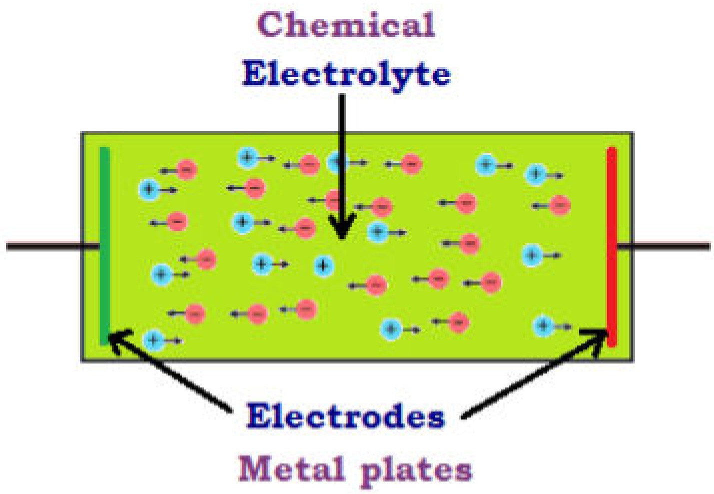
$$1\text{ Volt} = 1\text{ Joule}/1\text{ Coulomb}$$
$$1V = 1J/C$$

15) When electric current is allowed to pass through fluids, the positive ions (cations) and negative ions (anions) move in opposite directions.
16) The direction of the motion of positive charges in an electrolyte is always in the direction of the electric field while negative charges move in a direction opposite to that of positive charges.
17) Thus for conduction in fluids there exist motion of both positive and negative charges.
18) Whereas in case of metal conductors there will be only motion of electrons. (The positive charges are fixed in the lattice) 19) If positive charges move from point A to B in a conductor, the electric field does positive work, so W/q is positive for free positive charges.
20) We can say that the direction of the electric field is from A to B and the point A is at high potential and point B is at low potential.
21) As negative charges always move in a direction opposite to the electric field we consider that electrons move from low potential to high potential.
22) We know that in a battery or cell a constant potential difference is maintained till the battery is completely discharged.

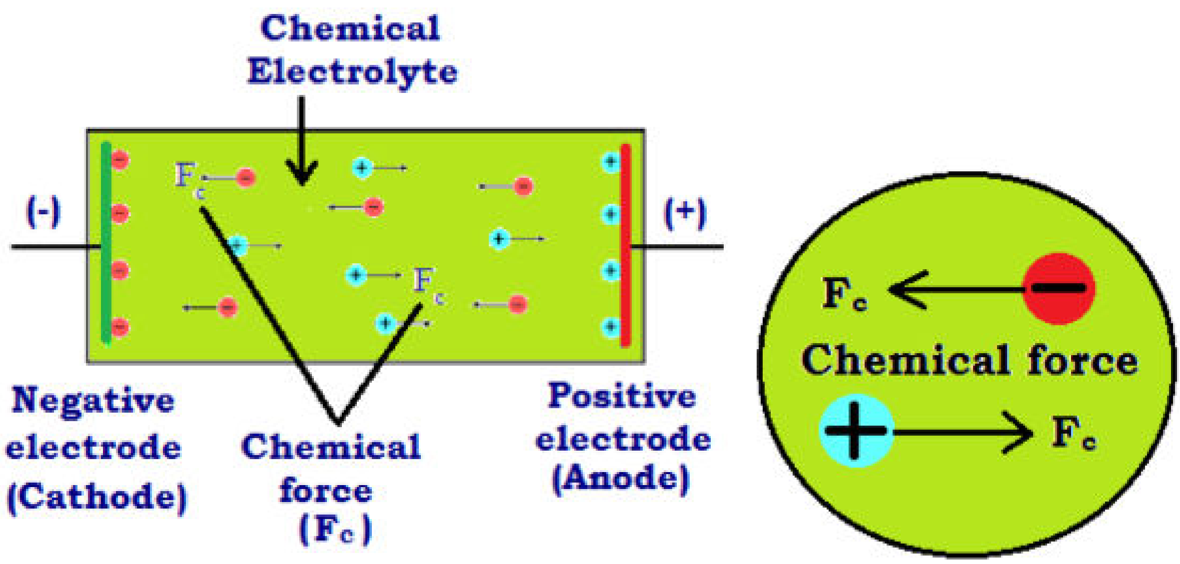
STRUCTURE OF A BATTERY:

1) A battery consists of two metal plates (electrodes) and a chemical (electrolyte).
2) The electrolyte (chemical) consists of positive and negative ions.

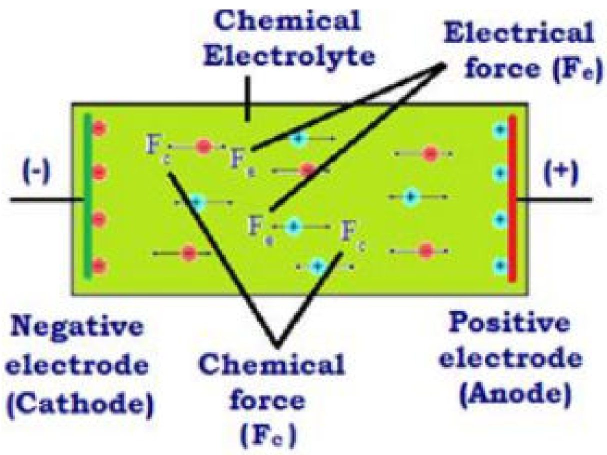
3) When we setup two different metal plates in the electrolyte, in the presence these two different metal plates, a chemical reaction starts in the electrolyte (chemical).
4) Due to this reaction, positive and negative ions in the electrolyte move in opposite directions (see the figure).

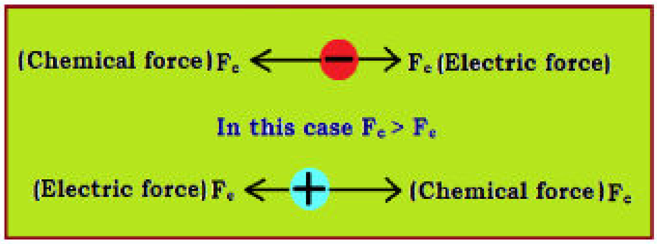


5) The electrolyte exerts a certain force on these ions and makes them move in a specified direction.
6) Let us call this force as a chemical force (Fc).
7) Depending upon the nature of the chemical, positive ions move towards one of the plates and accumulate on that plate.
8) As a result of this accumulation of charges on this plate it becomes positively charged (called anode).
9) Negative ions move in a direction opposite to the motion of positive ions and accumulate on the other plate.
10) As a result of this, the plate becomes negatively charged (called cathode).



11) This accumulation of different charges on respective plates continues till both plates are sufficiently charged.
12) But the ions in motion experience another force (repulsive force of like charges) when sufficient number of charges are accumulated on the plates.
13) Let us call this force as electric force (Fe).

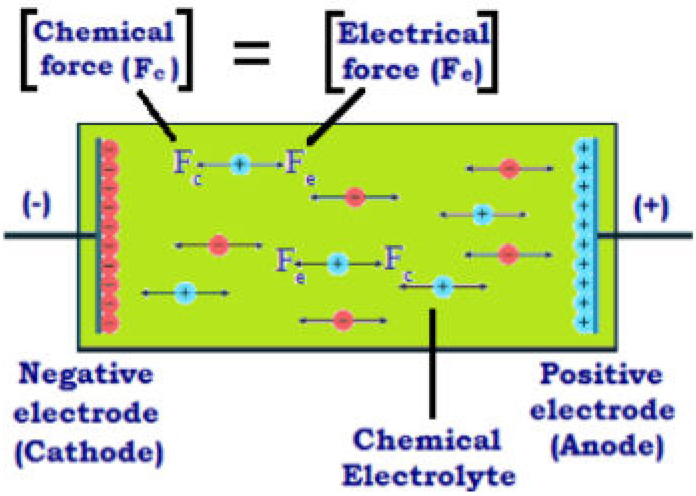


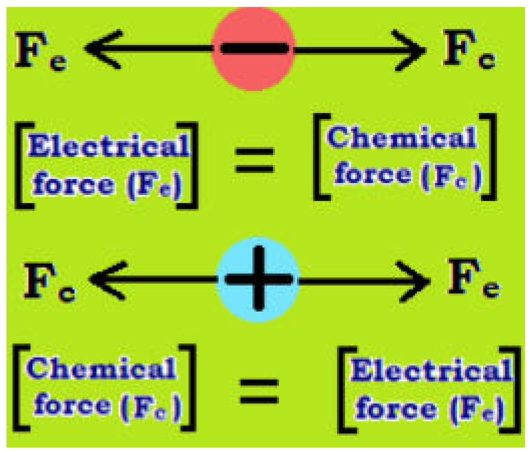


14) The direction of this force is opposite to the direction of chemical force Fc and the magnitude of this force depends on the amount of charge accumulated on the plates.

15) The motion of ions continue towards their respective plates if the chemical force Fc is stronger than electric force Fe (See the above figure).

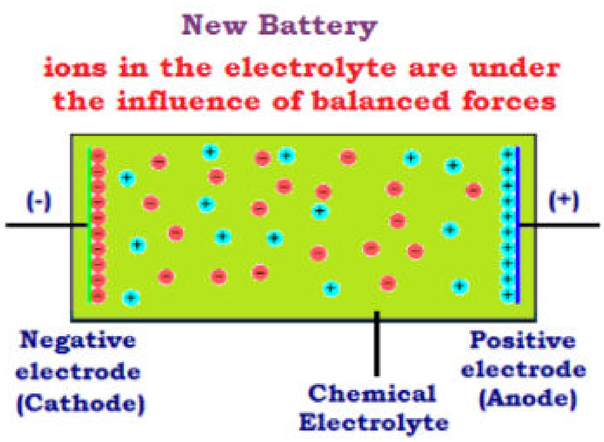
16) The accumulation of charges on plates is continuous till the electric force Fe becomes equal to chemical force Fc (as shown below).





17) At this situation there will not be any motion in ions due to balance of forces Fe and Fc (It is shown in the above figure).

18) The new battery that we buy from the shop is at a stage where the ions in the electrolyte are under the influence of balanced forces.



19) The reason for the constant potential difference between the terminals of a battery is the ions in the electrolyte of the battery are under the influence of balanced forces.

20) The amount of charge accumulated on the plates depends on nature of the chemical used in the battery (rate of chemical reaction in the electrolyte depends upon its nature).

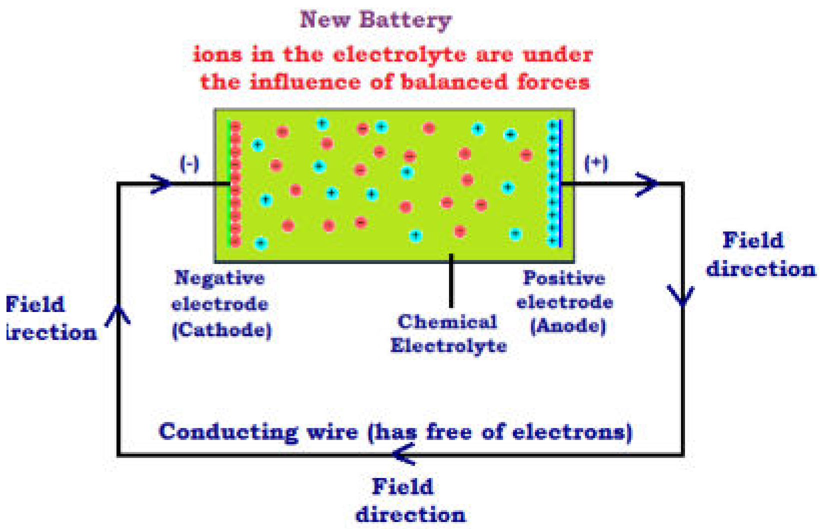
WORKING OF A BATTERY:

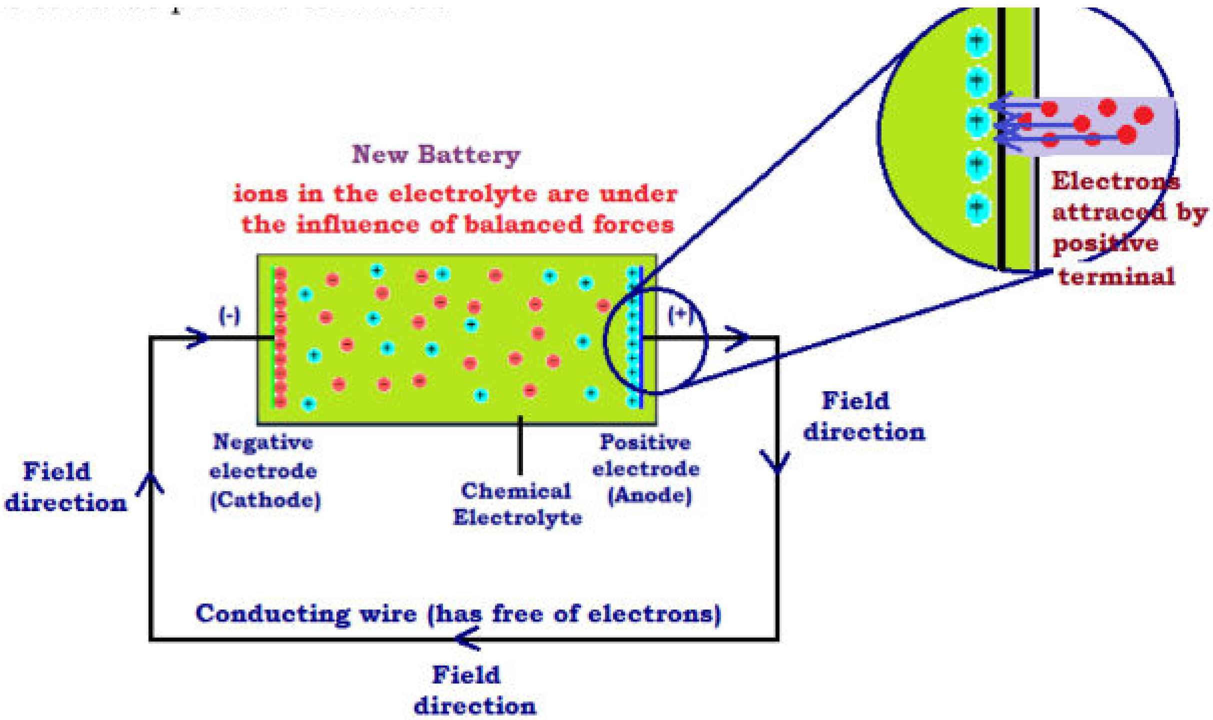
1) When a conducting wire is connected to the terminals of the battery, a potential difference is created between the ends of the conductor.

2) This potential difference sets up an electric field throughout the conductor (the direction of electric field is from positive terminal to negative terminal in the conductor).

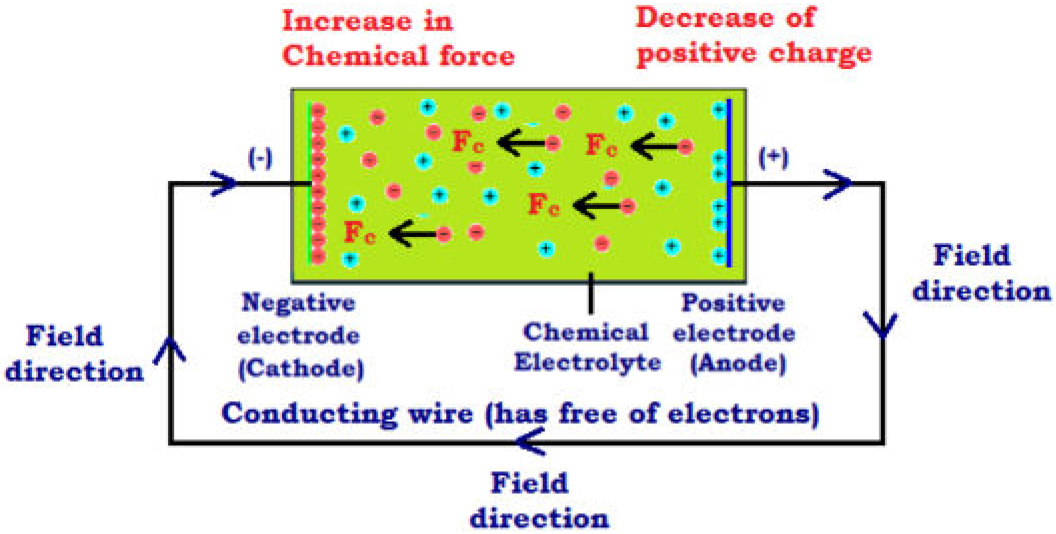
3) We know that the conductor contains large number of electrons.

4) The electrons near the positive terminal of the battery are attracted by it and start to move towards positive terminal.

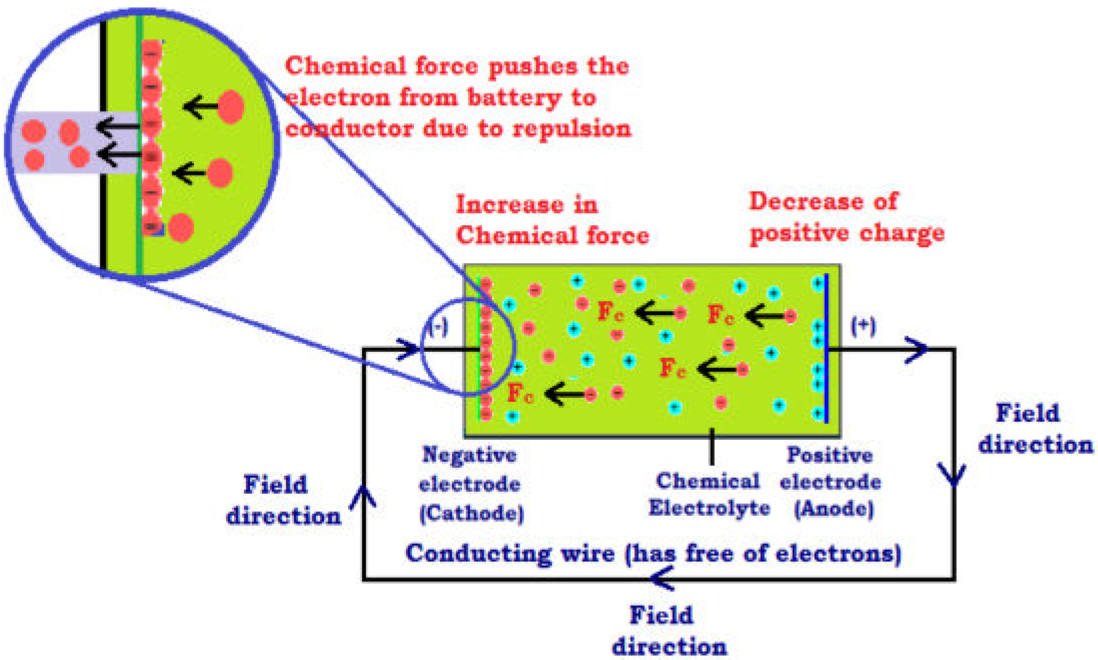




5) As a result, the amount of positive charge on this plate decreases.
6) So the electric force Fe becomes weaker than chemical force Fc and chemical force pulls negative ions from the positive plate (anode) and makes them move towards the negative plate (cathode).



7) The negative terminal pushes one electron into the conductor because of stronger repulsion between negative terminal and negative ion.



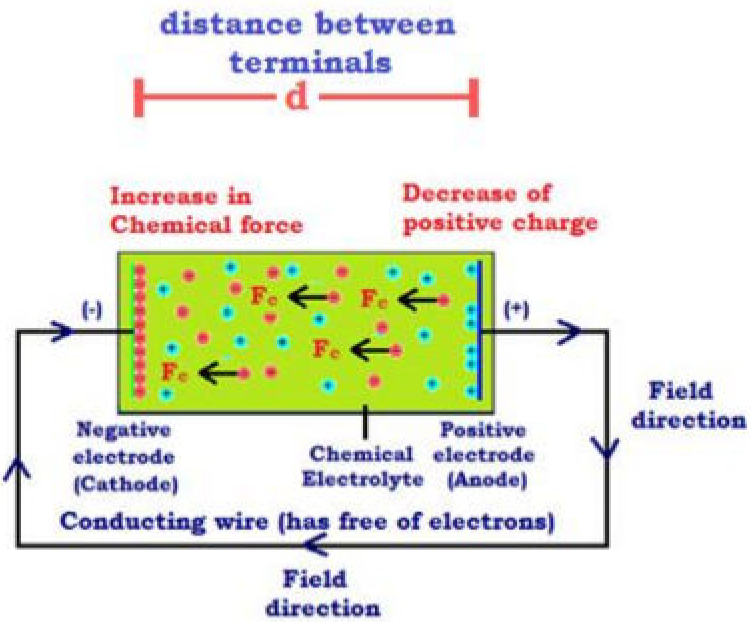
8) Hence, the total number of electrons in the conductor remains constant during the current flow.
9) At a certain time, the rate of chemical reaction in the electrolyte is decreases gradually.
10) Due to this, the battery power user in the circuit, like bulb, gradually decreases its light intensity of work efficiency.
11) The above said process continuous till equilibrium is attained between the forces Fe and Fc.
12) At that position the battery doesn’t give energy in the circuit and is said to be in discharge position.

EXPLANATION, HOW THE BATTERY DISCHARGES?

1. The battery works due to the chemical reaction in the electrolyte.
2. The power of battery (emf) is depends upon the rate of chemical reaction in the electrolyte.
3. When we connect the battery in the circuit, it gives energy to the electrons in the conductor to make them into move.
4. The battery's energy utilizes by the device, which is connected in the circuit say bulb).
5. As the energy of chemical (electrolyte) decreases, the rate of chemical reaction of electrolyte decreases gradually and becomes zero.
6. In this position the emf of battery is zero and is said to be discharged.

ELECTROMOTIVE FORCE (EMF)

1) When the ends of the conductor are connected to the terminals of a battery, the electrons in the conductor move with a drift speed from negative terminal to positive terminal because of the electric force acting on them.
2) At the same time negative ions of equal amount of charge move from positive terminal to negative terminal against the electric force (Fe) because of the chemical force acting on them within battery.
3) Thus, some chemical energy is spent to move ions in the battery.
It means that an amount of work is done by the chemical force (Fc).
4) Let us assume that work done by the chemical force to move a negative charge q from positive terminal to negative terminal against the electric force Fe be 'W' and also assume that the magnitude of chemical force Fc is equal to magnitude of electric force (Fe).



