Reflection of light. 23

Reflection of light:

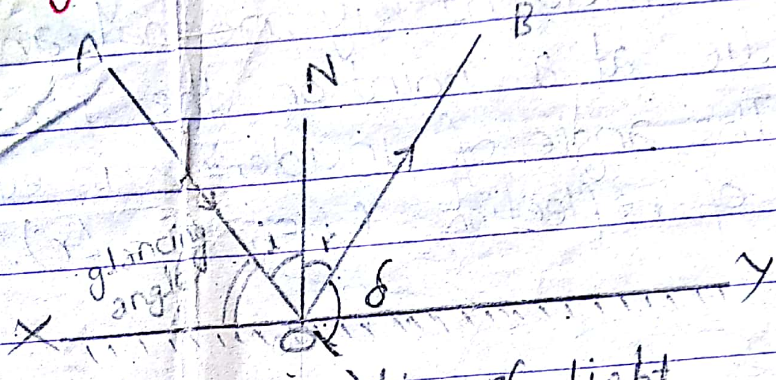


Fig: Reflection of light.

The phenomenon of returning of light ~~on~~ in- the same medium when it falls on the surface is known as reflection of light. This surface is known as reflecting surface.

Let. AO = incident ray

BO = reflected ray

NO = normal

$\angle i$ = angle of incidence

$\angle r$ = angle of reflection

$\angle AOX$ = glancing angle (θ)

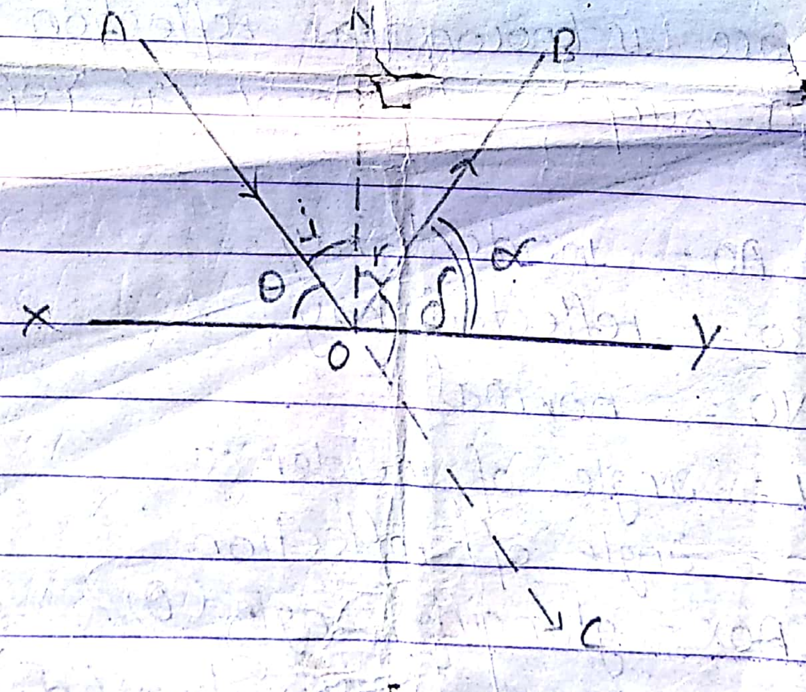
$\angle BOC$ = angle of deviation (δ)

Laws of reflection of light:

1. The incident ray, normal and reflected ray all lie at a point on the same plane.
2. The angle of incidence is equal to the angle of reflection (i.e., $\angle i = \angle r$).

Deviation produced on reflection of light.

(Deviation of light by plane mirror.)



Let, AO = incident ray

BO = reflected ray

NO = normal.

$\angle i$ = angle of incidence.

$\angle r$ = angle of reflection

$\angle AOX$ = glancing angle (θ)
$\angle BOC$ = angle of deviation (δ)
let, $\angle BOY = \alpha$.

Now

In NOX,
$i + \theta = 90°$ [$\because$ being right angle.] — (i)

Again, In NOY,
$r + \alpha = 90°$ — (ii) [$\because$ being right angle]

From eq^n (i) and (ii), we get
$i + \theta = r + \alpha$
$i + \theta - r = \alpha$
$i + \theta - i = \alpha$ [$\because i = r$]
$\therefore \alpha = \theta$ — (iii)

Again, $\angle AOX = \angle YOC = \theta$ [$\because$ being vertically opposite angle.]

