Chapter-13

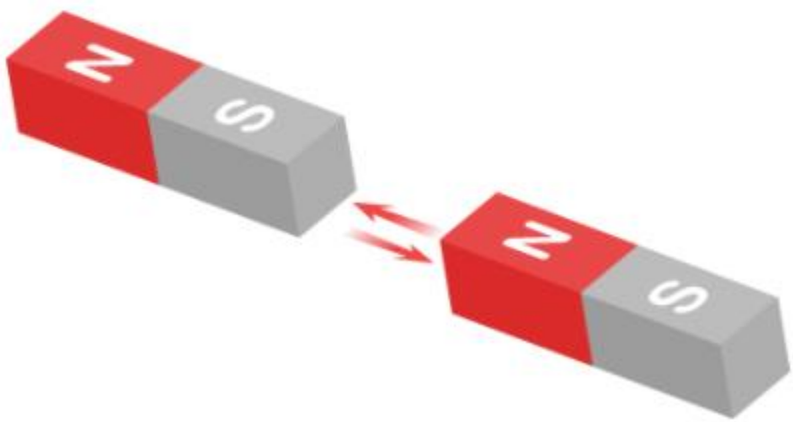
MAGNETIC EFFECT OF ELECTRIC CURRENT

STUDY NOTES

Field and Field Lines

Magnet

A magnet is a material that produces a field that attracts or repels other such materials of magnetic nature.
Lodestone is a naturally occurring magnet. It attracts materials like Iron, Nickel, Cobalt, etc.



North and South Poles

A magnet is always bipolar with poles named north and south poles. These two poles always exist together and can not be separated. North pole of a magnet is the side which points to Earth's geographic north when it is freely suspended.

Like poles repel and unlike poles attract

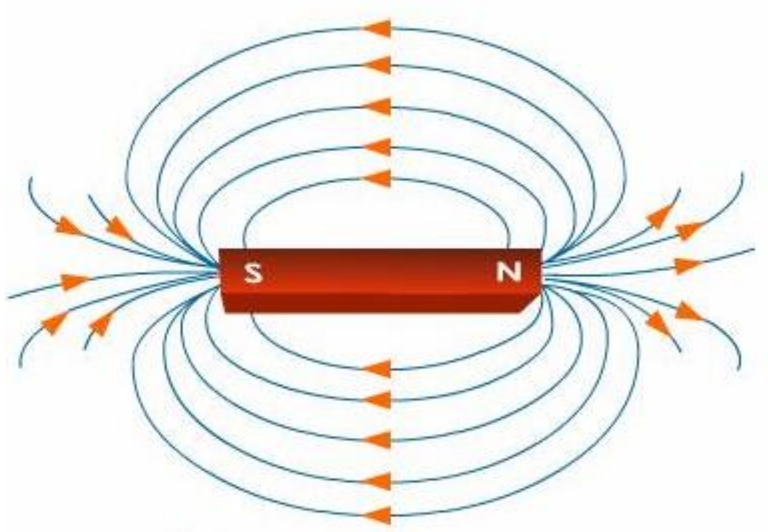
Similar to charges, poles attract and repel. Like poles repel while unlike poles attract each other.

Bar magnet

A bar magnet is a rectangular object, composed of iron, steel or any form of a ferromagnetic substance, that shows permanent magnetic properties. It has two different poles, a north and a south pole such that when suspended freely, the north pole aligns itself towards the geographic north pole of the Earth.

Magnetic field

The region around a magnet where its magnetic influence can be experienced is called a magnetic field. The



Magnet: Magnetic field and magnetic field lines, Magnetic field due to a current carrying conductor, Right hand thumb rule, Magnetic field due to current through a circular loop. Magnetic field due to current in a solenoid.
Magnet is an object that attracts objects made of iron, cobalt and nickle. Magnet comes to rest in North – South direction, when suspended freely.

Use of Magnets: Magnets are used

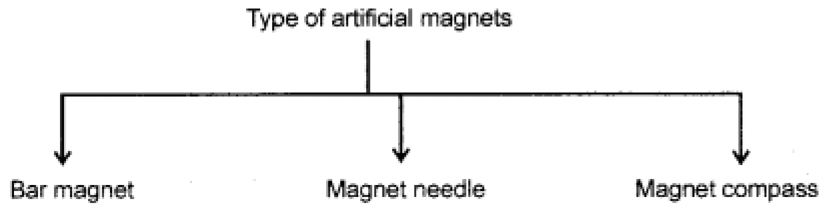
- in refrigerators.
- in radio and stereo speakers.
- in audio and video cassette players.
- in children's toys and;

Properties of Magnet

- A free suspended magnet always points towards the north and south direction.
- The pole of a magnet which points toward north direction is called north pole or north-seeking.

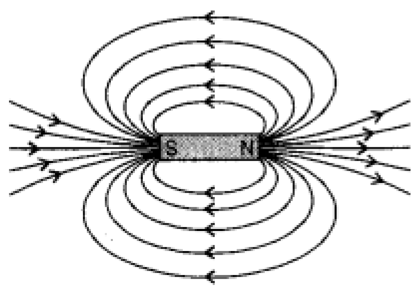
- The pole of a magnet which points toward south direction is called south pole or south seeking.
- Like poles of magnets repel each other while unlike poles of magnets attract each other.

Magnetic field: The area around a magnet where a magnetic force is experienced is called the magnetic field. It is a quantity that has both direction and magnitude, (i.e., Vector quantity).



Magnetic field and field lines: The influence of force surrounding a magnet is called magnetic field. In the magnetic field, the force exerted by a magnet can be detected using a compass or any other magnet.

Magnetic field and field lines: The influence of force surrounding a magnet is called magnetic field. In the magnetic field, the force exerted by a magnet can be detected using a compass or any other magnet.
The magnetic field is represented by magnetic field lines.



The imaginary lines of magnetic field around a magnet are called field line or field line of magnet. When iron fillings are allowed to settle around a bar magnet, they get arranged in a pattern which mimicks the magnetic field lines. Field line of a magnet can also be detected using a compass. Magnetic field is a vector quantity, i.e. it has both direction and magnitude.

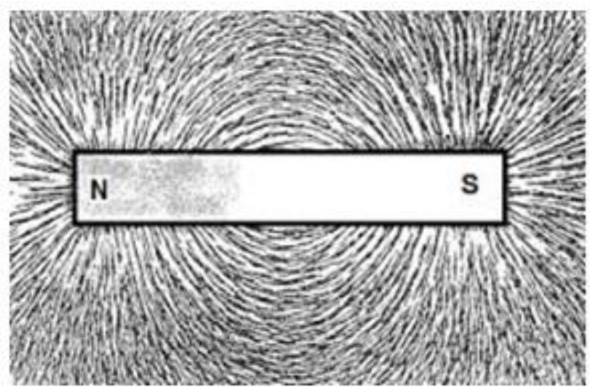
Direction of field line: Outside the magnet, the direction of magnetic field line is taken from North pole to South Pole. Inside the magnet, the direction of magnetic field line is taken from South pole to North pole.

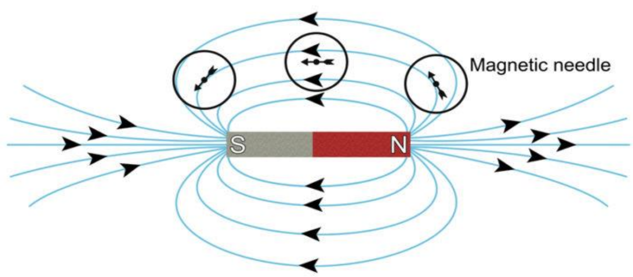
Strength of magnetic field: The closeness of field lines shows the relative strength of magnetic field, i.e. closer lines show stronger magnetic field and vice – versa. Crowded field lines near the poles of magnet show more strength.

Properties of magnetic field lines
(i) They do not intersect each other.
(ii) It is taken by convention that magnetic field lines emerge from North pole and merge at the South pole. Inside the magnet, their direction is from South pole to North pole. Therefore magnetic field lines are closed curves.

Iron filings test around a bar magnet

Iron filings around a bar magnet exhibit the magnetic field lines that engirdle the bar magnet. The magnetic field lines can be explained as imaginary lines that graphically represents the magnetic field that is acting around any magnetic substance.





Magnetic field lines

- Magnet’s magnetic field lines result in the formation of continuous/running closed loops.

- The tangent to the field line at any given point indicates the direction of the total magnetic field at that point.
- The greater the number of field lines crossing per unit area, the higher the intensity, the stronger the magnitude of the magnetic field.
- There is no intersection between the magnetic field lines.

Magnetic field lines for a closed loop

Since magnets have dipoles, magnetic field lines must originate and end. Therefore by convention, it starts at the north pole and moves towards the south pole outside the bar magnet and from south → north inside the magnet. Hence, it forms closed loops.

No two magnetic field lines intersect

Magnetic field lines do not intersect as there will be two tangential magnetic field directions associated with the same point, which does not occur. If a compass needle is placed at that point, it will show two different directions of the magnetic field which is absurd.

Relative strength of magnetic field inferred from magnetic field lines

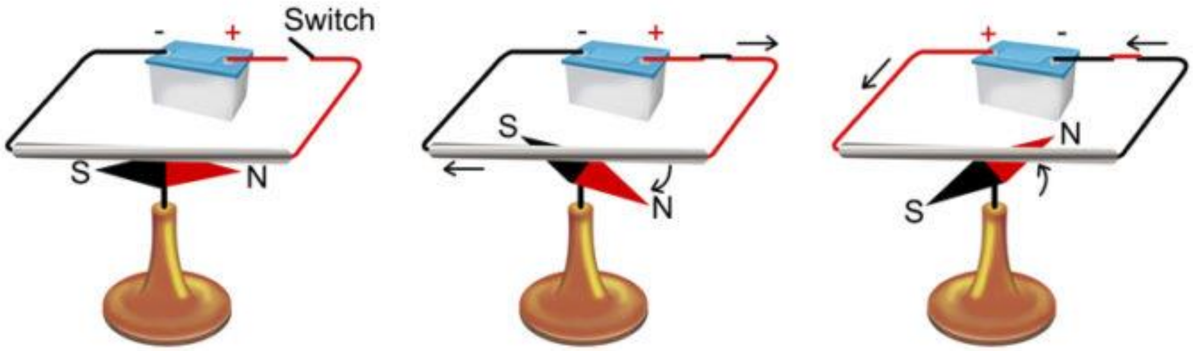
The closer or denser the magnetic field lines, greater is the magnetic field's strength.