5) The work done on negative charge q by the chemical force,

$$W = \text{force x distance} = Fc \times d$$

Here 'd' is the distance between the terminals.
6) Then work done by the chemical force to move 1 Columb charge from positive terminal to negative terminal is given by,

$$W/q = (Fc \times d)/q$$

[Work done for q Columb W Work done for 1 Columb W/q] We know that Fc = Fe, then we get, W/q = (Fe x d)/q 7)

This W/q is the work done by the chemical force on unit negative charge to move it from positive terminal to negative terminal.

This is called emf (ε).

$\varepsilon = W/q$

$\varepsilon = Fed/q$

8) Generally, emf is defined as the work done by the chemical force to move unit positive charge from negative terminal to positive terminal of the battery.

9) Generally a volt meter is used to measure potential difference or emf across an electric device like battery.

10)It must be connected in parallel to the electric device to measure the potential difference across the ends of the electric device.

11)When a battery in a torch is used for several weeks, the light from its bulb becomes dim. We say that the battery or cell in the torch is discharged.

12)It means the battery chemical energy decreases; the chemical force and the electric force become equal.

DIFFERENCE BETWEEN POTENTIAL DIFFERENCE AND EMF:

POTENTIAL DIFFERENCE	EMF
1) **Def:** Electric potential difference between points in an electric circuit is the work done to move a unit positive charge from one point to another.	1) EMF is defined as the work done by the chemical force to move unit positive charge from negative terminal to positive terminal of the battery.
2) Potential difference = V = W/q = Fel/q	2) emf = W/q = Fed/q
3) SI unit of Potential difference = Volt	3) SI unit of emf = Volt
4) Potential difference can be measured by Voltmeter.	4) emf can be measured by Voltmeter.
5) It is the potential difference that the terminals of the celll when it is delivering the current i.e circuit is closed	5) It is the potential difference across the terminals of the cell when it is delivering no current i.ewhen the cell is in open circuit.
6)It depends on circuit resistance and circuit current.	6)It is independent of circuit resistance and depends upon nature of elctrodes and electrolyte.
7)It causes current to flow in the circuit.	7)It maintains potential difference.
8)It is smaller than E.	8)It is greater than V.

Volt meter symbol

OHM'S LAW

1) OHM'S LAW: The current through a conductor element is proportional to the potential difference applied between its ends, provided the temperature remains constant. (or) The potential difference between the ends of a conductor is directly proportional to the electric current passing through it at constant temperature.

2) Ohm's law equation:

$$V=IR$$

In this, V = Potential difference
I = Current
R = Resistance

3) Ohm's law is valid for metal conductors at constant temperature.

4) Ohm's law is not applicable for gaseous conductors and semiconductors.

GEORGE SIMON OHM:

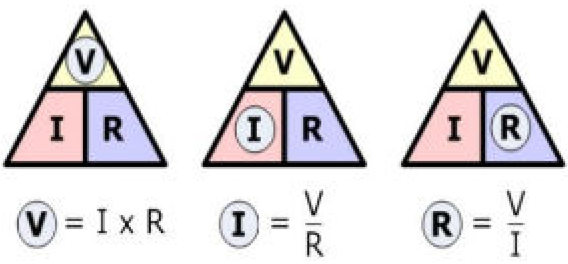
1) Georg Simon Ohm was a German physicist and mathematician.

2) As a school teacher, Ohm began his research with the new electrochemical cell, invented by Italian scientist Alessandro Volta.

3) Using equipment of his own creation, Ohm found that there is a direct proportionality between the potential difference (voltage) applied across a conductor and the resultant electric current. This relationship is known as Ohm's law.

4) In 1881, after his death, the SI unit for electrical resistance was named Ohm in his honour. The uppercase Greek letter Omega (Ω) is used for the unit.

Ohm's Law Triangle



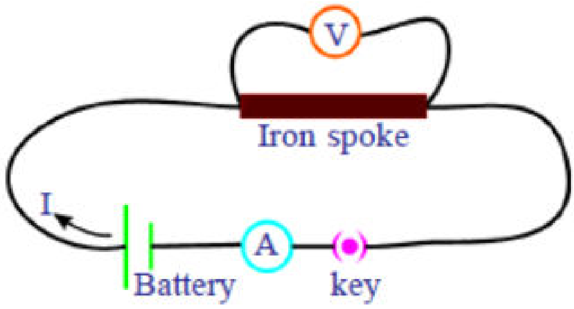
OHM'S LAW (ACTIVITY) (OR) OHM'S LAW PROOF (OR) ACTIVITY TO SHOW THAT THE RATIO V/I IS A CONSTANT FOR A CONDUCTOR:

AIM: To show that the ratio V/I is a constant for a conductor.

MATERIALS REQUIRED: 5 dry cells of 1.5V each, conducting wires, an ammeter, a volt meter, thin iron spoke of length 10cm, LED and key.

PROCEDURE:

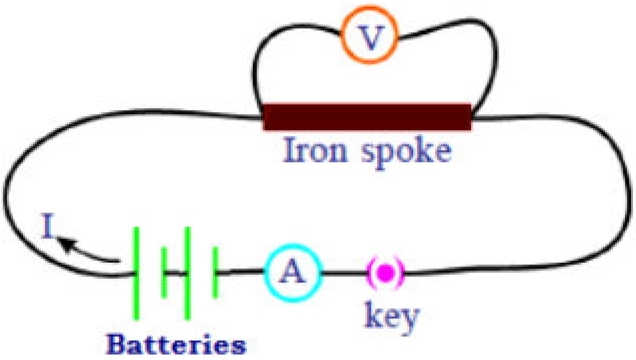
1) Connect a circuit as shown in figure.



2) Solder the conducting wires to the ends of the iron spoke and close the key.
3) Note the readings of current from ammeter and potential difference from volt meter in table.

SL. NO.	POTENTIAL DIFFERENCE (V)	CURRENT(I)	V/I
1			
2			
3			

4) Now connect two cells (in series) instead of one cell in the circuit and note the respective readings of the ammeter and volt meter and record the values in table.

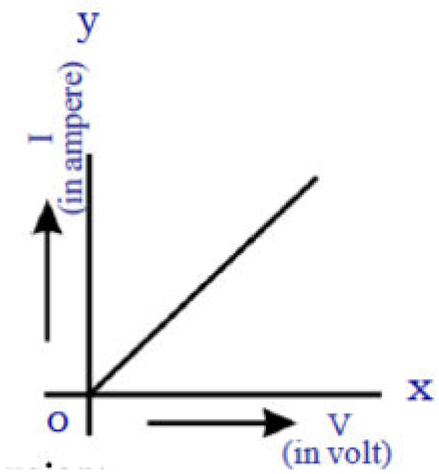


5) Repeat the same for three cells, four cells and five cells respectively and record the values of potential difference (V) and current (I) corresponding to each case in the table.
6) Find V/I for each set of values.
7) Then we notice that the ratio V/I is a constant.

GRAPH:

1) Draw a graph between V and I taking the current (I) along y-axis and potential difference (V) along x-axis with appropriate scale.

2) We will get a straight line graph passing through the origin as shown in figure.



CONCLUSION:

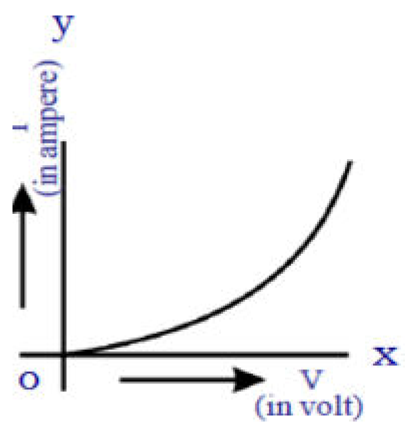
1) From this experiment we can conclude that the potential difference between the ends of the iron spoke (conductor) is directly proportional to the current passing through it (assuming the temperature of the iron spoke is constant during the flow of current through it).

RESULT:

Hence the Ohm's law proved.

EXPERIMENT WITH LED:

1) Repeat the process by using a LED instead of iron spoke.
2) The long terminal of the LED is connected to the positive terminal of the battery and short terminal of the LED is connected to negative terminal of the battery.
3) Note the values of current 'I' and potential difference 'V' in each case and record the values in table.
4) Find V/I for each set of values I and V.
5) We will notice that the ratio V/I is not a constant.
6) Draw a graph between V and I for LED.
7) We will get a curved graph as shown in figure.



8) From the above lab activity we can conclude that the ratio between V and I is constant for some materials at constant temperature.
9) This fact was established by German Physicist, George Simon Ohm and it is popularly known as Ohm's law.

10) **OHM'S LAW:** The potential difference between the ends of a conductor is directly proportional to the electric current passing through it at constant temperature.

OHM'S LAW EQUATION DERIVATION:

1) Let V be the potential difference between the ends of the conductor and I be the current passing through it.

$$V \propto I \text{ (temperature is constant)}$$
$$V/I = \text{constant}$$

2) This constant is called resistance of the conductor and is denoted by 'R'.
3) Then we get $V/I = R \rightarrow V = IR$
4) The SI unit of resistance is ohm. The symbol of ohm is Ω.
5) 1 ohm = 1 Volt/1 Ampere

$$1\ \Omega = 1V/A$$

6) Based on Ohm's law materials are classified into two categories.
7) **OHMIC MATERIALS:** The materials, which obey Ohm's law are called Ohmic materials.
8) Examples of Ohmic materials: Metals
9) **NON OHMIC MATERIALS:** The materials, which do not obey Ohm's law are called non Ohmic materials.
10) Examples of Non Ohmic materials: LEDs

LIMITATIONS OF OHM'S LAW

1) Ohm's law is valid for metal conductors provided the temperature and other physical conditions remain constant.
2) The resistance of the material changes with temperature.
3) Hence for changing temperature the V-I graph for a conductor will be non-linear.
4) Ohm's law is not applicable to gaseous conductors.
5) It is also not applicable to semiconductors such as germanium and silicon.
6) When a conductor is connected to a battery the free electrons start moving with a drift speed in a specified direction.
7) During the motion, the electrons collide with positive ions (fixed) of the lattice and come to halt.
8) This means that they lose mechanical energy in the form of heat.
9) Due to the electric field that was set up by the battery throughout the conductor, these electrons regain the energy from the field and proceed to move.
10)The motion of electrons is obstructed by the lattice ions.
11)The obstruction offered to the flow of electrons in a conductor by lattice ions depends upon the nature of the material.
12)Therefore, the resistance of a conductor is defined as the obstruction to the motion of the electrons in a conductor.
13)The material which offers resistance to the motion of electrons is called resistor.

NOTE: A multi-meter is an electronic measuring instrument that combines several measuring functions (electric potential difference, electric current and electric resistance) in one unit.

ELECTRIC SHOCK

1. The resistance of the human body generally varies from 100 Ω (if body is wet with salt water) to 5,00,000 Ω (if the skin is very dry).

CALCULATION OF THE AMOUNT OF CURRENT THAT FLOWS THROUGH THE HUMAN BODY:

1) Let us assume you have touched the two electrodes of a battery of 24V with dry fingers in such a way that the circuit is complete.

2) Let your body resistance be 1,00,000 Ω.

3) Then the current flowing through your body

$$\text{is given by } I = \frac{24}{100000} = 0.00024\ A$$

$$here, V = 24V\ and\ R = 1,00,000\ \Omega$$

$$\left[V = IR \rightarrow \ I = \frac{V}{R}\right]$$

4) This current is very small.

5) When such small current passes through the human body, it does not affect the functioning of various organs inside the body.

6) The current passing through our body when we touch a live wire of 240V is given by

$$I = \frac{240}{100000} = 0.0024\ A$$

7) When this quantify of current flows through the body the functioning of organs inside the body gets disturbed.

8) This disturbance inside the body is felt as electric shock.

9) If the current flow continues further, it damages the tissues of the body which leads to decrease in resistance of the body.

10) When this current flows for a longer time, damage to the tissues increases and thereby the resistance of human body decreases further.

11) Hence, the current through the human body will increase.

12) If this current reaches 0.07A, it effects the functioning of the heart and if this much current passes through the heart for more than one second it could be fatal.

13) If this current flows for a longer time, the person in electric shock is being killed.

Current in ampere	Effect
0.001	Can be felt
0.005	Is painful
0.010	Cause involuntary muscle contractions (spasms)
0.015	Causes loss of muscle control
0.070	If through the heart, causes serious disruption : probably fatal if current lasts for more than 1s

14)We can conclude that an electric shock can be experienced when there is a potential difference exists between one part of the body and another part.

15)When current flows through human body, it chooses the path which offers low resistance.

16)The resistance of a body is not uniform throughout it. For example, skin offers more resistance than the organs inside the body.

17)As long as current flow continues inside the body the current and resistance of human body goes on changing inversely.

18)Hence, the electric shock is a combined effect of potential difference, electric current and resistance of the human body.

REASON TO A BIRD DOESN'T GET A SHOCK WHEN IT STANDS ON A HIGH VOLTAGE WIRE:

1) There are two parallel transmission lines on electric poles.
2) The potential difference between these two lines is 240V throughout their lengths.
3) If we connect any conducting device across these two wires, it causes current to flow between the wires.
4) When the bird stands on a high voltage wire, there is no potential difference between the legs of the bird because it stands on a single wire.
5) So no current passes through the bird.
6) Hence, it doesn't feel any electric shock.

FACTORS AFFECTING THE RESISTANCE OF A MATERIAL:

Resistance of a material depends upon,
1) Temperature
2) Nature of material
3) Length of the conductor
4) Cross section area

1. TEMPERATURE AND RESISTANCE (ACTIVITY): (OR)

VERIFICATION OF THE RESISTANCE OF A CONDUCTOR IS TEMPERATURE DEPENDENT:

1) Measure the resistance of the bulb when it is in open circuit using a multi meter.
2) To measure the resistance of a bulb, set the multi meter as ohm meter and place the multi meter knob at 20K Ω.
3) Now place the leads of the multi meter on the terminals of the bulb.

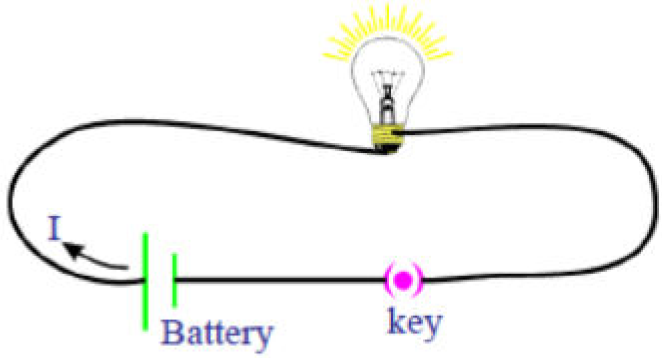
MULTIMETER READINGS:

4) The meter will show one of the following readings: 0.00 or 1 or the actual resistance of the bulb.

i. If the multi meter reads 0.00 or nearly 0, then we need to lower the mode to 2K Ω or 200 Ω.

ii. If the multi meter reads 1 or displays OL, its overloaded; we will need to try a higher mode such as 200K Ω or 2M Ω etc.

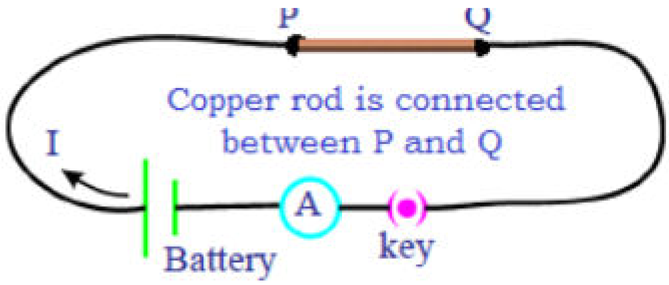
5) Note the value of resistance in your note book.
6) Connect a circuit with components as shown in figure and switch on the circuit.



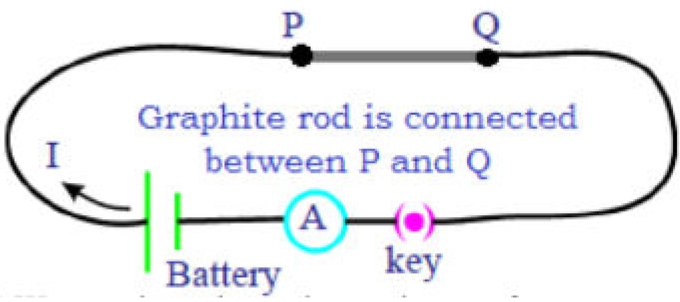
7) After few minutes, measure the resistance of the bulb again as explained above and note this value in your note book.
8) The value of resistance of the bulb in second instance is more than the resistance of the bulb in open circuit.
9) We will notice that the bulb gets heated.
10) The increase in temperature of the filament in the bulb is responsible for increase in resistance of the bulb.
11) Hence we can conclude that there is a relation between resistance of the bulb and its temperature.
12) Thus the value of resistance of a conductor depends on temperature for constant potential difference between the ends of the conductor.

2. NATURE OF MATERIAL AND RESISTANCE (ACTIVITY):

1) Collect different metal rods of the same length and same cross sectional area like Nichrome, Graphite, Copper, Aluminum, iron etc.
2) Make a circuit as shown in figure.



3) P and Q are the free ends of the conducting wires.
4) Connect one of the metal rods between the ends P, Q and switch on the circuit.
5) Measure the electric current using the ammeter connected to the circuit and note it in your notebook.
6) Repeat this with other metal rods and measure electric currents in each case.



7) We notice that the values of current are different for different metal rods for a constant potential difference.

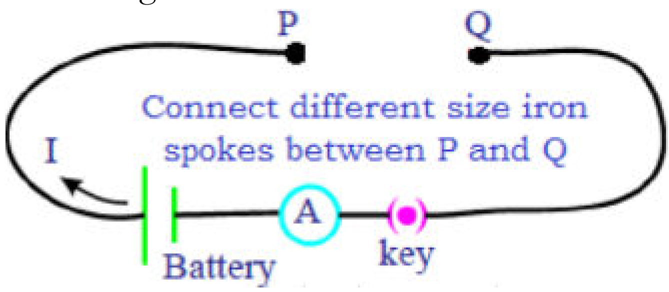
8) From this activity, we conclude that the resistance of a conductor depends on the material of the conductor.

DERIVATION OF R = ρ L/A:

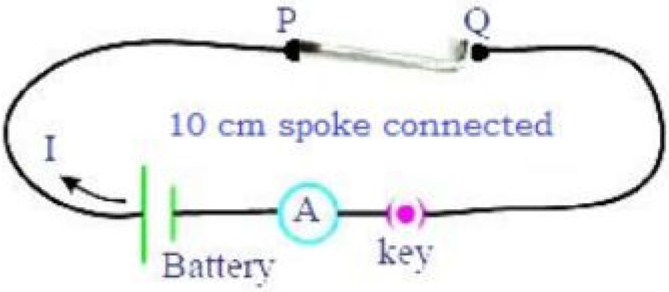
3. LENGTH OF THE CONDUCTOR AND RESISTANCE (ACTIVITY): (OR)

VERIFICATION THAT RESISTANCE OF A CONDUCTOR IS PROPORTIONAL TO THE LENGTH OF THE CONDUCTOR FOR CONSTANT CROSS SECTION AREA AND TEMPERATURE:

1) Collect iron spokes of different lengths with the same cross sectional areas.
2) Make a circuit as shown in figure.



3) Connect one of the iron spokes; say 10cm length, between P and Q.

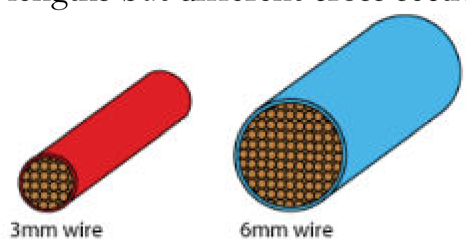


4) Measure the value of the current using the ammeter connected to the circuit and note the value in the note book.
5) Repeat this for other lengths of the iron spokes and note corresponding values of currents in the note book.
6) We notice that the current decreases with increase in the length of the spoke.
7) Thus the resistance of each spoke increases with increase in the length for a constant potential difference.
8) From this activity, we can conclude that the resistance (R) of a conductor is directly proportional to its length (l) for a constant potential difference.

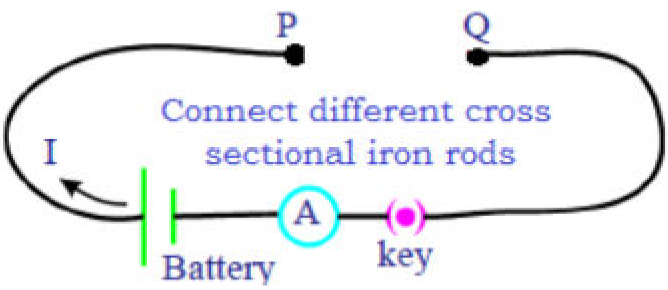
$R \propto l$ (at constant temperature and cross sectional area).........(1)

4. CROSS SECTION AREA AND RESISTANCE (ACTIVITY):

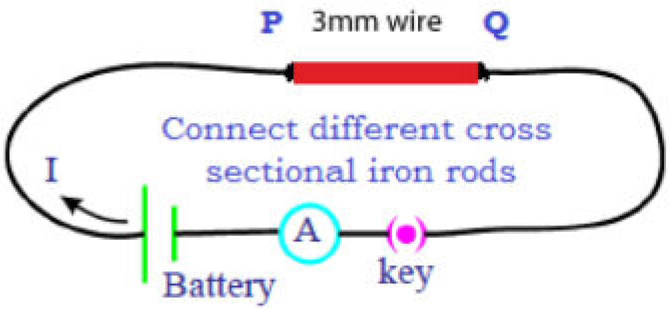
1) Collect iron rods of equal lengths but different cross section areas.



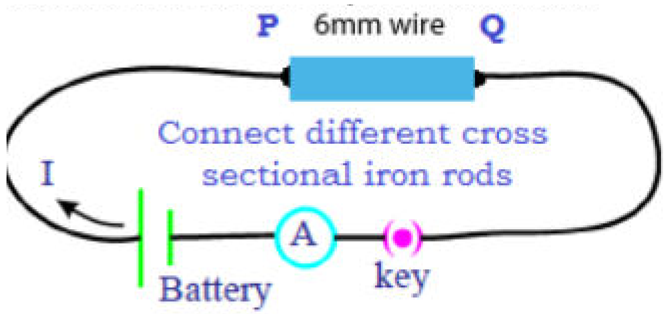
2) Make a circuit as shown in figure.



3) Connect one of the rods between points P and Q and note the value of the current using the ammeter connected to the circuit and note it in the note book.



4) Repeat this with other rods and note the corresponding values of currents in each case and note them in your note book.



5) We will notice that the current flowing through the rod increases with increase in its cross sectional area.

6) Hence, the resistance of a rod decreases with increase in the cross section area of the rod.

7) From this activity, we conclude that the resistance of a conductor is inversely proportional to its cross section area.

