Short Answer Type Question – II

Q.1. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. the two are kept 15 cm apart. A point object is placed 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the nature and the position of the image formed.

Ans. Here for convex lens

u = –60cm

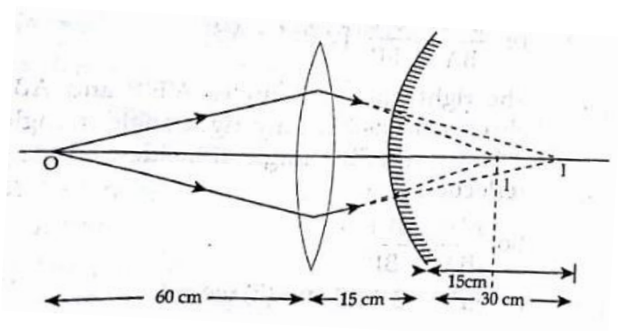
f = + 20 cm (convex lens)

using lens formula

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

$\frac{1}{v} + \frac{1}{60} = \frac{1}{20}$

$\frac{1}{v} = \frac{1}{20} - \frac{1}{60} = \frac{2}{60}$



So, v = 30 cm

Positive sign shows that image will be at the right-hand side of the lens.

Now this image would act as virtual source for convex mirror. Its distance from convex mirror is u = 30 – 15 = 15cm (+ve sign means virtual source) f = + 10cm (convex mirror)

Applying mirror formula

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

$\frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{1}{30}$

Hence $v = 30$ cm

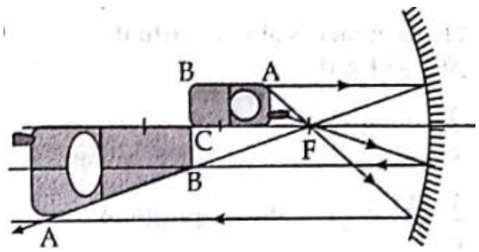
So, image would be at 30 cm from the mirror. As v is positive, image would be real and erect.

Q.2. (i) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image.

(ii) Explain why magnification is not uniform.

(iii) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain.

Ans. (i)



(ii) As mobile lies in the horizontal direction so different parts of the mobile has different distance from the mirror. According to their horizontal distance from the mirror linear magnification is not uniform in vertical plane.

(iii) The image would be sharp only intensity gets reduced due to blockage of lower half rays. In this situation, rays of light coming from the object will be reflected by the upper half of the mirror. These rays meet at the other side of the mirror to form the image of the given object.

Q.3. Use the mirror equation to show that

(i) An object placed between f and 2f of a concave mirror produces a real image beyond 2f.

(ii) A convex mirror always produces a virtual image independent of the location of the object.

(iii) An object placed between the pole and the focus of a concave mirror produces a virtual and enlarged image.

Ans. (i) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ (f is negative)

$u=-f \Rightarrow \frac{1}{v}=0 \Rightarrow v=\infty$

$u=-2f \Rightarrow \frac{1}{v}=\frac{-1}{2f} \Rightarrow v=-2f$

Hence if -2$f<u<-f$

$\Rightarrow -2f<v<\infty$

(ii) $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

Using sign convention, for convex mirror, we have

$f>0, u<0$

From the formula

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

$\because f$ is positive and u is negative,

⇨ v is always positive, hence image is always virtual.

(iii) Using mirror formula

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

For concave mirror, f < 0

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

For an object placed between focal and pole of mirror; $f < u < 0$

Hence $\frac{1}{u} < \frac{1}{f}$. It means $\frac{1}{v} > 0$

Hence image is always virtual.

Also, as f < 0

$\frac{1}{v} + \frac{1}{u} < 0$

$\frac{1}{v} - \frac{1}{u} < 0$ (v is always positive)

$\because u < v$

So, m = $\left|\frac{v}{u}\right| > 1,$

Hence, image is always enlarged.

Q.4. Show that the spherical mirror formula holds equally to a plane mirror.

Ans. Using mirror formula

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

For plane mirror f = ∞

Hence

$$\frac{1}{v} + \frac{1}{u} = 0$$

So, $v = -u$

It means the image is at equal distance and in opposite side of object. This is the true condition in image formation through plane mirror. Hence spherical mirror formula holds equally to a plane mirror.

Q.5. (i) Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light.

(ii) A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm.

Ans. (i) λ = $\frac{589 \text{ nm}}{1.33} = 442.8$ nm

Frequency v = $\frac{3\times10^8 \text{ms}^{-1}}{589 \text{ nm}} = 5.09 \times 10^{14}$ Hz

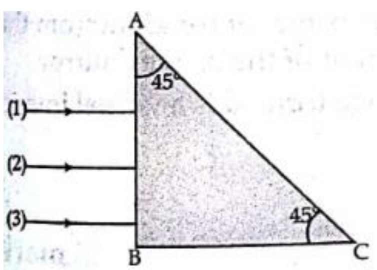
Speed $v = \frac{3\times10^8}{1.33} m/s = 2.25 \times 10^8 m/s$

(ii) $\frac{1}{f} = \left[\frac{\mu_{ga}}{u_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

∴ $\frac{1}{20} = \left[\frac{1.55}{1} - 1\right]\frac{2}{R}$

∴ R = (20 × 1.10) cm = 22 cm

Q.6. Three rays (1, 2, 3) of different colour fall normally on one of the sides of an isosceles right-angled prism as shown. The refractive index of prism for these rays is 1.39, 1.47 and 1.52 respectively. Find which of these rays get internally reflected and which get only refracted from AC. Trace the paths of rays. Justify your answer with the help of necessary calculations.



