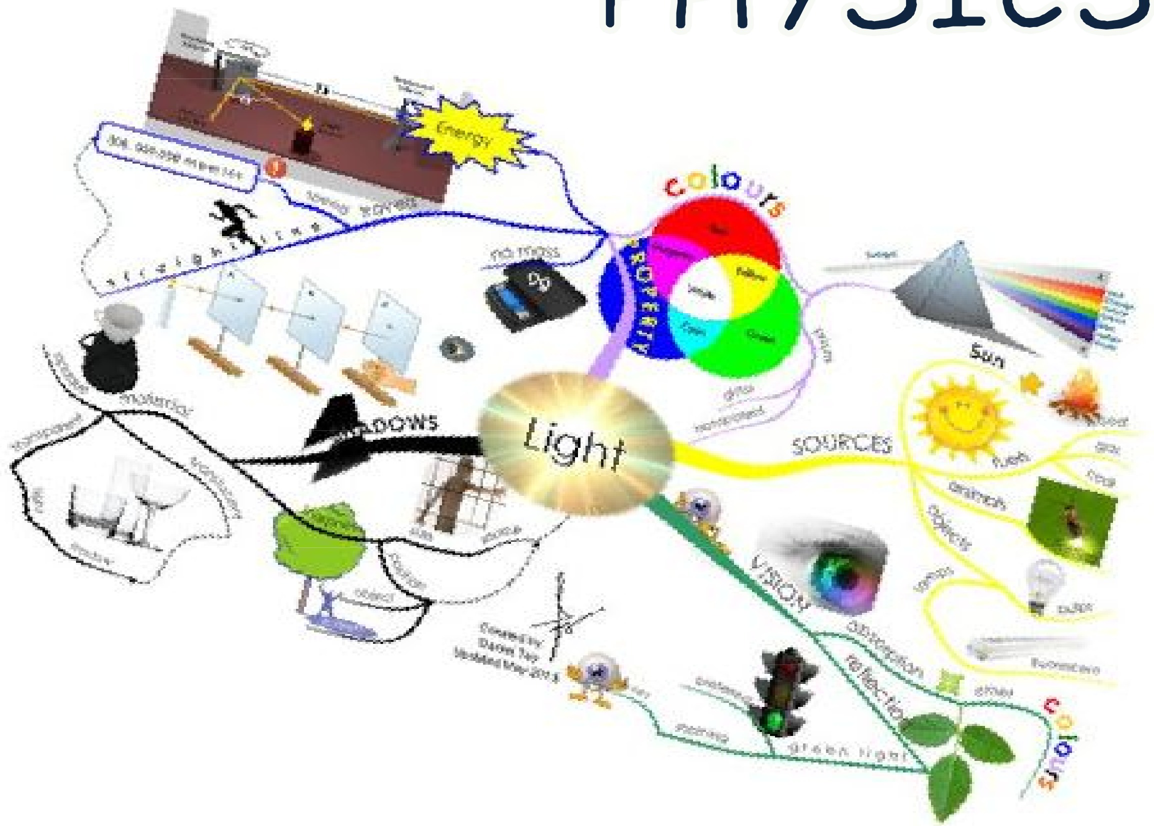
PHYSICS



Class - X

Light - Reflection and refraction

International School
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Reflection of light