$R \propto 1/A$ (at constant temperature and length of the conductor)...... (2)

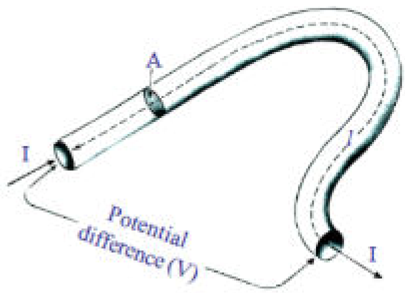
From the equations (1) and (2), we get

$R \propto l/A$ (at constant temperature)

$R \propto \rho\, l/A$

$\rho = RA/l$

❖ Where, ρ is a proportionality constant and it is called specific resistance or resistivity.



8) **The SI unit of resistivity (ρ):** Ω - m.
(Explanation: ρ = RA/l = Ω x m²/m = Ω –m)

NOTE-1: Specific resistance (ϱ) depends on the temperature and nature of the material.

NOTE-2: The resistance (R) of the conductor depends on nature of material, temperature and geometrical factors like length and cross section area of the conductor.

9) **CONDUCTIVITY (σ):** The reciprocal of resistivity is called conductivity (σ).

Conductivity (σ) = 1/ resistivity = 1/ϱ

10) The SI unit of Conductivity (σ):

1/ (Ω – m) = $\Omega^{-1} \cdot m^{-1}$ = Siemens per metre (S/m)

11) The values of resistivity of material determine their conductivity.

12) Metals with low resistivity behave as good conductors.

13) Reasons for metals such as copper are used for making electric wires: Metals such as copper are have low resistivity and behave as good conductors therefore we used metals such as copper for making electric wires.

14) Reason for filament of an electric bulb is usually made of tungsten: The filament of an electric bulb is usually made of tungsten, because of its higher resistivity values and melting point (3422^{0}C).

15) The values of resistivity of insulators are very high of the order of 1014 to 1016 Ω-m.

USAGE OF ALLOYS LIKE NICHROME AND MANGANESE:

1) Nichrome (Nickel, chromium and iron) and Manganese (86% copper, 12% manganese, 2% nickel) have 30-100 times larger values of resistivity than those of metals.

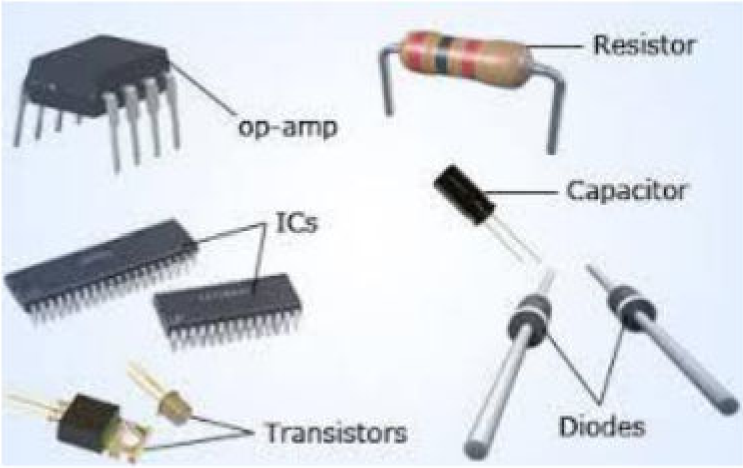
2) This makes them suitable for use in the heating elements of electric irons, toasters etc.

3) These alloys also have the advantage that their resistance varies very little with temperature and they do not oxidize easily.

SEMICONDUCTORS:

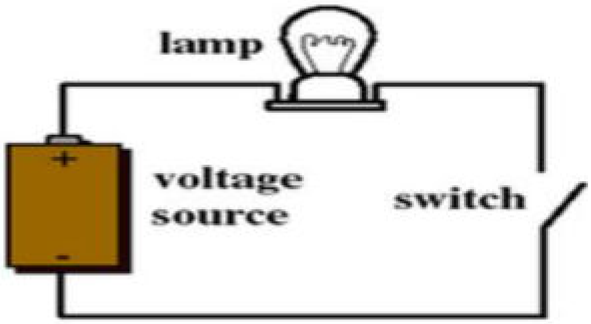
1) The materials which have resistivity 105 to 1010 times more than that of metals, but 1015 to 1016 times less than that of
insulators called semiconductors.

Ex: Silicon and Germanium.
2) Semiconductors are used to make diodes, transistors and integrated Circuits (ICs).
3) ICs are used in all sorts of electronic devices, including computer, TV, mobile phones etc.

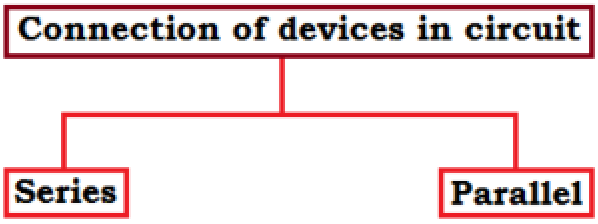


ELECTRIC CIRCUITS

1) **CIRCUIT:** A closed path created by the connecting wires through a battery along which electrons can flow is called a circuit.

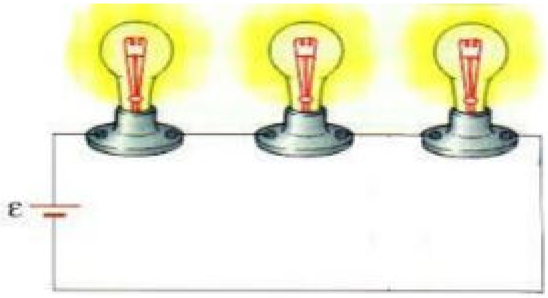


2) For a continuous flow of electrons in the circuit it must be a complete circuit with no gaps left in between.
3) Usually a gap is provided in the circuit by an electric switch that can be opened or closed to either cut off or allow current flow through the circuit.
4) Circuits may have more than one device (called as component) that receives electric energy from the source.
5) These devices are commonly connected in the circuit either in series or in parallel.
6) When the components of the circuit are connected in series, there will be a single path for flow of electrons between the terminals of the battery, generator or wall socket (which is simply and extension of these terminals).
7) When these components are connected in parallel, they form branches and each branch provides a separate path for the flow of electrons.
8) Both the series and parallel connections have their own distinctive characteristics.



SERIES CONNECTION OF RESISTORS:

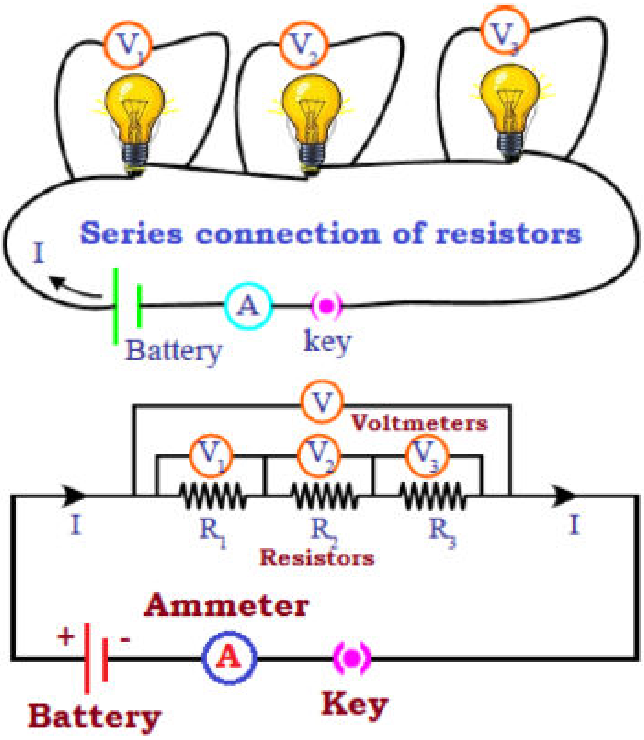
Two or more resistors are said to be connected in series if the same current flows through them.



SERIES CONNECTION OF RESISTORS (ACTIVITY):

1) Take different bulbs, measure their resistances with a multi meter and note their values in the book as R1, R2 and R3.

2) Connect them as shown in figure.



3) Measure the potential difference between terminals of the battery connected to the circuit.

4) Measure the potential differences between the ends of each bulb and note them as V1, V2 and V3 from voltmeters in the note book.

5) Compare the potential difference of the battery and resistors.

6) We notice that the sum of the potential differences of the bulbs is equal to potential difference across the combination of the resistors.

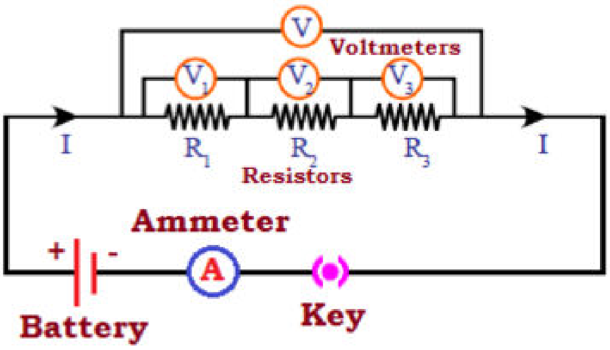
7) Then we get, V = V1 + V2 + V3

8) Measure the value of the current flowing in the circuit with help of the ammeter and note its values in the book as I.

EQUIVALENT RESISTANCE OF A SERIES CONNECTION

(or) the expression for the equivalent resistance of three resistors connected in series (or) Derivation of Req = R1 + R2 + R3 (or)

Explanation to show the sum of individual resistances is equal to their equivalent resistance when the resistors are connected in series:



1) In the above figure, the resistors are connected in series.

2) In series connection of resistors there is only one path for the flow of current in the circuit.

3) Hence, the current in the circuit is equal to I.

4) According to Ohm's law, at resistance R, Potential at R (V) = Current through R (I) x Resistance (R)

Potential difference across R1 is, V1 = IR1......(1)

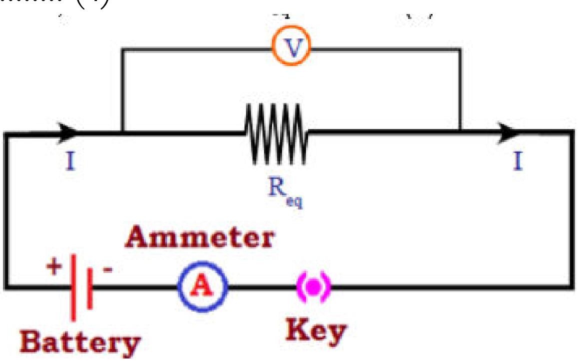
Potential difference across R2 is, V2 = IR2......(2)

Potential difference across R3 is, V3 = IR3......(3)

5) Let Req is the equivalent resistance of the combination of resistors in series.

6) If the current drawn by a resistor is equal to the current drawn by the combination of resistors then the resistor is called as equivalent resistor (provided the source in the circuit is constant).

So, we have V = I Req............ (4)



7) The resultant potential is equal to the sum of the potentials at each resistor.

Therefore, V = V1 + V2 + V3....... (5) Substituting the values of V1, V2, V3 and V in the equation (5), we get,

IReq = IR1 + IR2 + IR3

IReq = I (R1 + R2 + R3)

Req = R1 + R2 + R3

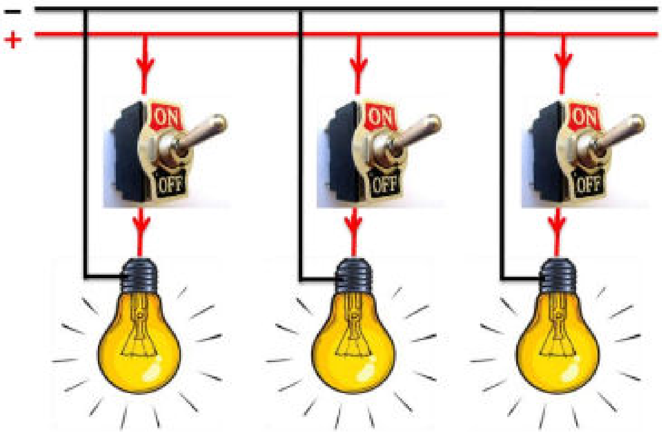
8) From the above equation we can conclude that the sum of individual resistances is equal to their equivalent resistance when the resistors are connected in series.

9) The equivalent resistance of a series combination is greater than the resistance of each of the resistors.

10) **REASON FOR THE HOUSEHOLD ELECTRICAL APPLIANCES ARE NOT CONNECTED IN SERIES:** When one of the household electrical appliances in series breaks down, the circuit becomes open and flow of current cannot take place in the circuit. Therefore, household electrical appliances are not connected in series.

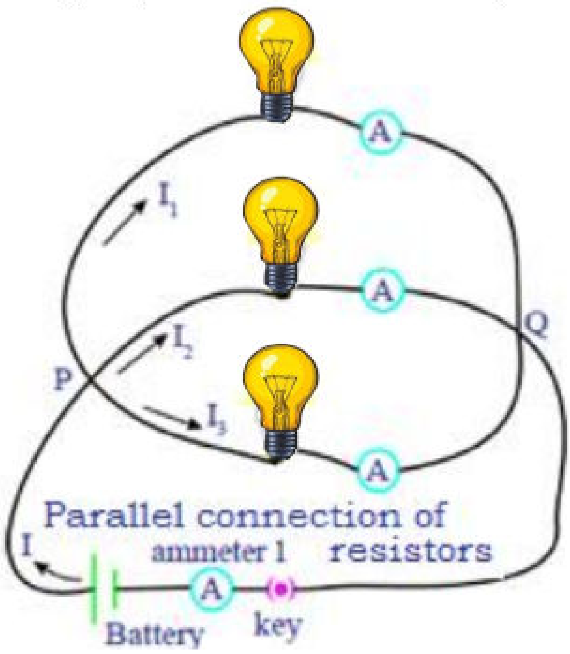
PARALLEL CONNECTION OF RESISTORS:

Two or more resistors are said to be connected in parallel if the same potential difference exist across them.



PARALLEL CONNECTION OF RESISTORS (ACTIVITY):

1) Take different bulbs and connect these bulbs as shown in figure.
2) Measure the potential difference across each bulb using a voltmeter or multi meter.
3) Note these values in the note book.
4) We notice that the potential difference at the ends of each bulb is the same.
5) These bulbs are said to be in parallel connection.
6) Measure electric currents flowing through each bulb using ammeters and note these values.
7) Let I1, I2 and I3 be the currents flowing through R1, R2 and R3 resistors respectively.



8) Measure the current (I) drawn from the battery using the ammeter 1.

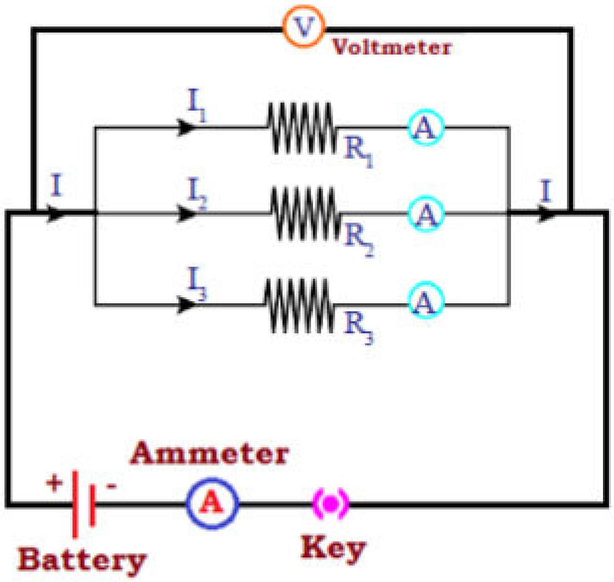
9) We will notice that the current drawn from the battery is equal to the sum of individual currents drawn by the bulbs.

Hence, we can write

$$I = I1 + I2 + I3$$

EQUIVALENT RESISTANCE OF A PARALLEL CONNECTION

(or) the expression for the equivalent resistance of three resistors connected in parallel (or) Derivation of 1/Req = 1/R1 + 1/R2 + 1/R3 (or) Explanation to show the sum of reciprocals of individual resistances is equal to the reciprocal of their equivalent resistance when the resistors are connected in parallel:



1) In the above figure, the resistors are connected in parallel.

2) In parallel connection of resistors, the potential difference is same for all resisters.

3) Hence, the potential difference in the circuit is equal to V.

4) According to Ohm's law, at resistance R, Potential at R (V) = Current through R (I) x Resistance (R)

$$Current\ through\ R\ (I) = \frac{Potential\ at\ R\ (V)}{Resistance\ (R)}$$

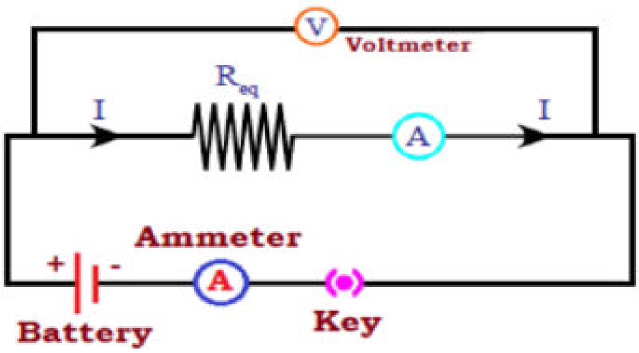
$$Current\ through\ R_1 is\ I_1 = \frac{V}{R_1} ....(1)$$

$$Current\ through\ R_2 is\ I_1 = \frac{V}{R_2} ....(2)$$

$$Current\ through\ R_3 is\ I_1 = \frac{V}{R_3} ....(3)$$

5) Let Req be the equivalent resistance of the resistors is parallel.

6) Then we get; $I_1 = \frac{V}{R_{eq}}$......... (4)



7) The current in the circuit is equal to the sum of individual currents through each resistance.

Hence, we can write

I = I1 + I2 + I3.......... (5)

Substituting the values I, I1, I2 and I3 in equation (5), we get

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R_{eq}} = V \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

8) From the above equation we can conclude that the sum of reciprocals of individual resistances is equal to the reciprocal of their equivalent resistance when the resistors are connected in parallel.

9) The equivalent resistance of a parallel combination is less than the resistance of each of the resistors.

10) **REASON FOR THE HOUSEHOLD ELECTRICAL APPLIANCES ARE CONNECTED IN PARALLEL:** When one of the household electrical appliances in parallel breaks down, the circuit can flow the current to the other household electrical appliances. Therefore, household electrical appliances are connected in parallel.

When two resistors R1 and R2 are connected in parallel the resultant resistance of equivalent resistance:

Let two resistors R1 and R2 are connected in parallel,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

EXPLANATION FOR THE RESISTANCE OF A METAL WIRE IS INVERSELY PROPORTIONAL TO ITS AREA OF CROSS SECTION:

1) Let us imagine a thick wire as a parallel combination of several thin wires.
2) Then the resistance of the combination is less than that of each thin wire.
3) In other words, the resistance of a thick wire is less than that of a thin wire.

REASON THAT WE USE COPPER WIRE FOR CONDUCTION OF ELECTRICITY INSTEAD OF SILVER, EVEN THOUGH, SILVER IS A BETTER CONDUCTOR OF ELECTRICITY THAN COPPER:

1) Even though Silver is a better conductor of electricity, copper wire is used as conduction in electricity because it has greater capacity for electrical conductivity as well as mechanical strength.
2) It also has a high thermal coefficient of expansion.
3) It can easily be drawn into wires and is much less expensive than silver.

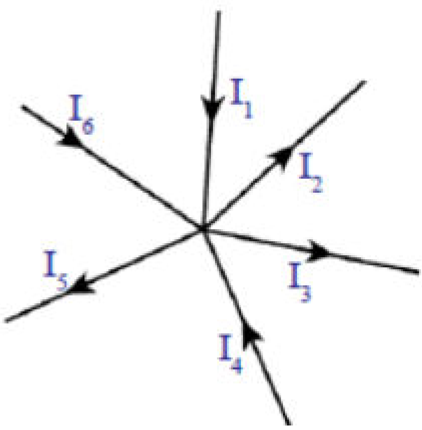
KIRCHHOFF'S LAWS

1) Kirchhoff's rules are applicable to any DC circuit containing batteries and resistors connected in any way.
2) Kirchhoff's rules are two.
3) They are
   (1) Junction Law,
   (2) Loop Law

KIRCHHOFF'S JUNCTION LAW:

1) **THE JUNCTION LAW (DEFINITION):** At any junction point in a circuit where the current can divide, the sum of the currents into the junction must equal the sum of the currents leaving the junction.
2) The junction law is based on the conservation of charge.

EXPLANATION



]

1) From the figure we have seen that the current divides at junction P.
2) The current drawn from the battery is equal to the sum of the currents through the resistors.

3) The junction is a point where three or more conducting wires meet.
4) At any junction point in a circuit where the current can divide, the sum of the currents into the junction must equal the sum of the currents leaving the junction.

At any junction point,

The sum of the currents into the junction = The sum of the currents leaving the junction

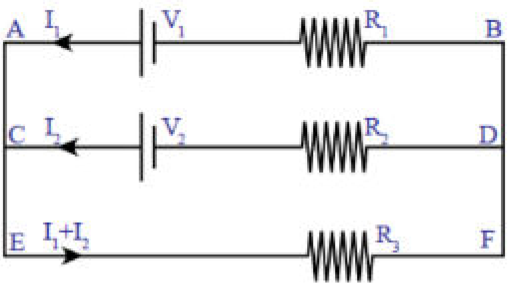
5) This means that there is no accumulation of electric charges at any junction in a circuit.
6) From figure, we have, I_1, I_4, I_6 are into the junction and I_5, I_2, I_3 are leaving the junction

$$I_1 + I_4 + I_6 = I_5 + I_2 + I_3$$

KIRCHHOFF'S LOOP LAW:

1) **THE LOOP LAW (DEFINITION):** The algebraic sum of the increases and decreases in potential difference across various components of a closed circuit loop must be zero.
2) The Loop law is based on the conservation of energy.

EXPLANATION:



1) Let us imagine in a circuit loop the potential difference between the two points at the beginning of the loop has a certain value.
2) As we move around the circuit loop and measure the potential difference across each component in the loop, the potential difference may decrease or increase depending upon the nature of the element likes a resistor or a battery.
3) But when we have completely traversed the circuit loop and arrive back at our starting point, the net change in the potential difference must be zero.
4) Thus, the algebraic sum of changes in potential differences is equal to zero.

Let us apply Loop law to the circuit shown in figure.