To know more about Properties of Magnetic Field Lines, visit here.

Magnetic Field Due to a Current Carrying Conductor

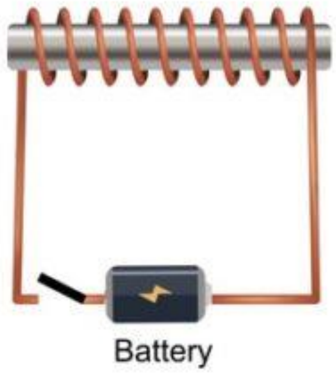
Oersted's experiment

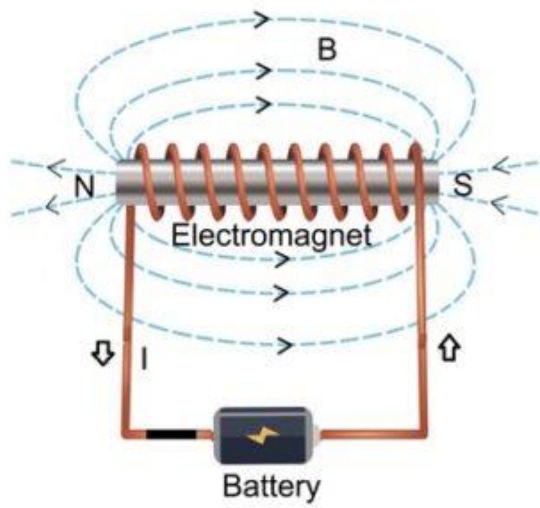
When electric current flows through a current carrying conductor, it produces a magnetic field around it. This can be seen with the help of a magnetic needle which shows deflection. The more the current, the higher the deflection. If the direction of current is reversed, the direction of deflection is also reversed.



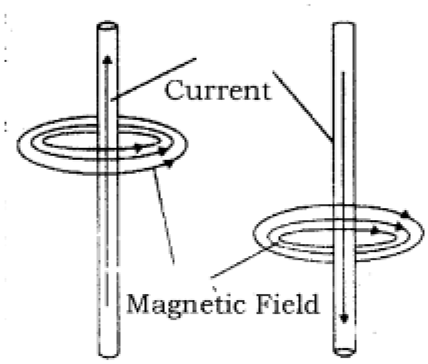
Electromagnetism and electromagnet

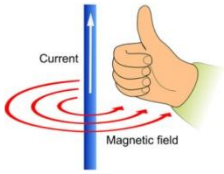
An electromagnet is an artificial magnet which produces a magnetic field on the passage of electric current through a conductor. This field disappears when the current is turned off. The phenomenon of producing or inducing a magnetic field due to the passage of electric current is called electromagnetism.

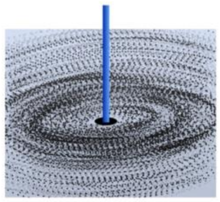




Magnetic field lines due to current a current carrying straight conductor
A current carrying straight conductor has magnetic field in the form of concentric circles, around it. Magnetic field of current carrying straight conductor can be shown by magnetic field lines. The direction of magnetic field through a current carrying conductor depends upon the direction of flow electric current.

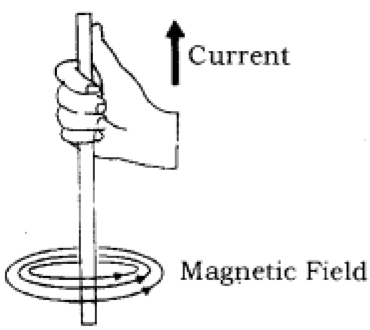


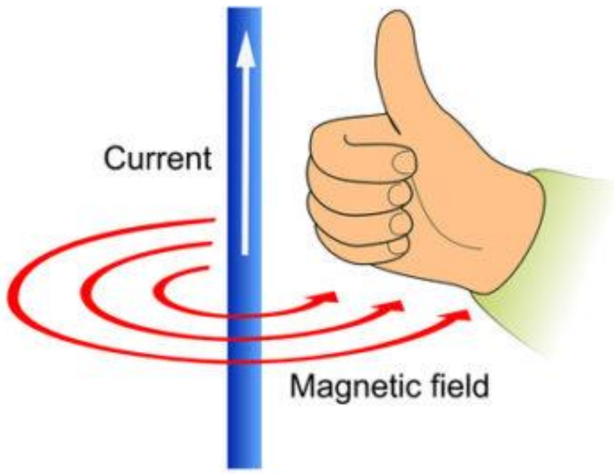




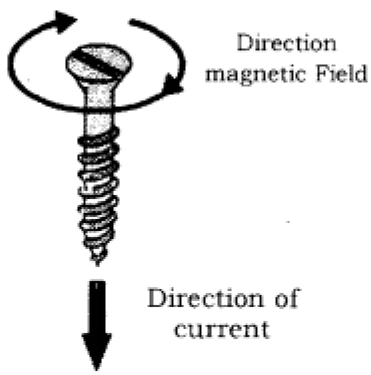
Let a current carrying conductor be suspended vertically and the electric current is flowing from south to north. In this case, the direction of magnetic field will be anticlockwise. If the current is flowing from north to south, the direction of magnetic field will be clockwise.
The direction of magnetic field, in relation to direction of electric
current through a straight conductor can be depicted by using the Right Hand Thumb Rule. It is also knownas Maxwell's Corkscrew Rule.

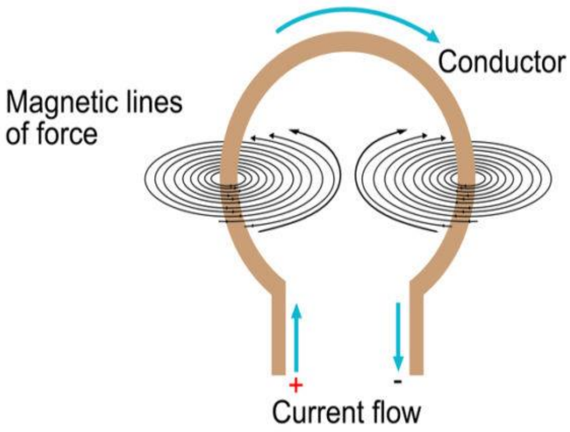
Right-Hand Thumb Rule: If a current carrying conductor is held by right hand, keeping the thumb straight and if the direction of electric current is in the direction of thumb, then the direction of wrapping of other fingers will show the direction of magnetic field.





Maxwell's Corkscrew rule: As per Maxwell's Corkscrew Rule, if the direction of forward movement of screw shows the direction of the current, then the direction of rotation of screw shows the direction of magnetic field.

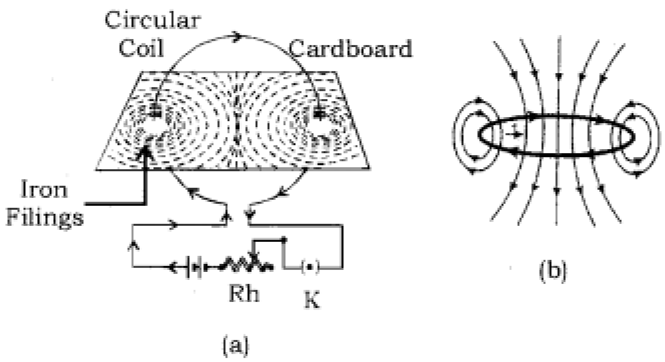




Properties of magnetic field

- The magnitude of magnetic field increases with increase in electric current and decreases with
- decrease in electric current.
- The magnitude of magnetic field produced by electric current decreases with increase in distance and vice – versa. The size of concentric circles of magnetic field lines increases with distance from the conductor, which shows that magnetic field decreases with distance.
- Magnetic field lines are always parallel to each other.
- No two field lines cross each other.

Magnetic field lines due to a current through a circular loop
In case of a circular current carrying conductor, the magnetic field is produced in the same manner as it is in case of a straight current carrying conductor.



In case of a circular current carrying conductor, the magnetic field lines would be in the form of iron concentric circles around every part of the FllmSs periphery of the conductor. Since, magnetic field lines tend to remain closer when near to the conductor, so the magnetic field would be stronger near the periphery of the loop. On the other hand, the magnetic field lines would be distant from each other when we move towards the centre of the current carrying loop. Finally, at the centre, the arcs of big circles would appear as a straight line.

The direction of the magnetic field can be identified using Right Hand Thumb's Rule. Let us assume that the current is moving in anti-clockwise direction in the loop. In that case, the magnetic field would be in clockwise direction, at the top of the loop. Moreover, it would be in an anti-clockwise direction at the bottom of the loop.

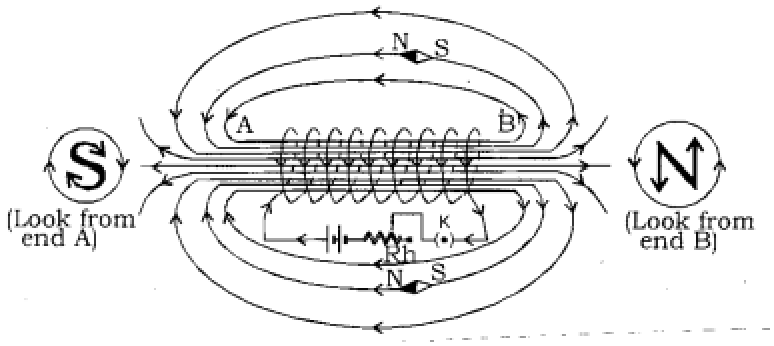
Clock Face Rule: A current carrying loop works like a disc magnet. The polarity of this magnet can be easily understood with the help of Clock Face Rule. If the current is flowing in anti – clockwise direction, then the face of the loop shows north pole. On the other hand, if the current is flowing in clockwise direction, then the face of the loop shows south pole.

Magnetic field and number of turns of coil: Magnitude of magnetic field gets summed up with increase in the number of turns of coil. If there are 'n' turns of coil, magnitude of magnetic field will be 'n' times of magnetic field in case of a single turn of coil.

The strength of the magnetic field at the centre of the loop(coil) depends on :
(i) The radius of the coil: The strength of the magnetic field is inversely proportional to the radius of the coil. If the radius increases, the magnetic strength at the centre decreases
(ii) The number of turns in the coil : As the number of turns in the coil increase, the magnetic strength at the centre increases, because the current in each circular turn is having the same direction, thus, the field due to each turn adds up.

