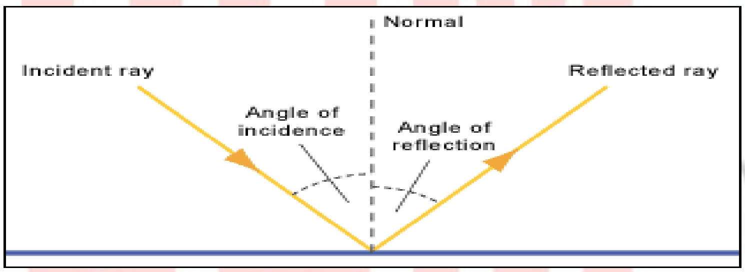
Chapter-13

Light: REFLECTION AND REFRACTION

STUDY NOTES

LIGHT: Light is a form of energy that enables us to see.

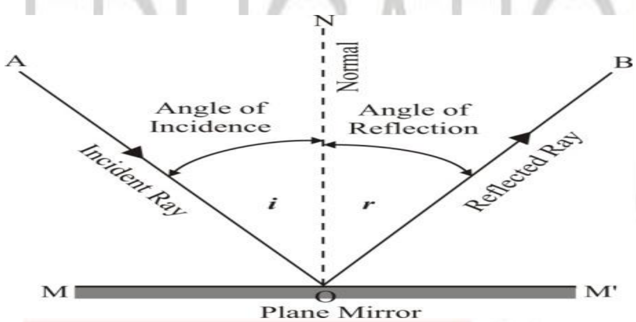
Reflection of light: The phenomenon of bouncing back of light rays in the same medium on striking a smooth surface is called reflection of light.



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

Spherical Mirror
- Concave Mirror
- Convex Mirror

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.

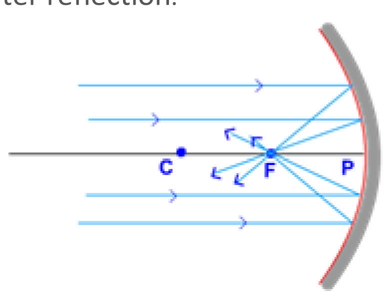
The magnification of image formed by a plane mirror is 1

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.

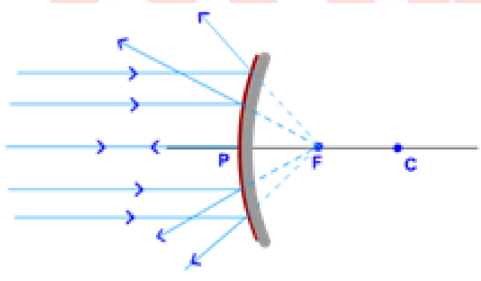


- In the case of a concave mirror, parallel rays coming from infinity converge after reflection in front of the mirror. Thus, the focus lies in front of a concave mirror.

- **Convex Mirror:**

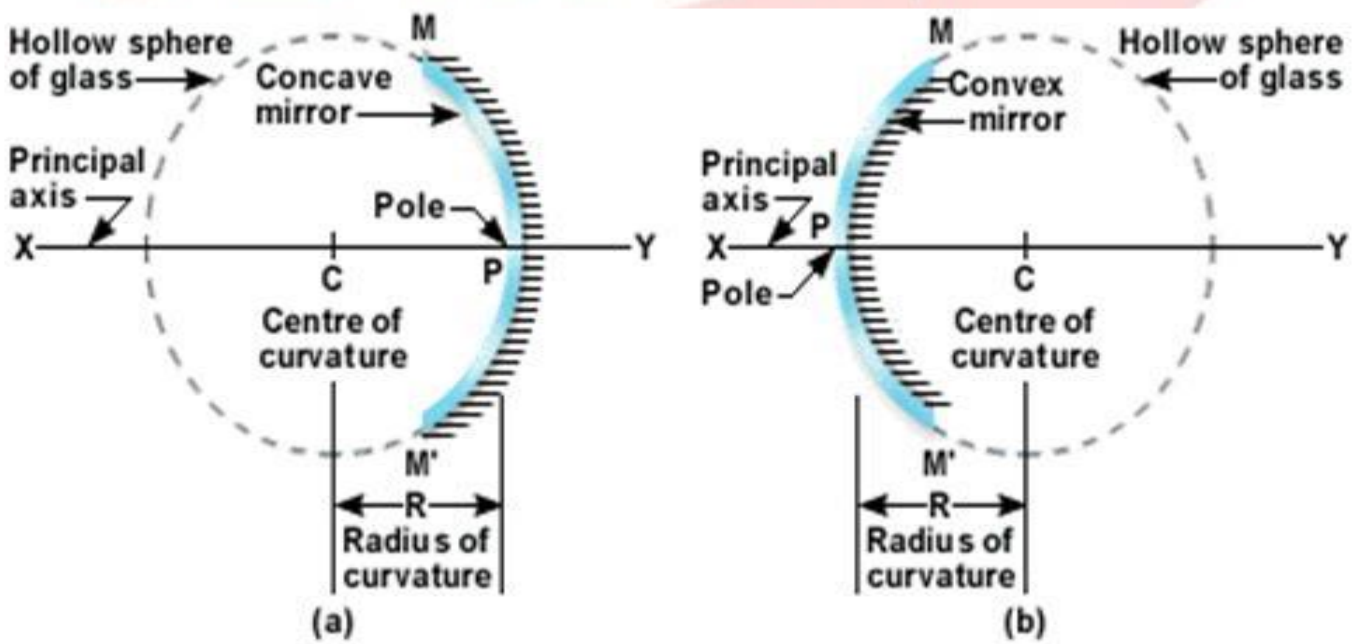
A spherical mirror, whose reflecting surface is curved outwards is called convex mirror.