For the loop ACDBA,

$$-V_2 + I_2R_2 - I_1R_1 + V_1 = 0$$

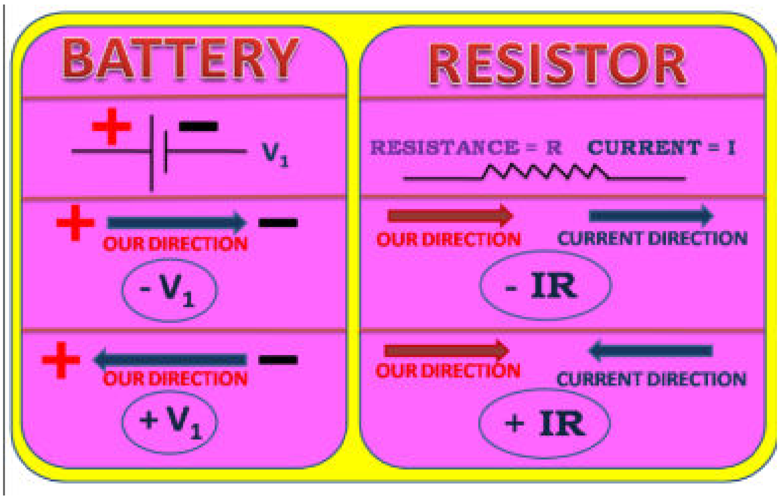
For the loop EFDCE

$$-(I_1+I_2) R_3 - I_2R_2 + V_2 = 0$$

For the loop EFBAE

$$-(I_1+I_2) R_3 - I_1R_1 + V_1 = 0$$

RULES IN SIMPLE VISIBLE WAY:RULES:



For the application of Loop Law to the given Loop we have two simple rules. They are,

1) When we move in the loop or circuit in any direction, the battery ending terminal sign in that direction is taken for battery emf sign.

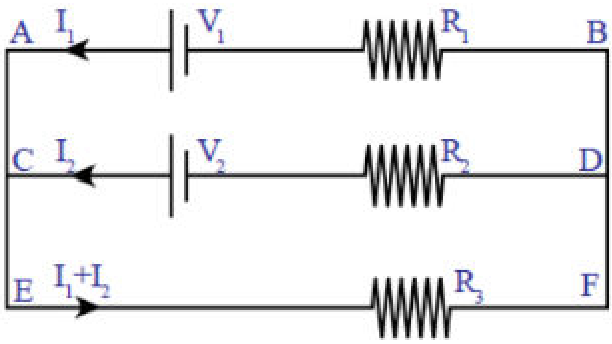
2) When we move in the loop or circuit in any direction, the sign for potential difference across the resistor (IR) is,

a) Positive (+ve) if the current direction is in the opposite direction of our direction.

b) Negative (-ve) if the current direction is in the same direction of our direction.

APPLICATION OF LOOP LAW IN A LOOP:

Let us understand by applying the rules for the given figure.



For the loop ACDBA:

In the loop ACDBA, we have two batteries of emfs' V1 and V2 and two resistors of resistances R1 and R2. For apply loop law for this loop, let us consider we move in the direction of ACDBA.

1) Between AC there is no battery and resistor.

2) Between CD there are one battery of emf V2 & resistor R2 and current I2. When we move from C to D,

a) We have the battery ending terminal is –ve, i.e., -V2.

b) The current direction is opposite to our direction, therefore, potential difference across R2, I2R2, is +ve, i.e., (+I2R2).

The potential difference across a resistor V= Current through it X Resistance of it.

Here I2 current passes through R2 resistor) 3) Between DB there is no battery and resistor.

4) Between BA there are resistor R1 and one battery of emf V1. When we move from B to A,

a) the current direction is same as to our direction, therefore, potential difference across R1, I1R1, is -ve, i.e., (-I2R2).
(The potential difference across a resistor V= Current through it X Resistance of it. Here I1 current passes through R1 resistor)

b) we have the battery ending terminal is +ve, i.e., (+V1).

According to Kirchhoff's loop law, the algebraic sum of the increases and decreases in potential difference across various components of the circuit in a closed circuit loop must be zero.

Now, add all these emf and potential differences, we get,

$$(-V_2) + (+I_2R) + (-I_1R_1) + (+V_1) = 0$$

$$\mathbf{- V_2 + I_2R - I_1R_1 + V_1 = 0 \text{ ---------- } (1)}$$

For the loop EFDCE:

In the loop EFDCE, we have two resistors R3 & R2 and one battery of emf V2. For apply loop law for this loop, let us consider we move in the direction of EFDCE.

1) Between EF there is one resistor R3 and current (I1+I2). When we move from E to F, the current direction is same as to our direction, therefore, potential difference across R3, (I1+I2)R3, is -ve, i.e., [-(I1+I2)R3].
(The potential difference across a resistor V= Current through it X Resistance of it. Here (I1+I2) current passes through R3 resistor) 2) Between FD there is no battery and resistor.
3) Between DC there are one resistor R2 & one battery of emf V2 and current I2. When, we move from D to C,

a) The current direction is same as to our direction, therefore, potential difference across R2, I2R2, is -ve, i.e., (-I2R2).
(The potential difference across a resistor V= Current through it X Resistance of it. Here I2 current passes through R2 resistor)

b) we have the battery ending terminal is +ve, i.e., (+V2).

4) Between FD there is no battery and resistor.

According to Kirchhoff's loop law the algebraic sum of the increases and decreases in potential difference across various components of the circuit in a closed circuit loop must be zero.

Now, add all these emf and potential differences, we get,

$$[-(I_1+I_2)R_3] + (-I_2R_2) + (+V_2) = 0$$

$$\mathbf{- (I_1+I_2)R_3 - I_2R_2 + V_2 = 0 \text{ ---------- } (2)}$$

For the loop EFBAE:

In the loop EFBAE, we have two resistors R3 & R1 and one battery of emf V1. For apply loop law for this loop, let us consider we move in the direction of EFBAE.

1) Between EF there is one resistor R3 and current (I1+I2). When we move from E to F, the current direction is same as to our direction, therefore, potential difference across R3, (I1+I2)R3, is -ve, i.e., [-(I1+I2)R3].
(The potential difference across a resistor V= Current through it X Resistance of it. Here (I1+I2) current passes through R3 resistor) 2) Between FB there is no battery and resistor.

3) Between BA there are one resistor R1 & one battery of emf V1 and current I1.
When, we move from B to A,

a) the current direction is same as to our direction, therefore, potential difference across R1, I1R1, is -ve, i.e., (-I1R1).

(The potential difference across a resistor V= Current through it X Resistance of it. Here I2 current passes through R2 resistor)

b) we have the battery ending terminal is +ve, i.e., (+V1).

4) Between AE there is no battery and resistor.

According to Kirchhoff's loop law the algebraic sum of the increases and decreases in potential difference across various components of the circuit in a closed circuit loop must be zero.

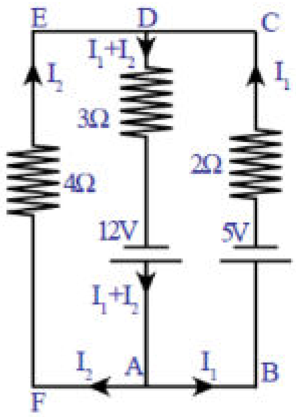
Now, add all these emf and potential differences, we get,

$$[-(I_1+I_2)R_3] + (-I_1R_1) + (+V_1) = 0$$

$$\mathbf{- (I_1+I_2)R_3 - I_1R_1 + V_1 = 0 \text{ ---------- } (3)}$$

This is only for understanding. You have not to write this in the examination. You write only equations simply.

APPLICATION PROBLEM: FIND ELECTRIC CURRENT DRAWN FROM THE BATTERY OF EMF 12V IN THE GIVEN CIRCUIT.



SOLUTION: For solving this we have to find out the values I1 & I2 and then (I1 + I2).

On Applying loop law for the loop DABCD, we get

- 3 (I1 + I2) + 12 – 5 – 2I1 = 0 ------ (1)

EXPLANATION:

In loop DABCD, between DA, current direction is same as to our direction. So, PD at resistor 3Ω is

[- (I1 + I2) x 3] = [-3(I1 + I2)].

At 12V battery, we have +ve as ending terminal. So, emf at 12V battery is [+ 12]. Between AB there is no resistor and battery. Between BC, At 12V battery, we have -ve as ending terminal. So, emf at 5V battery is [-5]. Current direction is same as to our direction. So, PD at resistor 2Ω is [- (I1) x 2] = (-2I1). Between CD there is no resistor and battery. By adding all we get equation (1)

On Applying loop law for the loop DAFED, we get

$$-3(I_1 + I_2) + 12 - 4I_2 = 0 \text{ ------ } (2)$$

EXPLANATION:

In loop DAFED, between DA, current direction is same as to our direction. So, PD at resistor 3Ω is [- (I1 + I2) x 3] = [-3(I1 + I2)]. At 12V battery, we have +ve as ending terminal. So, emf at 12V battery is [+ 12]. Between AF there is no resistor and battery. Between FE, current direction is same as to our direction. So, PD at resistor 4Ω is [- (I2) x 4] = (- 4 I2). By adding all we get equation (2)

By solving (1) & (2), we get I1 = 0.5 A and I2 = 1.5 A

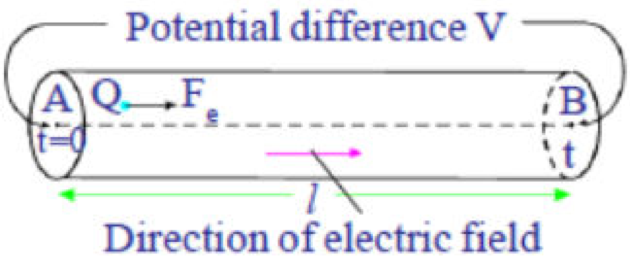
$$\text{So, } I_1 + I_2 = 0.5 + 1.5 = 2A$$

Therefore, electric current drawn from the battery of emf 12V = 2A.

ELECTRIC POWER:

1) The electric appliances that we use in our daily life like heater, cooker, fan, and refrigerator etc. consume electric energy.

2) Let us consider a conductor of resistance 'R' through which an electric current 'I' passes.



3) We know that when current passes through conductor, heat energy is generated.

4) Consider that a charge Q Coulomb passes through a point A moves to point B in the time interval 't' seconds as shown in figure.

5) Let V be the potential difference between the points A and B.

6) The work done by electric field in time 't' is given by, W = QV.................. (1) [According to the definition of potential V = work done (W) / Charge (Q) = W/Q →W = QV] 7) This work is equal to the energy lost by the charge while passing through the conductor.

8) Means, energy lost in time 't' = work done in time 't' = W

9) Therefore, the energy lost by the charge in 1 sec = W/t = electric power (P)

Electric power P = W/t............... (2) [the work done per second or the rate of doing work is power]

10) But, from (1) we know W = QV,

Hence, Power (P) = W/t = QV/t = V (Q/t) = VI Electric power P = VI................. (3)

11) This equation can be used to calculate power consumption by any electric device that is connected in a circuit.

12) According to the ohm's law, V = IR (or) I = V/R

We can write equation (3) as

$$P = VI = (IR) \times I = I^2R$$

Electric power $P = I^2R$................. (4)

$$P = VI = V \times (V/R) = V^2/R$$

Electric power $P = V^2/R$.............. (5)

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Electric power P = I2R................. (4) P = VI = V x (V/R) = V2/R

Electric power P = V2/R.............. (5) 13) The equation P = VI can also be used to know the power that can be extracted from a battery or any source.

14) In such case we modify the equation P = VI as P = ε I.

Here ε is the emf of the battery.

Power consumption (Explanation):

1) A bulb is marked 60W and 120V. This means that if this bulb is connected to 120V source, it will able to convert 60J of electrical energy into heat or light in one second.

2) From the marking of bulb we can measure the resistance of the bulb.

From the relation $P = V^2/R$ $R = V^2/P$

3) Substituting the values V and P in above equation, we get

R = (120 x 120)/ 60 = 240 Ω

4) Thus, the bulbs marked as 60W and 120V will offer a resistance of 240 Ω to the flow current through it in normal condition.

5) If this bulb is connected to the 12V a battery, the consumption by the bulb is given by

P = V11) This equation can be used to calculate power consumption by any electric device that is connected in a circuit.

12) According to the ohm's law,

V = IR (or) I = V/R

We can write equation (3) as

P = VI = (IR) x I = I2R

Electric power P = I2R................. (4) P = VI = V x (V/R) = V2/R

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R = (120 x 120)/ 60 = 240 Ω

4) Thus, the bulbs marked as 60W and 120V will offer a resistance of 240 Ω to the flow current through it in normal condition.

5) If this bulb is connected to the 12V a battery, the consumption by the bulb is given by

P = V2/R = (12 x 12)/ 240 = 3/5 = 0.6 W 6) Since watt is a small unit of power, a bigger unit Kilowatt is generally used to express power consumption.

1 KW = 1000 W = 1000 J/S

7) We might have seen the current bill that comes to our home every month. In that bill, consumption of electricity is marked in units.
8) The unit of electric power consumption is equal to 1 KWH (one Kilo Watt Hour).

VALUE OF 1 KWH IN JOULES:

1 KWH = (1000 J/S) (60 x 60 S)
= 3600 x 1000 J
= 3.6×10^5 J

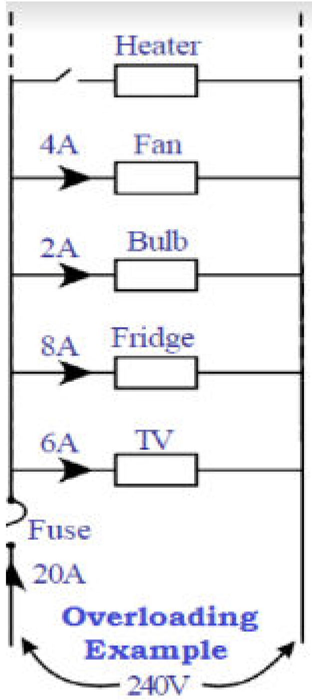
OVERLOAD:

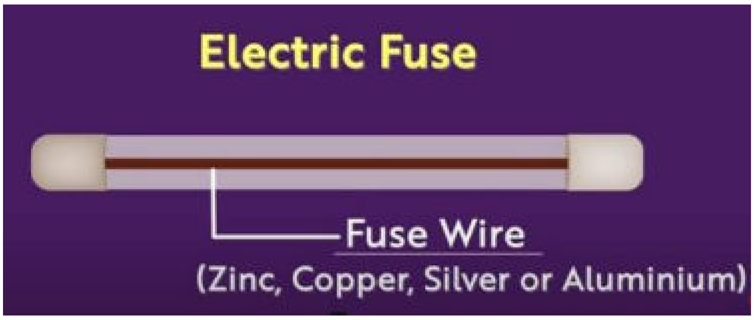
1) We frequently hear news about overload of current and damages caused by this overload.
2) Electricity enters our homes through two wires called lines.
3) These line wires have low resistance and the potential difference between the wires is usually about 240V.
4) These two line wires run throughout the household circuit, to which we connect various appliances such as fan, TV, refrigerator etc.
5) All the electric devices of our home are connected at different points between these two wires. This means all the electric appliances are in parallel connection.
6) Hence, potential drop across each device is 240V.
7) If we know the value of resistance of the electric device, we can calculate the current passing through it using the equation $I = V/R$.

EXAMPLE: The current passing through a bulb with resistance 240 Ω is 1 A.
(Here V= 240V, R = 240 Ω)
8) Based on the resistance of each electric device, it draws some current from the supply.
9) Total current drawn from the mains is equal to the sum of the currents passing through each device (Junction law).
10) If we add more devices to the household circuit the current drawn from the mains also increases.
11) To answer this, observe the values noted on digital meters fixed at your home.
12) We will notice the following values on the meter.
Potential difference (V) : 240 V
Current (I) : 5 – 20A
13) This means the line wires that are entering the meter have a potential difference of 240V.
14) The minimum and maximum limit of current that can be drawn from the mains is 5 – 20A.
15) Thus, the maximum current that we can draw from the mains is 20A.
16) When the current drawn from the mains is more than 20A, overheating occurs and may cause a fire. This is called over loading.

OVERLOADING OF HOUSE HOLD CIRCUIT EXPLANATION WITH EXAMPLE:

1) If we switch on devices, such as heater shown in figure, the current drawn from the mains exceeds the max limit 20A.

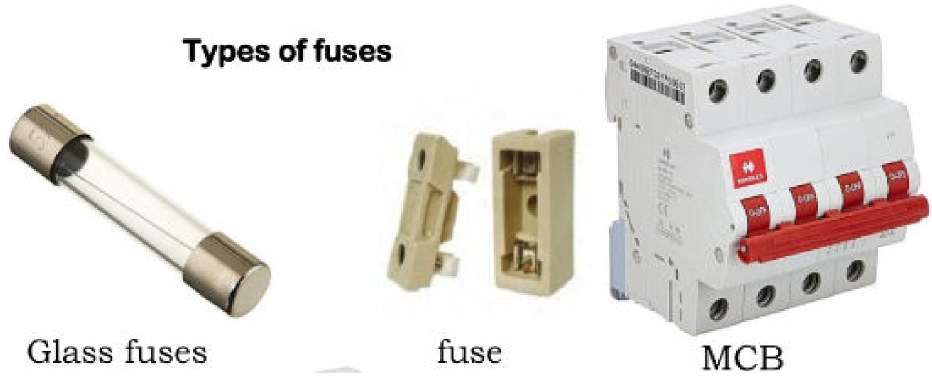




USE OF FUSE IN HOUSEHOLD CIRCUIT:

2) To prevent damages due to overloading we connect an electric fuse to the household circuit as shown in figure.
3) In this arrangement, the entire current from the mains must pass through the fuse.
4) The fuse consists of a thin wire of low melting point.
5) When the current in the fuse exceeds 20A, the wire will heat up and melt.
6) The circuit then becomes open and prevents the flow of current into the household circuit.
7) So all the electric devices are saved from damage that could be caused by overload.
8) Thus we can save the house holding wiring and devices by using fuses.

NOTE: The value of overload current varies from the household currents to factories.



10. ELECTROMAGNETISM

INTRODUCTION

1) We use many electric appliances in our daily life.
Ex: Electric motor, Electric generators, Electric calling bells, Electric cranes etc.

OERSTED EXPERIMENT:

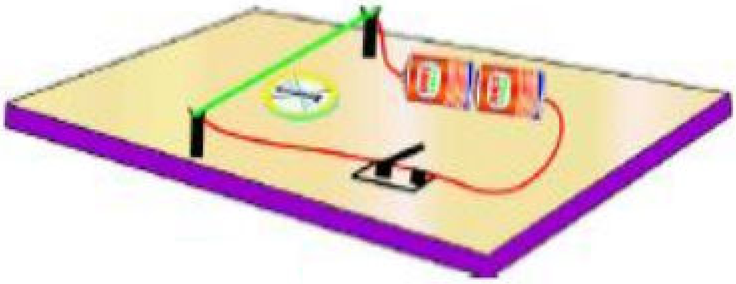
(or) An activity to understand the idea of magnetic field and the influence of electric field on magnetic field: (or)
Experiment to verify that a current carrying wire produces a magnetic field:

AIM: To do Oersted experiment (or) to
understand the influence of electric field on magnetic field (or) to verify that a current carrying wire produces a magnetic field.

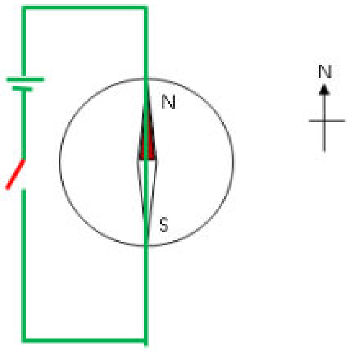
APPARATUS: Thermocole sheet, thin wooden sticks-2, 24 gauge copper wire, 9V battery and key.

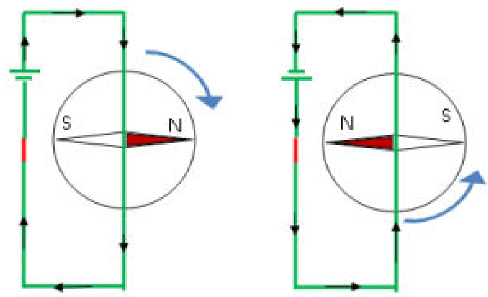
PROCEDURE:

1) Take a thermocole sheet and fix two wooden sticks (height 1cm) which have small slit at the top of their ends.
2) Arrange a copper wire of 24 gauge through these slits and make a circuit with 9V battery and key as shown in figure.



3) Keep a magnetic compass below the wire and bring a bar magnet close to the compass.
4) Take the bar magnet far away from the circuit and switch on the circuit and observe.





5) Then the compass needle deflects due to the magnetic field produced by the current carrying wire.

OBSERVATIONS: The compass needle deflects.

RESULT OR CONCLUSIONS:

1. A magnetic field produced by the current carrying wire.
2. The produced field applied same force on the needle of the compass and made it deflect.
3. Oersted experiment observed.

OERSTED:

1) Oersted had demonstrated that electric and magnetic fields were interconnected.
2) He showed that electricity and magnetism were related phenomena.
3) Some scientists, influenced by this experiment, continued to work in the modern field of "electromagnetism".
4) Their research resulted in several new scientific theories and various vital inventions like the dynamo and the electric motor, with this a new technology prospered, leading to inventions such as radio, television and fiber optics.
5) The unit of magnetic field strength is named Oersted in his honor.

MAGNETIC FIELD:

1. The term field is used when a force gets applied on an object by another object without there being any physical contact between them.
2. The current carrying wire produces magnetic field around it.
3. When we put a magnetic compass in this field it deflects the needle of magnetic compass without any physical contact.
4. Therefore magnetic field applied here is by a magnetic field and is a field force or force at a distance.
5. In other words, the field which is responsible for deflection of the compass needle is "magnetic field".

AN ACTIVITY TO SHOW THE STRENGTH OF THE MAGNETIC FIELD VARIES WITH DISTANCE FROM THE BAR MAGNET

(or) an activity to show the magnetic field is three dimensional (magnetic field surrounds its source) for a bar magnet (or) an experiment to show a magnetic field exists in the region surrounding a bar magnet and is characterized by strength and direction:

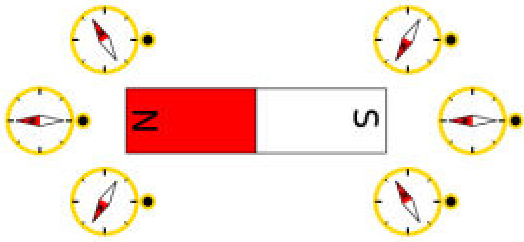
AIM: To show the strength of the magnetic field varies with distance from the bar magnet (or) to show the magnetic field is three dimensional (magnetic field surrounds its source) for a bar magnet (or) to show a magnetic field exists in the region surrounding a bar magnet and is characterized by strength and direction

APPARATUS: Bar magnet, magnetic compass, white paper and pencil.

PROCEDURE:

1. Take white paper, place on the horizontal table and place a barmagnet in the middle of it.
2. Place a magnetic compass near the magnet and observe.
3. It settles to a certain direction.
4. Use a pencil and put dots on the sheet on either side of the needle.
5. Remove the compass and draw a small line segment connecting the two dots.

