Short Answer Questions – II (PYQ)

Q. 1. Answer the following question: [CBSE (East) 2016]

(i) What is total internal reflection? Under what conditions does it occur?

(ii) Find a relation between critical angle and refractive index.

(iii) Name one phenomenon which is based on total internal reflection.

Ans. (i) When a ray of light travels from an optically denser medium into a rarer medium at an angle greater than the critical angle, it reflects back into the denser medium. This phenomenon is called total internal reflection.

(ii)

$\frac{1}{\mu} = \frac{\sin\ i}{\sin\ r}$, for total internal reflection to occur $i \geq i_c$ at critical angle, angle of refraction, $r = 90°$ hence $\frac{1}{\mu} = \frac{\sin\ i_c}{\sin\ 90^o} \quad \Rightarrow \quad \mu = \frac{1}{\sin\ i_c}$

(iii) (a) Mirage (b) optical fibre (c) sparkling of diamond (d) shinning of air bubbles in water (e) totally reflecting Prism.

Q. 2. (i) Name the phenomenon on which the working of an optical fibre is based.

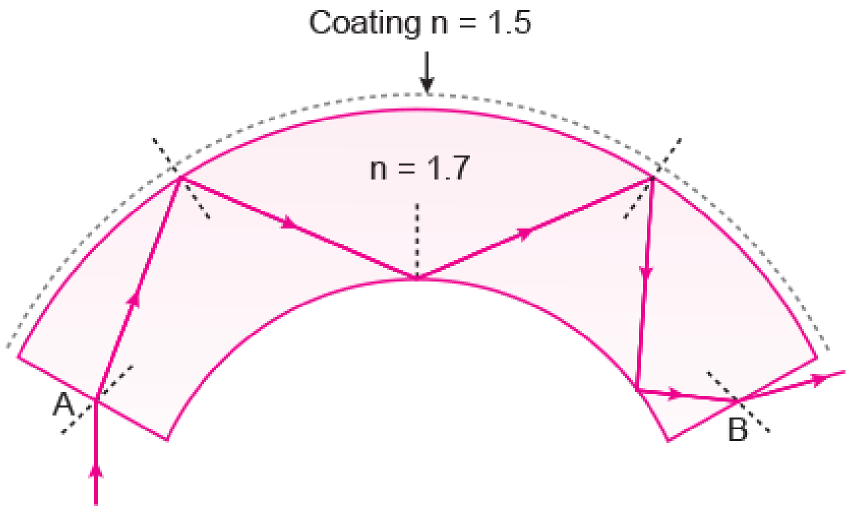
(ii) What are the necessary conditions for this phenomenon to occur?

(iii) Draw a labelled diagram of an optical fibre and show how light propagates through the optical fibre using this phenomenon. [CBSE (South) 2016]

Ans. (i) Working of an optical fibre is based on total internal reflection.

(ii) (a) Rays of light have to travel from optically denser medium to optically rarer medium and (b) Angle of incidence in the denser medium should be greater than critical angle.

(iii)



Q. 3. How is the working of a telescope different from that of a microscope? [CBSE Delhi 2012]

Ans. Difference in working of telescope and microscope

(i) Objective of telescope forms the image of a very far off object at or within the focus of its eyepiece. The microscope does the same for a small object kept just beyond the focus of its objective.

(ii) The final image formed by a telescope is magnified relative to its size as seen by the unaided eye while the final image formed by a microscope is magnified relative to its absolute size.

(iii) The objective of a telescope has large focal length and large aperture while the corresponding parameters for a microscope have very small values.