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.

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

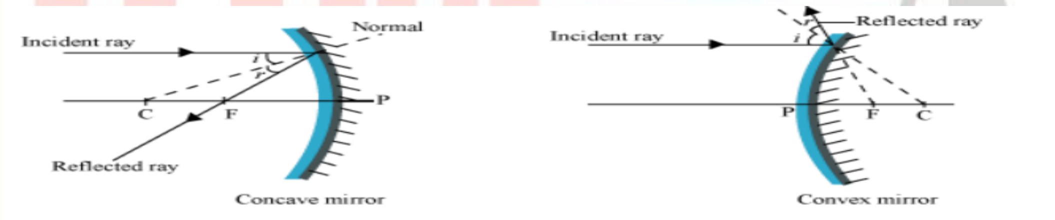
- **Principal focus and focal length of a convex mirror:**

- **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:

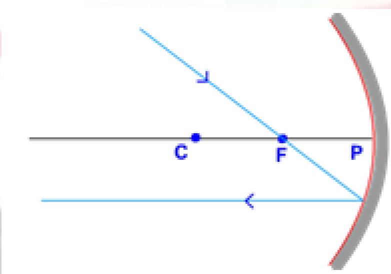
In the case of concave mirror: A ray parallel to principal axis passes through the principal focus after reflection from a concave mirror.



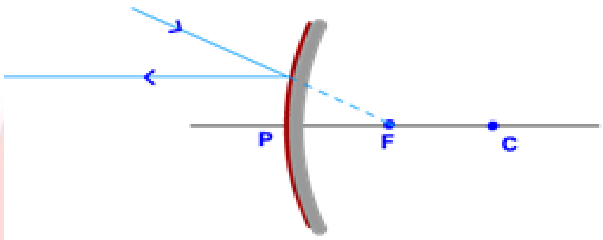
In the case of convex mirror: A ray parallel to principal axis appears to diverge from the principal focus after reflecting from the surface of a convex mirror.

- **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.



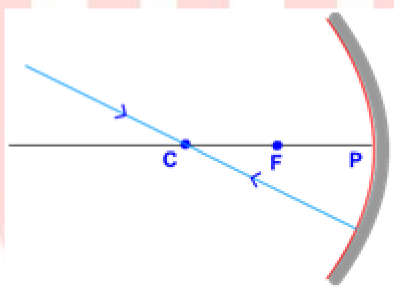
In the case of convex mirror: A ray directed towards principal focus goes parallel to principal axis after reflecting from the surface of a convex mirror.