6. Draw an arrow on it from South Pole of the needle to North Pole of the needle. Repeat the same by placing the compass needle at various positions on the paper.
7. The compass needle settles in different directions at different positions.



8. Remove the bar magnet and place the magnetic compass on the paper then it comes to rest along the north-south direction.
9. Now place the bar magnet in its previous place.
10.The needle of the magnetic compass is affected by the bar magnet without any physical contact.
11.A force acts on the needle from a distance is due to the magnetic field of the bar magnet causes the needle to deflect and makes it to come to rest in a certain direction
12.When we change the place of the compass near the bar magnet we can observe that its orientation changes from point to point.
13.Therefore, the magnetic field has direction and it varies from one point to another.
14.Now take the needle to places far away from bar magnet on the sheet and observe the orientation of the compass needle in each case.
15.The compass needle shows almost the same direction along north and south at places far from the magnet.
16.From the above we conclude that the strength of the field varies with distance from the bar magnet.
17.Now hold the compass a little above the table and at the top of the bar magnet and we observe that field exists in all directions around the bar magnet.
18.Hence we can say that the magnetic field is three dimensional i.e., magnetic field surrounds its source such as bar magnet.

So, we generalize that a magnetic field exists in the region surrounding a bar magnet and is characterized by strength and direction.

NOTE: The direction of the field can be determined by using a compass or by drawn a tangent on the line of force.

EXPERIMENT TO FIND THE MAGNETIC FIELD DIRECTION OF A BAR MAGNET

(or) Process of drawing the lines of forces of a bar magnet (Activity):

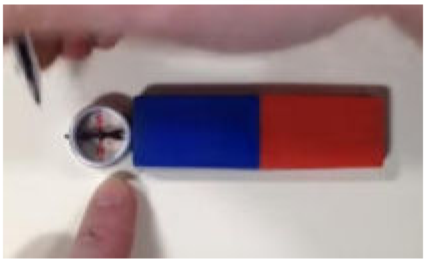
AIM: To find the magnetic field direction of a bar magnet (or) to drawing the lines of forces of a bar magnet.

APPARATUS: Bar magnet, compass, white paper, pencil and drawing board.

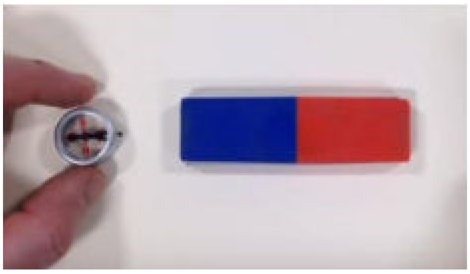
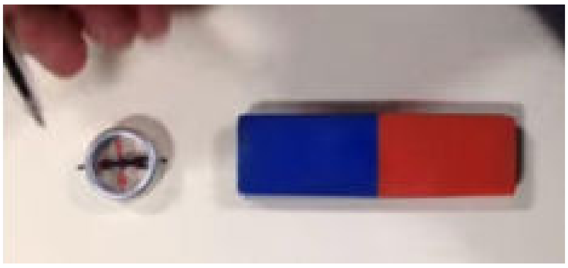
PROCEDURE:

1. Place a white paper on a table and place a compass in the middle of it.
2. Put two dots on either side of the compass needle, take it out and draw a line connecting the dots shows the North and South of the earth.

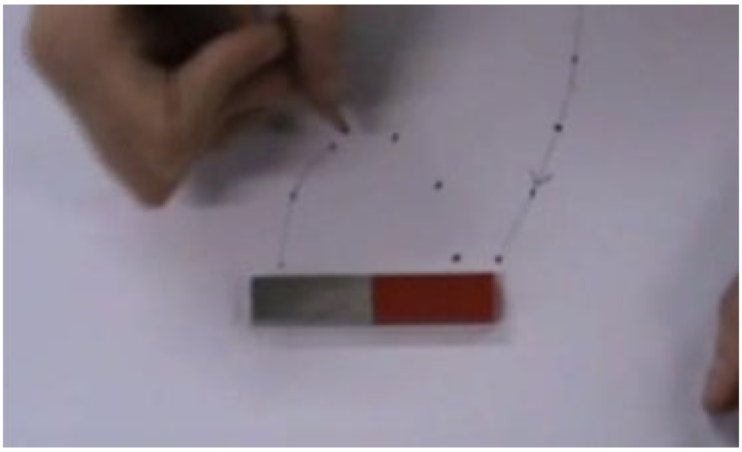
3. Place the bar magnet on the line drawn in such a way that its north pole points towards geographic north.
4. Now place the compass at the north pole of the bar magnet and put a dot at the north pole of the compass needle.



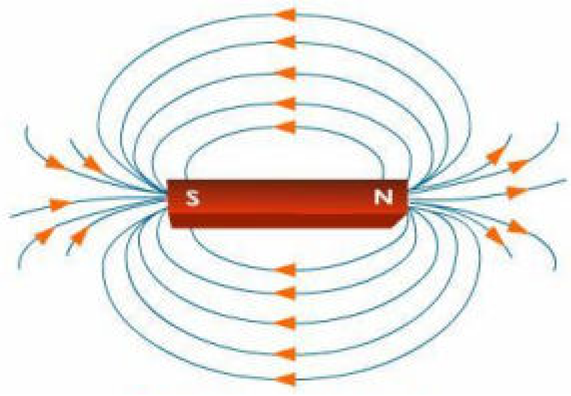
5. Remove the compass and place it at the dot then it will point in other direction.
6. Again put a dot at the north pole of the compass needle.

7. Repeat the process till we reach the south pole of the bar magnet.
8. Connect the dots from "N" of the bar magnet to "S" of the bar magnet then we will get a curved line.



9. Now select another point from the North Pole of the bar magnet.
10.Repeat the process for many points taken near the North Pole then we will get different curves as shown in figure. These curved lines represent the field lines.



OBSERVATIONS:

If you place a compass at any point on the line, the needle comes to rest along the tangent to the line.

CONCLUSION:

The tangent drawn to the field line at a point gives the direction of the field.

NOTE: Magnetic field lines are imaginary lines.These lines help us to understand the nature of the field. So, these curved lines represent the field lines.

MAGNETIC FIELD LINES:

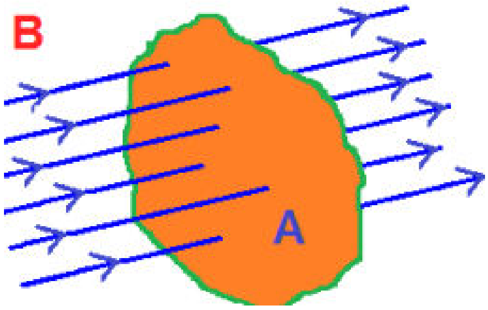
1. The imaginary lines which are very useful in visualizing the strength and direction of the magnetic field are called magnetic field lines.
2. The field lines appear to be closed loops, but you can"t conclude that lines are closed or open loops by looking at the picture of field lines because we do not know about the alignment of lines that are passing through the bar magnet.
3. Observe the spacing between lines. In some places the field lines are crowded (near the poles of a bar magnet) and in some places the field lines are spread apart (at long distances from the bar magnet).
4. From this picture we can conclude that the field is strong when lines are crowded and field is weak when lines are spaced apart.
5. Thus, the field drawn is non uniform because the strength and direction both change from point to point.
6. We may define the nature of the field with its characteristics such as its strength and direction.
7. The field is said to be non uniform when any one of the characteristics of field i.e., strength or direction changes from point to point, similarly the field is said to be uniform if both strength and direction are constant throughout the field.

MAGNETIC FLUX (Φ) (OR) STRENGTH OF A UNIFORM MAGNETIC FIELD:

DEFINITION: The number of lines passing through the plane of area "A" perpendicular to the field is called magnetic flux. It is denoted by "Φ".

EXPLANATION:

1. Consider a uniform magnetic field "B" in space.
2. Imagine a plane of certain area "A" placed perpendicular to the field at a certain point in the magnetic field as shown in figure.



3. We notice that a few field lines pass through this plane.
4. This number gives an estimation of strength of the field at that point.
5. The number of lines (for example, from the figure consider 6 magnetic lines passes) passing through the plane of area "A" perpendicular to the field is called magnetic flux (i.e., 6 Wb). It is denoted by "Φ".
6. Magnetic flux represents the number of lines passing through the imagined plane in the field.
7. Flux depends on the orientation of the plane in the field (here we are concerned only with the perpendicular case).
8. The S.I unit of magnetic flux is Weber (Wb).

MAGNETIC FLUX DENSITY (B) (OR) STRENGTH OF THE FIELD (OR) MAGNETIC FIELD INDUCTION (B):

DEFINITION: Magnetic flux density is defined as the magnetic flux passing through unit area taken perpendicular to the field. (or) The ratio of magnetic flux passing through a plane perpendicular to the field and the area of the plane is called the magnetic flux density. It is represented by "B".

Magnetic flux density = magnetic flux/ area.

$$B = \Phi/A$$

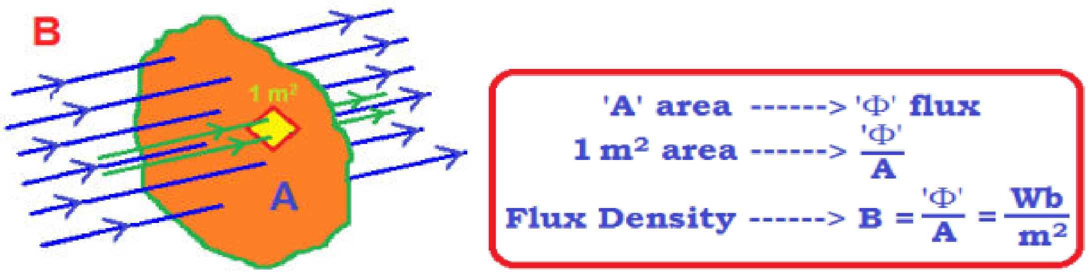
S.I. units for magnetic flux density (B) = Wb/m2 = Tesla

EXPLANATION:

1. If the imagined plane is perpendicular to the field and has unit area, then the flux through this plane of unit area gives the strength of the field.
2. This strength of the field is technically called Magnetic flux density (B).
3. Magnetic flux density (B) is also known as Magnetic field induction (B).

EQUATION DERIVATION FOR MAGNETIC FLUX DENSITY (B):

1. Let the flux through the area "A" be Φ.



2. Then the flux per unit area be Φ/A.
3. According to the definition it is equal to Magnetic flux density (B), therefore, B = Φ/A.
4. The ratio of magnetic flux passing through a plane perpendicular to the field and the area of the plane is called the magnetic flux density. So,

Magnetic flux density = magnetic flux/ area.

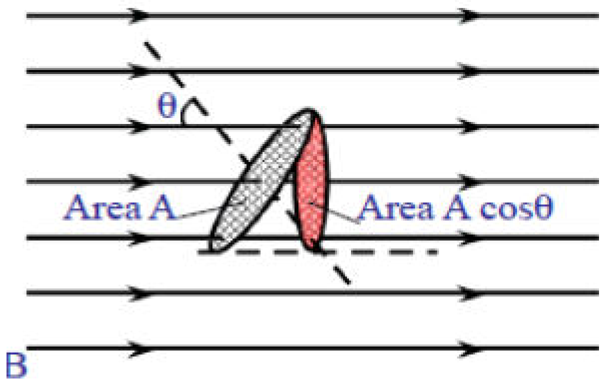
$$B = \Phi/A$$

$$\Phi = BA$$

5. Units of magnetic flux density is Weber/(meter)^2. It is also called Tesla.

DERIVATION OF THE MAGNETIC FLUX DENSITY (B) FOR ANY ORIENTATION OF THE PLANE:

1. Let "θ" be the angle between magnetic field ($\vec{B}$ - a vector) and normal to the plane with area ($\vec{A}$ - a vector) as shown in figure.



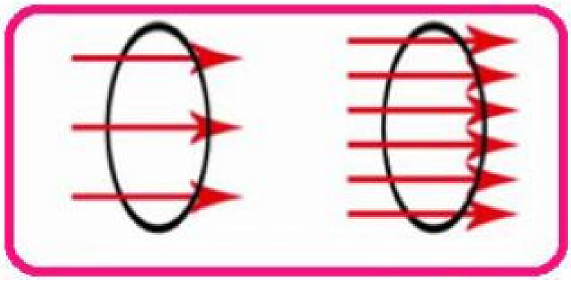
2. The effective area of the plane perpendicular to the field is A cosθ.
3. Then magnetic flux density is given by, B = magnetic flux /effective area (this formula is used when plane makes an angle with the field).
Then, B = Φ/A cosθ
The flux through the plane, is given by Φ = BA cosθ.
4. Here "θ" calculated between the normal of the surface and direction of the field.

CLEAR EXPLANATION:

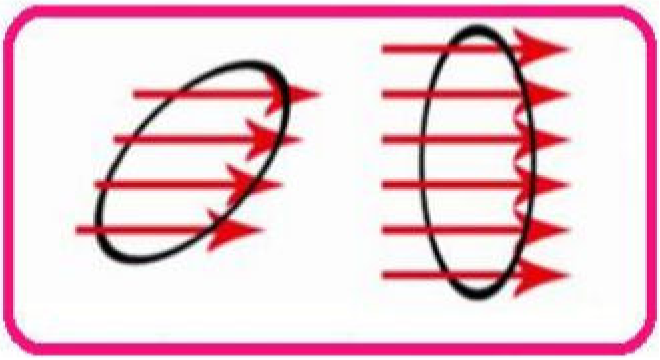
1.The magnetic flux is the dot product of vectors magnetic flux density B and area vector A.
2. Therefore, Flux (Φ) = $\vec{B} \cdot \vec{A} = |\vec{B}| \cdot |\vec{A}|$ Cosθ = B·A cosθ

FLUX DEPENDING FACTORS:

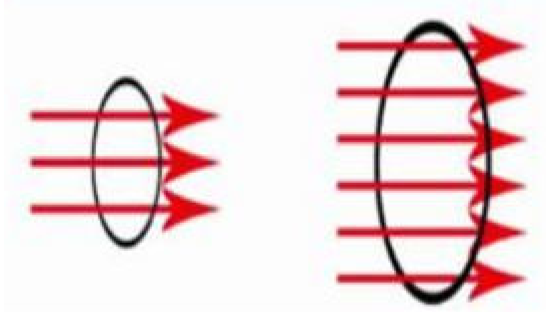
Flux depends upon the following factors,
1. Density of the field: Flux is proportional to the density of the magnetic field.



2. Angle of the area or the boundary faces the direction of flow: Flux is decreases when the angle "θ" between "B" and normal to the plane with area "A" decreases.



3. Area: Flux is proportional to the area within the boundary affected by the magnetic field.



MAGNETIC FIELD DUE TO CURRENTS:

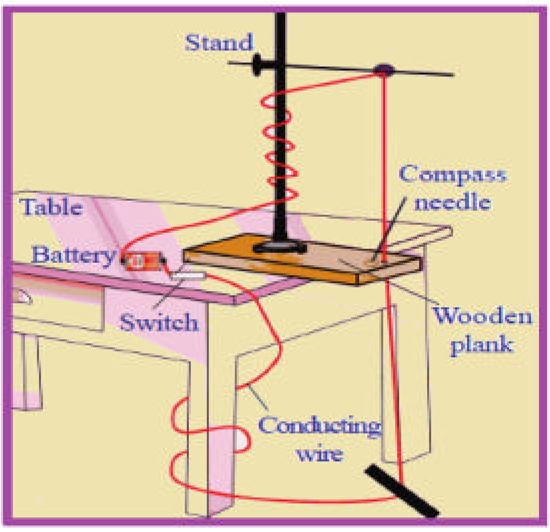
Let us study about some cases of magnetic fields produced by current carrying wire.
i. Magnetic field due to straight wire carrying current
ii. Magnetic field due to circular coil iii. Magnetic field due to solenoid

I EXPERIMENT TO OBSERVE THE MAGNETIC FIELD DUE TO STRAIGHT WIRE CARRYING CURRENT (OR) EXPERIMENT TO SHOW THAT MAGNETIC FIELD LINES ARE CLOSED LINES:

AIM: To observe the Magnetic field due to straight wire carrying current (or) to show that magnetic field lines are closed lines.

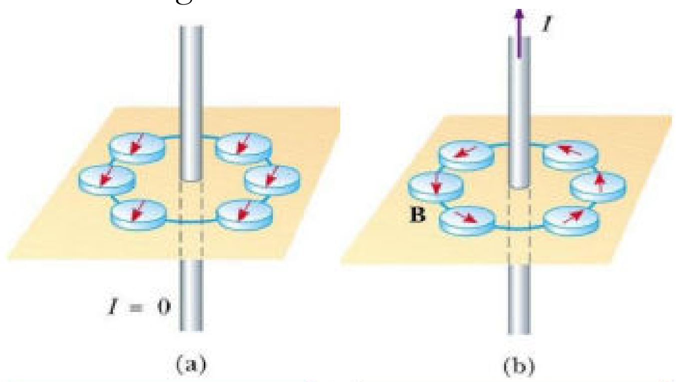
APPARATUS: Wooden Plank, Table, copper wire, battery, switch, stand and needle.

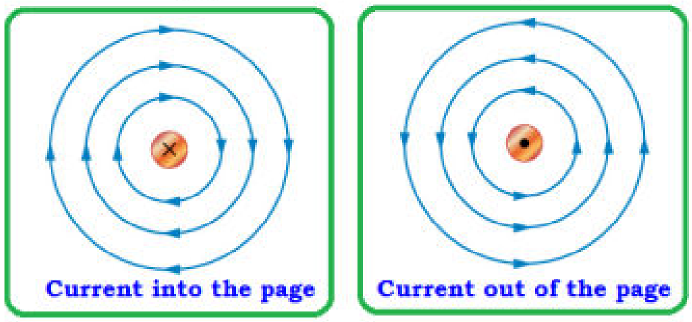
PROCEDURE:



1. Take a wooden plank, make a hole and place this plank on the table as shown in figure.
2. Place a retort stand on the plank and pass 24 gauge copper wire through hole of the plank and rubber knob of the retort stand in such a way that the wire be arranged in a vertical position and not touch the stand.

3. Connect the two ends of the wire to a battery via switch.
4. Place 6 to 10 compass needles in a circular path around the hole so that its centre coincides with the hole.
5. Switch on. Current flows through the wire.



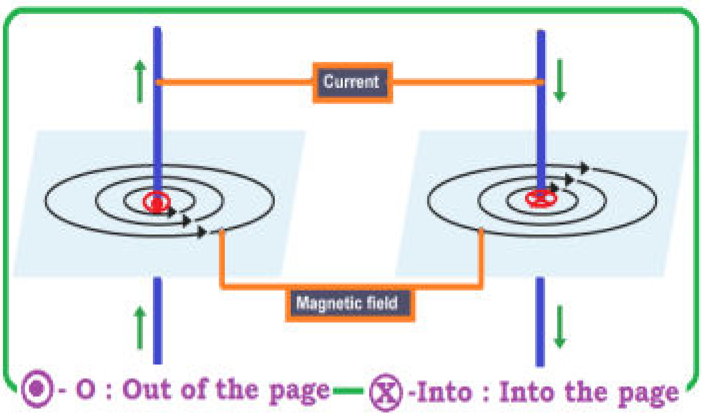


OBSERVATION: The compass needles are directed as tangents to the circle and the magnetic field produced is in a circular line.

RESULT: The magnetic field lines are closed lines.

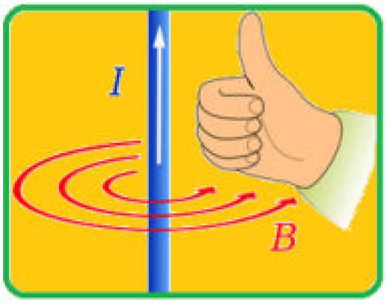
FINDING THE MAGNETIC FIELD DIRECTION:

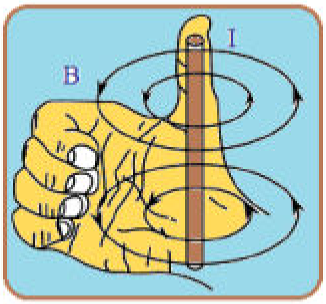
The magnetic field lines due to straight wire carrying the current is shown in the following figures. This can be verified by sprinkling iron filings around the wire when current flows in the wire.



1. If the current flow is vertically upwards (out of the page), the field lines are in anticlockwise direction.
2. If current flows into the page, in downward direction, the field lines are in clockwise direction.
3. We can easily determine the direction of magnetic field produced with right hand thumb rule.

RIGHT HAND THUMB RULE (DEFINITION): If we grab the current carrying wire with our right hand in such way that thumb is in the direction of current, then the curled fingers show the direction of the magnetic field as shown in figure.



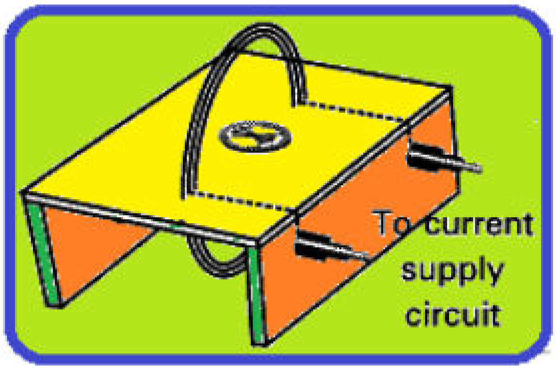


(II) EXPERIMENT TO FIND OUT THE DIRECTION OF MAGNETIC FIELD DUE TO CIRCULAR COIL: AIM: TO FIND OUT THE DIRECTION OF MAGNETIC FIELD DUE TO CIRCULAR COIL

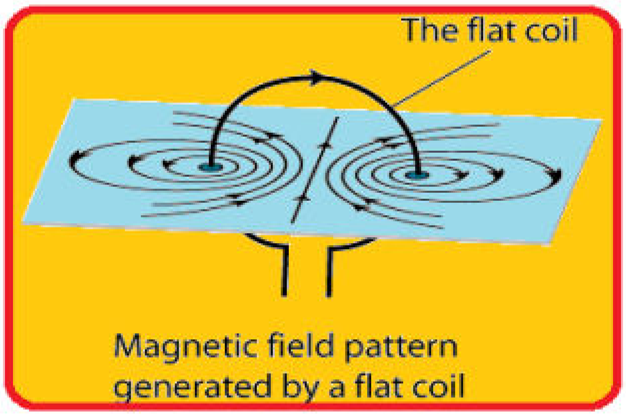
APPARATUS: Wooden plank, white paper, copper wire, battery, switch and compass.

PROCEDURE:

1. Take a thin wooden plank covered with white paper and make two holes on its surface as shown in figure.
2. Pass insulated copper wire of 24 gauge through the holes and wind the wire 4 to 5 times through holes such that it looks like a coil.