Ans. At plane AC, the incident angle for ray 1, ray 2 and ray 3 = 45o

Let the critical angle for total internal reflection for ray 1 = C_1

'1.39 = $\frac{1}{\sin C_1}$ ⇨ $\sin C_1 = \frac{1}{1.39} = 0.719$

hence $C_1 > 45^o$ (sin 45 = 0.707)

Let critical angle for total internal reflection for ray 2 = C_2

1.47 = $\frac{1}{\sin C_2}$ ⇨ $\sin C_2 = \frac{1}{1.47} = 0.0.68$

hence $C_2 < 45^o$

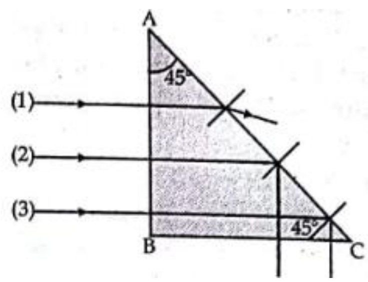
Let critical angle for total internal reflection for ray 3 = C_3

$1.52 = \frac{1}{\sin C_3}$ ⇨ $\sin C_3 = \frac{1}{1.52} = 0.0.657$

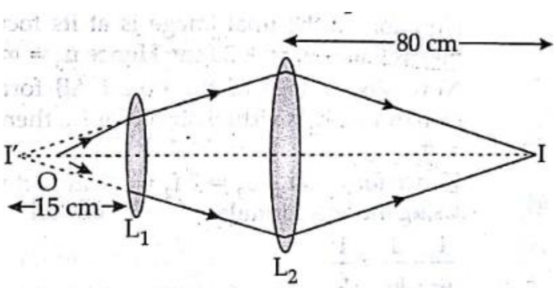
hence $C_3 < 45^o$

As in case of ray 1, incident angle is less than critical angle, it would emerge out from AC. In the figure path of the ray 1 is shown.

In case of ray 2, ray 3, incident angle is greater than critical angle, they would get total internal reflection at AC and emerge from BC. In the figure path of the ray and 3 are shown.



Q.7. In the following diagram, an object 'O' is placed 15 cm in front of a convex lens L_1 of focal length 20 cm and the final image is formed at 'I' at a distance of 80 cm from the second lens L_2. Find the focal length of the lens L_2.



Ans. For lens L_1

u = -15cm

f = +20 cm

using lens formula

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

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

$$\frac{1}{v} = -\frac{1}{15} + \frac{1}{20} = -\frac{1}{60}$$

$v = -60$ cm

This image will act as object for lens L_2 lens

u = $-20 - 60 = -80$cm

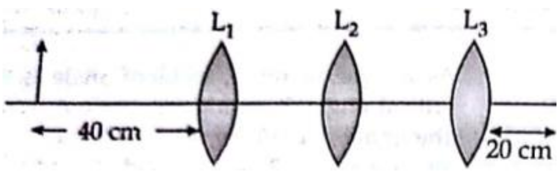
v = + 80 cm

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

$\frac{1}{80} + \frac{1}{80} = \frac{1}{f}$

$\frac{1}{f} = \frac{1}{40}$ or f = 40cm

Q.8. You are given three lenses L_1, L_2, L_3 each of focal length 20 cm. An object is kept at 40 cm in front of L_1. The final real image is formed at the focus I of L_3. Find the separations between L_1,L_2 and L_3.



Ans. Given $f_1 = f_2 = f_3 = 20$ cm

For lens L_2

u = –40 cm

f = 20 cm

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

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

$\frac{1}{v} = -\frac{1}{40} + \frac{1}{20}$

$\frac{1}{v} = \frac{1}{40}$

$v = 40$ cm (+ ve sign shows it is right hand side of lens L_1)

Now for L_3, the final image is at its focus, that means that is v_3 = + 20 cm. Hence $u_3 = \infty$

Now, since image of the object AB formed by convex lens L_2 is virtual object for L_3, therefore $v_2 = \infty$.

Hence for lens L_2, $u_2 = ?\, f_2 = 20$ cm and $v_2 = \infty$. Using the lens formula

$\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$

⇨ $\frac{1}{\infty} - \frac{1}{u_2} = \frac{1}{20}$

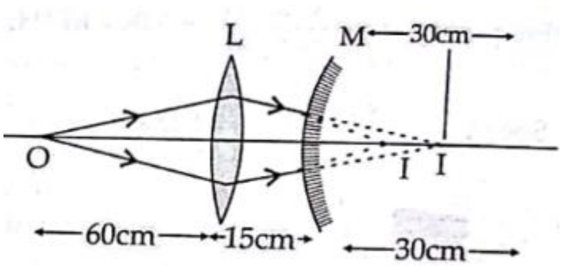
$u_2 = -20$ cm

So, the separation between L_1 and L_2 = 40 + 20 = 60 cm

As $v_2 = \infty$ and $u_3 = \infty$, therefore lenses L_2 and L_3 are in contact. Or the distance between L_2 and L_3 does not matter it may take any value because image by L_2 is formed at infinity.