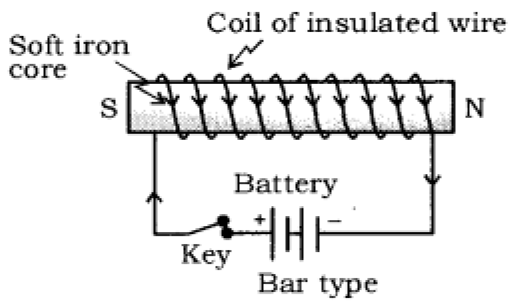
(iii) The strength of the current flowing in the coil: As the strength of the current increases, the strength of three magnetic fields also increases.

Magnetic field due to a current in a Solenoid: Solenoid is the coil with many circular turns of insulated copper wire wrapped closely in the shape of a cylinder. A current carrying solenoid produces similar pattern of magnetic field as a bar magnet. One end of solenoid behaves as the north pole and another end behaves as the south pole.



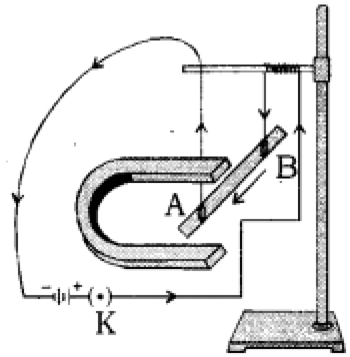
Magnetic field lines are parallel inside the solenoid, similar to a bar magnet, which shows that magnetic field is same at all points inside the solenoid.
Magnetic field produced by a solenoid is similar to a bar magnet.
The strength of magnetic field is proportional to the number of turns and magnitude of current.
By producing a strong magnetic field inside the solenoid, magnetic materials can be magnetized. Magnet formed by producing magnetic field inside a solenoid is called electromagnet.

Electromagnet, Fleming's Left-Hand Rule, Electric motor, Electromagnetic induction, Fleming's right hand rule, Electric generator and domestic electic circuits.
Electromagnet: An electromagnet consists of a long coil of insulated copper wire wrapped on a soft iron.
Magnet formed by producing magnetic field inside a solenoid is called electromagnet.



Force on a current carrying conductor in a magnetic field: A current carrying conductor exerts a force when a magnet is placed in its vicinity. Similarly, a magnet also exerts equal and opposite force on the current carrying conductor. This was suggested by Marie Ampere, a French Physicist and considered as founder of science of electromagnetism.

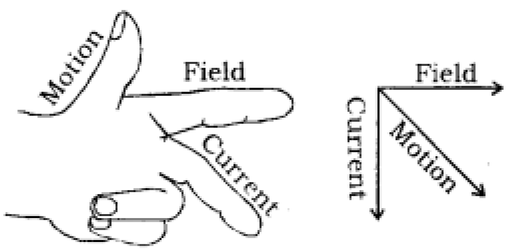
science of electromagnetism.



The direction of force over the conductor gets reversed with the change in direction of flow of electric current. It is observed that the magnitude of force is highest when the direction of current is at right angles to the magnetic field.

Fleming's Left-Hand Rule: If the direction of electric current is perpendicular to the magnetic field, the direction of force is also perpendicular to both of them. The Fleming's Left Hand Rule states that if the left hand is stretched in a way that the index finger, the middle finger and the thumb are in mutually perpendicular directions, then the index finger and middle finger of a stretched left hand show the direction of magnetic field and direction of electric current respectively and the thumb shows the direction of motion

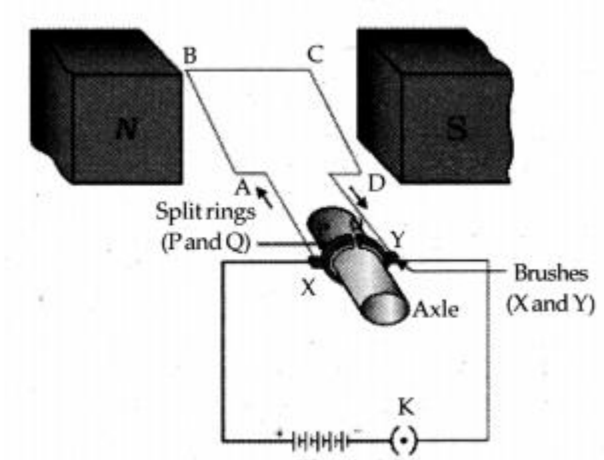
or force acting on the conductor. The directions of electric current, magnetic field and force are similar to three mutually perpendicular axes, i.e. x, y, and z-axes.
Many devices, such as electric motor, electric generator, loudspeaker, etc. work on Fleming's Left Hand Rule.



Electric motor: A device that converts electrical energy to mechanical energy. It is of two types : AC and DC

Electrical energy is converted into mechanical energy by using and electric motor. Electric motor works on the basis of rule suggested by Marie Ampere and Fleming's Left Hand Rule.

Principle of Electric Motor: When a rectangular coil is placed in a magnetic field and a current is passed through it, force acts on the coil, which rotates it continuously. With the rotation of the coil, the shaft attached to it also rotates.



Electric Motor

Construction: It consists of the following parts :

- Armature: It is a rectangular coil (ABCD) which is suspended between the two poles of a magnetic field.
  The electric supply to the coil is connected with a commutator.
- Commutator or Split – ring: Commutator is a device which reverses the direction of flow of electric current through a circuit. It is two halves of the same metallic ring.
- Magnet: Magnetic field is supplied bv a permanent magnet NS.
- Sliding contacts or Brushes Q which are fixed.
- Battery: These are consists of few cells.

Working: When an electric current is supplied to the coil of the electric motor, it gets deflected because of magnetic field. As it reaches the halfway, the split ring which acts as commutator reverses the direction of flow of electric current. Reversal of direction of the current, reverses the direction of forces acting on the coil. The change in direction of force pushes the coil, and it moves another half turn. Thus, the coil completes one rotation around the axle. Continuation of this process keeps the motor in rotation.

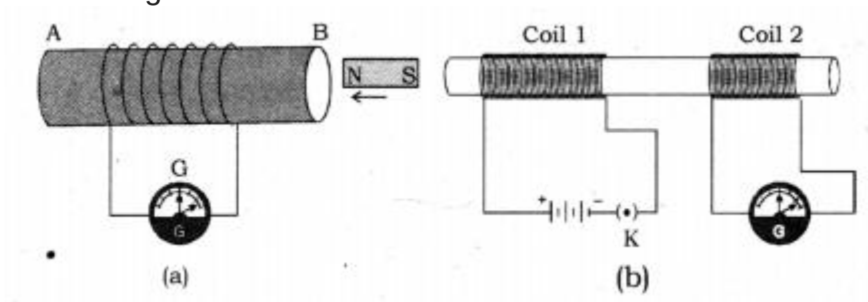
In commercial motor, electromagnet instead of permanent magnet and armature is used. Armature is a soft iron core with large number of conducting wire turns over it. Large number of turns of conducting wire enhances the magnetic field produced by armature.

Uses of motors :

- Used in electric fans.

- Used for pumping water.
- Used in various toys.

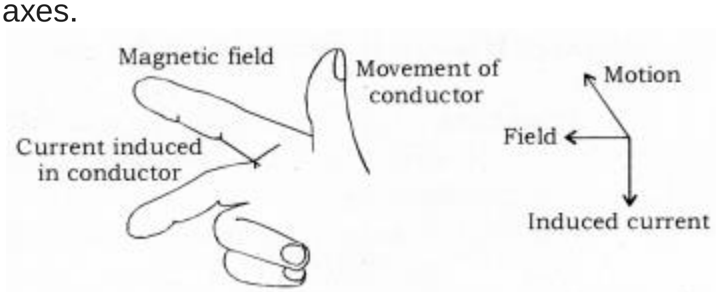
Electromagnetic Induction: Michael Faraday, an English Physicist is supposed to have studied the generation of electric current using a magnetic field and a conductor. Electricity production as a result of magnetism (induced current) is called Electromagnetic Induction.



When a conductor is set to move inside a magnetic field or a magnetic field is set to be changing around a conductor, electric current is induced in the conductor. This is just opposite to the exertion of force by a current carrying conductor inside a magnetic field. In other words, when a conductor is brought in relative motion vis – a – vis a magnetic field, a potential difference is induced in it. This is known as electromagnetic induction.

Fleming's Right-Hand Rule: Electromagnetic induction can be explained with the help of Fleming's Right Hand Rule. If the right hand is structured in a way that the index (fore ginger) finger, middle finger and thumb are in mutually perpendicular directions, then the thumb shows direction of induced current in the

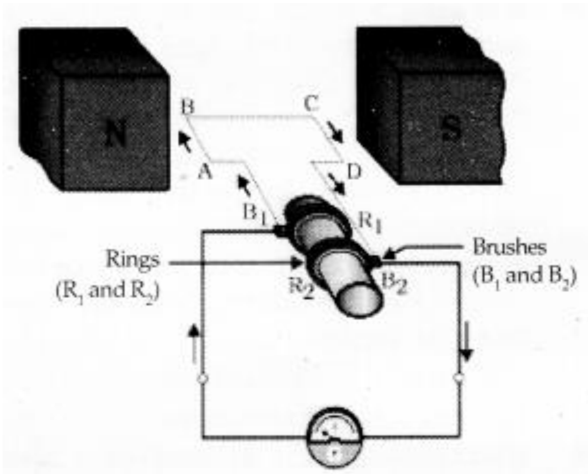
conductor, in conductor The directions of movement of conductor, magnetic field and induced current can be compared to three mutually perpendicular axes, i.e. x, y and z axes.



The mutually perpendicular directions also point to an important fact that when the magnetic field and movement of conductor are perpendicular, the magnitude of induced current would be maximum.
Electromagnetic induction is used in the conversion of kinetic energy into electrical energy.

Electric Generator: A device that converts mechanical energy into electrical energy is called an electric generator.
Electric generators are of two types: AC generator and a DC generator. Principle of electric generator: Electric motor works on the basis of electromagnetic induction.

Electric motor works on the basis of electromagnetic induction.