Now,
$\angle BOC = \angle BOY + \angle YOC$
or, $\delta = \theta + \theta$
or, $\delta = 2\theta$

$\boxed{\therefore \delta = 2\theta}$

Hence, angle of deviation is equal to the twice of the glancing angle.

Regular reflection of light:

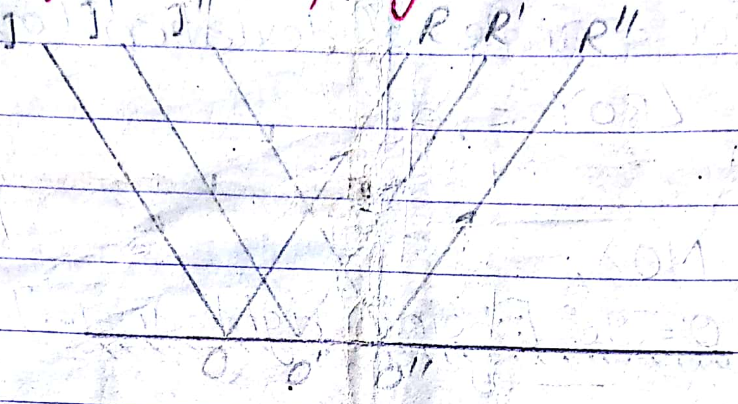


Fig: regular reflection of light.

When a parallel beam of light is incident on a plane surface so that the combination of reflected light rays is also parallel to each other. Such type of reflection of light is known as regular reflection of light. In this reflection, more amount of light is reflected but few amount of light is absorbed.

For example:

Reflection of light by plane mirror.

Diffuse reflection of light:

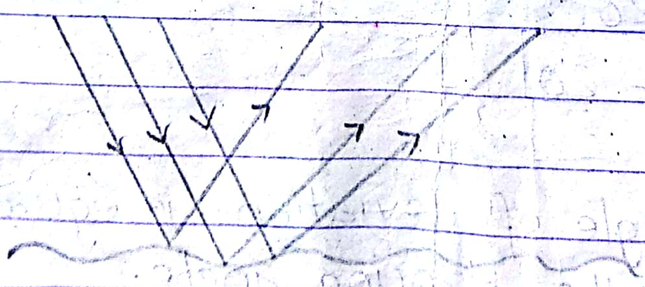


Fig: Diffuse reflection of light.

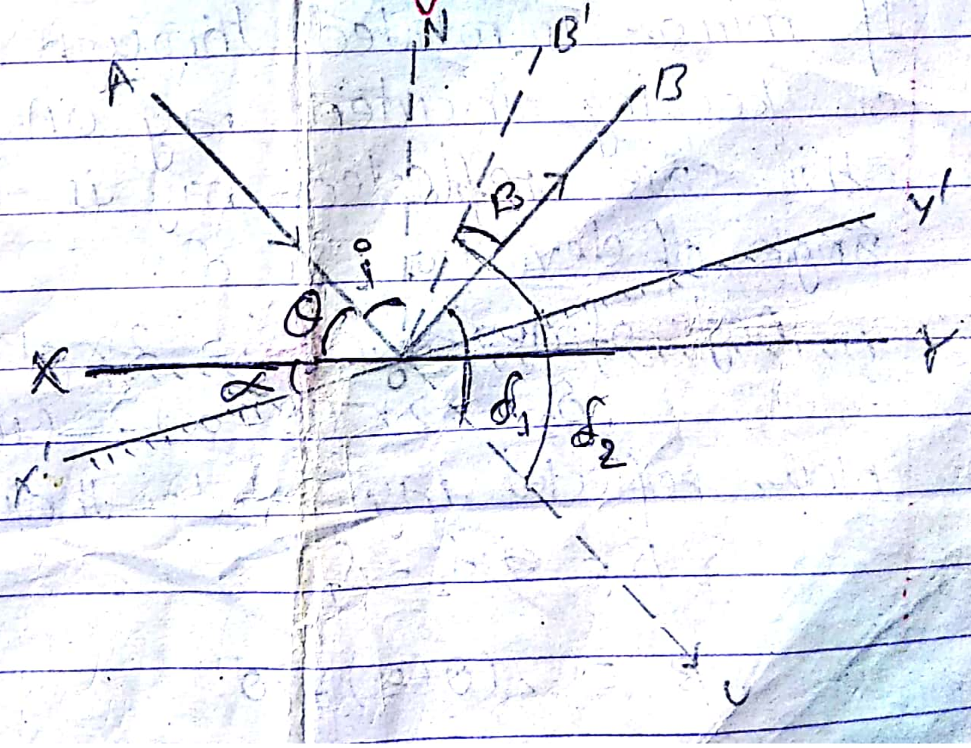
When a parallel beam of light is incident on a ~~plane~~ rough surface so that the combination of reflected light rays are not parallel to each other. Such type of reflection of light is known as diffuse or non-regular reflection of light. In this reflection, more amount of light is absorbed but few amount of light is reflected.