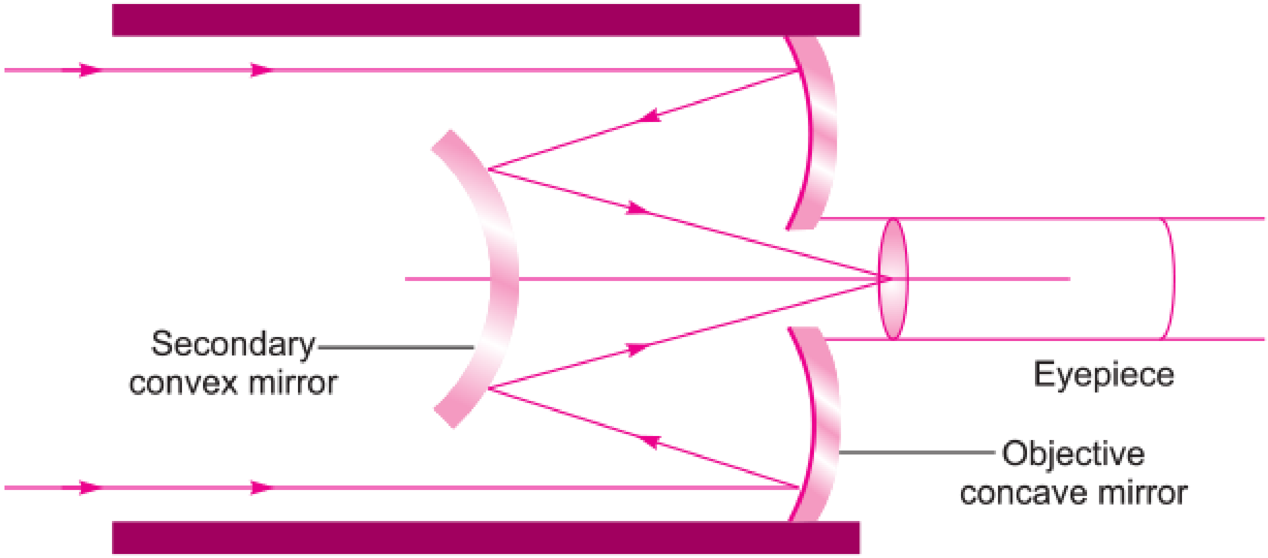
Q. 4. (i) Draw a schematic labelled ray diagram of a reflecting type telescope (cassegrain).

(ii) The objective of a telescope is of larger focal length and of larger aperture (compared to the eyepiece). Why? Give reasons. [CBSE (F) 2013]

OR

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 refracting telescope. [CBSE Delhi 2016]

Ans. (i)



(ii) In normal adjustment, magnifying power of the telescope $M \frac{f_o}{f_e}$.

(a) If focal length of the objective lens is large in comparison to the eyepiece, magnifying power increases.

(b) Resolving power of the telescope RP = $\frac{D}{1.22\lambda}$.

D being the diameter of the objective.

To increase the resolving power of the telescope, large aperture of the objective lens is required.

Advantages:

(i) No chromatic aberration.

(ii) Easy mechanical support (height mechanical support is required, because mirror weights much less than a lens of equivalent optical quality.)

(iii) Large gathering power.

(iv) Large magnifying power.

(v) Large resolving power.

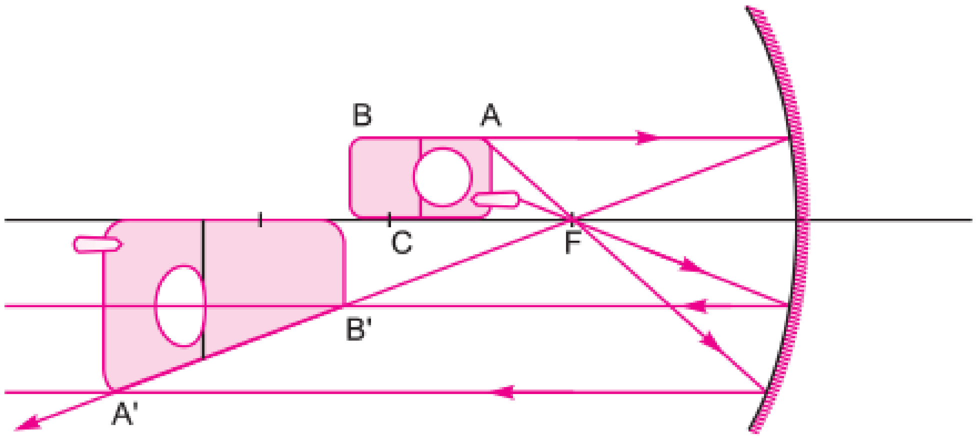
(vi) Spherical aberration can be removed by using parabolic mirror.

Q. 5. Answer the following question : [CBSE (Delhi) 2014]

(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. Explain why magnification is not uniform.