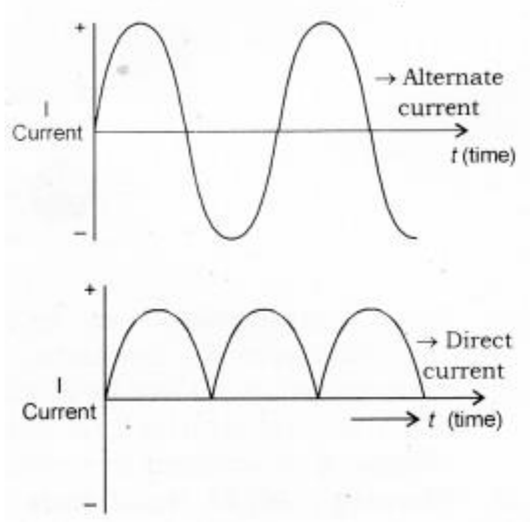


Construction and Working: The structure of an electric generator is similar to that of an electric motor. In case of an electric generator, a rectangular armature is placed within the magnetic field of a permanent magnet. The armature is attached to wire and is positioned in a way that it can move around an axle. When the armature moves within the magnetic field, an electric current is induced. The direction of induced current changes, when the armature crosses the halfway mark of its rotation.

Thus, the direction of current changes once in every rotation. Due to this, the electric generator usually produces alternate current, i.e. A.C. To convert an A.C generator into a D.C generator, a split ring commutator is used. This helps in producing direct current. Electrical generator is used to convert mechanical energy into electrical energy.

A.C and D.C Current
A.C – Alternate Current: Current in which direction is changed periodically is called Alternate Current. In India, most of the power stations generate alternate current. The direction of current changes after every 1/100 second in India, i.e. the frequency of A.C in India is 50 Hz. A.C is transmitted upto a long distance without much loss of energy is

advantage of A.C over D.C.



D.C – Direct Current: Current that flows in one direction only is called Direct current. Electrochemical cells produce direct current.
Advantages of A.C over D.C

- Cost of generatior of A.C is much less than that of D.C.
- A.C can be easily converted to D.C.
- A.C can be controlled by the use of choke which involves less loss of power whereas, D.C can be controlled using resistances which involves high energy loss.
- AC can be transmitted over long distances without much loss of energy.
- AC machines are stout and durable and do not need much maintenance.

Disadvantages of AC

- AC cannot be used for the electrolysis process or showing electromagnetism as it reverses its polarity.
- AC is more dangerous than DC.

Domestic Electric Circuits: We receive electric supply through mains supported through the poles or cables. In our houses, we receive AC electric power of 220 V with a frequency of 50 Hz.
The 3 wires are as follows

- Live wire – (Red insulated, Positive)
- Neutral wire – (Black insulated, Negative)
- Earth wire – (Green insulated) for safety measure to ensure that any leakage of current to a metallic body does not give any serious shock to a user.

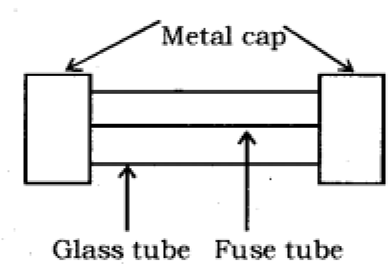
Short Circuit: Short-circuiting is caused by the touching of live wires and neutral wire and sudden a large current flows.
It happens due to

- damage pf insulation in power lines.
- a fault in an electrical appliance.

Overloading of an Electric Circuit: The overheating of electrical wire in any circuit due to the flow of a large current through it is called overloading of the electrical circuit.
A sudden large amount of current flows through the wire, which causes overheating of wire and may cause fire also.

Electric Fuse: It is a protective device used for protecting the circuit from short-circuiting and overloading. It is a piece of thin wire of material having a low melting point and high resistance.

- Fuse is always connected to live wire.
- Fuse is always connected in series to the electric circuit.
- Fuse is always connected to the beginning of an electric circuit.
- Fuse works on the heating effect.
- Fuse works on the heating effect.



Magnetic field: The area around a magnet in which other magnet feels force of attraction or repulsion is called Magnetic field.

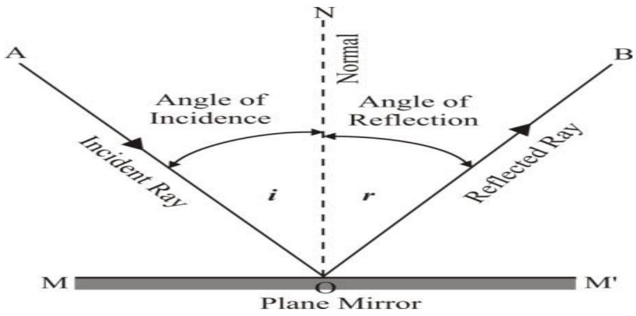
Magnetic field lines: The closed curved imaginary lines in the magnetic field which indicate the direction of motion of north pole in the magnetic field if a magnet is free to do so.

Properties of magnetic field lines.

Laws of reflection of light:

The two laws of reflection of light are:

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



- The metal which is the best reflector of light: Silver
- A ray of light which is incident normally on a mirror is reflected back among its own path.

Image: If light rays coming from a point after reflection meet at another point or appear to meet at another point, then the second point is called the image of the first point.

Types:

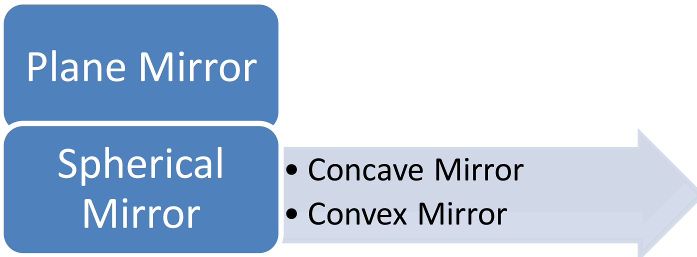
- Real Image
- Virtual Image

Real Image	Virtual Image
• If the light rays coming from a point actually meet after reflection, then the image formed is called a real image.	• If the light rays coming from a point, after reflection does not meet actually, but appear to meet at another point then the image formed is called virtual image.
• It can be formed on a screen.	• It cannot be formed on a screen.
• It is inverted	• It is erect.
• Image formed by a concave mirror when the object is at c	• Image formed by a plane mirror.

Mirror:

Mirror is a polished surface, which reflects almost all the light incident on it.

- **Types**



Plane Mirror: If the reflecting surface of a mirror is plane, then the mirror is called a plane mirror.

Characteristics of image formed by a plane mirror:

1. Virtual and erect
2. Size of image is equal to size of the object.
3. Image distance is equal to the object distance.
4. The image is laterally inverted (left seems to be right and vice-versa.

Uses of Plane Mirror:

1. Looking glass
2. Making periscope
3. Making kaleidoscope.

The focal length of a plane mirror is infinity.

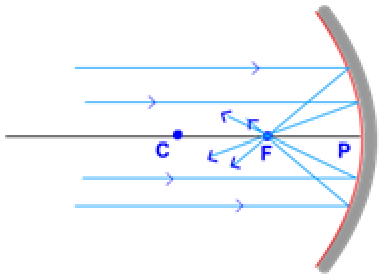
The magnification of image formed by a plane mirror is 1

Spherical Mirrors:

If the reflecting surface of the mirror is curved inward or out ward, then the mirror is called a spherical mirror.

- **Concave Mirror:**

A spherical mirror whose inner side is the reflecting surface is called **concave mirror**. A concave mirror is also known as **converging mirror** as it converges the incident rays after reflection.

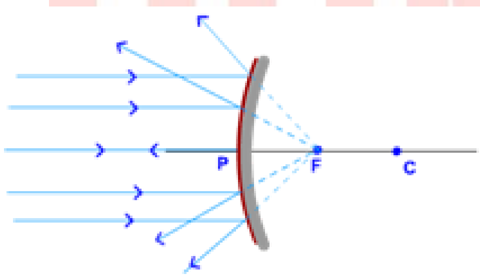


- In the case of a concave mirror, parallel rays coming from infinity converge after reflection in front of the mirror. Thus, the focus lies in front of a concave mirror.

- **Convex Mirror:**

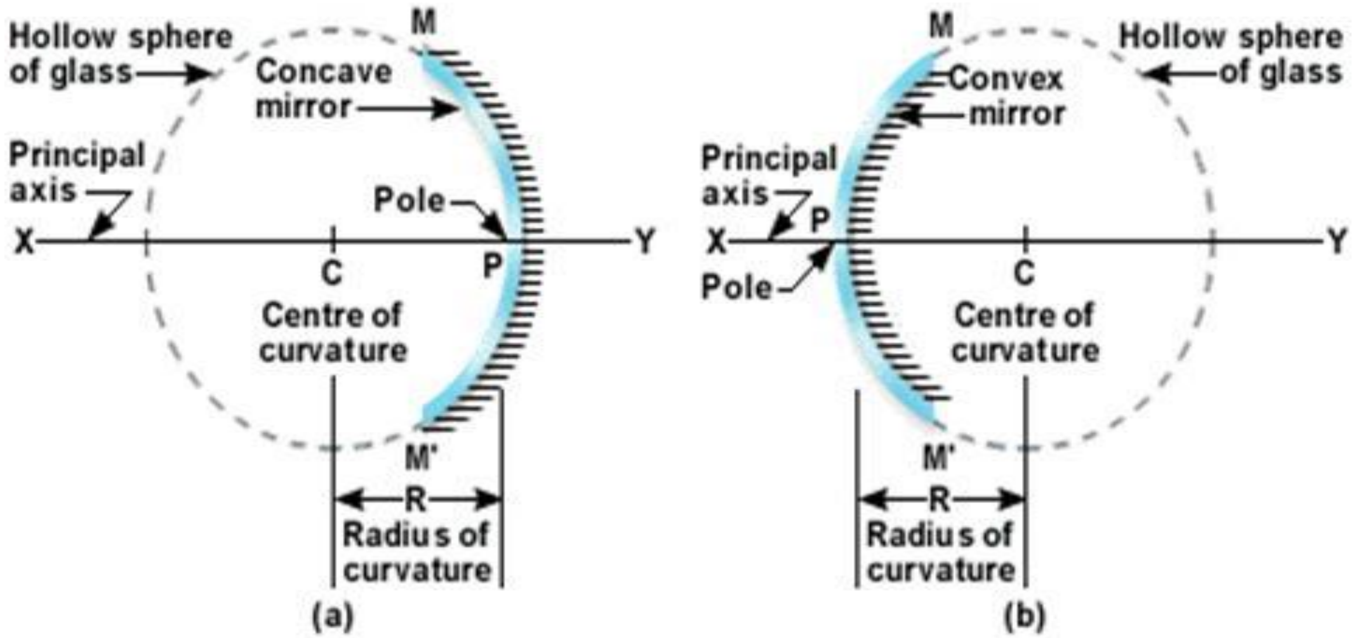
A spherical mirror, whose reflecting surface is curved outwards is called convex mirror.