For example:

Reflection of light by walls of building, floor etc.

Imp.

Law of rotation of light:



Statement:

It states that, "when a mirror rotates through an angle α, then the reflected ray rotates through an angle 2α."

Proof:

Let us consider an incident ray OA incident on XY at a glancing angle θ as shown in figure. Let OB is reflected ray.

Let, OC = initial direction of incident ray.

Now Deviation produced by plane mirror is the twice of glancing angle.

$\therefore \delta_1 = 2 \times$ glancing angle

$\delta_1 = 2\theta$ ——— (i)

If mirror is rotated through an angle α on keeping incident ray OA fixed. In this case, reflected ray is OB' and angle of deviation is δ_2.

$\therefore$ Angle of deviation $(\delta_2) = 2 \times$ glancing angle

$\delta_2 = 2 \times (\theta + \alpha)$ ——— (ii)

Now, reflected ray rotates through an angle β.

$\therefore \beta = \delta_2 - \delta_1$

$\beta = 2(\theta + \alpha) - 2\theta$

$\beta = \cancel{2\theta} + 2\alpha - \cancel{2\theta}$

$\angle i$ = angle of incidence
$\angle r$ = angle of reflection.
Here,
Virtual image I is formed.
In $\Delta OAO'$ and $\Delta AO'I$
(i) $AO' = AO'$ (common side)
(ii) $\angle OAO' = \angle IAO'$ (Right angle)
(iii) $\angle i = \angle r$ (Law of reflection of light)
$\therefore$ $\Delta OAO'$ and $\Delta AO'I$ are congruent triangle)

$\therefore$ $AI = AO$ [corresponding sides of congruent triangle are equal.]
$\boxed{\therefore \; v = u}$

Hence, object distance is equal to the image distance.
The image formed by plane mirror is
(i) virtual
(ii) erect
(iii) Same size
(iv) object and ~~eq~~ image are equidistance from mirror.

Real and virtual images:

If the images produced by mirrors or lenses are formed by ~~actura~~ actual ~~or r~~ interaction of reflected light rays, the images formed are known as real images. Real image is always inverted and can be projected on the screen.

If the images produced by mirror or lenses are formed by virtual interaction of reflected light rays the images formed are known as virtual images. Virtual image is erect and cannot be ~~obt~~ projected on the screen.

Curved mirror: (spherical mirror)

~~When~~ When A small portion of hollow spherical glasses is cut and polished in one side, a spherical mirror is formed. They are widely used in optical instrunments like microscopes, vehicles.

There are two types of spherical mirror.

(i) concave mirror

(ii) Convex mirror.

Concave mirror

A spherical mirror in which reflection takes place in the inner side of sphere of which the mirror forms a part is called concave mirror. It is also called converging mirror because it converges all the parallel rays of light incident on it.