(ii) 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)



The position of the image of different parts of the mobile phone depends on their position with respect to the mirror. The image of the part which is on the plane perpendicular to principal axis will be on the same plane. It will be of the same size, i.e., B′C = BC. The images of the other parts of the phone are getting magnified as when the object is placed between C and F it gets magnified.

(ii) Taking the laws of reflection to be true for all points of the remaining (uncovered) part of the mirror, the image will be that of the whole object. As the area of the reflecting surface has been reduced, the intensity of the image will be low (in this case half).

Q. 6. Answer the following question : [CBSE Delhi 2016]

(i) Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also.

(ii) Using mirror formula, explain why does a convex mirror always produce a virtual image.

Ans. (i)

R = – 20 cm and M = –2

Focal length $f = \frac{R}{2} = -10$ cm

Magnification $M = -\frac{v}{u} = -2$ (given) $\therefore v = 2u$

Using mirror formula

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{2u} + \frac{1}{u} = -\frac{1}{10}$$

$$\Rightarrow \frac{3}{2u} = -\frac{1}{10} \Rightarrow u = -15 \text{ cm}$$

$$\therefore \quad v = 2(-15) = -30 \text{ cm}$$

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

Using sign convention for convex mirror we get

$f > 0$, $u < 0$

∴ From the formula:

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

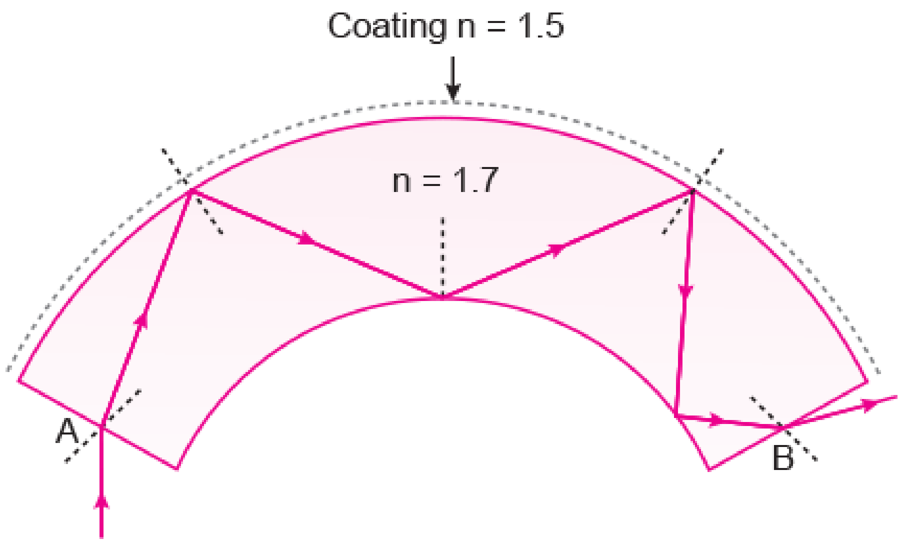
As f is positive and u is negative, v is always positive, hence image is always virtual.

Q. 7. What are optical fibres? Mention their one practical application.
[CBSE Delhi 2011, Guwahati 2015]

Ans. Optical Fibre: An optical fibre is a device based on total internal reflection by which a light signal may be transmitted from one place to another with a negligible loss of energy. It is a very long and thin pipe of quartz (n = 1.7) of thickness nearly ≈ 10^{-4} m coated all around with a material of refractive index 1.5. A large number of such fibres held together form a light pipe and are used for communication of light signals. When a light ray is incident on one end at a small angle of incidence, it suffers refraction from air to quartz and strikes the quartz-coating interface at an angle more than the critical angle and so suffers total internal reflection and strikes the opposite face again at an angle greater than critical angle and so again suffers total internal reflection. Thus the ray within the fibre suffers multiple total internal reflections and finally strikes the other end at an angle less than critical angle for quartz-air interface and emerges in air.

As there is no loss of energy in total internal reflection, the light signal is transmitted by this device without any appreciable loss of energy.

Application : Optical fibre is used to transmit light signal to distant places.



Q. 8. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33.

(i) Will it behave as a converging or a diverging lens in the two cases?