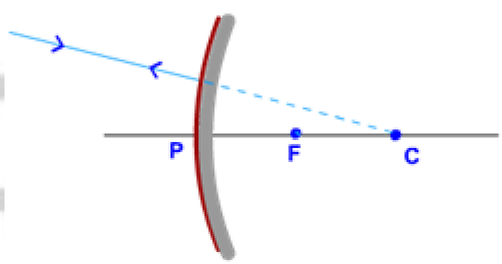


- **Ray passing through the Centre of curvature:**

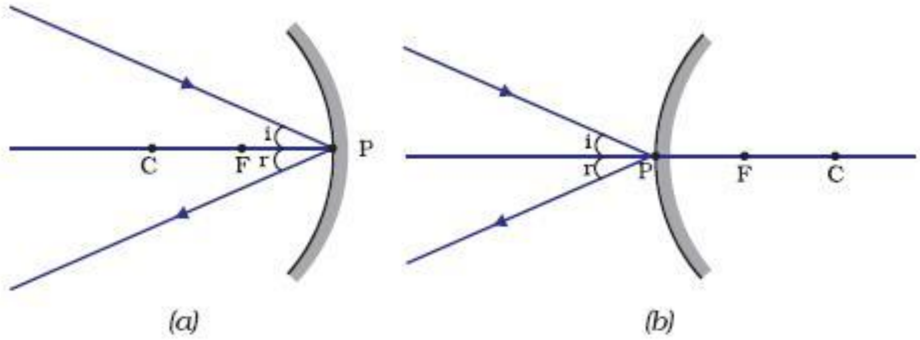
A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path.

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





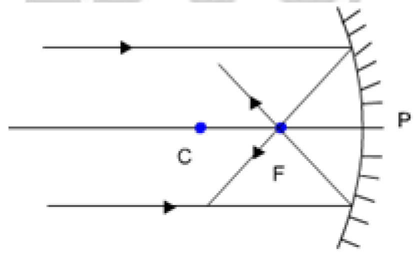
- **Ray incident obliquely to the principal axis:** Ray obliquely to the principal axis goes obliquely after reflecting from the pole of the both concave and convex mirror and at the same angle.



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. **<u>Object at infinity</u>:** when the object is **at infinity** the image will form **at F.**

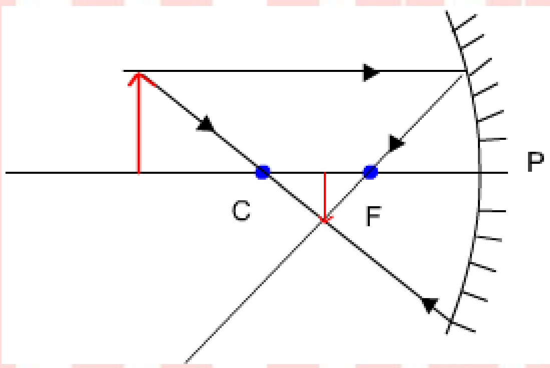


<u>Properties of image:</u>

- 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).**

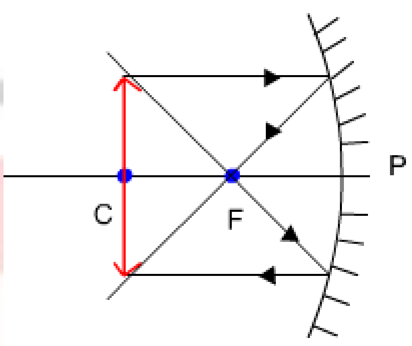


Properties of image:

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

3. **Object at C**

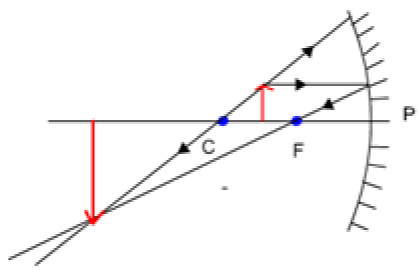
   When the object is placed **at centre of curvature (C)** of a concave mirror, a real and inverted image is formed **at the same position.**



Properties of image:

- Same size as object
- Real and inverted

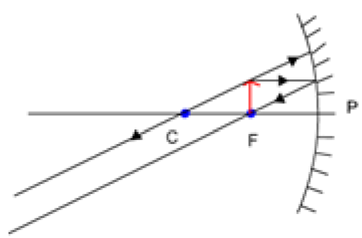
4. **Object between Centre of curvature (C) and Principal Focus (F):**
   When the object is placed between centre of curvature and principal focus of concave mirror, a real image is formed beyond the centre of curvature (C).



Properties of image:

- Larger than object
- Real and inverted

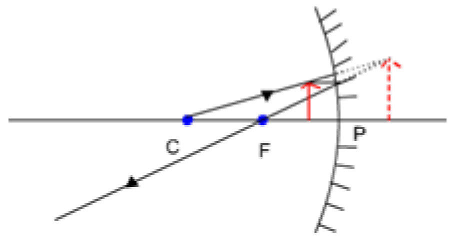
5. **Object at Principal Focus (F):**
   When the object is placed at principal focus (F) of a concave mirror, a highly enlarged image is formed at infinity.



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.