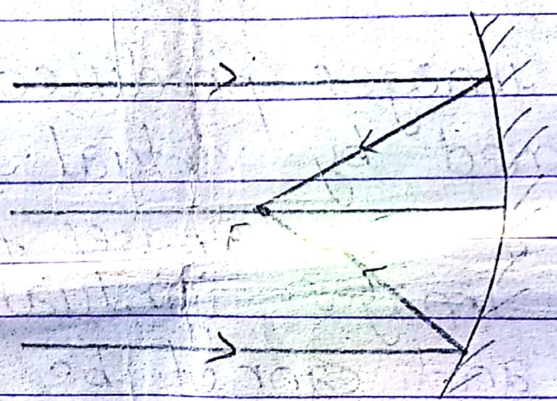


Fig: Converging mirror

Convex mirror:

A spherical mirror in which reflection takes place in the outerside of sphere of which the mirror is a part is called convex mirror.

It is also called diverging mirror because it diverges all the parallel beam of light incident on it.

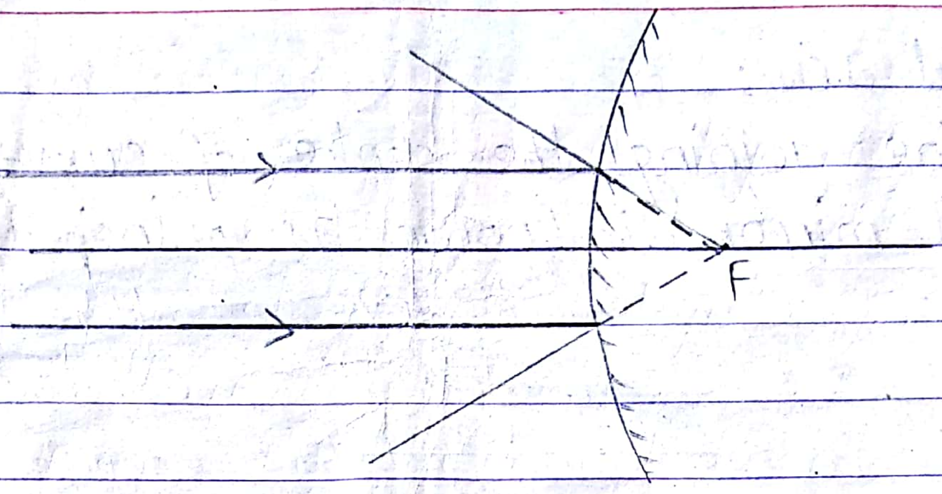


Fig: Convex mirror.

Some terms related to spherical mirror:

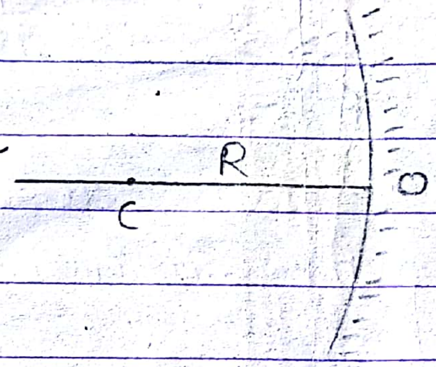
- **Centre of curvature:**
  It is the centre of sphere of which ~~mirror~~ is a part. It is denoted by C. It has only one centre of curvature.

- **Radius of curvature:** It is the radius of sphere of which mirror is a part. It is denoted by R.

- **Pole:**
  It is the middle point ~~part~~ of mirror through which its principal axis passes.

Principal axis:

The line joining the centre of curvature and pole of mirror is known as principal axis.



Here,
C= centre of curvature
O: pole of curvature
R= radius of curvature
CO= principal axis.

Fig: Concave mirror.

Principal focus:

It is a point on a principal axis in which rays of light converge after reflection from concave mirror but appears to diverge after reflection from convex mirror.

Focal length:

The distance between pole of mirror and principal focus is called focal length. It is denoted by f. It's value is positive for concave mirror and negative for convex mirror.