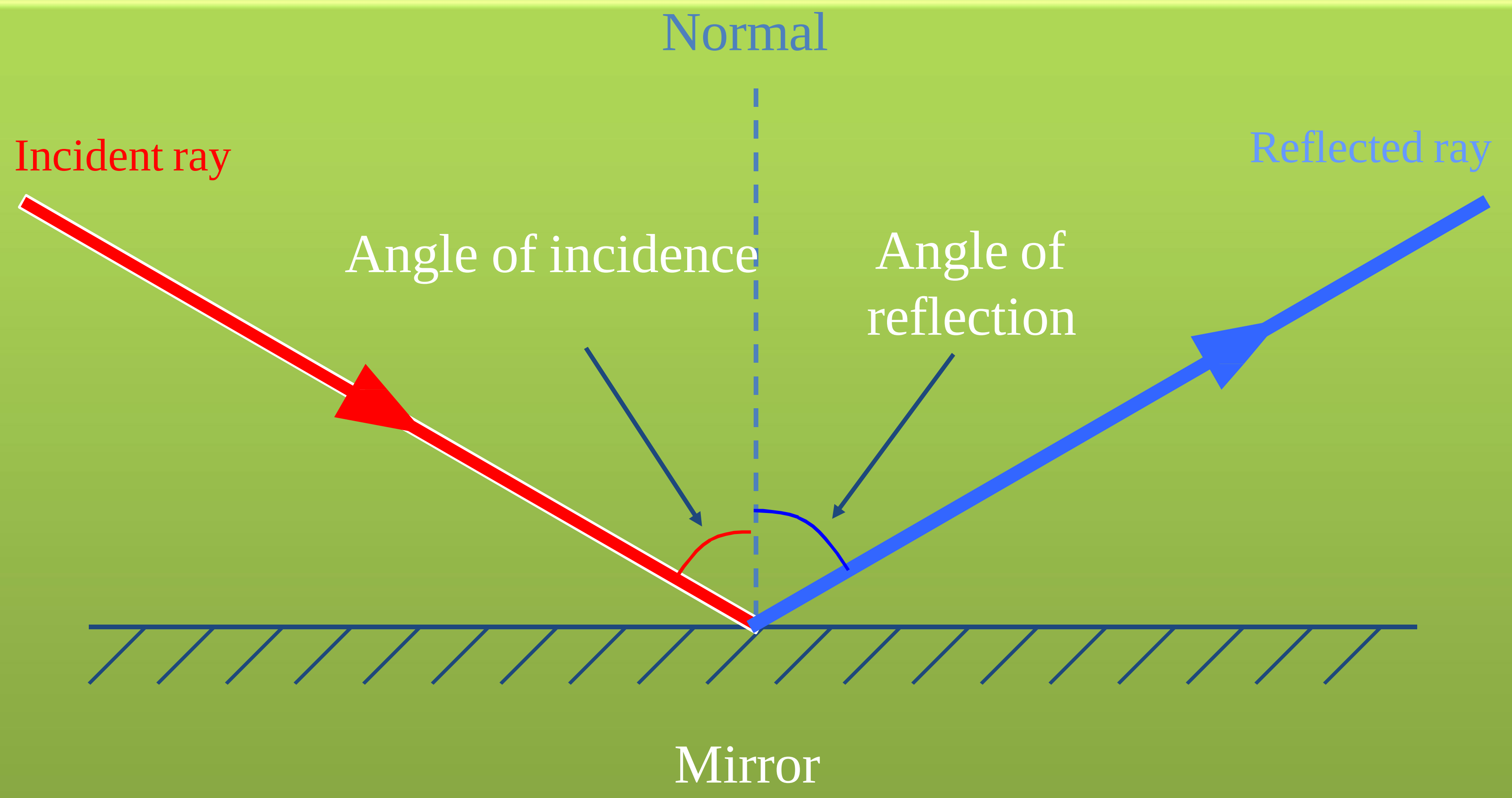
Reflection : It is the process of sending back the incidents light.

θ Law of reflection of light:

i. The angle of incident is equal to the angle of reflection.

ii. The incidence ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.

Reflection from a mirror:



¬These law of reflection are applicable to all type of reflecting surfaces including spherical surface.

¬Image formed by a plane mirror is always virtual and erect. The size of the image is equal to that of the object. The image formed is as far behind the mirror as the object is in front of it. It is laterally inverted, i.e., the image is inverted sideways

Spherical mirror

¬The reflecting surface of such mirrors can be considered to form a part of the surface of a sphere. Such mirrors, whose reflecting surfaces are spherical, are called spherical mirrors.

¬A spherical mirror, whose reflection surface is curved inwards is called a concave mirror and the one whose reflecting surface is curved outwards is called a convex mirror.

(a) Concave mirror

(b) Convex mirror

Important Terms

- Pole:-The centre of the reflecting surface of a spherical mirror is a point called the pole. It lies on the surface of the mirror. The pole is usually represented by the letter P.
- 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. Please note that the centre of curvature is not a part of the mirror It lies outside its reflecting surface. The centre of curvature of a concave mirror lies in front of it. However, it lies behind the mirror in case of a convex

- **Principal Axis:-** A straight line passing through the pole and the centre of curvature of a spherical mirror. This line is called the principal axis. The principal axis is normal to the mirror at its pole.
- **Principal Focus of Concave Mirror:-** The reflected rays are all meeting at a point on the principal axis of the concave mirror. This point is called the principal focus of the concave mirror.
- **Principal Focus of Convex Mirror:-** The reflected rays appear to come from a point on the principal axis of a Convex mirror. This point is called the principal focus of the convex mirror. It is represented by the letter F.
- The distance between the pole and the principal focus of a spherical mirror is called the focal length. It is represented by the letter *f*.

Concave Spherical Mirrors:

¬A ray parallel to the principal axis, after reflection, will pass through the principal focus in case of a concave mirror.

¬A ray passing through the principal focus of a concave Mirror after reflection, will emerge parallel to the principal axis.