3. The ends of the wire are connected to terminals of the battery through a switch.
4. Now switch on the circuit. Place a compass needle on the plank at the centre of the coil and put dots on either side of the compass.
5. Again place compass at one of the dots, put other dot further.
6. Do the same till we reach the edge of the plank.
7. Now repeat this for the other side of the coil from the centre and then draw a line joining the dots.
8. We will get a field line of the circular coil.
9. Do the same for the other points taken in between the holes and draw corresponding lines.
10. We will get field lines of the circular coil.



11. When the compass needle is kept at the centre of the coil, then the direction in which the compass needle comes to rest indicates the direction of the field due to the coil.
12.Thus the direction of the field is
perpendicular to the plane of the coil.

OBSERVATIONS:

1. When we place the compass in front of one of the faces of the coil then we observe the pole of the compass needle faces the coil.
2. We know that South Pole is attracted to the North Pole.
3. The needle is oriented in such a way that its south pole points towards the north pole of the coil.

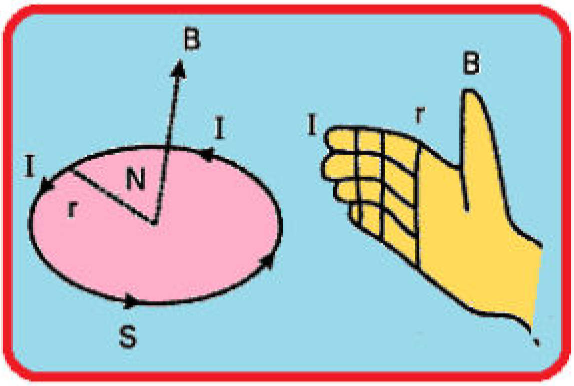
RESULT:

1. So, the direction of magnetic field, due to coil, points towards us when the current in the coil is in anticlockwise direction.
2. When the current in the coil is in clockwise direction, the direction of magnetic field due to the coil points away from us.

NOTE: The direction of the field due to coil or solenoid is determined by using right hand rule.

RIGHT HAND RULE (DEFINITION): When you curl your right hand fingers in the direction of current, thumb gives the direction of magnetic field.

Observe the direction of magnetic field in figure.



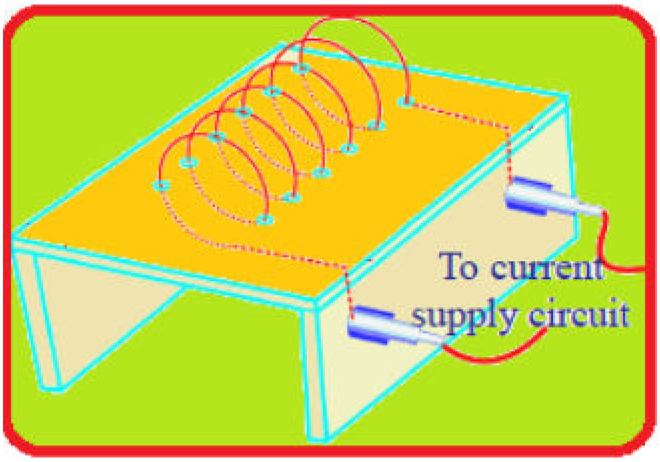
III) MAGNETIC FIELD DUE TO SOLENOID

(or) find the direction of magnetic field around the solenoid (or) show the current carrying wires produce magnetic field (or) show the magnetic field lines are closed loops (or) show electric charges in motion produce magnetic fields:

AIM: To find the direction of magnetic field around the solenoid (or) to show the current carrying wires produce magnetic field (or) to show the magnetic field lines are closed loops (or) to show electric charges in motion produce magnetic fields.

APPARATUS: wooden plank, white paper, battery and copper coil

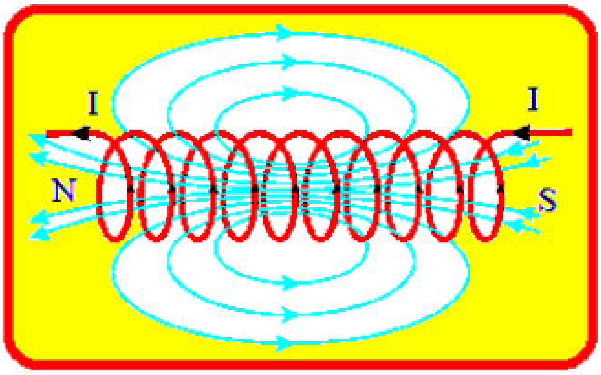
PROCEDURE:

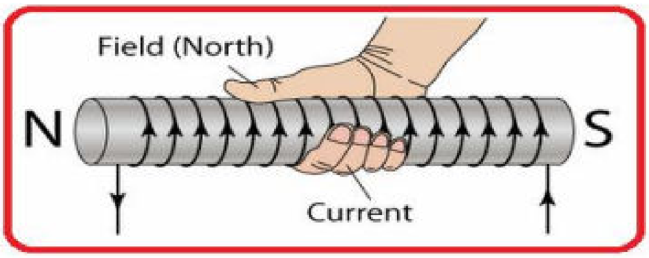


1. Take a wooden plank covered with white paper.
2. Make equidistant holes on its surface and pass copper wire through the holes as a coil as shown in figure.
3. Join the ends of the coil to a battery through a switch and switch on the circuit, then current passes through the coil.
4. Now sprinkle iron filings on the surface of the plank around the coil (this coil is called solenoid) and give a small jerk to it.

OBSERVATIONS:

1. An orderly pattern of iron filings is seen on the paper.
2. The field of solenoid is shown in the figure.





3. The magnetic field lines set up by solenoid resemble those of a bar magnet indicating that a solenoid behaves like a bar magnet.
4. The direction of the field due to solenoid is determined by using right hand rule.

5. One end of the solenoid behaves like a north pole and other end behaves like a south pole.
6. The field lines outside the solenoid are continuous with those inside.
7. Outside the solenoid the direction of the field lines is from north to south while inside the direction is from south to north.

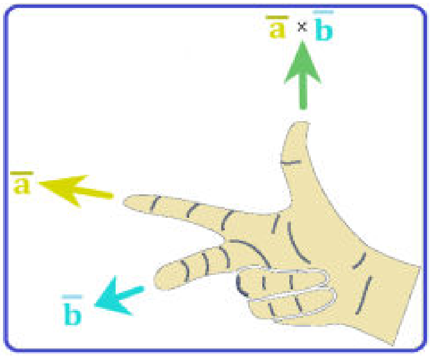
RESULT:

1. Thus the magnetic field lines are closed loops.
2. This is so for the bar magnet too.
3. Therefore the current carrying wires produce magnetic field.
4. So, electric charges in motion produce magnetic fields.

SOLENOID (DEFINITION): A solenoid is a long wire wound in a close packed helix.

MAGNETIC FORCE ON MOVING CHARGE AND CURRENT CARRYING WIRE: INTRODUCTION:

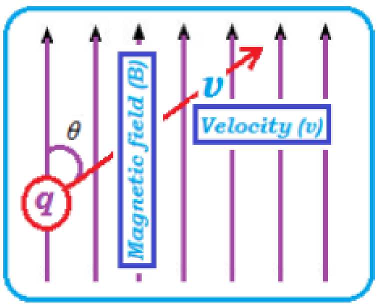
1. Stand near the TV screen and switch on the TV.
2. Take a bar magnet and bring it near the TV screen then we observe that the picture on the screen is distorted.
3. Move the bar magnet away from the screen.
4. Now we will get a clear picture.
5. Repeat this to confirm that the motion of electrons is affected by the field produced by the bar magnet.
6. This is due to the magnetic field exerts a force on the moving charges.
7. This force is called magnetic force.



DERIVATION OF THE APPLIED FORCE ON THE 'Q' CHARGE WHEN IT MOVE IN THE MAGNETIC FIELD (B)

(or) Finding the magnetic force on moving charge and current carrying wire (or) explanation of the magnetic force effect on moving charge and current carrying wire:

1. Let a charge "q" move with a velocity " v " with an angle "θ" to the magnetic field " B ".
2. The value of magnetic force F on the moving unit charge is the cross product of the velocity vector (v) and magnetic field vector (B).



$$\vec{F} = \vec{v} \times \vec{B}$$
$$= |\vec{v}|\,|\vec{B}|\ \sin\theta$$
$$F = vB \sin\theta$$

For "q" charge, the applied Magnetic Force F = qvB sinθ

This is generalized equation for magnetic force on charge when there is an angle "θ" between the directions of field B and velocity v.

Here we consider two cases,

(1) When "q" charge move perpendicular to the magnetic field "B"

(2) When "q" charge move parallel to the magnetic field "B"

CASE1: WHEN 'Q' CHARGE MOVE PERPENDICULAR TO THE MAGNETIC FIELD (B):

When "q" charge move perpendicular to the magnetic field (B), θ=90 and sinθ =sin90 =1.

Therefore,

The applied Magnetic Force

$$F = qvB \sin\theta = qvB \sin 90 = qvB\ (1) = qvB$$
$$F = qvB.$$

So, when q charge move perpendicular to the magnetic field (B),

applied magnetic force F = qvB.

CASE2: WHEN 'Q' CHARGE MOVE PARALLEL TO THE MAGNETIC FIELD (B):

When "q" charge move parallel to the magnetic field (B) then θ = 0 and sinθ = sin0 = 0.

Therefore,

The applied Magnetic Force

$$F = qvB \sin\theta = qvB \sin 0 = qvB\ (0) = 0$$
$$F = 0$$

So, when "q" charge move parallel to the magnetic field (B),

applied magnetic force F = 0.

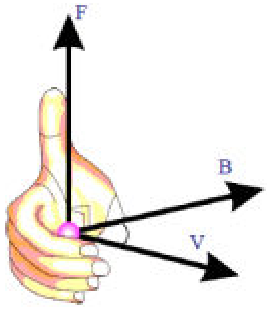
Thus the charge experiences no force when it is moving parallel to the magnetic field (along field direction or against field direction).

IMPORTANT POINTS:

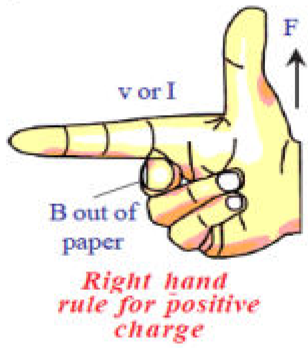
1. Magnetic force on the charge is the product of three quantities charge (q), speed (v) and magnetic flux density (B).
2. The equation for magnetic force acting on a charge "q" is F = q v B and holds well only when the direction of velocity of charged particle "v" is perpendicular to the direction of the magnetic field "B".
3. It is experimentally proved that when there is an angle between direction of field and velocity, the magnetic force experienced by the charge is given by, F = q v B sinθ.
4. When charge moves parallel to the magnetic field (along the magnetic field or against the field) the value of θ becomes zero. In the above equations θ is 0 so that sinθ = 0.

EASY METHOD TO FIND OUT THE DIRECTION OF MAGNETIC FORCE ACTING ON A CHARGE MOVING IN A MAGNETIC FIELD:

1. Keep your right hand fingers along the direction of velocity of moving charge and next curls your fingers towards the direction of magnetic field then the thumb gives the direction of magnetic force as shown in figure.
2. This rule is applied for any case of angle between directions of velocity and field.



3. The direction of magnetic force is always perpendicular to the direction of both velocity and magnetic field.
4. Generally right hand rule is used when velocity and field are perpendicular to each other.
5. This law states that, "If the fore-finger points towards the direction of velocity of charge or current, middle finger points to the direction of field (B) then thumb give direction of force when the three fingers are stretched in such a way that they are perpendicular to each other"" (as shown in figure).



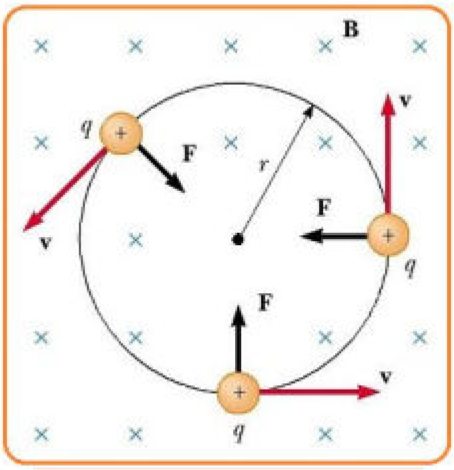
6. This rule is applicable to positive charge.
7. For the direction of negative charge, first find the direction of force acting on a positive charge and reverse its direction this new direction is the direction of force acting on the negative charge.

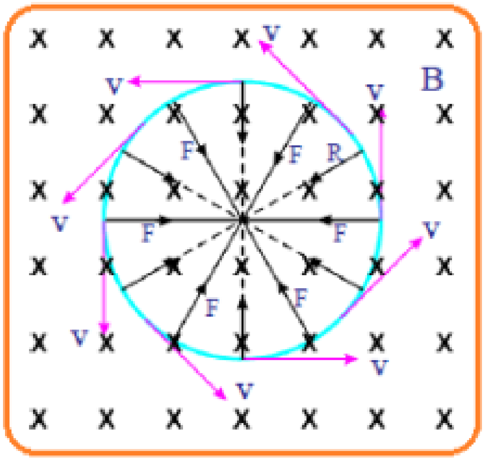
FINDING THE RADIUS OF THE PATH AND TIME PERIOD OF A CHARGED PARTICLE 'Q' WHEN IT IS MOVING WITH A SPEED 'V' PERPENDICULAR TO THE MAGNETIC FIELD OF INDUCTION B

(or) Solve: A charged particle 'q' is moving with a speed 'v' perpendicular to the magnetic field of induction B. Find the radius of the path and time period of the particle.

SOLUTION:

Let us assume that the field is directed into the page as shown in figure.





Then the force experienced by the particle is F = q v B (1)

This force is always directed perpendicular to velocity. Hence the particle moves along a circular path and the magnetic force on a charged particle acts like a centripetal force.

Let r be the radius of the circular path. Then, we know that,

Centripetal force = mv^2 / r → (2)

From (1) and (2) we get,

$$qvB = mv^2 / r$$

On solving, $r = mv / Bq$ → (3)

But, Time period of the particle,

$$T = \frac{2\pi r}{v} \rightarrow (4)$$

On substituting (3) in above equation, we get

$$T = \frac{2\pi(\frac{mv}{Bq})}{v} = \frac{2\pi m}{Bq}$$

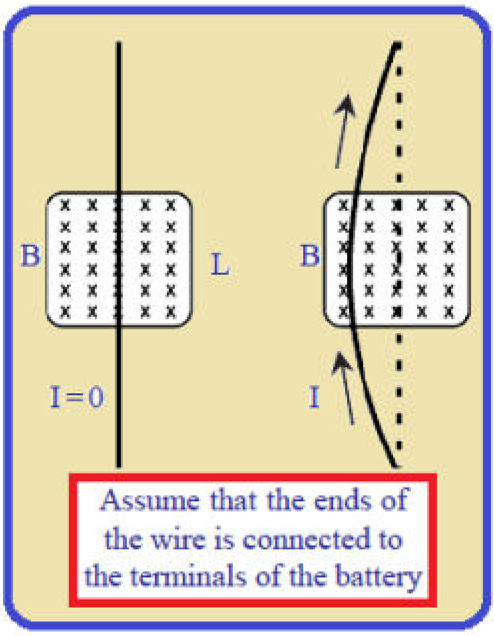
DETERMINATION OF THE MAGNETIC FORCE ON A CURRENT CARRYING WIRE WHICH IS PLACED ALONG A MAGNETIC FIELD:

1. Electric current is charges in motion and each charge experiences a magnetic force.
2. Thus the current carrying wire (collection of charges in motion) experiences magnetic force when it is kept in a magnetic field.

CASE-I: WHEN THE CURRENT CARRYING WIRE PLACED ALONG THE MAGNETIC FIELD:

1. Each charge experiences no magnetic force because they are moving parallel to the direction of field along the field.
2. So the force acting on wire is zero when it is kept along a magnetic field.

CASE-II: WHEN THE CURRENT CARRYING WIRE KEPT PERPENDICULAR TO THE MAGNETIC FIELD:



1. Let a straight wire carrying current is kept perpendicular to a uniform magnetic field "B".

2. Let this "B" is directed into the page and it is represented by "x" as shown in the figure and the field be confined to the length L.

3. So only the part of the wire of the length "L" is inside the magnetic field and the remaining wire is outside the magnetic field.

4. The electric current means charges in motion hence they move with a certain velocity called drift velocity "v".

The magnetic force on a single charge is given by, $F_0 = q\, v\, B$

Let total charge inside the magnetic field is Q.

So magnetic force on the current carrying wire is given by,

$$F = Q\, v\, B \text{ .... } (1)$$

If the time taken by the charge (Q) to cross the field is "t" then,

$$\text{drift velocity } v = \text{displacement}/\text{ time} = L/t \text{.................. } (2)$$

On substituting (2) in equation (1), we get,

$$F = Q\, (L/t)\, B$$

$$F = (Q\,/\,t)\, LB \text{.................. } (3)$$

We know that, according to the definition Q / t is equal to the electric current in the wire,

$$\text{i.e., } I = Q\,/\,t$$

Substituting " I " in the equation (3), we get

$$F = ILB \text{................. } (4)$$

This equation holds well only when direction of electric current is perpendicular to magnetic field.

In figure, we can observe the bending in the wire due to the force F = ILB applied on it.

CASE-III: WHEN THE CURRENT CARRYING WIRE LENGTH MAKES AN ANGLE ‘ θ ’ WITH THE MAGNETIC FIELD:

1. Let "θ" be the angle between direction of current and magnetic field, then the force acting on the current carrying wire is given by

$$F = ILB \sin\theta \text{ (at any angle)}$$

2. We can use right hand rule to find out the direction of force on the current carrying wire.

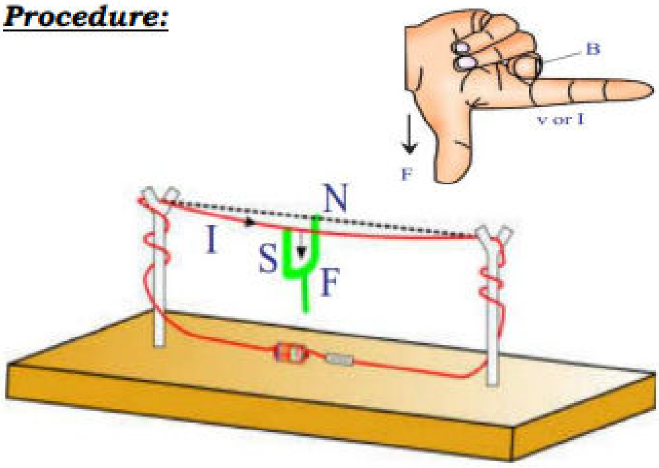
FINDING THE RESULT OF THE FORCE APPLIED ON A CURRENT CARRYING WIRE BY AN EXPERIMENT

(or) Experiment to show that the current carrying conductor experiences a force when it is kept in a magnetic field:

AIM: To Finding the result of force applied on a current carrying wire (or) to show that the current carrying conductor experiences a force when it is kept in a magnetic field.

APPARATUS: wooden plank, wooden sticks, copper wire, battery and switch.

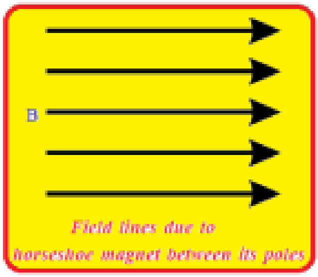
Procedure:



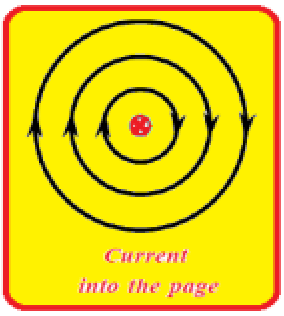
1. Take a wooden plank and fix two long wooden sticks having split at their top ends on it.
2. A copper wire is passed through these splits and the ends of the wire are connected to battery of 3 volt, through a switch.
3. Close the switch to make the circuit then current passes through the wire.
4. Now bring a horseshoe magnet near the copper wire as shown in figure.
5. Use the right thumb rule to find the direction of force.
6. Change polarities of the horse shoe magnet and observe the deflection.
7. Repeat this by changing the direction of current in the circuit.
8. Right hand rule helps us to find the direction of magnetic force exerted by the magnetic field on current carrying wire.
9. It does not help you explain the reason for deflection of wire.
10. Imagine a situation where there is no current in the wire and then there exists only magnetic field due to external source (horse shoe magnet).
11. When there is a current in the wire, it also produces a magnetic field.
12. These fields overlap and give non- uniform field.

CLEAR EXPLANATION:

1. The field in between North and South Pole of horse shoe magnet is shown in the figure.



2. Let us imagine a wire passing perpendicular to the paper and the current pass through it (into the page).
3. It produces a magnetic field as shown in figure.

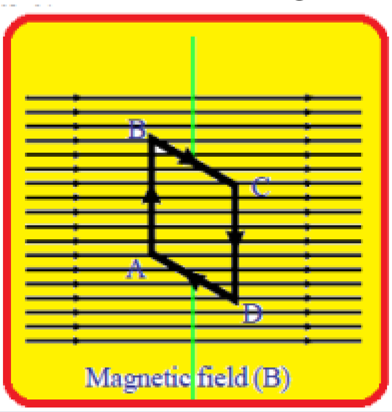


4. Now let us try to sketch the resultant field by observing the field lines.
5. We can see that the direction of the field lines due to the wire in upper part (of circular lines) coincides with the direction of the field lines of horse shoe magnet.
6. The direction of field lines by wire in lower part (of circular lines) is opposite to the direction of the field lines of horse shoe magnet.
7. So that the net field in upper part is strong and in lower part it is weak.
8. Hence a non-uniform field is created around the wire.
9. This non uniform field is shown in figure.

10.Therefore the wire tries to move to the weaker field region.

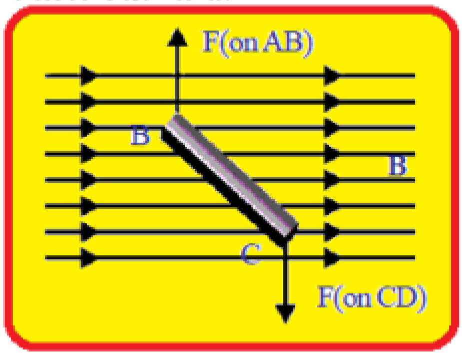
ELECTRIC MOTOR (OR) UNDERSTAND THE WORKING OF AN ELECTRIC MOTOR:

1. To understand the working of an electric motor we need to understand the behavior of a current carrying coil kept in a uniform magnetic field.
2. Consider a rectangular coil kept in a uniform magnetic field as shown in figure.
3. Switch on the circuit so that the current flows through the rectangular coil.
4. The direction of current in the coil is shown in figure

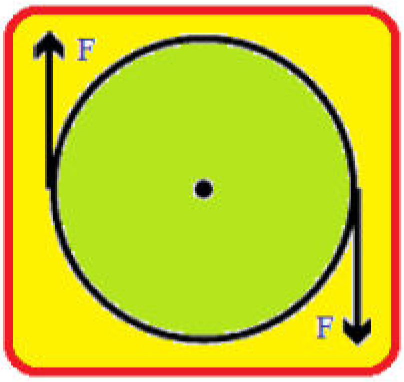


5. We will notice that they are always at right angles to the magnetic field B.

6. Apply right hand rule to get the direction of magnetic force.
7. At AB, the magnetic force acts inward perpendicular to field of the magnet and on CD, it acts outward.