Q.9. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed.

Ans.



For the convex lens $u = -60cm, f = +20cm$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ given V = +30cm

For convex mirror,

$u = +(30 - 15)cm = 15cm, f = +\frac{20}{2}cm = 10cm$

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ given V = +30cm

The final image is formed at the distance of 30 cm from the convex mirror (or 45 cm from the convex lens) to the right of the convex mirror.

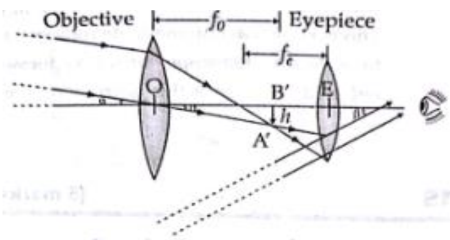
The final image formed is a virtual image.

Q.10. (i) Draw a ray diagram depicting the formation of the image by an astronomical telescope in normal adjustment.

(ii) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an object to construct an astronomical telescope? Give reason.

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

Ans. (i) Ray diagram of astronomical telescope



(Note: Deduce ½ mars if the ‘arrows’ are not marked)

(ii) Objective Lens: Lens L_1

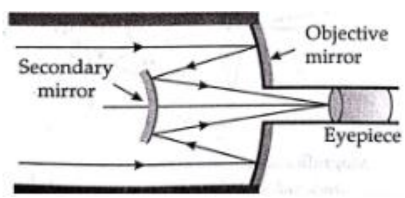
Eyepiece lens: Lens L_2

Reason:

The objective should have large aperture and large focal length while the eyepiece should have small aperture and small focal length.

Q.11. Draw a schematic ray diagram of reflecting telescope showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope.

Ans.

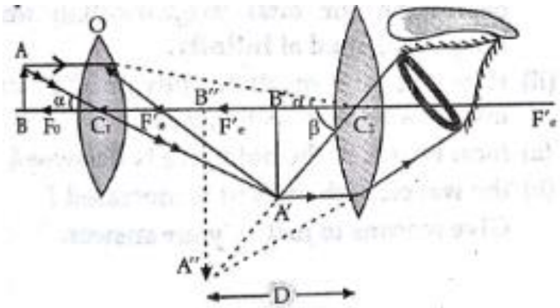


(i) Large gathering power
(ii) Large magnifying power
(iii) No chromatic aberration
(iv) Spherical aberration is also removed
(v) Easy mechanical support
(vi) Large resolving power

Q.12. (i) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at the least distance of distinct vision.

(ii) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focused on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If the least distance of distinct vision is 20 cm, calculate the focal length of the objective lens and the eye piece.

Ans. (i) A labelled ray diagram of a compound microscope for formation of image at the near point of the eye.



(ii) Given, $m = 20, m_e = 5, \mathrm{D} = 20\mathrm{cm}$

$m_e = \frac{D}{u_e}$ (For eyepiece)

5 = $\frac{20}{u_e}$

$u_e = 4$ cm

$u_e = -4\mathrm{cm}, v_e = D = -20\mathrm{cm}$

$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$

= $\frac{1}{-20} + \frac{1}{4}$

$\frac{1}{f_e} = \frac{-1+5}{20}$

$\frac{1}{f_e} = \frac{4}{20}$

Hence, focal length of eyepiece,

$f_e = 5$ cm

$m = m_e \times m_e$

$m_e = \frac{m}{m_e} = \frac{20}{5} = 4$

$v_o = 14 - 4 = 10$ cm

For objective lens,

$m_o = -\frac{v_o}{u_o}$

4 = $-\frac{10}{u_o}$ [$\because \ m_o = 4$)

⇨ $u_o = -\frac{10}{4} = -2.5\mathrm{cm}$

Now, $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$$\frac{1}{f_o} = \frac{1}{10} - \frac{1}{-2.5}$$

$$\frac{1}{f_o} = \frac{1}{10} + \frac{10}{25}$$

$$\frac{1}{f_o} = \frac{1}{2}$$

$f_o = 2$ cm

Hence, focal length of objective, f = 2.0 cm.

Q.13. Which two aberrations do objectives of refracting telescope suffer from? How are these overcome in reflecting telescope?

Ans. The two aberrations that objectives of refracting telescope suffer from are

(i) **Spherical aberrations:** Because of the surface geometry of the lens, sharp point image of star is difficult to obtain on a point.

In reflecting telescope, we use parabolic mirror to remove this aberration.

(ii) **Chromatic aberrations:** Different colours of light have different refractive index with respect to glass. Hence different colour would focus at different points. hence image of white object would appear as different colour point images. This is known as chromatic aberrations.

in reflecting telescope, image is formed with reflected rays hence this aberration is removed.