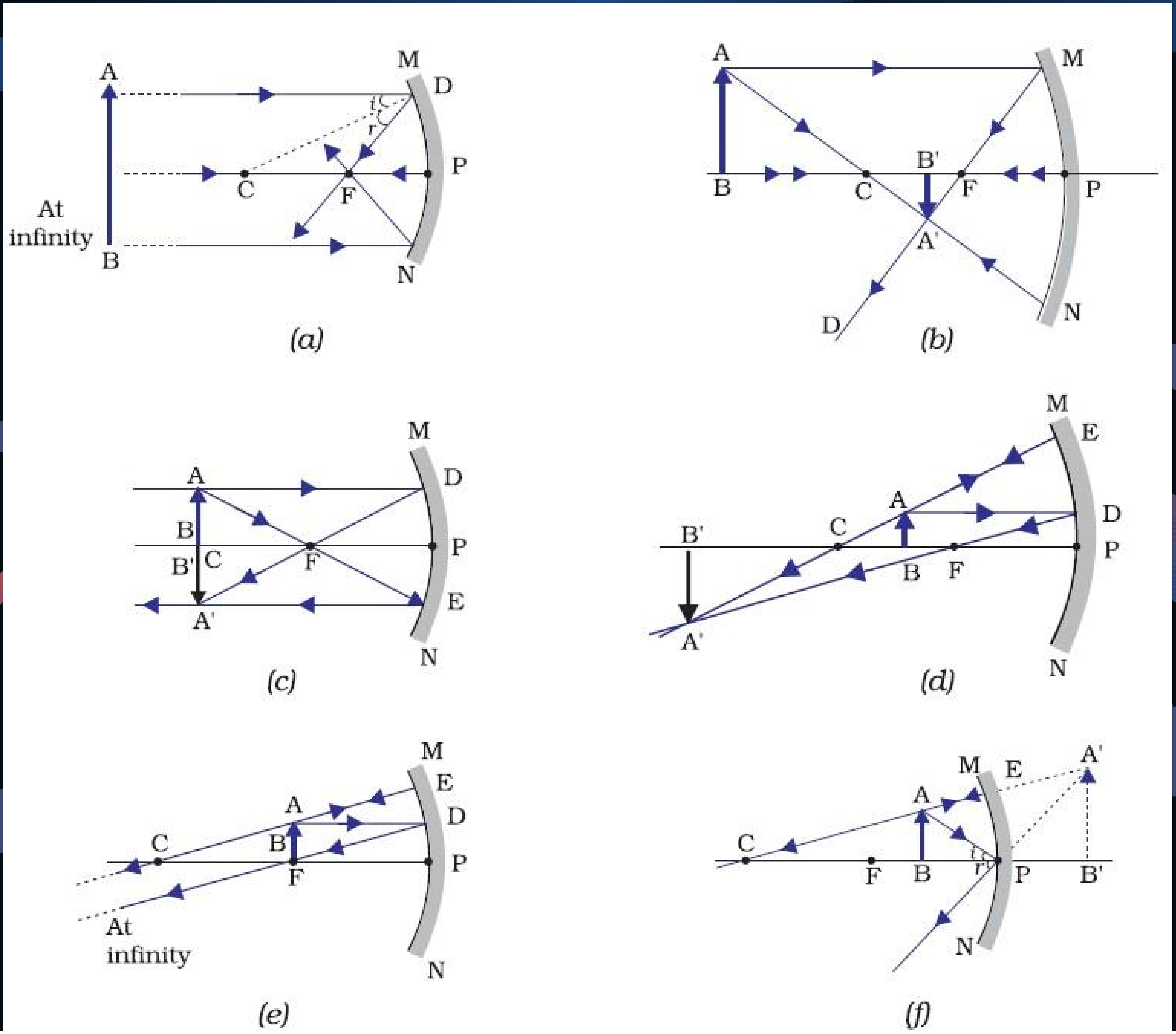
¬A ray passing through the centre of curvature of concave mirror after reflection, is reflected back along the same path.

¬A ray incident obliquely to the principal axis, towards a point P (pole of the mirror), on the concave mirror is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis.

Image formation by Concave Mirror

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

Ray Diagrams for image formation by Concave Mirror



¬Uses of concave mirrors

Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light.

They are often used as shaving mirrors to see a larger image of the face. The dentists use concave mirrors to see large images of the teeth of patients.

Large concave mirrors are used to concentrate sunlight to produce heat in solar furnaces.

Convex Spherical Mirrors

¬A ray parallel to the principal axis, after reflection, appear to diverge from the principal focus in case of a convex mirror.

¬A ray passing through the principal focus of a convex mirror, after reflection, will emerge parallel to the principal axis.