(ii) How will its focal length change in the two media? [CBSE (AI) 2011]

Ans. Focal length of lens in liquid (l)

$$f_l = \frac{n_g - 1}{\frac{n_g}{n_l} - 1} \text{fa}$$

a. (i) $n_g = 1.5$, $n_l = 1.65$

$\frac{n_g}{n_1} = \frac{1.5}{1.65} < 1$, so f_l and fa are of opposite sign, so convex lens in liquid $n_l =$ 1.65 behaves as a diverging lens

(ii) $n_g = 1.5$, $n_l = 1.33$

$\therefore \quad \frac{n_g}{n_l} = \frac{1.5}{1.33} > 1$

so f_l and f_a are of same sign, so convex lens in liquid $(n_l = 1.33)$ behaves as a convergent lens.

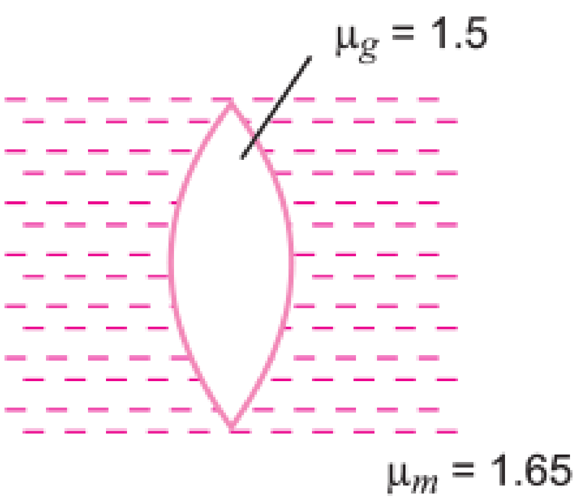
b. (i) Focal length, $f_1 = \frac{1.5 - 1}{\frac{1.5}{1.65} - 1} f_a = - 5.5 f_a$

(Focal length becomes negative and its magnitude increases)

(ii) Focal length $f_2 = \frac{1.5 - 1}{\frac{1.5}{1.33} - 1} f_a = 4 f_a$ (Focal length increases)

Q. 9. A biconvex lens of glass of refractive index 1.5 having focal length 20 cm is placed in a medium of refractive index 1.65. Find its focal length. What should be the value of the refractive index of the medium in which the lens should be placed so that it acts as a plane sheet of glass? [CBSE Bhubaneshwar 2015]

Ans. From lens formula, when lens in a medium



Ans. From lens formula, when lens in a medium

$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \ldots(i)$$

When lens in air $\frac{1}{f_a} = (\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \ldots(ii)$

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

$$\frac{f_a}{f_m} = \frac{\left(\frac{\mu_g}{\mu_m} - 1\right)}{(\mu_g - 1)}$$

$$\frac{20 \text{ cm}}{f_m} = \frac{\left(\frac{1.5}{1.65} - 1\right)}{(1.5 - 1)}$$

$$\Rightarrow \qquad f_m = \frac{20 \times (1.5 - 1)}{\left(\frac{1.5}{1.65} - 1\right)} = \frac{20 \times 0.5 \times 1.65}{-0.15} = -110 \text{ cm}$$

If lens in the medium behave as a plane sheet of glass. Then $f_m = \infty$

$$\frac{1}{\infty} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \quad \left(\frac{\mu_g}{\mu_m} - 1\right) = 0 \quad \Rightarrow \quad \mu_g = \mu_m = 0$$

The refractive index of the medium must be 1.5.

Q. 10. A converging lens has a focal length of 20 cm in air. It is made of a material of refractive index 1.6. If it is immersed in a liquid of refractive index 1.3, find its new focal length. [CBSE (F) 2017]

Ans. For spherical lens (thin) having same medium in both sides

$$\frac{1}{f_{eq}} = (\mu_{net} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \text{where } \mu_{net} = \frac{\mu_{lens}}{\mu_{med.}}$$

$$\frac{1}{f_{eq}} = \left(\frac{1.6}{1.3} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad \dots (i)$$

$$\text{Also, } \frac{1}{20} = \frac{1}{f_{eq}} = (1.6 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad \dots (ii)$$

$$\Rightarrow \qquad \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{20 \times 0.6} = \frac{1}{12}$$