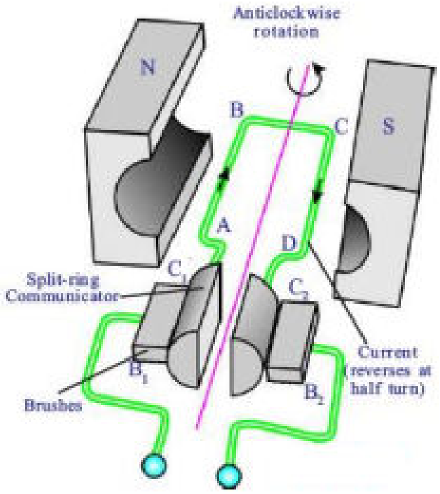


8. This figure is drawn showing top view. The force on the sides BC and DA varies because they make different angles at different positions of the coil in the field.
9. At BC, magnetic force pulls the coil up and at DA magnetic force pulls it down.10. The force on AB is equal and opposite to the force on CD due to external magnetic field because they carry equal currents in the opposite direction.
11. Sum of these forces is zero; similarly the sum of the forces on sides BC and DA is also zero for the same reason. So, net force on the coil is zero.
12. But there is rotation of the coil.
13. Let us consider opening a cap of the bottle as an example where two equal and opposite forces act on the cap.
14. Two forces equal in magnitude but opposite in direction must act on the either side of cap of the bottle as shown in figure.



15. These forces bring the cap into rotation.
16. Similarly the rectangular coil comes into rotation in clockwise direction because of equal and opposite pair of forces acting on the two sides of the coil.
17. If the direction of current in the coil is unchanged, it rotates up to a vertical position then due to its inertia it rotates further in clockwise direction.
18. But now the sides of the coil experience forces which are in the opposite direction to the previous case.
19. Hence these forces try to rotate it in anti clockwise direction.
20. As a result, this coil comes to halt and rotates in anti clock wise direction; this will go on if the direction of current remains unchanged.
21. If the direction of current in the coil, after the first half rotation, is reversed, the coil will continue to rotate in the same direction.

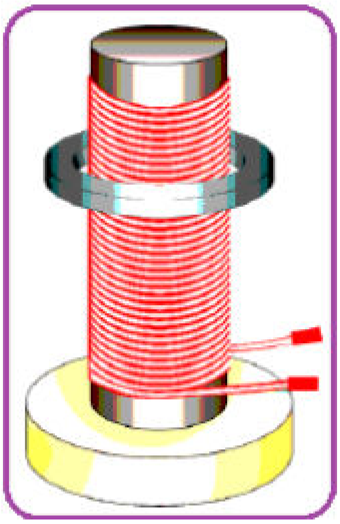
22. Thus if the direction of current through the coil is reversed every half rotation, the coil will rotate continuously in one and the
same direction.
23. To achieve this, brushes B1 and B2 are used, as shown in figure.



24. These brushes are connected to the battery and the ends of the coil are connected to slip rings C1 and C2, which rotate along with the coil.
25. Initially C1 is in contact with B1 and C2 is in contact with B2.
26. After half rotation, the brushes come into contact with the other slip rings in such a way that the direction of current through the coil is reversed.
27. This happen every half rotation.
28. Thus the direction of rotation of the coil remains the same.
29. This is the principle used in "electric motor."
30. In electric motors, electrical energy is converted into mechanical energy.

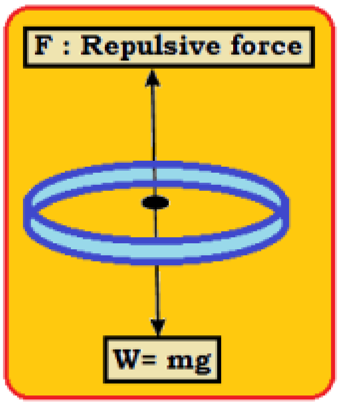
FARADAY'S LAW - ELECTROMAGNETIC INDUCTION (ACTIVITY):

1. Take a wooden base and fix a soft iron cylinder on the wooden base vertically 2. Wind copper wire around the soft iron as shown in the figure.
3. Now take a metal ring which is slightly greater in radius than the radius of the soft iron cylinder and insert it through the soft iron cylinder on the wooden base.
4. Connect the ends of the coil to an AC source and switch on the current.



5. We notice that the metal ring is levitated on the coil.
6. Switch off the current, the ring will jump into the air very dramatically.

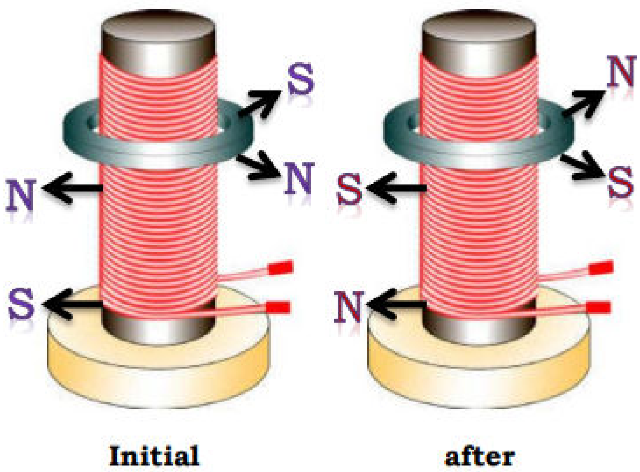
7. Remove the AC supply and connect a DC supply and then we observe that the metal ring lifts up and falls down immediately.
8. The metal ring levitates when AC is used, therefore the net force on it should be zero according to Newton"s second law.
9. The free body diagram of metal ring is shown in figure.

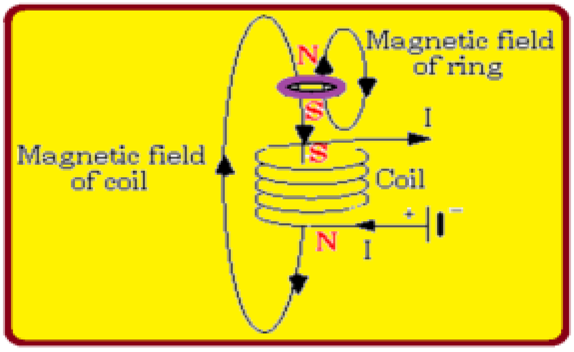


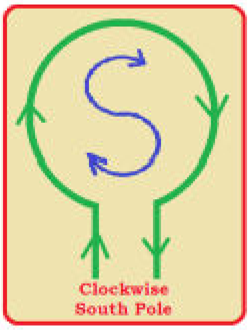
10.Weight (w= mg) acts down and a force (F) equal in magnitude and opposite in direction should act on the ring for balance it as shown in figure.

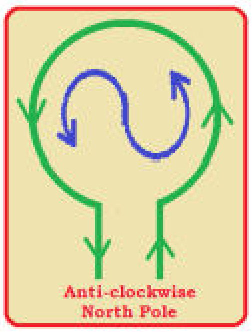
EXPLANATION:

1. In this activity we used AC.
2. AC changes both its magnitude and direction in regular time intervals.
3. We know that the current through the coil, produces a magnetic field so that the coil acts as a bar magnet.
4. One end of the coil behaves like North Pole and other end behaves like South Pole for a certain time interval.
5. For the next interval, the current in the coil changes its direction so that the coil changes its polarities.
6. Hence we can say that coil undergoes changes in its poles in the same intervals of time.
7. Let us suppose the coil produces North Pole at the top and South Pole at the bottom.
8. Then the magnetic field in the coil induces a magnetic field in the metal ring as a result the magnetic ring gets the North Pole at its bottom surface which is faced towards the coil and at the top it gets South Pole.
9. As the poles of the top of the coil and the bottom of the metal ring are like poles (North – North), they repel each other.
10.Therefore the metal ring levitates on the metal cylinder (Coil).









11.Assume that the current flows in clockwise direction in the solenoid as viewed from the top and then the upper end becomes a south pole.
12.An upward force is applied on the ring only when South Pole of the ring faces towards the South Pole of solenoid (i.e. the upper side of the ring becomes a North Pole.
13.It is only possible when there exists anticlockwise current (viewed from the top) in the ring and then the top of the solenoid becomes North Pole and the bottom of metal ring get North Pole.
14.Then the metal ring is levitated.
15.After certain intervals, solenoid changes its polarities, so that the ring should also change its polarities in the same intervals.
16.This is the reason why the metal ring is levitated.
17.AC is not a constant current.
18.So that, the magnetic induction changes in both magnitude and direction in the solenoid and in the ring.
19.Here the area of the metal ring is constant, but the field through the metal ring changes so that flux linked with the metal ring changes.
20.This produced the current in the metal ring.
21.The flux linked with metal ring is zero when no current flows through the solenoid. 22. When the current is allowed to flow through the solenoid, it behaves like bar magnet, so the flux is linked to the metal ring when the switch is on.
22.At that instant there is a change in flux linked with ring. Hence the ring rises up.
23.Thereafter, there is no change in flux linked with coil, hence it falls down.
24.If the switch is off, the metal ring again lifts up and falls down.
25.In this case also, there is a change in flux linked with ring when the switch is off

FARADAY'S LAW:

DEFINITION: "Whenever there is a continuous change of magnetic flux linked with a closed coil, a current is generated in the coil." This is one form of Faraday"s law.

ACTIVITY ON FARADAY'S LAW:

1. Connect the terminals of a coil to a sensitive ammeter or a galvanometer as shown in the figure.
2. Normally, we would not observe any deflections of needle in the galvanometer because there is to be no electromotive force in this circuit.
3. Now if we push a bar magnet towards the coil, with its north pole facing the coil, a remarkable thing happens.

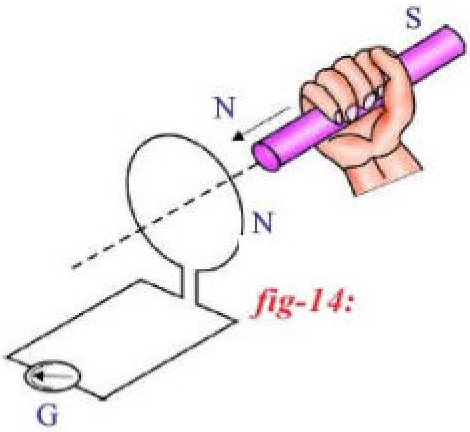


fig-14:

4. While the magnet is moving towards the coil, the needle in galvanometer deflects, showing that a current has been set up in the coil; the galvanometer does not deflect if the magnet is at rest.
5. If the magnet is moved away from the coil, the needle in the galvanometer again deflects, but in the opposite direction, which means that a current is set up in the coil in the opposite direction.
6. If we use the end of South Pole of a magnet instead of North Pole in the above activity, the experiment works just as described but the deflections are exactly reversed.
7. Further experimentation enables us to understand that the relative motion of the magnet and coil set up a current in the coil.
8. It makes no difference whether the magnet is moved towards the coil or the coil towards the magnet.
9. The current generated is called induced current and is set up by an induced electromotive force (induced EMF).
10. This phenomenon of getting induced current is called electromagnetic induction.
11. Faraday observed that the changes in the magnetic flux through the coil are responsible for the generation of current in the coil.
12. He also observed that the rapid changes in flux through coil generate greater induced current or induced EMF.
13. After observing this important factor, he proposed a law of electromagnetic induction.

LAW OF ELECTROMAGNETIC INDUCTION

(Definition): The induced EMF generated in a closed loop is equal to the rate of change of magnetic flux passing through it.
Law of electromagnetic induction

(Definition): The induced EMF generated in a closed loop is equal to the rate of change of magnetic flux passing through it.

Mathematical form:

Its mathematical form is written as, Induced EMF = change in flux/ time

$\varepsilon = \Delta\Phi/\Delta t$

This is called Faraday"s law of induction, where Φ (phi) is the flux linked with coil.

Explanation:

Let Φ0 be the flux linked with single turn. If there are "N" turns in the coil, the flux linked with the coil is N Φ_0.

$$\therefore \Phi = N\,\Phi_0$$

$$\text{Induced EMF for 'N' turns } (\varepsilon) = \Delta\,\Phi/\Delta t$$

$$= \Delta\,(N\,\Phi_0)/\Delta t = N\,(\Delta\Phi_0/\Delta t)$$

So far we have not specified the direction of the induced EMF or induced current. In the previous example, we have observed that an induced current is set up in the loop.

LENZ LAW:

Lenz Law is discovered by Heinrich Lenz.

LENZ LAW (DEFINITION):

The induced current will appear in such a direction that it opposes the changes in the flux in the coil.

EXPLANATION:

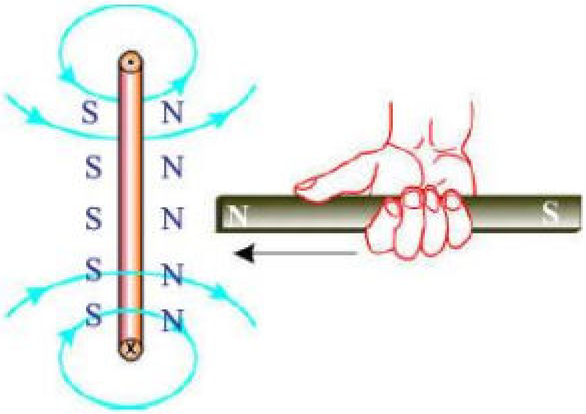
When we push the bar magnet towards
the coils, current is generated, in other word electromagnetic induction takes place and mechanical energy is converted into electrical energy. Let us observe two cases,

a. When a bar magnet is pushed towards a coil.

b. When a bar magnet is pulled away from the coil.

I. WHEN A BAR MAGNET IS PUSHED TOWARDS A COIL:

1. When a bar magnet is pushed towards a coil with its north pole facing the coil an induced current is set up in the coil.
2. Let the direction of current in the coil be in clockwise direction with respect to north pole of the bar magnet.
3. Then this current carrying loop behaves like a magnet, with its south pole facing the north pole of bar magnet.
4. In such a case, the bar magnet attracts the coil and then it gains kinetic energy.
5. This is contradictory to conservation of energy means it cannot obeys the law of conservation of energy.
6. So our assumed clockwise direction of induced current is wrong.
7. Hence the correct direction of induced current has to be in anticlockwise direction with respect to north pole of the bar magnet.
8. In such a case, the north pole of the coil faces the north pole of the bar magnet as shown in figure.



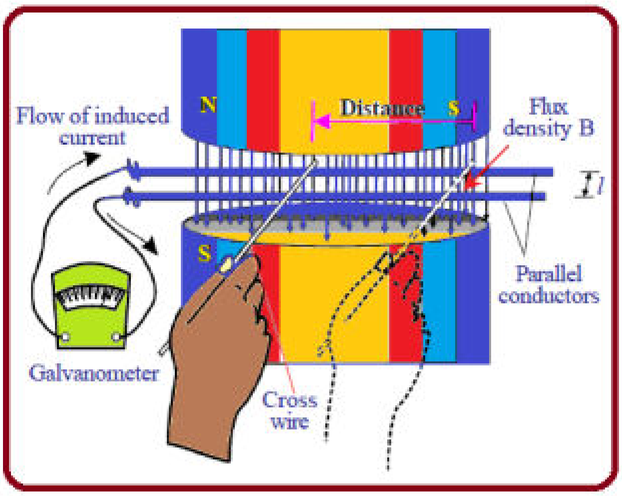
9. Then north pole of bar magnet is repelled by the north pole of the coil.
10.Therefore we need to do work to overcome this force.
11.This work done on the magnet is converted into electrical energy in the coil.
12.In this way conservation of energy takes place in electromagnetic induction.

II. WHEN A BAR MAGNET IS PULLED AWAY FROM THE COIL:

1. When the bar magnet is pulled away from the coil, with north pole facing the coil, the coil opposes the motion of bar magnet to balance the conversion of mechanical energy into electric energy.
2. This happens only when the north pole of the magnet faces the south pole of the coil.
3. The direction of induced current in the coil must be in anti clock wise direction.
4. Means, when flux increases through coil, the coil opposes the increase in the flux and when flux decreases through coil, it opposes the decrease in the flux. This is Lenz"s law.
5. Lenz's law states that "the induced current will appear in such a direction that it opposes the changes in the flux in the coil."

FARADAY'S LAW OF INDUCTION FROM CONSERVATION OF ENERGY

(or) Derivation of the expression for Electric Power:



1. Let us arrange an apparatus consists of a pair of parallel bare conductors are spaced l meters apart in uniform magnetic field of "B" as shown in the figure.
2. We can hold another bare conductor that is in contact with the two parallel wires as shown in the figure.
3. A galvano meter is connected to the ends of parallel conductors to complete an electric circuit.

4. Now if the cross wire (cross conductor) placed across parallel conductors is moved to the left, galvanometer needle will deflect in one direction.
5. If this cross wire is moved to the right, its needle deflects in a direction opposite to the previous deflection.
6. Let us suppose that the crosswire is moved to the left to a distance of "s" meters in a time interval of "Δ t".
7. Then the reading of galvanometer gives us the amount of current that flows in the circuit.
8. A current will be set up in the circuit only when there is an EMF "ε" in the circuit.
9. The principle of conservation of energy tells us that this electric energy (associated with flow of current) must come from the work that we have done in moving the crosswire. Let the work done be W.
10. Then the Electric power

$$P = W/\Delta t \ldots\ldots\ldots\ldots (1)$$

11. If we ignore friction everywhere, in the arrangement, the work done by this applied force

$$W = F \times S \ldots\ldots\ldots\ldots (2)$$

12. A current of "I" amperes flowing through the length of l meters of the cross wire, and the cross wire is in a magnetic field.
13. Then the force applied on crosswire by the field B is equal to BIl.

$$\text{i.e., } F = BIL \ldots\ldots\ldots (3)$$

14. This force must oppose the applied force.
15. The direction of applied force determines the direction of current through the cross wire.
16. Here we are doing positive work and the work done by us in moving the cross wire converts into electric energy.
17. So the work done is given by,

$$W = F \times s = (BIl) \times s = (Bls) \times I \ldots\ldots\ldots (4)$$

(On substituting equation-3 in equation-2)

18. When we put the cross wire across parallel conductors it makes a complete electrical circuit which encloses a certain amount of magnetic flux.
19. Now as we move the cross wire to the left, the area of the loop (formed by the parallel conductors and cross wire) decreases and the flux through the loop also decreases.
20. The decrease in flux is given by,

$$\Delta\Phi = B.A \text{ (A= Area)} = Bls$$

(A= Area = length x breadth,here breadth is equal to displacement)

$$\Delta\Phi = Bls \ldots\ldots\ldots\ldots (5)$$

Here B is perpendicular to the area A=ls.
On substitute equation-5in equation-4 we get,

$$W = (\Delta\Phi)\, I \ldots\ldots\ldots\ldots (6)$$

21. On substitute equation-6 in equation-1 then we get,
Electric power $P = W/\Delta t = (\Delta\Phi)\, I / \Delta t$ Electric power $P = (\Delta\Phi/ \Delta t)\, I$ ……………… (7)
22. Here $\Delta\Phi/\Delta t$ represents emf ε.

$$\text{i.e., } \Delta\Phi/\Delta t = \varepsilon \ldots\ldots\ldots\ldots (8)$$

23. Therefore Electric power

$$P = \varepsilon I \ldots\ldots\ldots\ldots (7)$$

24. Thus the electric power generated in the circuit is equal to product of induced EMF and the current. The voltage is obviously equal to induced EMF.

25. Therefore the mechanical energy utilized to move the cross wire in one second is converted into electric power $P = (\Delta\Phi/\Delta t) I$.

This is nothing but conservation of energy.

On changing Electric power

$$P = W/\Delta t = (F \times s)/\Delta t = (BIl \times s)/\Delta t = (BIl) \times (s/\Delta t)$$

Here $s/\Delta t$ (displacement/ time = speed) gives the speed of the cross wire, let it be taken as v.

26. Then we get, Electric power

$$P = Fv = BIlv\ldots\ldots\ldots (8)$$

Therefore Power is also given as force times velocity.

From equations-8 and equation-7, we get $\varepsilon I = BIlv$

We get, $\varepsilon = Blv$

This is called motional EMF. The above equation is not Faraday"s law of induction because it is not related to the loop. It is useful when a conductor moves in a uniform magnetic field.

APPLICATIONS OF FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION:

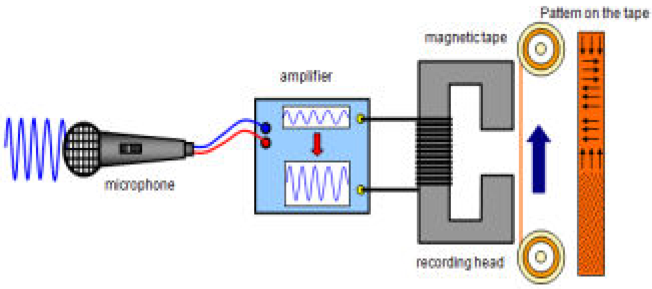
The following are works on the principle of electromagnetic induction.

I. SECURITY CHECKUP DOOR:

1. During security check, people are made to walk through a large upright coil of wire which produces a weak AC (alternating) magnetic field.
2. If we are carrying any significant quantities of iron, the magnetic flux linked with the large coil changes and the induced current generated in coil triggers an alarm.

II. THE TAPE RECORDER:

1. The tape recorder which we use to listen to songs (or) record voices works on the principle of electromagnetic induction.
2. It consists of a piece of plastic tape coated with iron oxide and is magnetized more in some parts than in others.
3. When the tape is moved past as a small coil of wire (head of the tape recorder), the magnetic field produced by the tape changes, which leads to generation of current in the small coil of wire.



III. ATM CARD:

1. When we insert ATM card into the ATM machine, it reads the information on the magnetic strip on the back of the card.
2. The ATM then asks for our PIN to verify our authorization to access account funds and information.
3. When we have verified our PIN, the ATM communicates with our bank to access our account information.
4. It can then display your account balance or distribute cash to you from your bank account balance.