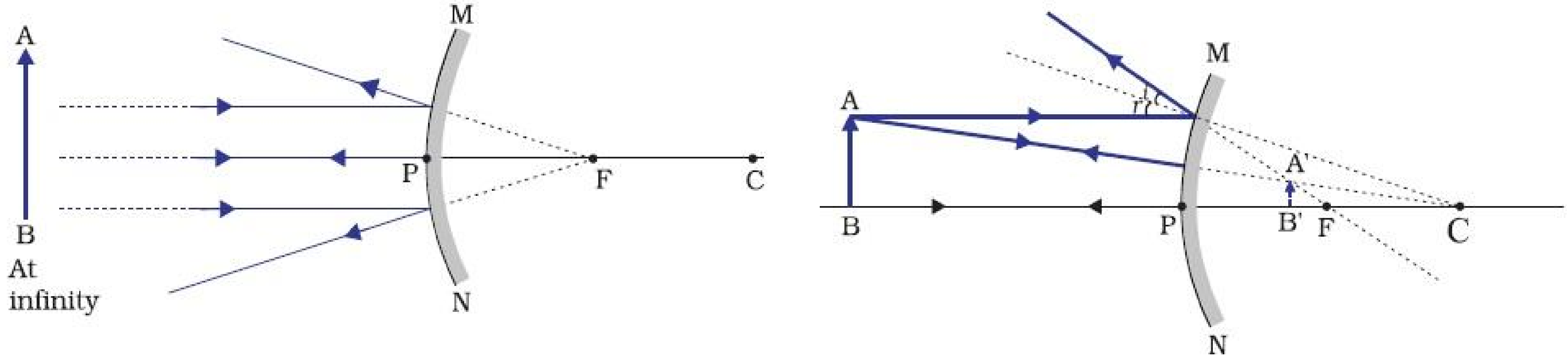
¬A ray passing through the centre of curvature of a convex mirror, after reflection, is reflected back along the same path. The light rays come back along the same path.

¬A ray incident obliquely to principal axis, towards a point P, on the convex mirror is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis

Image formation by Convex Mirror

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

Ray Diagrams for image formation by Convex Mirror



(a) (b)

• Uses of convex mirrors

- Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles. These mirrors are fitted on the sides of the vehicle, enabling the driver to see traffic behind him/her to facilitate safe driving.
- Convex are preferred because they always give an erect, though diminished, image.
- They have a wider field of view as they are curved outwards.
- Convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

Sign Convention for reflection by Spherical Mirrors

- While dealing with the reflection of light by spherical mirrors, we 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 are as follows –
- (i) 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.
- (ii) All distances parallel to the principal axis are measured from the pole of the mirror.
- (iii) 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.
- (iv) Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.
- (v) Distances measured perpendicular to and below the principal axis (along –y-axis) are taken as negative.

Mirror Formula

- In a spherical mirror, the distance of the object from its pole is called the object distance (u). The distance of the image from the pole of the mirror is called the image distance (v). You already know that the distance of the principal focus from the pole is called the focal length (f). There is a relationship between these three quantities given by the mirror formula which is expressed as

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

- This formula is valid in all situations for all spherical mirrors for all positions of the object. We can use the New Cartesian Sign Convention while substituting numerical values for u, v, f, and R in the mirror formula for solving problems.

Magnification

- 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.
- If h is the height of the object and h′ is the height of the image, then the magnification m produced by a spherical mirror is given by

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

- The magnification m is also related to the object distance (u) and image distance (v). It can be expressed as:

$$\text{Magnification } (m) = \frac{h'}{h} = -\frac{v}{u}$$

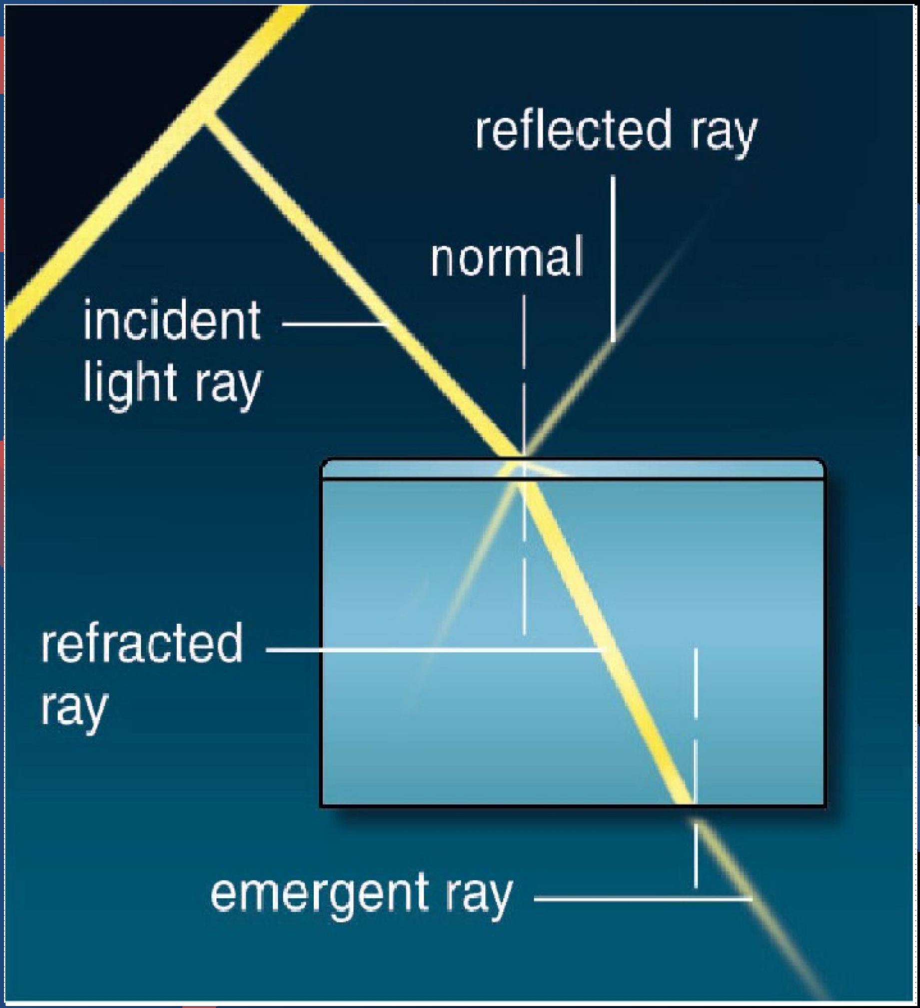
- A negative sign in the value of the magnification indicates that the image is real. A positive sign in the value of the magnification indicates that the image is virtual.

Refraction of light

When a ray of light travels obliquely one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as refraction of light.

REFRACTION OF LIGHT

During refraction, light bends first on passing from air to glass and again on passing from the glass to the air.



Cause of Refraction

The speed of light is different in different media. i.e., refraction is due to change in the speed of light on going from one medium to another.

Law of Refraction of light

1. The incident ray, the refracted ray and the normal to the interface to two transparent media at the point of incidence, all lie in the same plane.
2. The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media. This law is known as Snell's law of refraction. If the angle of incident and r is the angle of refraction then,

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

This constant value is called the refractive index of the second medium with respect to the first.

RefRactive index

The extent of the change in direction that takes place in given pair of media is expressed in terms of the refractiv index.

The refractive index can be linked to the relative speed o propagation of light in different media. The value of the refractive index for a given pair of media depends upon the speed of light in the two media.

- The refractive index of medium 2 with respect to medium 1

$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v_1}{v_2}$$

- The refractive index of medium 1 with respect to medium 2

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

- If medium 1 is vacuum or air, then the refractive index of medium 2 is considered with respect to vacuum. This is called the absolute refractive index of the medium.. If c is the speed of light in air and v is the speed of light in the medium

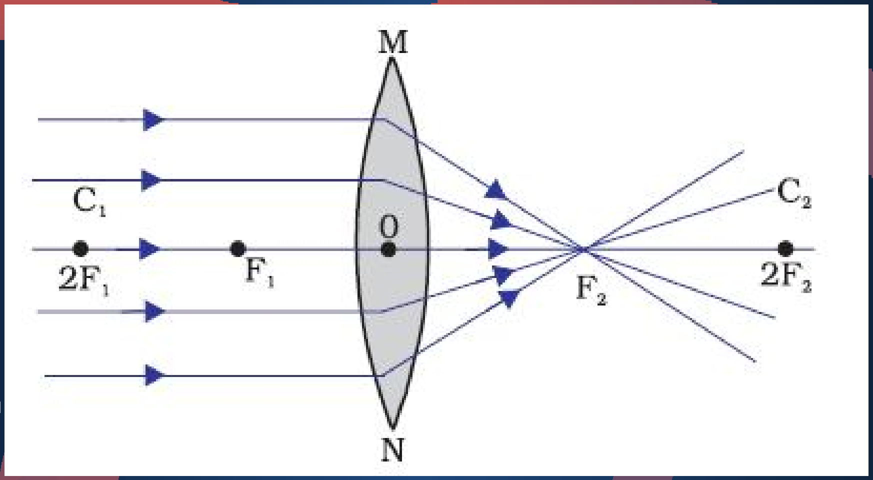
$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