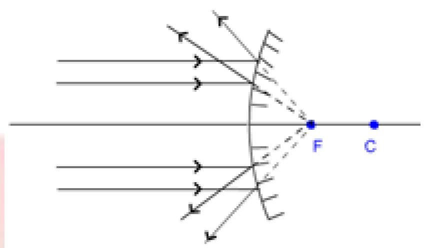


Properties of image:

- Enlarged
- Virtual and erect

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

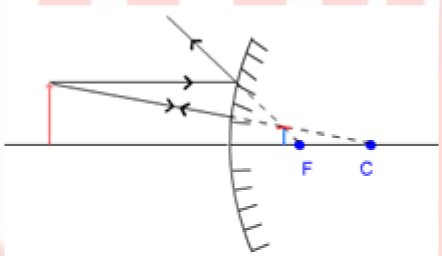
1. **Object at infinity**: When the object is **at the infinity**, a point sized image is formed at **principal focus** behind the convex mirror.



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

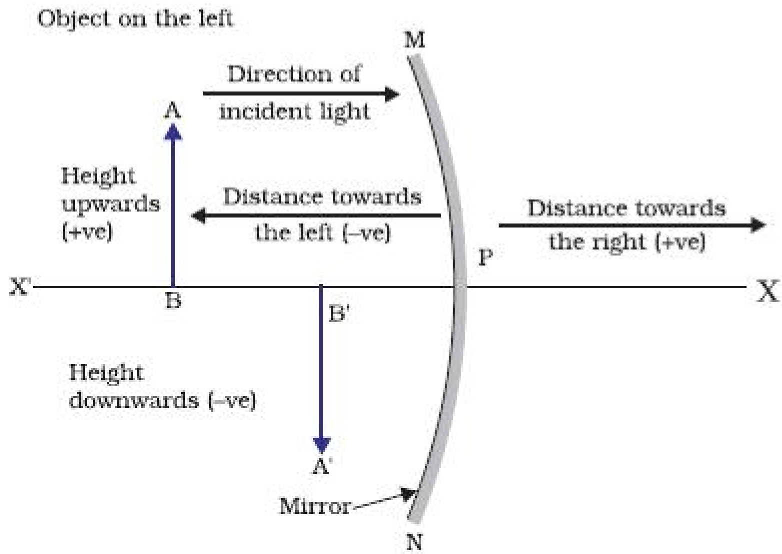
Sign Convention for Reflection by Spherical Mirrors

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.

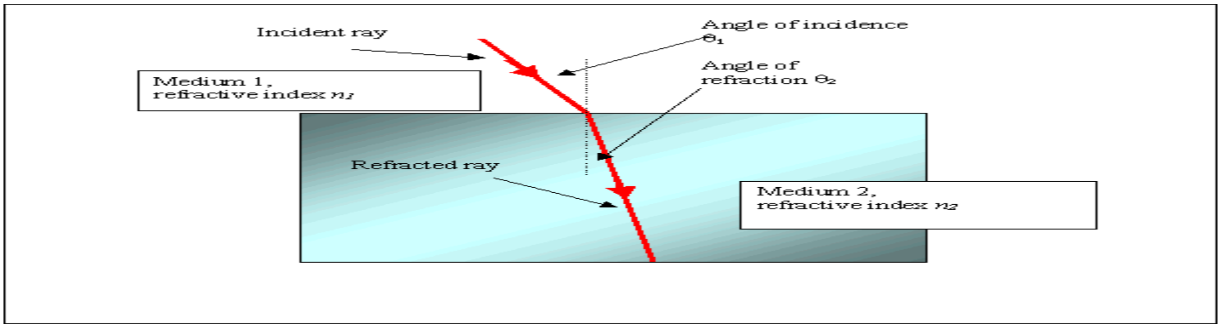
The height of the image should be taken as positive for virtual images and as negative for real images.

- 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.