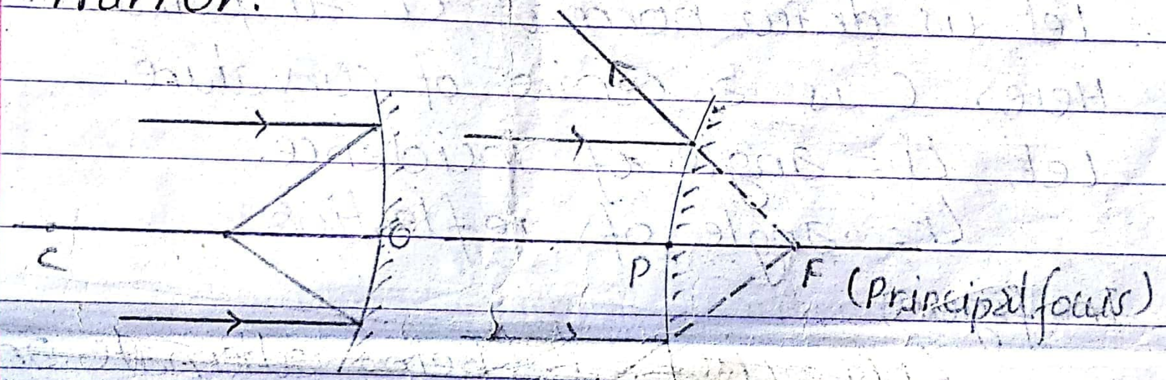


Fig: Concave mirror   Fig: Convex mirror

Relation between focal length and radius of curvature:

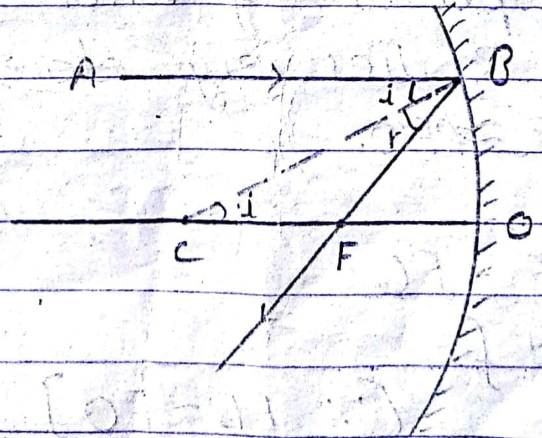


Fig: Concave mirror

Let us consider a concave mirror having focal length f and radius of curvature R.
Let a ray of light AB incident on mirror at point B and passes through principal focus F after reflection.
Let us draw normal CB at point B.
Here, C is a centre of curvature.
Let, $\angle i$ = angle of incidence.
$\angle r$ = angle of reflection.

In figure,

$\angle ABC = \angle BCF = i$ (being alternate angle.)

In $\triangle BCF$,

$\angle BCF = \angle CBF$

$\angle i = \angle r$ (law of reflection of light)

$\therefore CF = FB$

When the aperture of mirror is very small, then point B lies very close to O.

$\therefore FB \approx FO$.

Now,

$CO = CF + FO$

or, $R = FB + f$

or, $R = f + f$ $[\because FB \approx FO]$

or, $R = 2f$

$\therefore f = \frac{R}{2}$

Hence, focal length is equal to the half of the radius of curvature.

Sign convection:

(i) All the distances ~~should be~~ (object distance, image distance, focal length) should be measured from pole of mirror.

(ii) Distance is positive for real and negative for virtual.

(iii) Focal length and radius of curvature of concave mirror is taken as positive while that of convex mirror is taken as negative.

Mirror formula:

The relation between object distance, image distance and focal length of mirror is known as mirror formula.

Mirror formula for concave mirror:

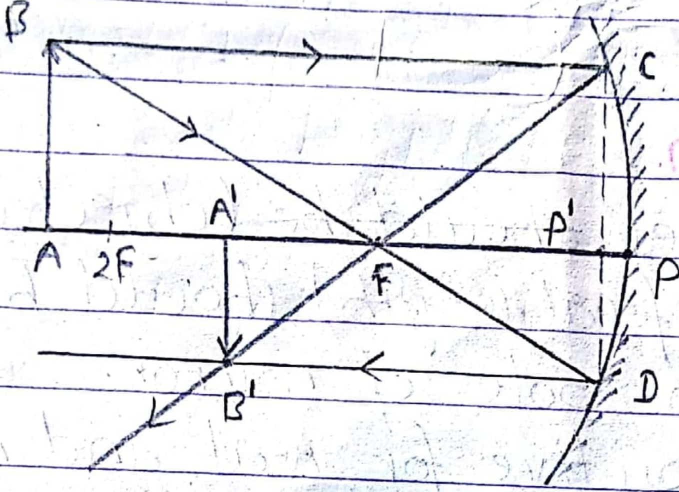


Fig: mirror formula for concave mirror.