Absolute Refractive Index of some material

Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada Balsam	1.53
Ice	1.31		
Water	1.33	Rock salt	1.54
Alcohol	1.36		
Kerosene	1.44	Carbon disulphide	1.63
Fused quartz	1.46	Dense flint glass	1.65
Turpentine oil	1.47	Ruby	1.71
Benzene	1.50	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

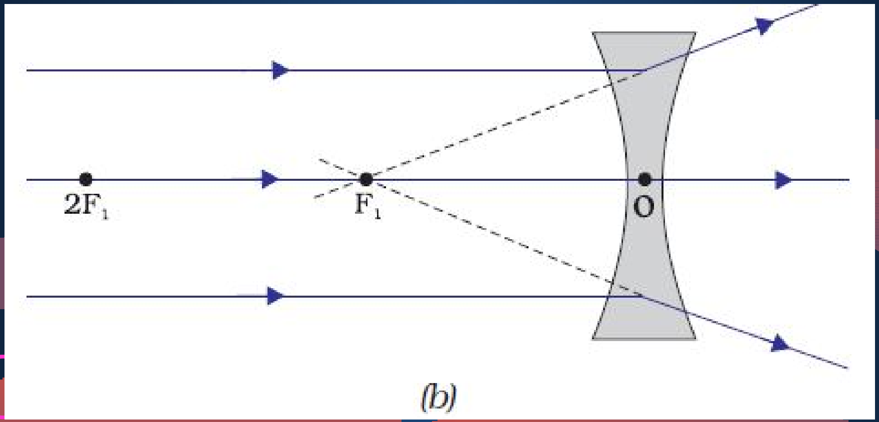
Important Terms

- **Lens:-** A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. This means that a lens is bound by at least one spherical surface.
- **Convex Lens:-** A lens having two spherical surfaces, bulging outwards is called a double convex lens or simply a convex lens. It is thicker at the middle as compared to the edges.



- **Aperture:-** T ircular outline of a spherical lens is called its aperture.

¬Concave Lens:- A lens having two spherical surfaces, bulging inwards is called a double concave lens or simply a concave lens. It is thicker at the edges as compared to middle.



- Centre of C urfaces forms a part of a sphere. The centres of these spheres are called centres of curvature of the lens. The centre of curvature of a lens is usually represented by the letter C.
- Optical Centre:-The central point of a lens is its optical centre. It is usually represented by the letter O.