Substituting in (i)

$$\Rightarrow \qquad \frac{1}{f_{eq}} = \frac{0.3}{1.3} \times \frac{1}{12}$$

$$\Rightarrow \qquad f_{eq} = \frac{12 \times 1.3}{0.3} = 52 \text{ cm}$$

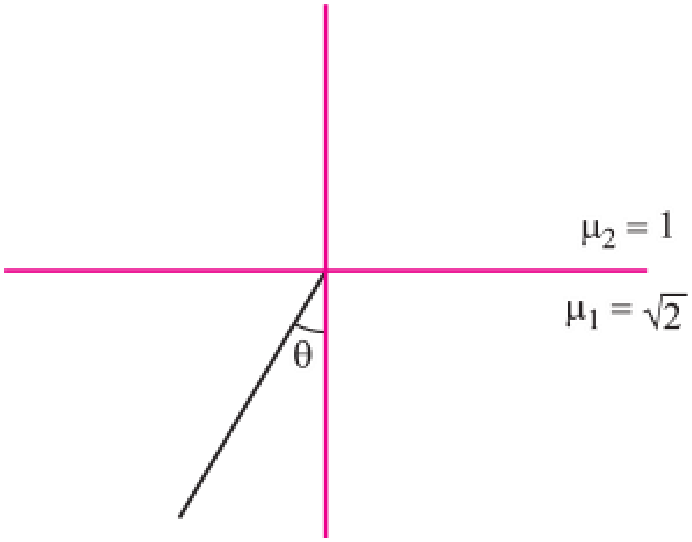
Q. 11. Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = \sqrt{2}$ into the medium of refractive index μ_1 = 1, so that it just grazes along the surface of separation. [CBSE (F) 2017]

Ans. According to Snell's law,

$$\mu_1 \sin i = \mu_2 \sin r$$

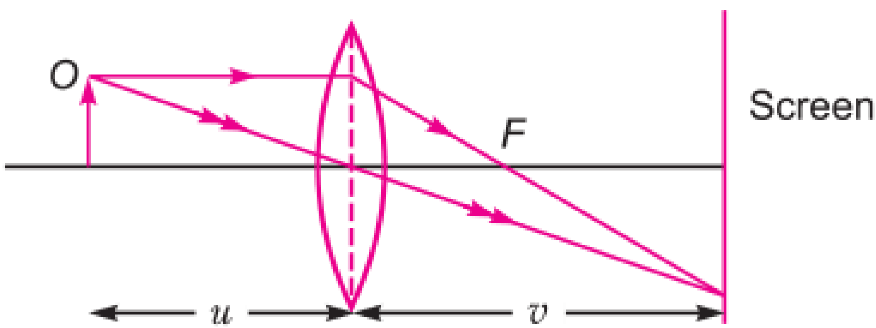
$$\Rightarrow \qquad \sqrt{2} \sin\theta = 1. \sin 90^\circ$$

$$\Rightarrow \qquad \theta = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45^\circ$$



Q. 12. An illuminated object and a screen are placed 90 cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object. [CBSE (AI) 2010]

Ans.



Given u + v = 90 cm …(i)

$\frac{I}{O} = \frac{v}{u}$ *gives*

$2 = \frac{|v|}{|u|}$

or $|v| = 2\,|u|$ (numerically) ...(*ii*)

From (*i*) and (*ii*)