A convex mirror is also known as diverging mirror as it diverges the incident rays after reflection.



In the case of a convex mirror, parallel rays coming from infinity appear to be diverging from behind the mirror. Thus, the focus lies behind the convex mirror.

Some definitions related to Spherical mirrors:



- **Pole**: The centre of reflecting surface of a spherical mirror is known as Pole. Pole lies on the surface of spherical mirror.

Pole is generally represented by **'P'**.

The middle point of the mirror is called pole of the mirror.

- **Centre of Curvature**: The reflecting surface of a spherical mirror forms a part of a sphere.

This sphere has a centre. This point is called the centre of curvature of the spherical mirror.

It is represented by the letter **C**.

In the case of concave mirror centre of curvature lies in front of the reflecting surface.

Centre of curvature lies behind the reflecting surface in the case of convex mirror.

- **Radius of Curvature**: The radius of sphere of which the reflecting surface of a spherical mirror is a part is called the Radius of Curvature of the spherical mirror.

The radius of curvature of a spherical mirror is denoted by letter '**R**'.

- **Aperture:** The diameter of reflecting surface of a spherical mirror is called aperture(shown as MM' i.e., vertical line joining M and M')
- **Principal Axis**: Imaginary line passing through the centre of curvature and pole of a spherical mirror is called the Principal Axis.
- **Focus or Principal Focus**: Point on principal axis at which parallel rays coming from infinity converge after reflection is called the Focus or Principal Focus of the spherical mirror. Focus is represented by letter 'F'.
- **Focal length**: The distance from pole to focus is called focal length. Focal length is denoted by letter 'f'. Focal length is equal to half of the radius of curvature.

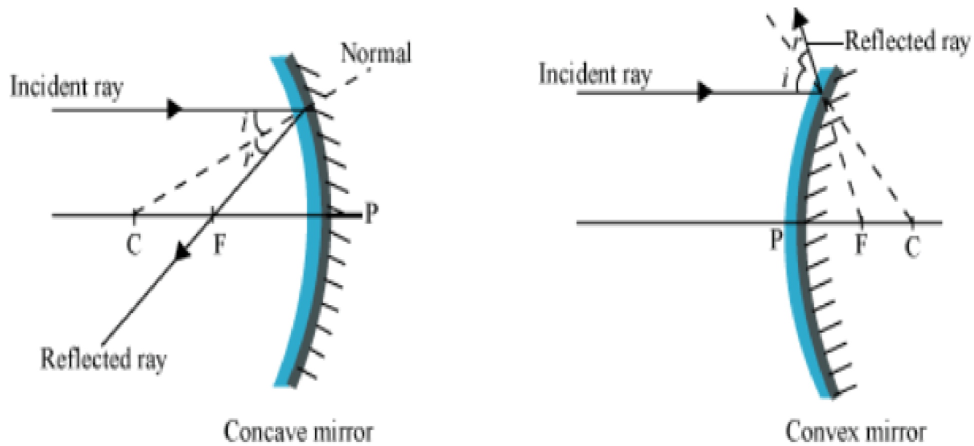
$$Or, f = \frac{R}{2} \qquad Or, R = 2f$$

- **Principal focus and focal length of a convex mirror:**

- **Principal focus**: When a beam of light initially parallel to principal axis is incident on a convex mirror then after reflection it diverges in such a way that it appears to have originated from a single point on principal axis. This point is known as principal focus of convex mirror.
- **Focal length**: It is the distance between the principal focus and pole of the mirror.

Representation of Images Formed by Spherical Mirrors Using Ray Diagrams:

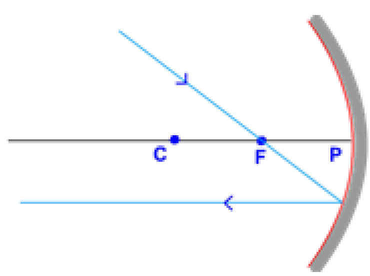
In the case of concave mirror: A ray parallel to principal axis passes through the principal focus after reflection from a concave mirror.



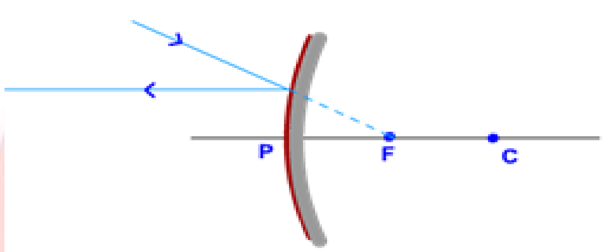
In the case of convex mirror: A ray parallel to principal axis appears to diverge from the principal focus after reflecting from the surface of a convex mirror.

- **Reflection of ray passing through the Principal Focus:**

In the case of concave mirror: Ray passing through the principal focus goes parallel to principal axis after reflection in the case of concave mirror.



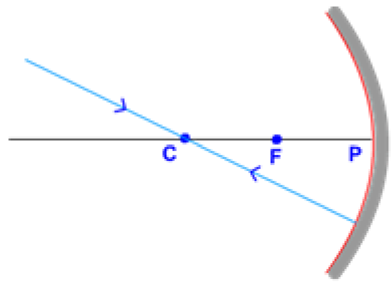
In the case of convex mirror: A ray directed towards principal focus goes parallel to principal axis after reflecting from the surface of a convex mirror.

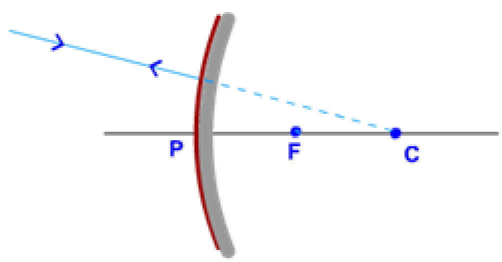


- **Ray passing through the Centre of curvature:**

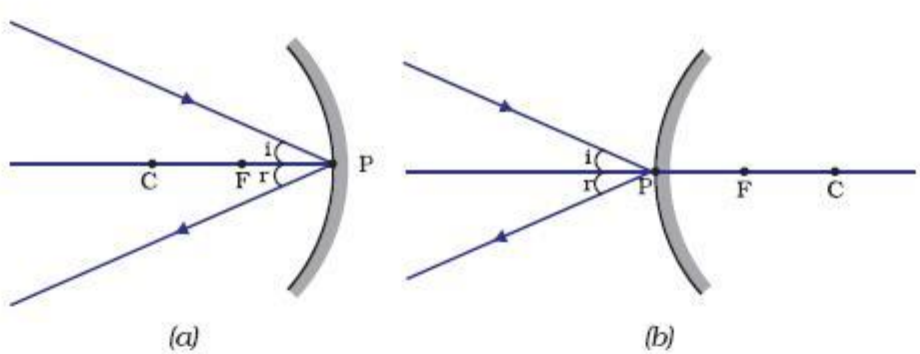
A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path.

The light rays come back along the same path because the incident rays fall on the mirror along the normal to the reflecting surface.





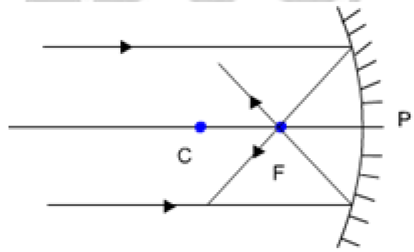
- **Ray incident obliquely to the principal axis:** Ray obliquely to the principal axis goes obliquely after reflecting from the pole of the both concave and convex mirror and at the same angle.



Ray diagrams for the formation of image by a concave mirror for various positions of the object are-

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

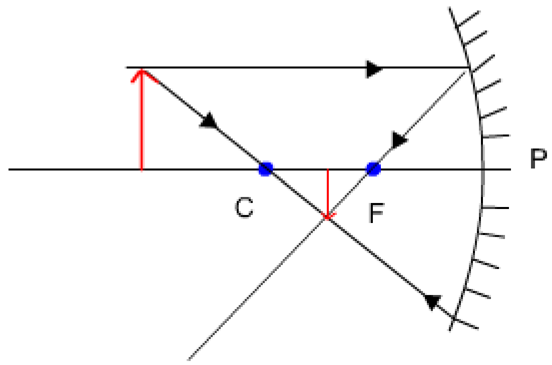
1. **Object at infinity:** when the object is **at infinity** the image will form **at F.**



Properties of image:

- Point sized
- Highly diminished
- Real and inverted

2. **Object between infinity and centre of curvature:**
   When object is placed **between infinity and centre of curvature** of a concave mirror the image is formed **between centre of curvature (C) and focus (F).**

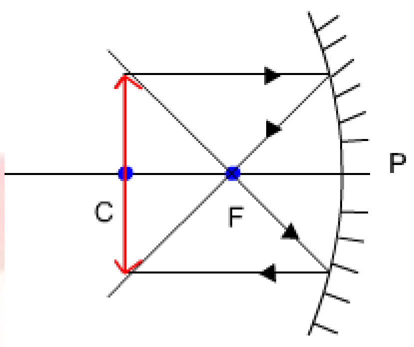


Properties of image:

- Diminished compared to object
- Real and inverted
- Object at Centre of Curvature (C):

3. **Object at C**

   When the object is placed **at centre of curvature (C)** of a concave mirror, a real and inverted image is formed **at the same position.**

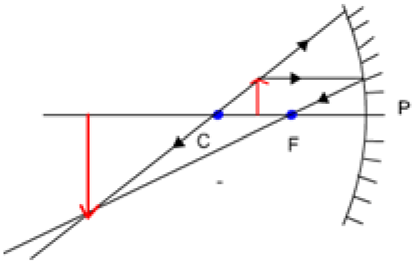


Properties of image:

- Same size as object
- Real and inverted

4. **Object between Centre of curvature (C) and Principal Focus (F):**

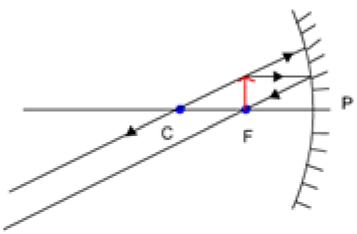
   When the object is placed between centre of curvature and principal focus of concave mirror, a real image is formed beyond the centre of curvature (C).



Properties of image:

- Larger than object
- Real and inverted

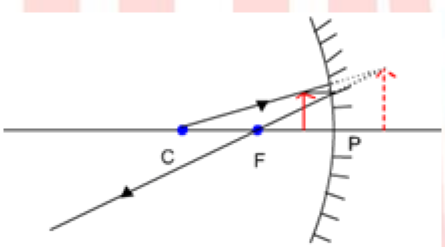
5. **Object at Principal Focus (F):**
   When the object is placed at principal focus (F) of a concave mirror, a highly enlarged image is formed at infinity.