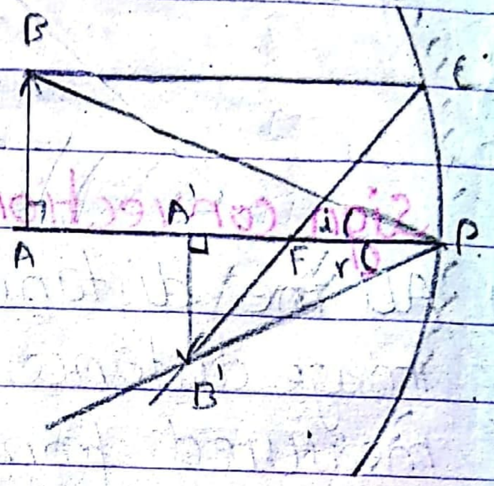


Fig: For magnification

Let an extended object AB is placed beyond '2F' of concave mirror having focal length f.
Let, a ray BC parallel to principal axis passes through focus F after reflection. Let another ray BD passes through focus incident at point D and passes parallely after reflection.
The image A'B' is formed which is real and inverted as shown in figure.
Here $AP = u$, object distance
$A'P = v$, image distance
$PF = f$, focal length.

Let us join C and D.

In similar triangle ABF and P'DF,

$$\frac{AB}{P'D} = \frac{AF}{P'F}$$

or, $$\frac{AB}{A'B'} = \frac{AP - PF}{PF}$$ [∵ P' is very closed to P] — (i)

In similar triangle A'B'F and P'CF,

$$\frac{CP'}{A'B'} = \frac{P'F}{A'F}$$

or, $$\frac{AB}{A'B'} = \frac{PF}{A'P - PF}$$ [∵ P' is very closed to P.] — (ii)

From eq^n (i) and (ii), we get

$$\frac{AP-PF}{PF} = \frac{PF}{A'P-PF}$$

or, $$\frac{u-f}{f} = \frac{f}{v-f}$$

or, $uv - uf - vf + f^2 = f^2$

or, $uv - uf - vf = 0$

or, $uv = vf + uf$

Dividing both sides by uvf, we get

$$\frac{uv}{uvf} = \frac{vf}{uvf} + \frac{uf}{uvf}$$

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

This is mirror formula for concave mirror.

Magnification:

It is defined as the ratio of height of the image to height of the object. It is denoted by m.

$$\therefore \text{Magnification } (m) = \frac{\text{height of image}}{\text{height of object}}$$

$$\text{or, } m = \frac{A'B'}{AB}$$

$$\text{or, } m = \frac{A'P}{AP} \quad \left[\because \text{from eq}^n \text{ (i) } \frac{AB}{A'B'} = \frac{AP}{A'P} \Rightarrow \frac{A'B'}{AB} = \frac{A'P}{AP}\right.$$

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

This is the required formula for magnification.

Mirror formula for convex mirror.

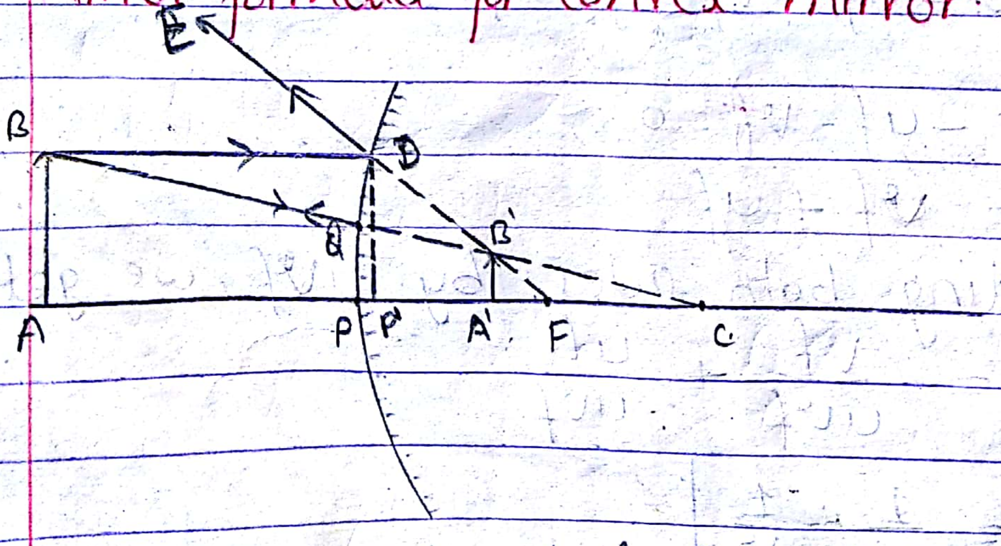


Fig: mirror formula for convex mirror.