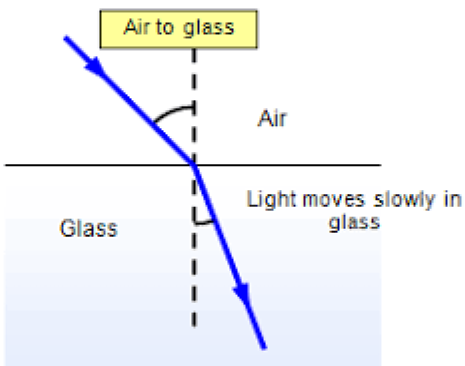
REFRACTION OF LIGHT:

- 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.**

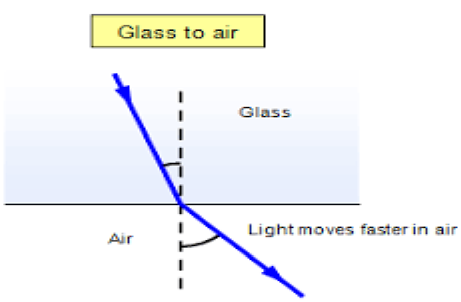


Refraction of light through a rectangular glass slab :

- 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. $_{water}n_{glass}$

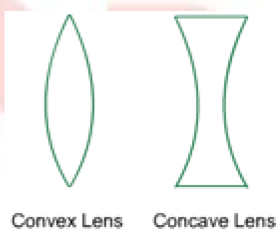
$$Thus, n_2 = \frac{Speed\ of\ light\ in\ vacuum}{Speed\ of\ light\ in\ given\ medium}$$

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:

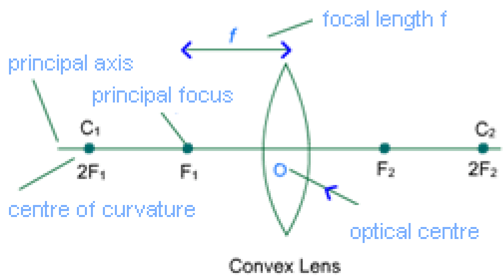
(a) Focal Length:- The distance between optical centre and principal focus is called focal length of a lens.

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) Centre of curvature:



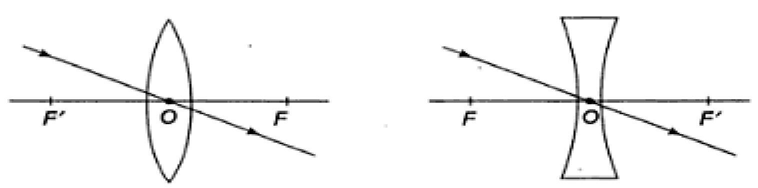
- The centre of sphere of which the lens is a part. It has two centre of curvature C1 and C2.
- **Optical centre**: The centre of the lens. Light remains un deviated on passing through it.
- **Principal axis**: The line joining both the centre of curvature.

Principal focus and focal length of convex lens

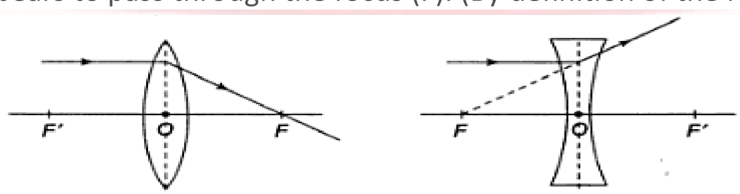
- **Principal focus**: When a parallel beam of light is incident on a convex lens then after refraction they converge to meet at a point on the principal axis. This point is known as the principal focus of convex lens.
- **Focal length**: The distance between optical centre and the principal focus is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

Rules for drawing ray diagrams:

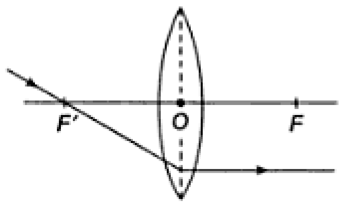
1. A ray passing through the optical centre (O) of the lens proceeds un deviated through the lens.



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)



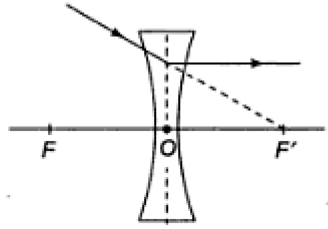
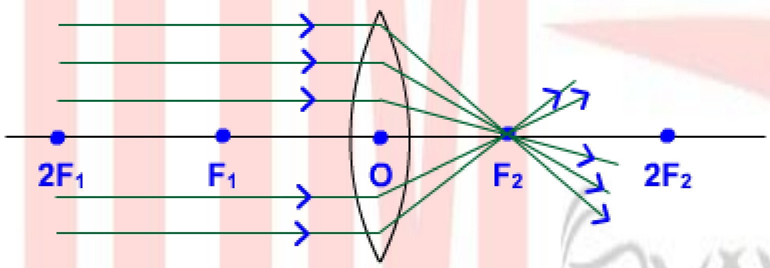


Image formation by convex lens by placing objects in the following positions:

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.