Properties of image:

- Highly enlarged
- Real and inverted

6. **Object between Principal Focus (F) and Pole (P):**
   When the object is placed between principal focus and pole of a concave mirror, an enlarged, virtual and erect image is formed behind the mirror.

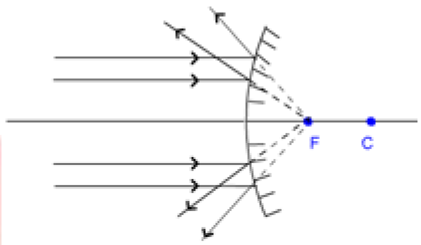


Properties of image:

- Enlarged
- Virtual and erect

The ray diagrams the image formation by a convex mirror for different positions of the object

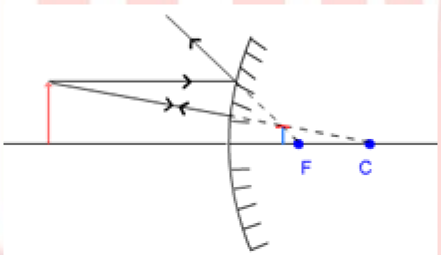
1. **Object at infinity**: When the object is **at the infinity**, a point sized image is formed at **principal focus** behind the convex mirror.



Properties of image:

- Image is highly diminished
- Virtual and erect.

2. **Object between infinity and pole**: When the object is **between infinity and pole** of a convex mirror, a diminished, virtual and erect image is formed **between pole and focus behind the mirror.**



Properties of image:

- Image is diminished, virtual and erect.

Position and Nature of Image in Convex Mirror			
Position of object	Position of image	Size of image	Nature of image

At infinity	At F, behind mirror	Highly diminished	Virtual and Erect
Between infinity and pole	Between F and P, behind mirror	Diminished	Virtual and Erec

Uses of concave mirror:

- Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light.
- **As shaving mirror**: to produce larger image of face to facilitate better viewing during shaving.
- **By dentists** to see larger image of teeth of the patient. When a tooth is placed between focus and pole, the concave mirror produces a magnified image of the tooth.
- As reflector in solar furnace: By using concave mirror in solar furnace the concentrated rays of sunlight is obtained at focus which produces enormous amount of heat because of concentration.
- In doctor's head mirror to see details of various body parts like nose, ears etc.
- In dish TV antennas to focus signals.

Uses of convex mirrors

- Convex mirror is used in **rear view mirror of vehicles** so that the driver can see the traffic coming from behind. The field of view is widest in case of a convex mirror, which enables it to show a wider area from behind.
- In big shops for security

Sign Convention for Reflection by Spherical Mirrors

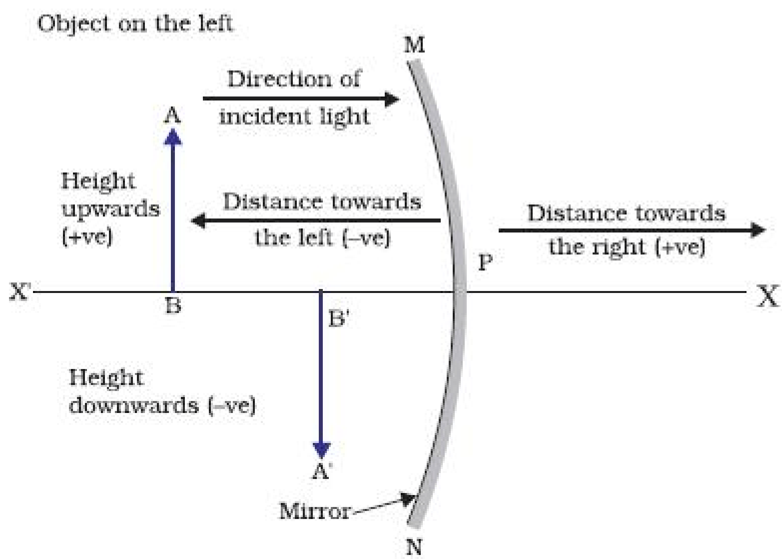
Reflection of light by spherical mirrors follow a set of sign conventions called the **New Cartesian Sign Convention.**

- In this convention, **the pole (P)** of the mirror is taken as the **origin**.
- The **principal axis** of the mirror is taken as **the X-axis (X'X)** of the coordinate system.

The conventions for spherical mirrors are:-

- The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left hand side.

- All distances parallel to the principal axis are measured from the pole of the mirror.
- All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along – x-axis) are taken as negative.
- Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.
- Distances measured perpendicular to and below the principal axis (along –y-axis) are taken as negative



Magnification

- Magnification is the ratio of the height of the image to the height of the object. It is usually represented by the letter 'm'.

$$Magnification(m) = \frac{Height\ of\ image\ (h')}{Height\ of\ object\ (h)}$$

$$Or, \quad m = \frac{h'}{h}$$

- Relation among magnification, distance of object and distance of image:

$$Magnification\ (m) = \frac{Distance\ of\ image}{Distance\ of\ object} = -\frac{v}{u}$$

$$Thus, m = \frac{h'}{h} = -\frac{v}{u}$$

- Where, m = magnification, h' = height of image, h = height of object, v = image distance and u = object distance.

Magnification produced by a spherical mirror gives the relative extent to which the image of an object is magnified with respect to the object size.

The height of the object is taken to be positive as the object is usually placed above the principal axis.

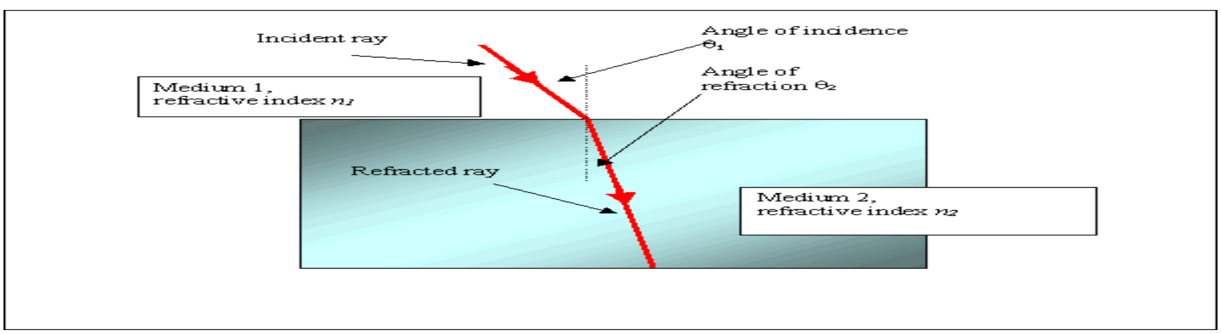
The height of the image should be taken as positive for virtual images and as negative for real images.

- A negative sign in the value of the magnification indicates that the image is **real.**
- A positive sign in the value of the magnification indicates that the image is **virtual.**

Mirror Formula: 1/f = 1/v + 1/u.

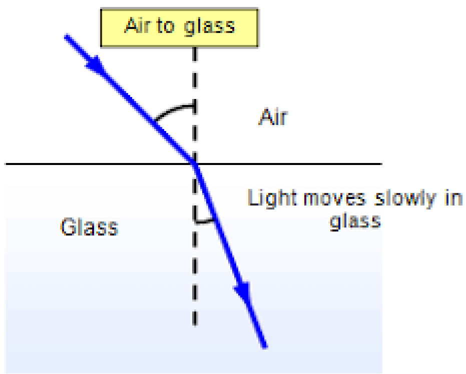
REFRACTION OF LIGHT:

- It is a phenomenon of bending of light when it travels from one medium to another.
- The refraction of light takes place on going from one medium to another because **the speed of light is different in two media.**

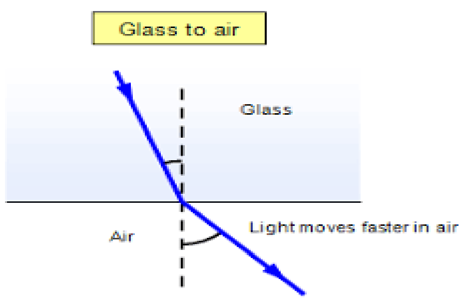


Refraction of light through a rectangular glass slab :

- When a ray of light enters glass slab it moves from rarer medium to denser medium. Hence it bends towards the normal.



- When the ray of light exits from the glass slab it moves from denser medium to rarer medium. Hence it bends away from the normal.



- The emergent ray is parallel to the incident ray.
- The perpendicular distance between the incident ray and the emergent ray is known as **lateral displacement**.

Laws of refraction:

- **First law**: The incident ray, the refracted ray and the normal all lie on the same plane.
- **Second law**: The ratio of sine of angle of incidence to sine of angle of refraction is constant.

Mathematically, Sin i / Sin r = Constant.

IMP: The second law of refraction is also known as Snell's law of refraction.

The refractive index :

- The ratio of sine of angle of incidence to sine of angle of refraction is known as refractive index.
- It is a unit less, dimensionless quantity.
- It is the measure of degree of bending of light.
- The expression 1n2 means refractive index of medium 2 with respect to medium 1.
- The expression n21 also means the same as above.

$$Refractive\ Index\ of\ medium\ 2\ with\ respect\ to\ medium\ 1\ (n_{21}) = \frac{Speed\ of\ light\ in\ medium\ 1}{Speed\ of\ light\ in\ medium\ 2}$$

$$Or, n_{21} = \frac{v_1}{v_2}$$

$$Therefore, \quad n_{12} = \frac{Speed\ of\ light\ in\ medium\ 2}{Speed\ of\ light\ in\ medium\ 1} = \frac{v_2}{v_1}$$

n12 = 1/ n21

Absolute and relative refractive index:

Absolute refractive index: The refractive index of a medium with respect to vacuum or air is known as absolute refractive index. E.g. $_{air}n_{glass}$

Relative refractive index: The refractive index of a medium with respects to any medium other then vacuum is known as relative refractive index. E.g. $_{water}n_{glass}$

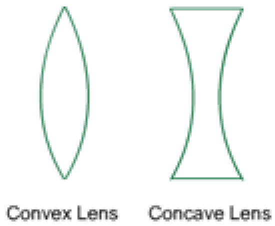
$$Thus, n_2 = \frac{Speed\ of\ light\ in\ vacuum}{Speed\ of\ light\ in\ given\ medium}$$

Spherical lens:

- A transparent medium made up of glass bounded by two curved surfaces through which
- **Types:**

Convex lens (Thicker at the middle and thinner at the edges).