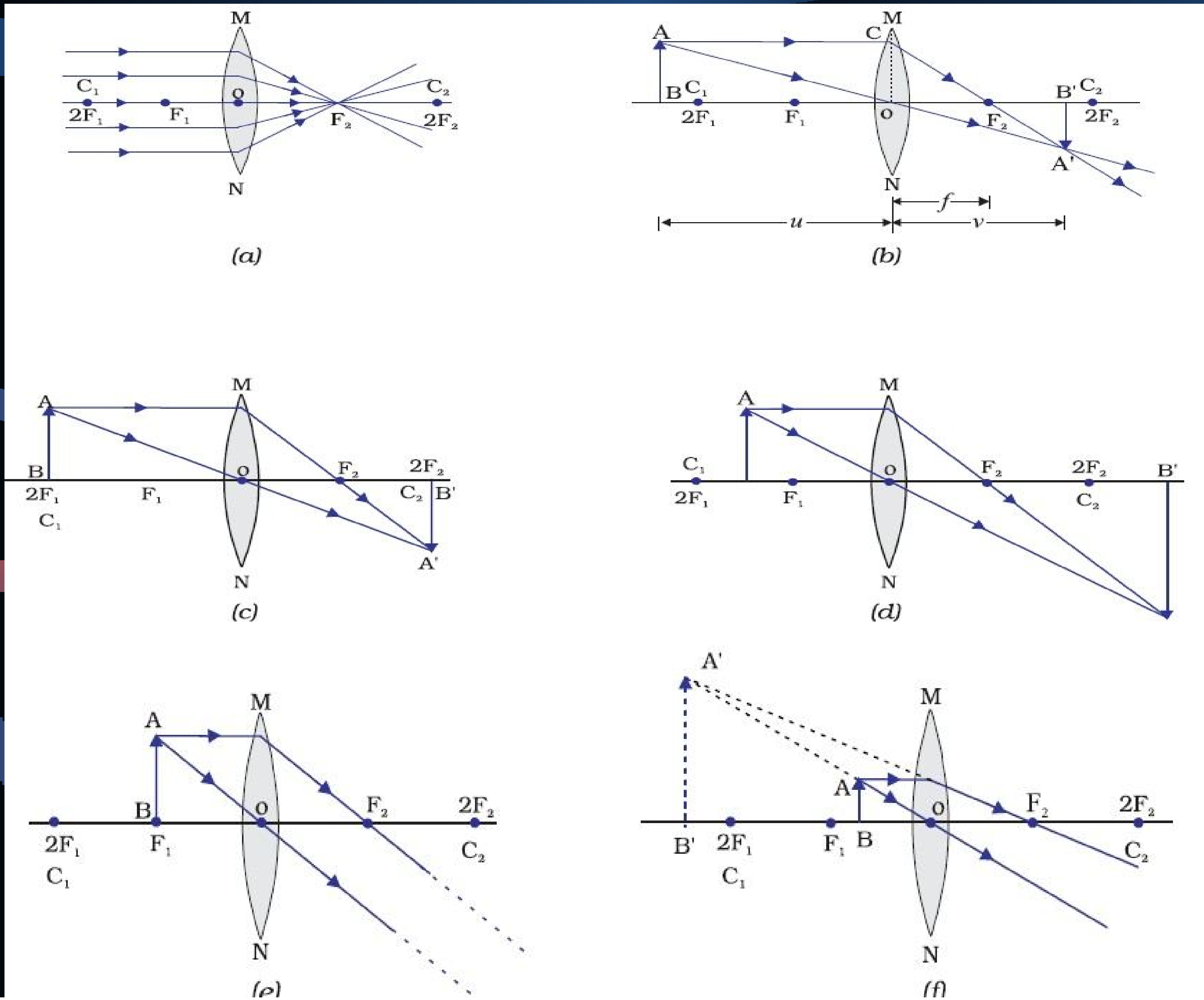
Convex Spherical Lens

- A ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus.
- A ray of light passing through a principal focus, after refraction from a convex lens, will emerge parallel to the principal axis.
- A ray of light passing through the optical centre of a lens will emerge without any deviation.

Nature, position and relative size of the image formed by a convex lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Ray Diagrams formed by Convex Spherical Lens



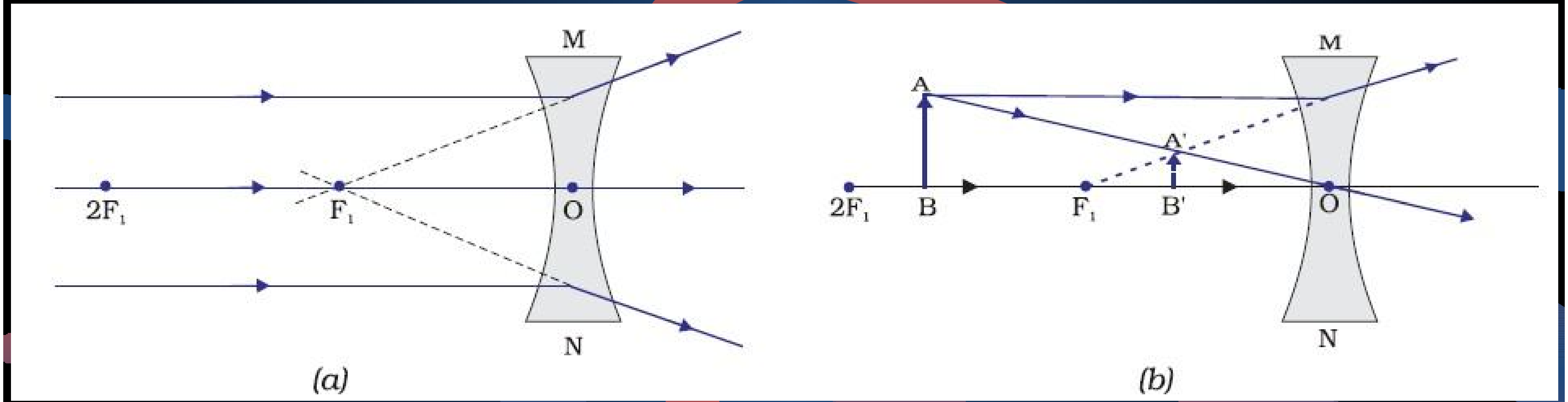
Concave Spherical Lens

- In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens.
- A ray of light appearing to meet at the principal focus of a concave lens, after refraction, will emerge parallel to the principal axis.
- A ray of light passing through the optical centre of a lens will emerge without any deviation.

Nature, position and relative size of the image formed by a concave lens for various positions of the object

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and erect

Ray Diagrams formed by Convex Spherical Lens



Sign Convention for Spherical Lenses

- For lenses too, similar sign conventions as that for spherical mirrors is used. We apply the rules for signs of distances, except that all measurements are taken from the optical centre of the lens. According to the convention, the focal length of a convex lens is positive and that of a concave lens is negative. You must take care to apply appropriate signs for the values of *u, v, f, object height h and image height h'*.