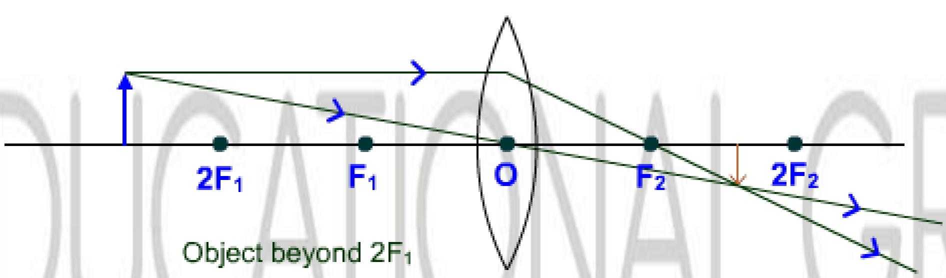


Object at infinity

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

2. **Object beyond 2F**:

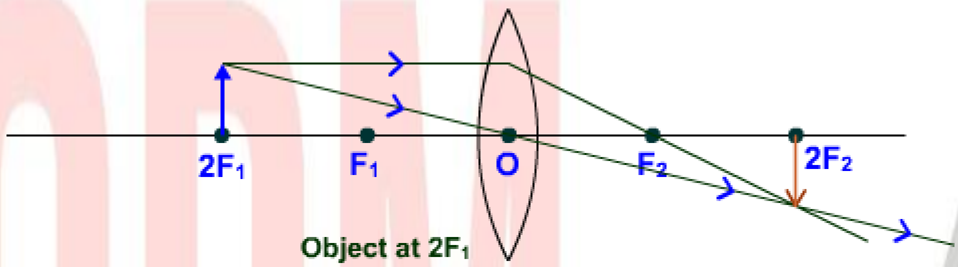
   A diminished, real and inverted image is formed between principal focus, F_2 and centre of curvature, C_2 at the opposite side when an object is placed beyond C_1 of a convex lens.



- **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 $2F_1$:**

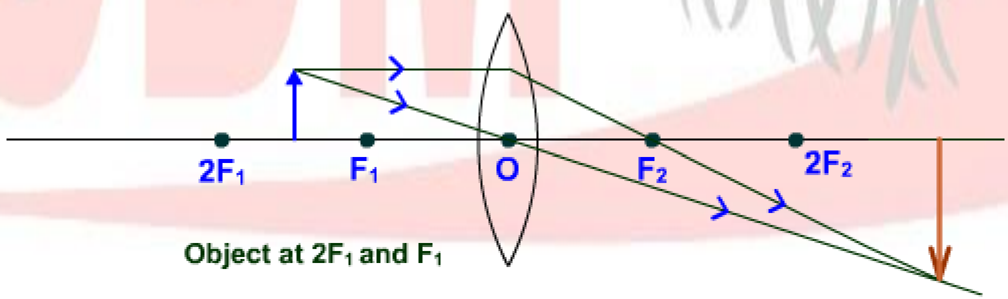
A same sized, real and inverted image is formed at centre of curvature, C_2 when object is placed at centre of curvature, C_1 of a convex lens.



- **Position of image**: At $2F_2$
- **Nature of image**: Real and inverted
- **Size of image**: Same sized.

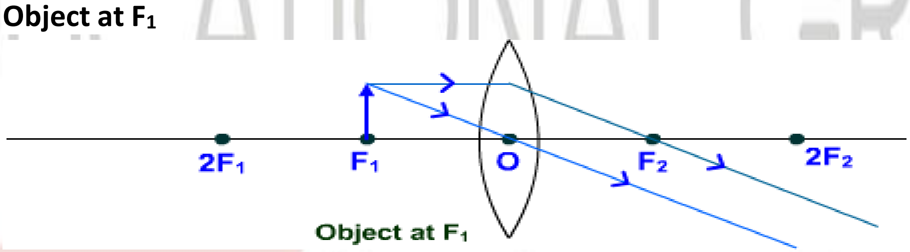
4. **Object between centre of curvature, C_1 and principal focus, F_1:**