Concave lens (Thinner at the middle and thicker at the edges).



Important terms in the case of spherical lenses:

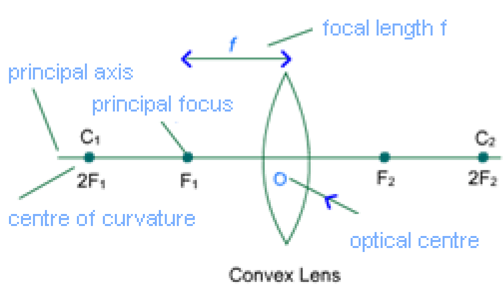
(a) <u>Focal Length</u>:- The distance between optical centre and principal focus is called focal length of a lens.

Focal length of a lens is half of the radius of curvature.

$$i.e.\ 2f = R \quad Or, f = \frac{R}{2}$$

This is the cause that the centre of curvature is generally denoted by 2F for a lens instead of C

(b) <u>Centre of curvature</u>:



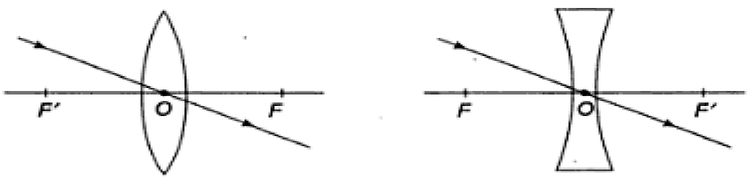
- The centre of sphere of which the lens is a part. It has two centre of curvature C1 and C2.
- **Optical centre**: The centre of the lens. Light remains un deviated on passing through it.
- **Principal axis**: The line joining both the centre of curvature.

<u>Principal focus and focal length of convex lens</u>

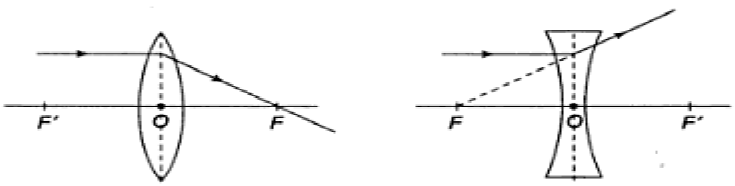
- **Principal focus**: When a parallel beam of light is incident on a convex lens then after refraction they converge to meet at a point on the principal axis. This point is known as the principal focus of convex lens.
- **Focal length**: The distance between optical centre and the principal focus is known as focal length.

Rules for drawing ray diagrams:

1. A ray passing through the optical centre (O) of the lens proceeds un deviated through the lens.



2. A ray passing parallel to the principal axis after refraction through the lens passes or appears to pass through the focus (F). (By definition of the focus)



A ray through the focus or directed towards the focus (F'), after refraction from the lens, becomes parallel to the principal axis. (Principal of reversibility of light)

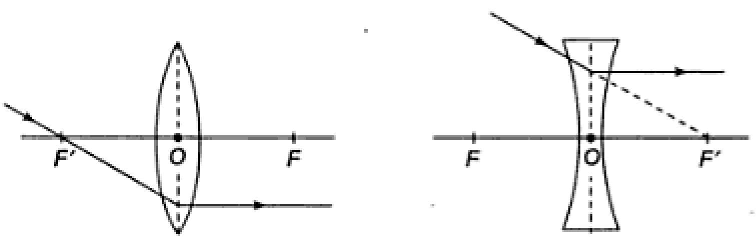
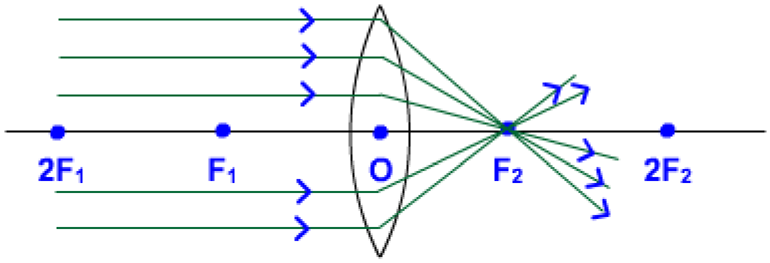


Image formation by convex lens by placing objects in the following positions:

1. **Object at infinity**:
   Convex lens converge parallel rays coming from objet at infinity and a highly diminished - point sized, real and inverted image is formed at principal focus F_2.

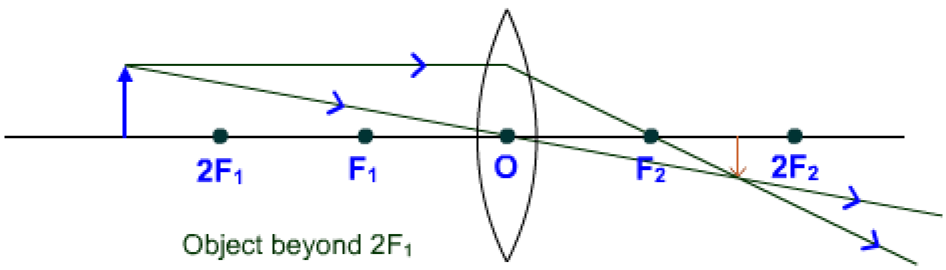


Object at infinity

- **Position of image**: At F_2
- **Nature of image**: Real and inverted
- **Size of image**: Point sized, highly diminished.

2. **Object beyond 2F:**

   A diminished, real and inverted image is formed between principal focus, F_2 and centre of curvature, C_2 at the opposite side when an object is placed beyond C_1 of a convex lens.

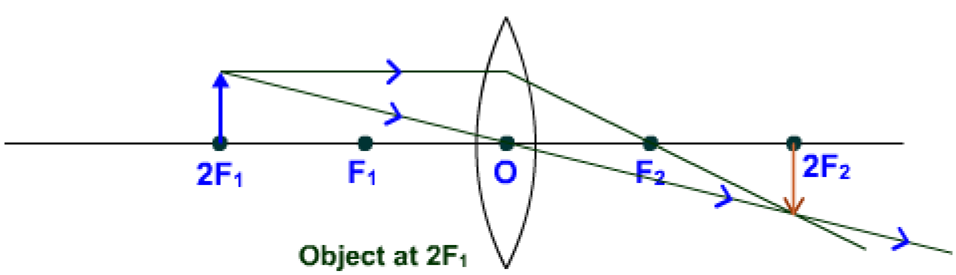


Object beyond $2F_1$

- **Position of image:** Between $2F_2$ and F_2
- **Nature of image**: Real and inverted
- **Size of image**: Diminished.

3. **Object at centre of curvature, C_1 or $2F_1$:**

A same sized, real and inverted image is formed at centre of curvature, C_2 when object is placed at centre of curvature, C_1 of a convex lens.



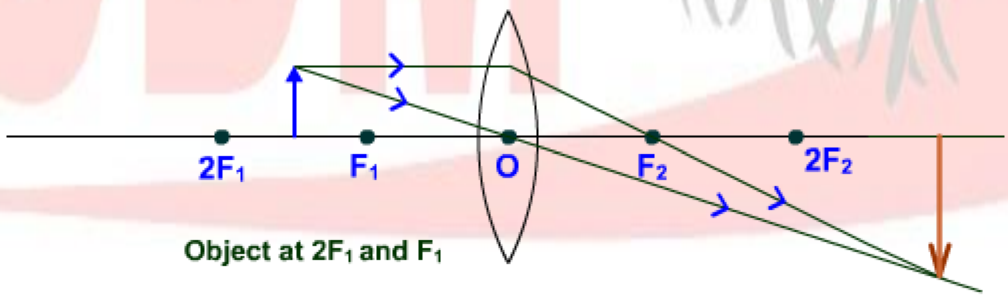
Object at $2F_1$

- **Position of image**: At $2F_2$

- **Nature of image**: Real and inverted
- **Size of image**: Same sized.

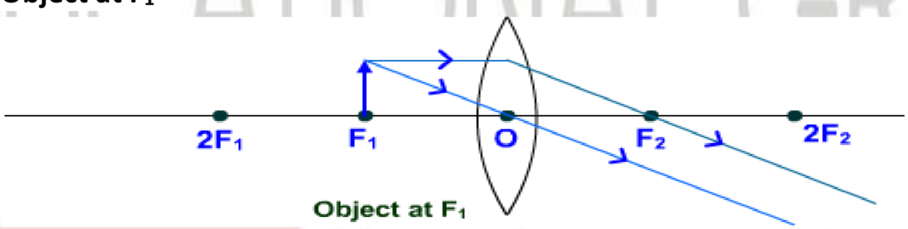
4. **Object between centre of curvature, C_1 and principal focus, F_1:**

An enlarged, real and inverted image is formed beyond centre of curvature, C_2 when an object is placed between centre of curvature, C_1 and principal focus, F_1 of a convex lens.



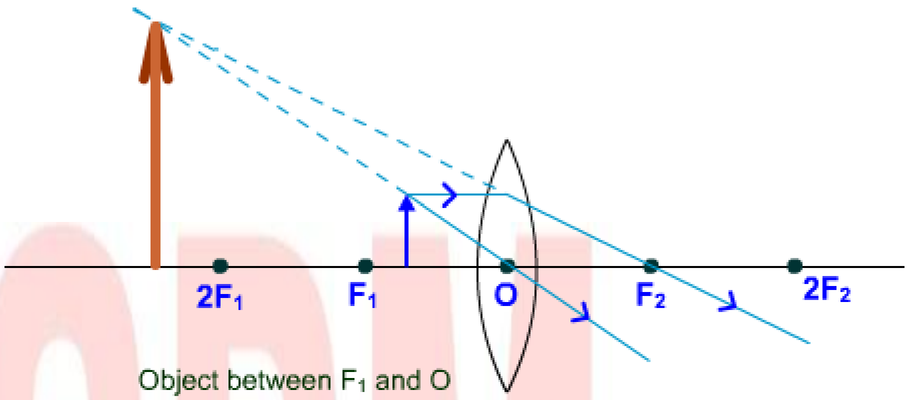
- **Position of image**: Beyond $2F_2$
- **Nature of image**: Real and inverted
- **Size of image**: Enlarged

5. **Object at F_1**



- **Position of image:** At infinity
- **Nature of image:** Real and inverted
- **Size of image:** Highly enlarged

6. ***between principal focus, F_1 and optical centre O:-***



Object between F_1 and O

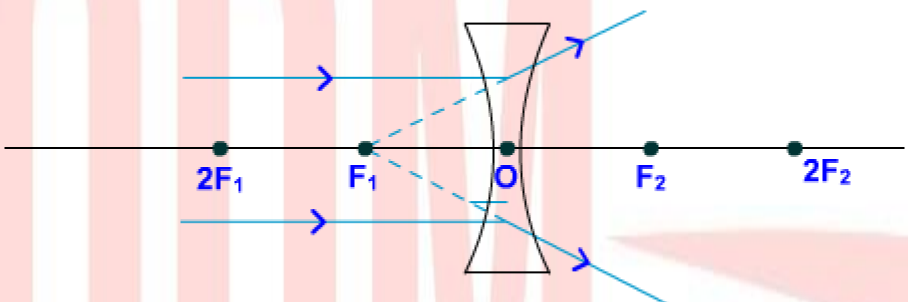
- **Position of image**: Beyond 2F1
- **Nature of image**: Virtual and erect
- **Size of image**: Enlarged.