$|u| = 30$ cm, $|v| = 60$ cm

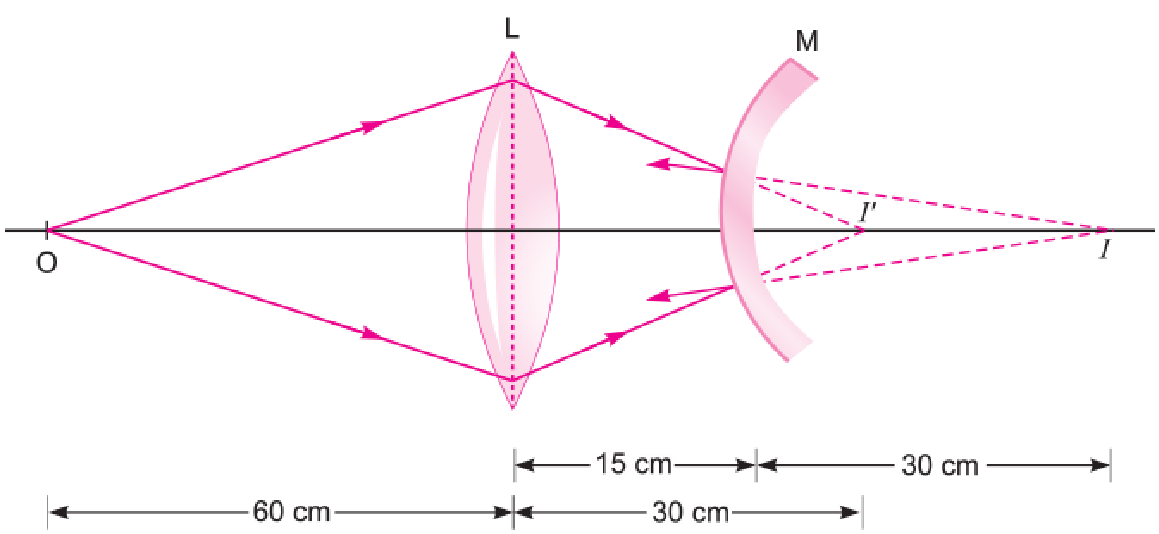
By sign convention $u = -30$ cm, $v = 60$ cm

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{60} + \frac{1}{30} = \frac{1+2}{60}$

$\Rightarrow \quad f = 20$ cm (convex lens)

Q. 13. 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.
[CBSE (AI) 2014]

Ans.



For convex lens $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$f = + 20$ cm, $u = - 60$ cm

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

$\frac{1}{v} = \frac{1}{20} + \frac{1}{60} = \frac{1}{30} \quad \Rightarrow \quad v = +30 \text{ cm}$

In the absence of the mirror, the lens would have formed the image of I′ which acts as a virtual object for the convex mirror.

u_2 = distance of virtual object I′ from mirror = + 30 cm – 15 cm = + 15 cm

$f = \frac{R}{2} = \frac{+20}{2} = +10\,cm$

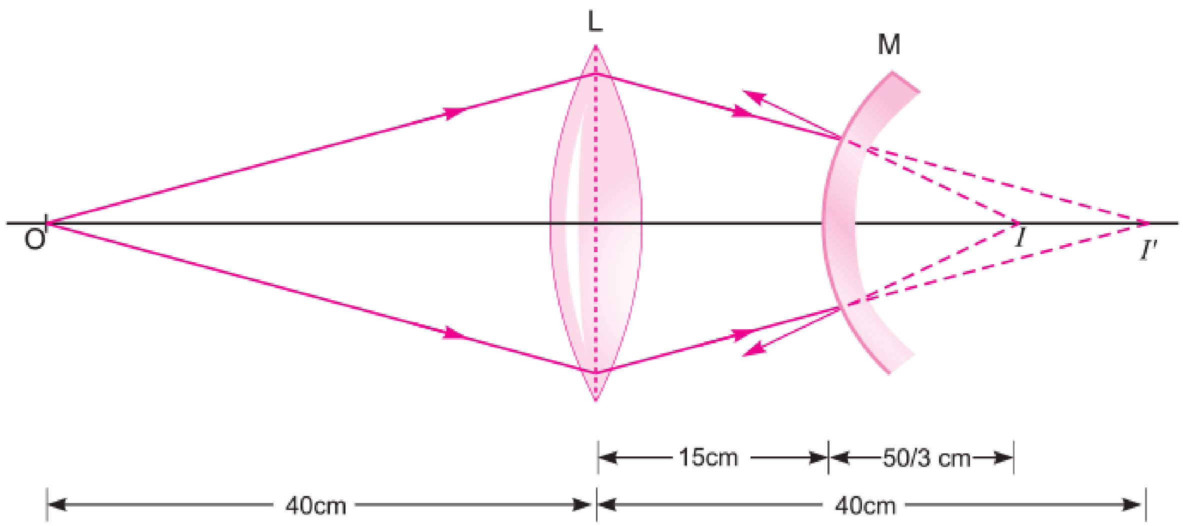
From mirror formula $\frac{1}{f_m} = \frac{1}{v_2} + \frac{1}{u_2}$

$\frac{1}{10} = \frac{1}{v_2} + \frac{1}{+15} \quad \Rightarrow \quad \frac{1}{v_2} = \frac{1}{10} - \frac{1}{15} = \frac{1}{30} \quad \Rightarrow \quad v_2 = +30$

Hence the final image ***I*** is a virtual image formed at a distance of 30 cm to the right of convex mirror or 45 cm from the convex lens.