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

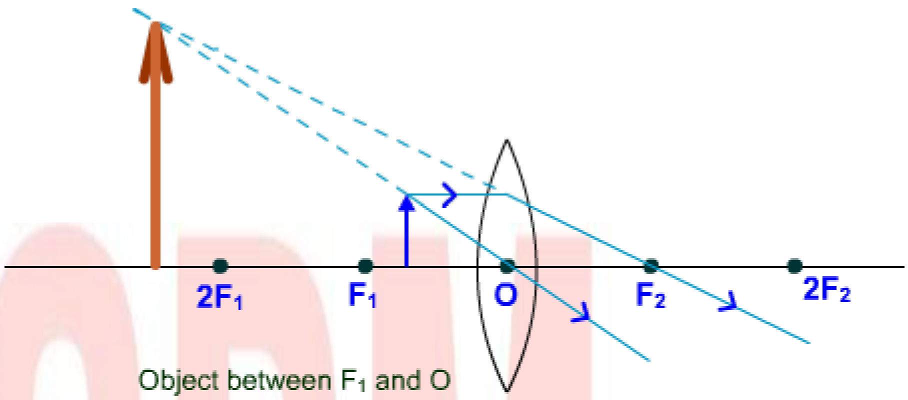
5. **Object at F_1**



- **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:-**



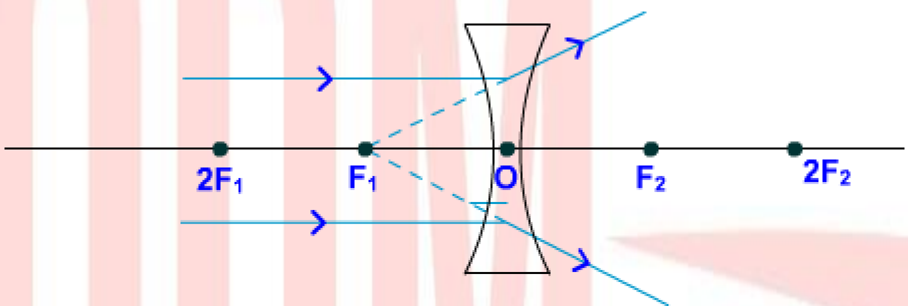
- **Position of image**: Beyond 2F1
- **Nature of image**: Virtual and erect
- **Size of image**: Enlarged.

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:

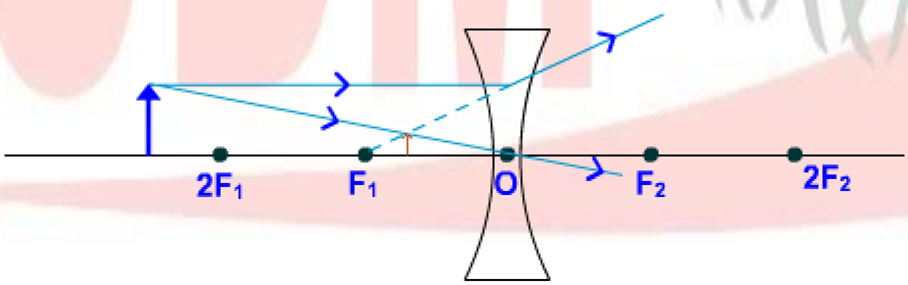
(a) <u>Object is at infinity</u>



Object is at Infinity

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

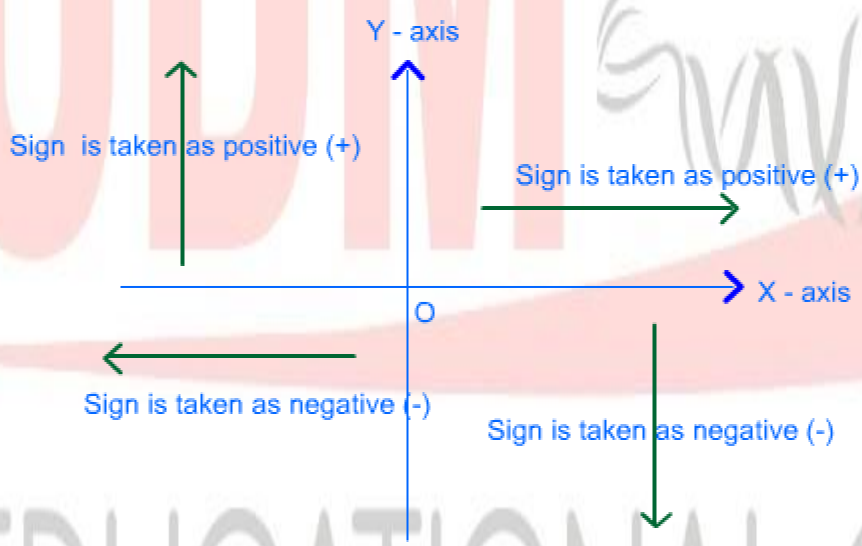
(b) <u>Object between infinity and optic centre</u>:



Object between Infinity and Optical centre

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

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

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

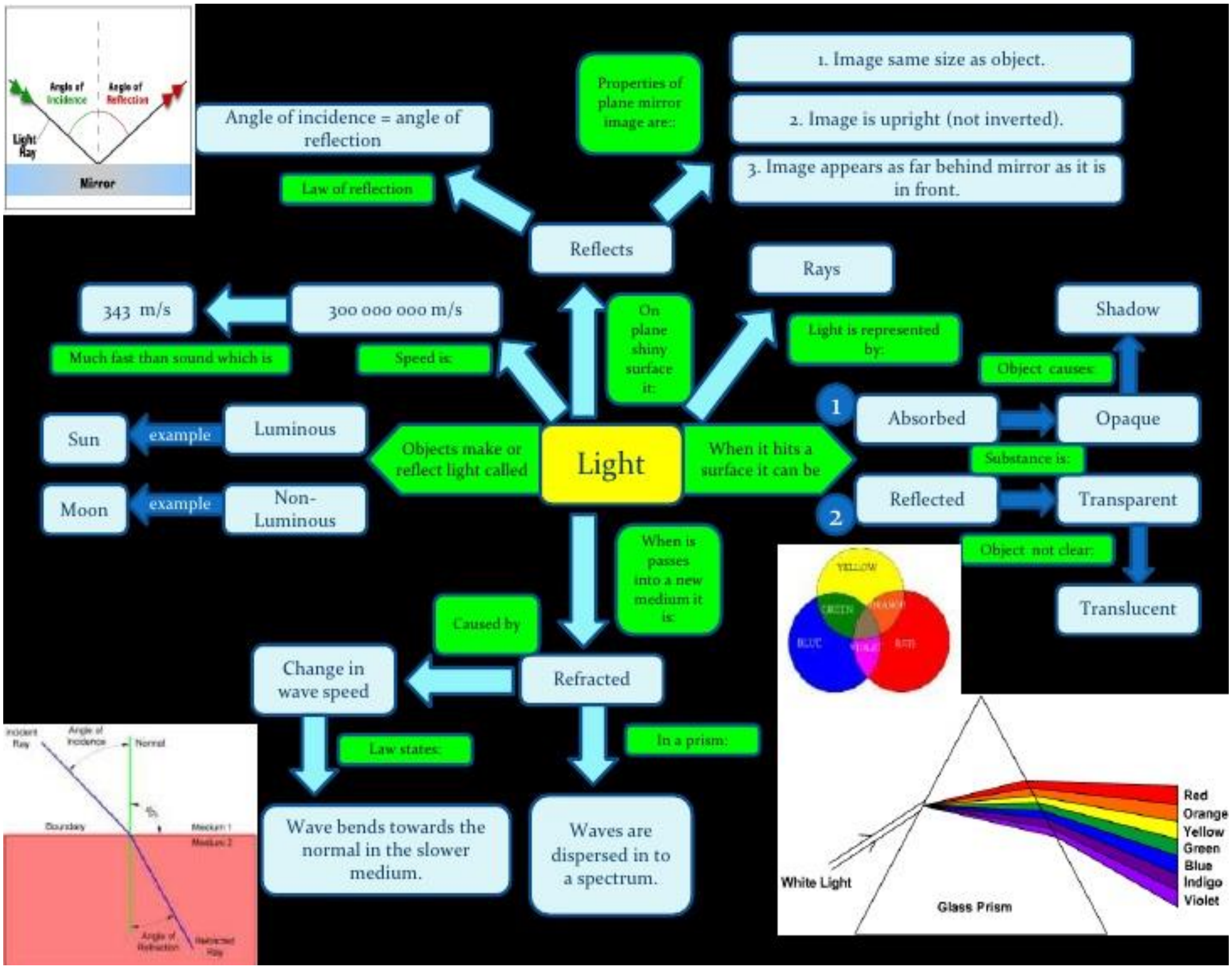
- The positive (+) sign of magnification shows that image is erect and virtual
- a negative (-) sign of magnification shows that image is real and inverted.

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:
Sun
example
Luminous
Objects make or reflect light called
Light
When it hits a surface it can be
1
Absorbed
Opaque
Substance is:
Moon
example
Non-Luminous
2
Reflected
Transparent
Object not clear:
Translucent
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.
Normal
Boundary
Medium 1
Medium 2
Angle of Refraction
Refracted Ray
White Light
Glass Prism
Red
Orange
Yellow
Green
Blue
Indigo
Violet