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F2	Highly diminished, point-sized	Real and inverted
Beyond 2F1	Between F2 and 2F2	Diminished	Real and inverted
At 2F1	At 2F2	Same size	Real and inverted
Between F1 and 2F1	Beyond 2F2	Enlarged	Real and inverted
At focus F1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F1and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

The image formation by concave lens by placing the objects in the following positions:

Position of the object	Position of the image	Relative size of the image	Nature of the image

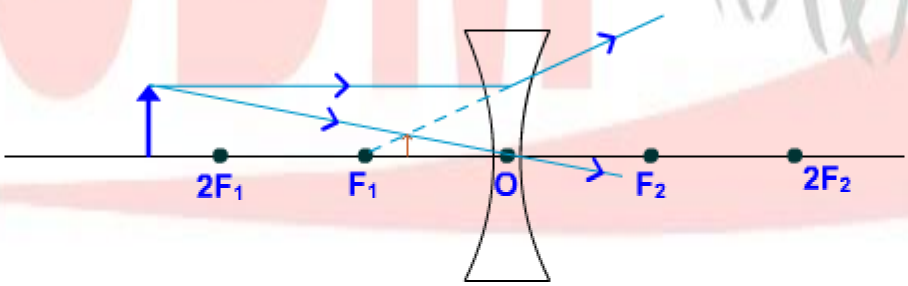
(a) Object is at infinity



Object is at Infinity

- **Position of image**:-At F_1
- **Nature of image**: Virtual and erect
- **Size of image**: Point sized, highly diminished.

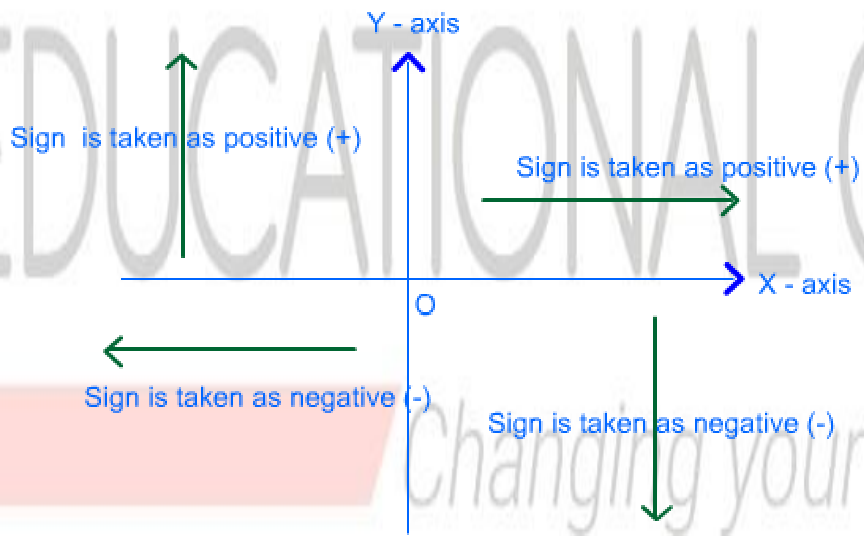
(b) Object between infinity and optic centre:



Object between Infinity and Optical centre

At infinity	At focus F1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F1 and optical centre O	Diminished	Virtual and erect

Sign conventions for spherical lenses:



New Cartesian Sign Convention

The relation between distance of object, distance of image and focal length for a lens is called **lens formula.**

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

Magnification:

- The ratio of height of image and that of object or ratio of distance of image and distance of object gives magnification.

- It is generally denoted by 'm'.
- If h is the height of the object and h' is the height of the image given by a lens, then the magnification produced by the lens is given by,

$$(m) = \frac{Height\ of\ image\ (h')}{Height\ of\ object\ (h)}$$

$$= \frac{Distance\ of\ image\ (v)}{Distance\ of\ object\ (u)}$$

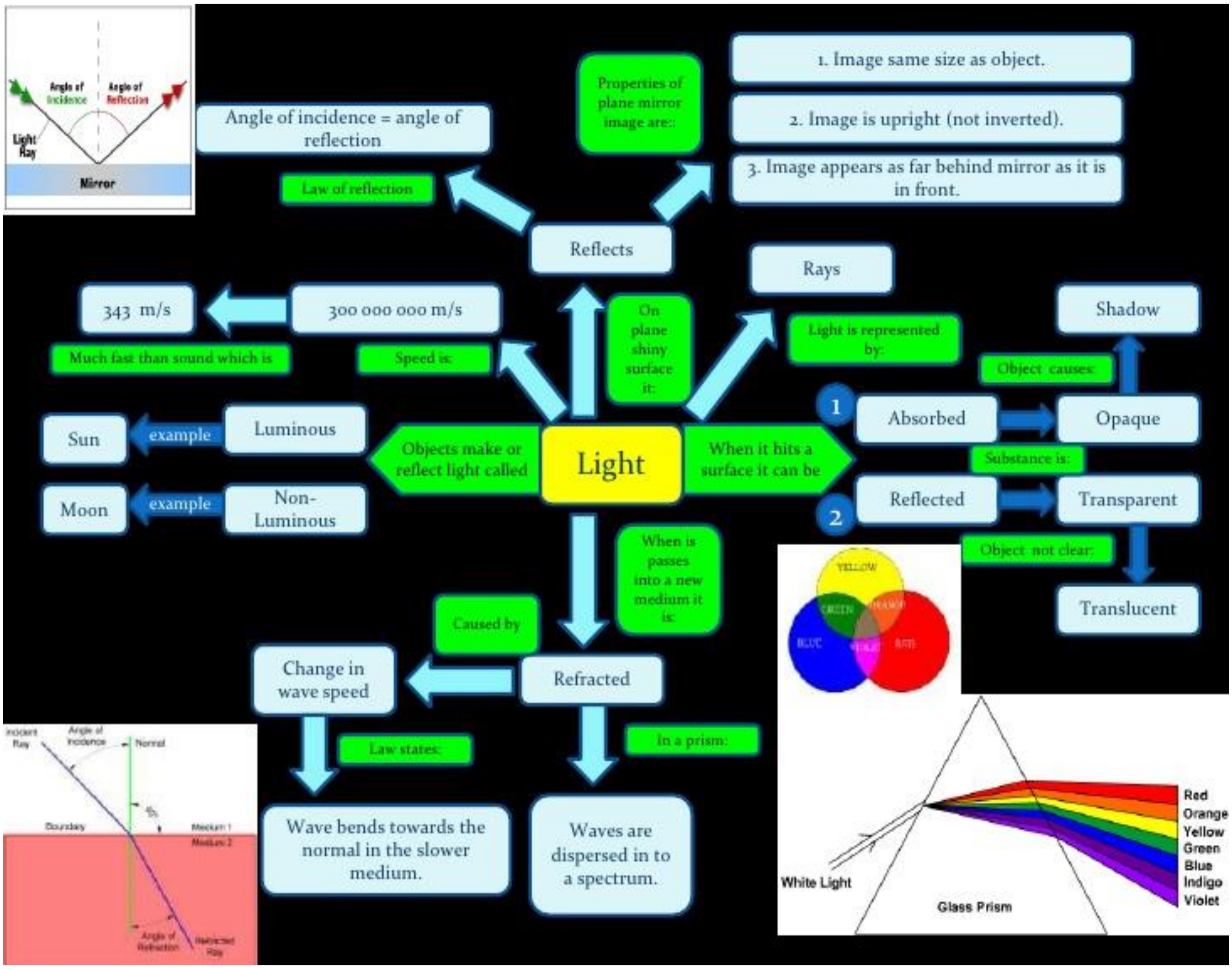
- The positive (+) sign of magnification shows that image is erect and virtual
- a negative (-) sign of magnification shows that image is real and inverted.

Power of a Lens

- The degree of divergence or convergence of ray of light by a lens is expressed in terms of the power of lens.
- Degree of convergence and divergence depends upon the focal length of a lens.
- The power of a lens is denoted by 'P'.
- The power of a lens is reciprocal of the focal length.

P=1/f

- The SI unit of Power of lens is dioptre and it is denoted by 'D'.
- Power of a lens is expressed in dioptre when the focal length is expressed in meter. Thus, a lens having 1 meter of focal length has power equal to 1 dipotre.
  $Therefore, 1D = 1m^{-1}$
- A convex lens has power in positive and a concave lens has power in negative.


Angle of Incidence
Angle of Reflection
Light Ray
Mirror
Angle of incidence = angle of reflection
Law of reflection
Properties of plane mirror image are::
1. Image same size as object.
2. Image is upright (not inverted).
3. Image appears as far behind mirror as it is in front.
Reflects
Rays
343 m/s
300 000 000 m/s
Much fast than sound which is
Speed is:
On plane shiny surface it:
Light is represented by:
Shadow
Object causes
1
Absorbed
Opaque
Substance is:
2
Reflected
Transparent
Object not clear:
Translucent
Sun
example
Luminous
Moon
example
Non-Luminous
Objects make or reflect light called
Light
When it hits a surface it can be
When is passes into a new medium it is:
Caused by
Change in wave speed
Refracted
Law states:
In a prism:
Wave bends towards the normal in the slower medium.
Waves are dispersed in to a spectrum.
Incident Ray
Angle of Incidence
Normal
Boundary
Medium 1
Medium 2
Angle of Refraction
Refracted Ray
White Light
Glass Prism
Red
Orange
Yellow
Green
Blue
Indigo
Violet