Lens Formula

- This formula gives the relationship between object distance (*u*), *image-distance (v) and the focal length (f). The lens formula* is expressed as

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

- The lens formula given above is general and is valid in all situations
- for any spherical lens.

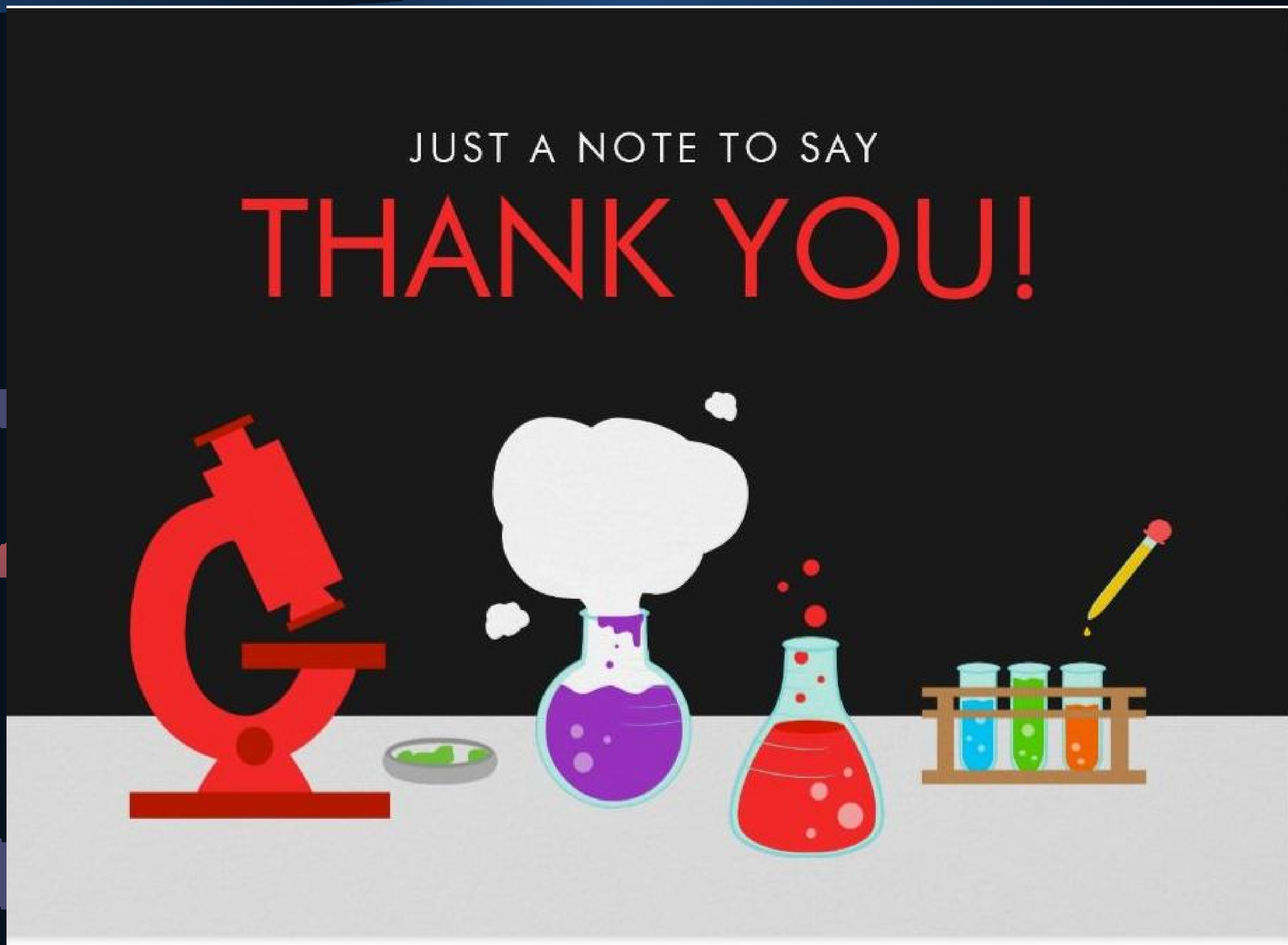
Magnification

- The magnification produced by a lens, similar to that for spherical mirrors, is defined as the ratio of the height of the image and the height of the object. It is represented by the letter 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

$$m = \frac{\text{Height of the Image}}{\text{Height of the object}} = \frac{h'}{h}$$

- Magnification produced by a lens is also related to the object-distance u, and the image-distance v. This relationship is given by

$$\text{Magnification } (m) = h'/h = v/u$$


JUST A NOTE TO SAY
THANK YOU!