IV. INDUCTION STOVE:

1. An induction stove works on the principle of electromagnetic induction.
2. A metal coil is kept just beneath the cooling surface.
3. It carries alternating current (AC) so that AC produces an alternating magnetic field.
4. When we keep a metal pan with water on it, the varying magnetic field beneath it crosses the bottom surface of the pan and an EMF is induced in it.
5. Because the pan is metal the induced EMF generates an induced current in it.
6. Since the pan has a finite resistance, the flow induced current in it produces heat in it and this heat is conducted to the water.
7. That"s why we call this stove as induction stove.

ELECTRIC GENERATOR:

Electric generators are two types. They are,

I. Alternating Current Generator

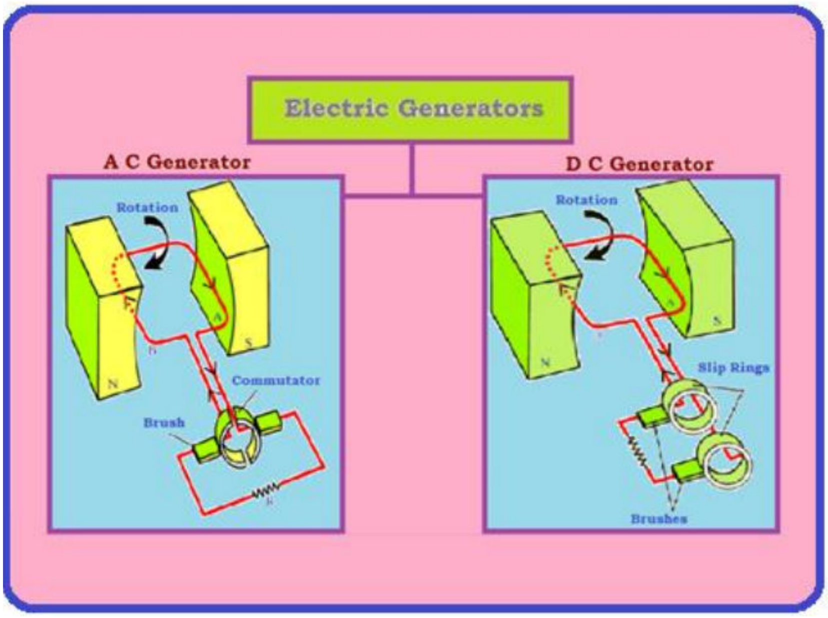
II. Direct Current Generator

ELECTRIC GENERATOR AND ALTERENATING – DIRECT CIRCUITS:

Electric Generator is a machine that converts mechanical energy into electrical energy. It works based on the principle of Faraday"s Law of Electromagnetic Induction.

According to the Faraday"s Law, whenever a conductor is placed in a varying magnetic field, EMF is induced and this induced EMF is equal to the rate of change of flux linked to the conductor.

Electric Generators are two types. They are AC generator and DC generator. Here AC means Alternating Current generator and DC means Direct Current generator.

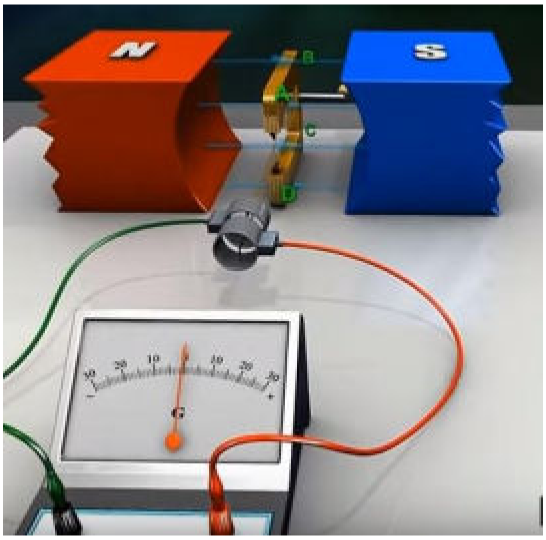


STRUCTURE OF ELECTRIC GENERATOR:

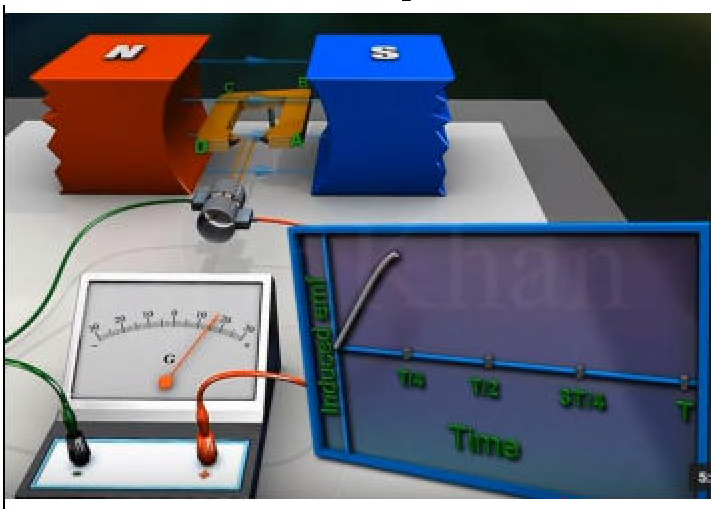
1. Consider a rectangular coil.
2. Let it be held between the poles of Curveshaped permanent magnet as shown in figure.
3. The ends of the coil are connected to two slip rings.
4. Two carbon brushes arranged in such a way that they press the slip rings to obtain current from the coil.
5. When these brushes are connected to external devices like TV, radio, we can make them work with current supplied from ends of carbon brushes.
6. As the coil rotates, the magnetic flux passing through the coil changes.
7. According to the law of electromagnetic induction an induced current is generated in the coil.

WORKING OF AC GENERATOR:

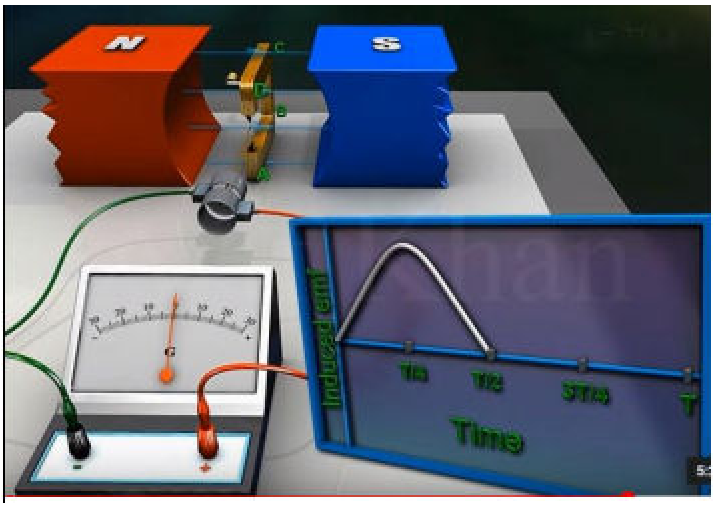
1. Consider initially the coil, positioned in such a way that magnetic flux passes through it.
2. When the coil is at rest in vertical position, with side (A) of coil at top position and side (B) at bottom position, no current will be induced in it.



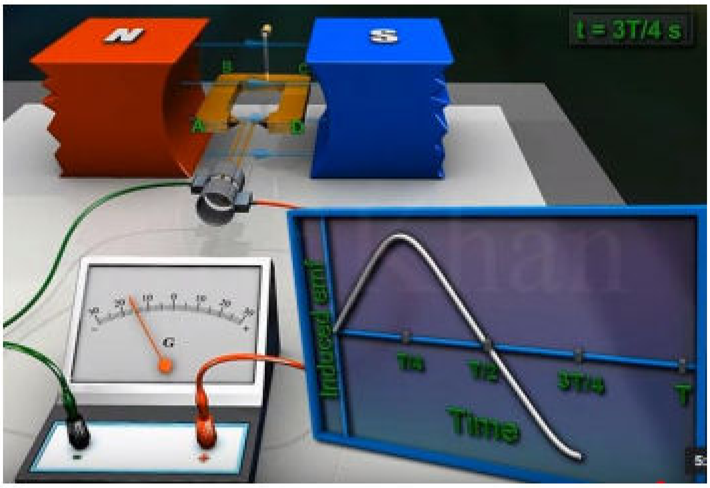
3. Thus current in the coil is zero at this position.
4. When the coil is rotated in clockwise direction, current will be induced in it and it flows from A to B.
5. During the first quarter of rotation, the current increases from zero to a maximum and reaches peak value when the coil is in horizontal position.

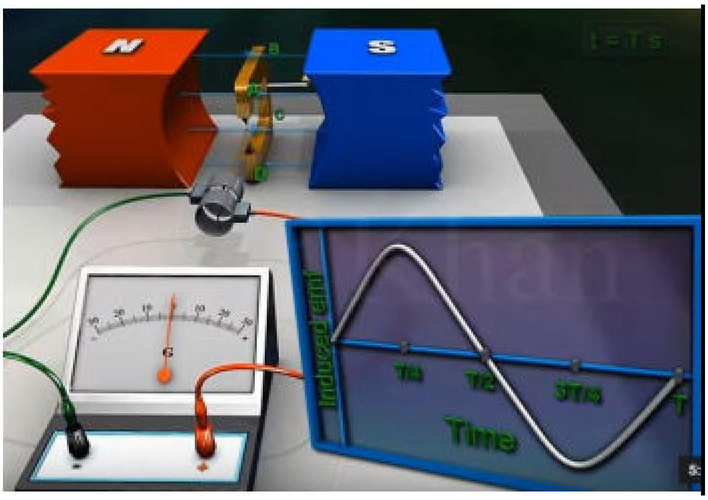


6. If we continue the rotation of coil, current decreases during the second quarter of the rotation and once again becomes zero when coil comes to vertical position with side B at top (A) at bottom position.

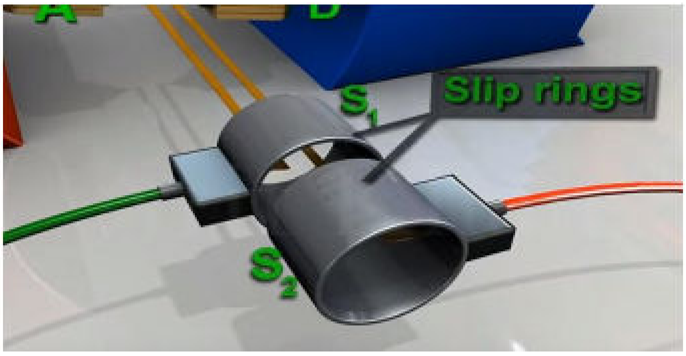


7. During the second part of the rotation, current generated follows the same pattern as that in the first half except that the direction of current is reversed.

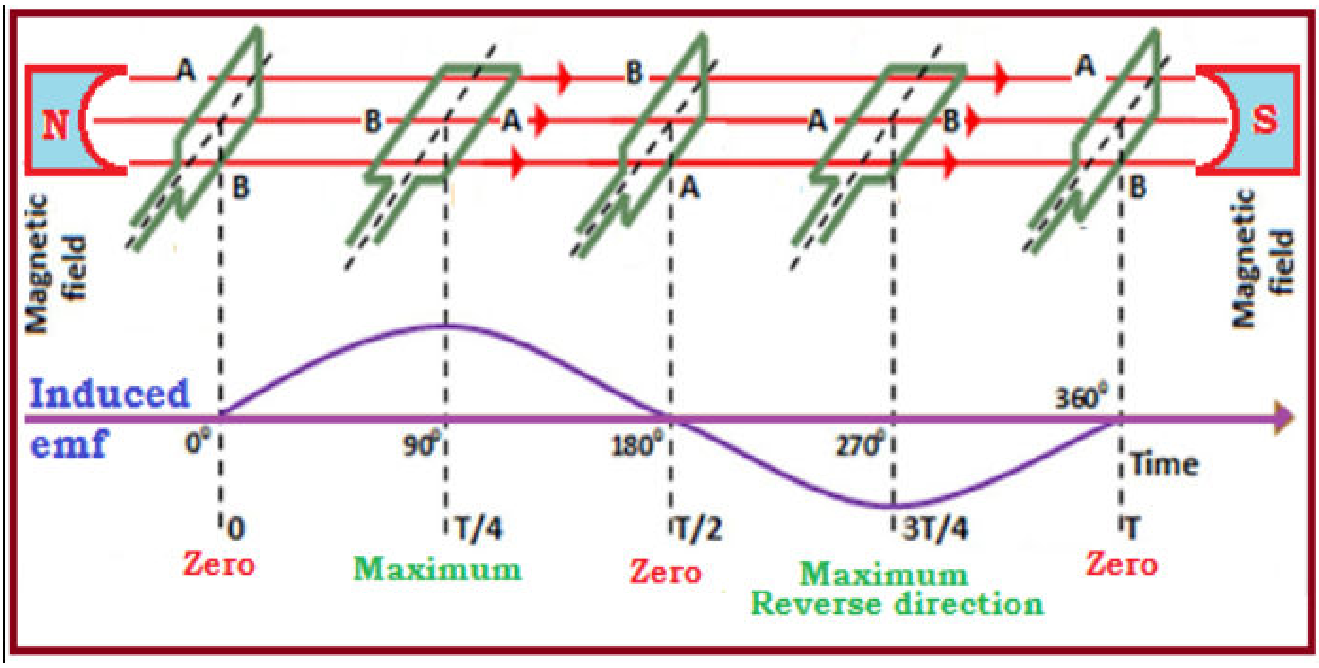


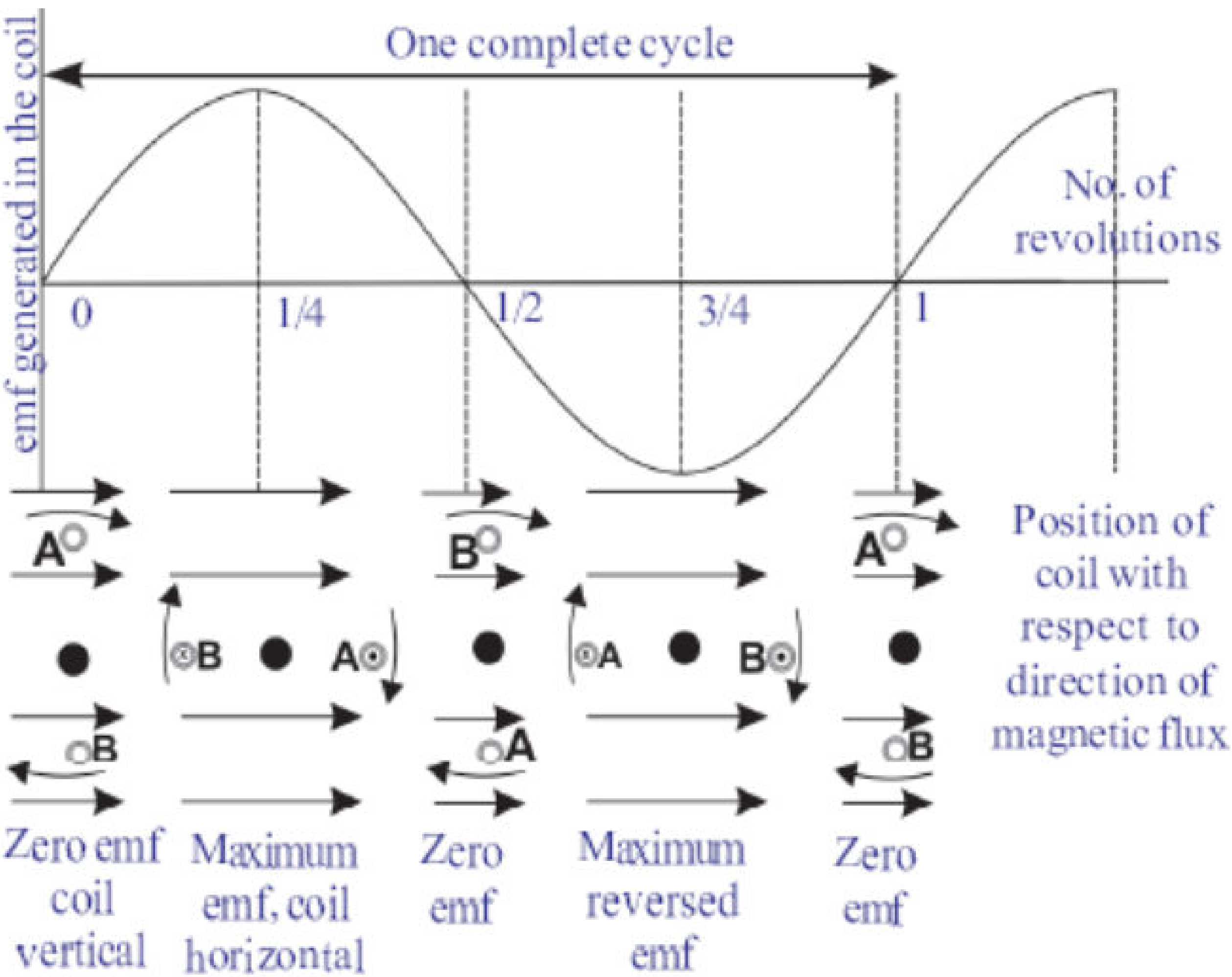


8. The ends of the coil are connected to two slip rings.
9. To use this current, two carbon brushes arranged in such a way that they press the slip rings to obtain current from the coil.



10. When these brushes are connected to external devices like TV, radio, we can make them work with current supplied from ends of carbon brushes.
11. The current obtained by this process changes its direction alternatively for each half cycle as shown in figure and is called alternating current (AC) in which, the direction of charge flow reverses periodically.
12. So AC possesses certain frequency.





EXPRESSION OF AC (V0) EMF AND AC (I0):

These AC - EMF and AC are expressed in terms of rms values. Let I0 and V0 be the peak values of AC and AC - EMF. Then,

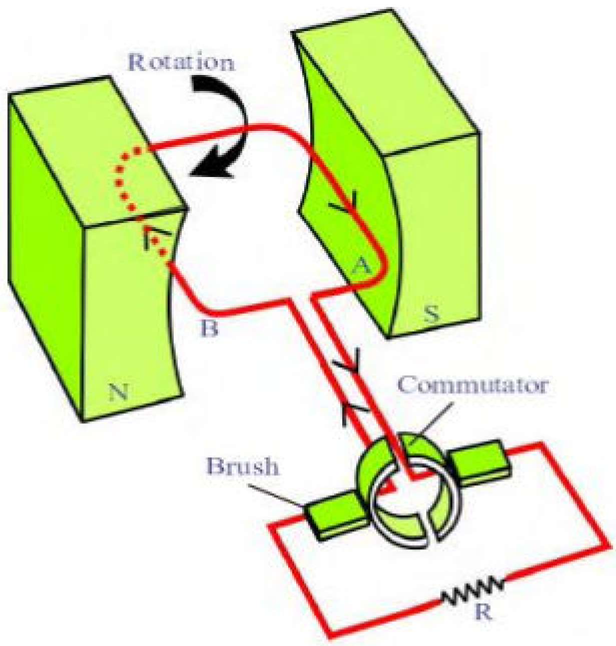
$$I_{rms} = I_0/\sqrt{2} \text{ and } V_{rms} = V_0/\sqrt{2}$$

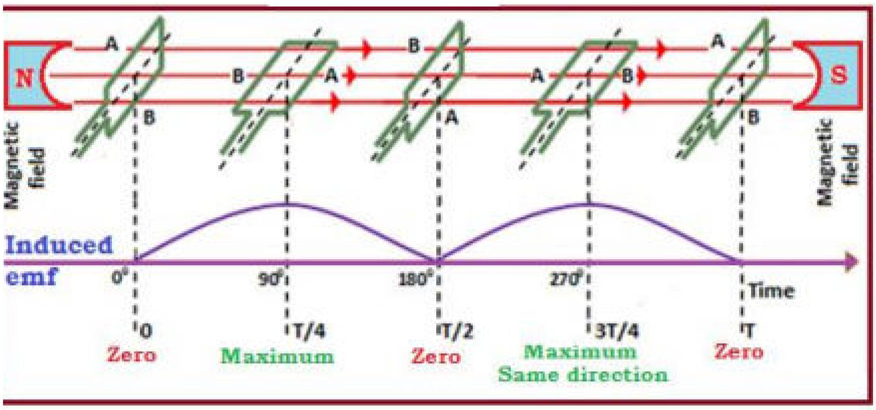
CONVERTING AC GENERATORS INTO DC GENERATOR:

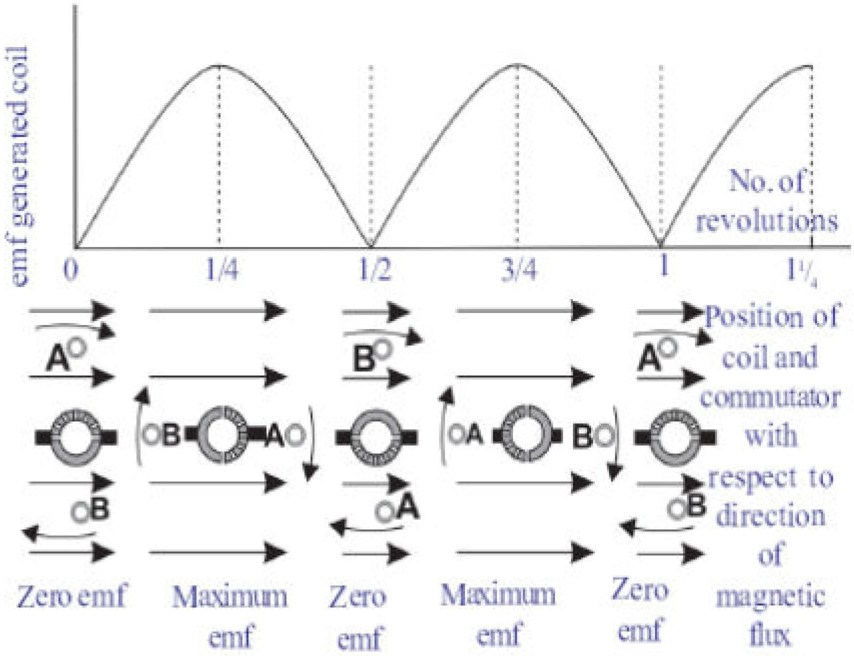
1. If two half slip rings are connected to ends of the coil as shown in figure, the AC generator works as DC generator to produce DC current.

WORKING OF DC GENERATOR

1. When the coil is in the vertical position the induced current generated during the first half rotation, rises from zero to maximum and then falls to zero again.
2. As the coil moves further from this position due to inertia, the ends of the coil go to other slip rings.
3. Hence during the second half rotation, the current is reversed in the coil itself, the current generated in the second half rotation of the coil is identical with that during the first half of direct current (DC) as shown in figure for one revolution.






emf generated coil
No. of revolutions
0
1/4
1/2
3/4
1
1¼
A
B
B
A
A
B
A
B
A
B
Position of coil and commutator with respect to direction of magnetic flux
Zero emf
Maximum emf
Zero emf
Maximum emf
Zero emf