Let an extended object AB is placed infront of convex mirror having focal length f.
Let a ray BD parallel to principal axis incident on mirror and reflected along DE. Another ray BQ incident normally on mirror and reflected back normally.
The image A'B' is formed which is virtual and erect as shown in figure.
Let, AP = u, object distance
A'P = v, image distance
PE = f, focal length

Let us draw DP' ⊥ PC
In similar triangle ABC and A'B'C,

$$\frac{A'B'}{AB} = \frac{A'C}{AC} \quad \text{— (i)}$$

~~or~~, In similar triangle A'B'F and DP'F,

$$\frac{A'B'}{DP'} = \frac{A'F}{P'F}$$

or, $$\frac{A'B'}{AB} = \frac{PF - A'P}{PF} \quad \text{— (ii)}$$ [∵ P' is very close to P.]

From eqn (i) and (ii), we get

$$\frac{A'C}{AC} = \frac{PF - A'P}{PF}$$

or, $$\frac{PC - A'P}{AP + PC} = \frac{PF - A'P}{PF}$$

or, $\frac{-R-(-v)}{u+(-R)} = \frac{-f-(-v)}{-f}$

or, $\frac{-2f+v}{u-2f} = \frac{-f+v}{-f}$ $[\because R = 2f]$

or, $2f^2 - vf = -uf + uv + 2f^2 - 2vf$

or, $-vf + 2vf = -uf + uv$

or, $vf = -uf + uv$

or, $uv = vf + uf$

Dividing both sides by uvf, we get

$$\frac{uv}{uvf} = \frac{vf}{uvf} + \frac{uf}{uvf}$$

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

This is mirror formula for convex mirror.

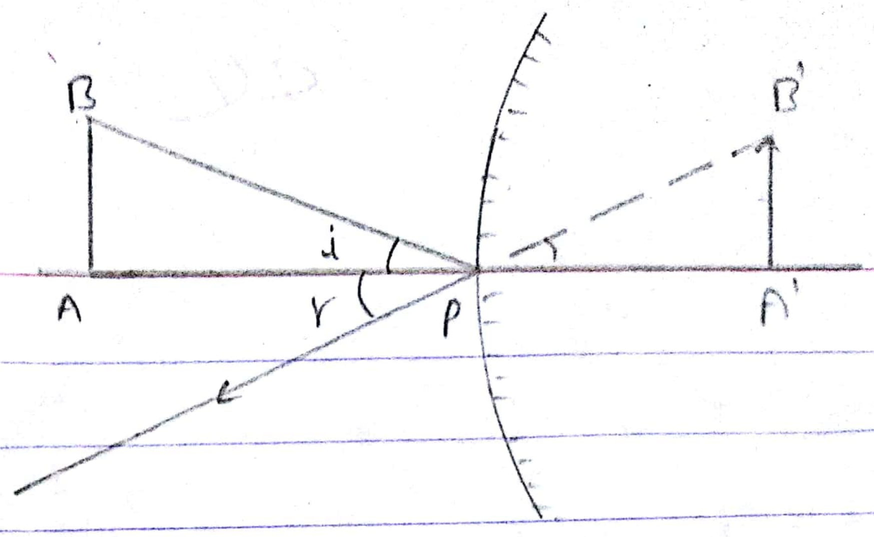
Magnification:

It is defined as the ratio of height of the image to height of the object. It is denoted by m.

$\therefore$ Magnification (m) $= \frac{A'B'}{AB} = \frac{\text{height of image}}{\text{height of object}}$

or, $m = \frac{A'B'}{AB} = \frac{A'P}{AP}$

Q3



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