Q. 14. 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 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation. [CBSE (AI) 2014]

Ans. For convex lens, u = – 40 cm, f = 20 cm



$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{20} = \frac{1}{v} - \frac{1}{-40}$$

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

This image acts as a virtual object for the convex mirror.

$$\therefore \quad u = 40 - 15 = 25\,cm \Rightarrow f = \frac{20}{2} = +10\,cm$$

Using mirror formula,

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{10} = \frac{1}{v} + \frac{1}{25}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{25} \Rightarrow v = \frac{15}{3} \text{ cm} \simeq 16.67 \text{ cm}$$

Hence, the final image is a virtual image formed at a distance of 16.67 cm.

Q. 15. A convex lens of focal length 20 cm is placed coaxially with a concave mirror of focal length 10 cm at a distance of 50 cm apart from each other. A beam of light coming parallel to the principal axis is incident on the convex lens. Find the position of the final image formed by this combination. Draw the ray diagram showing the formation of the image. [CBSE (AI) 2014]

Ans. For the convex lens,

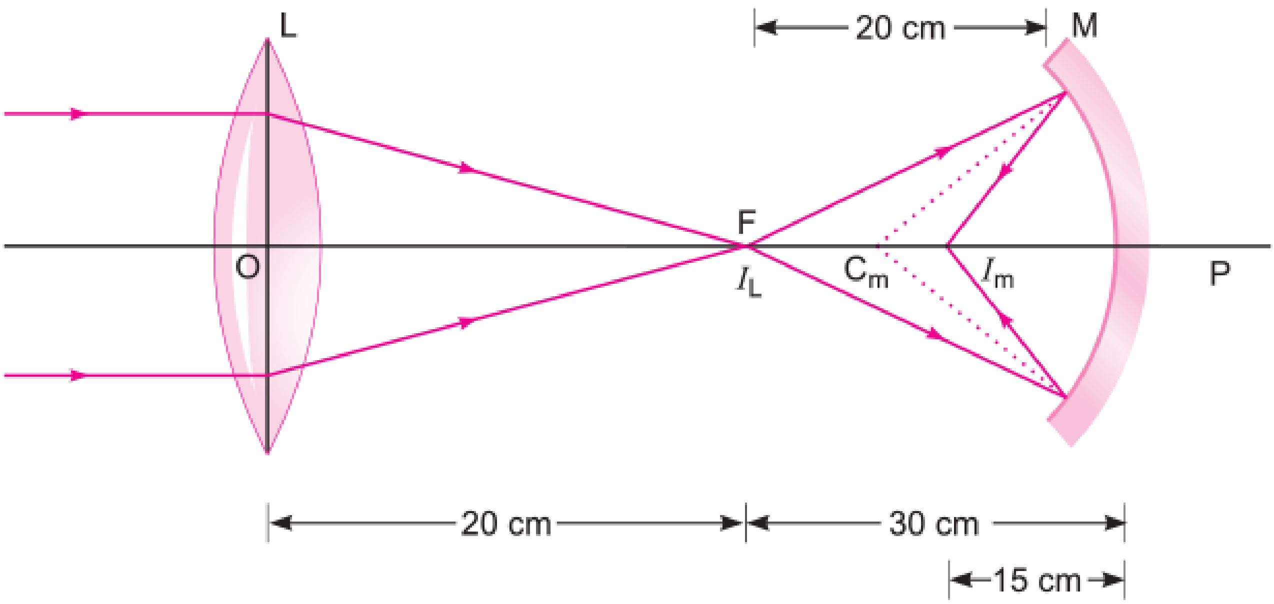
u = ∞, f = 20 cm

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

∴ v = 20 cm

For the concave mirror, the image formed by the lens acts as the object.

Hence, u = – (50 – 20) cm = – 30 cm and f = – 10 cm



Using mirror formula, we get

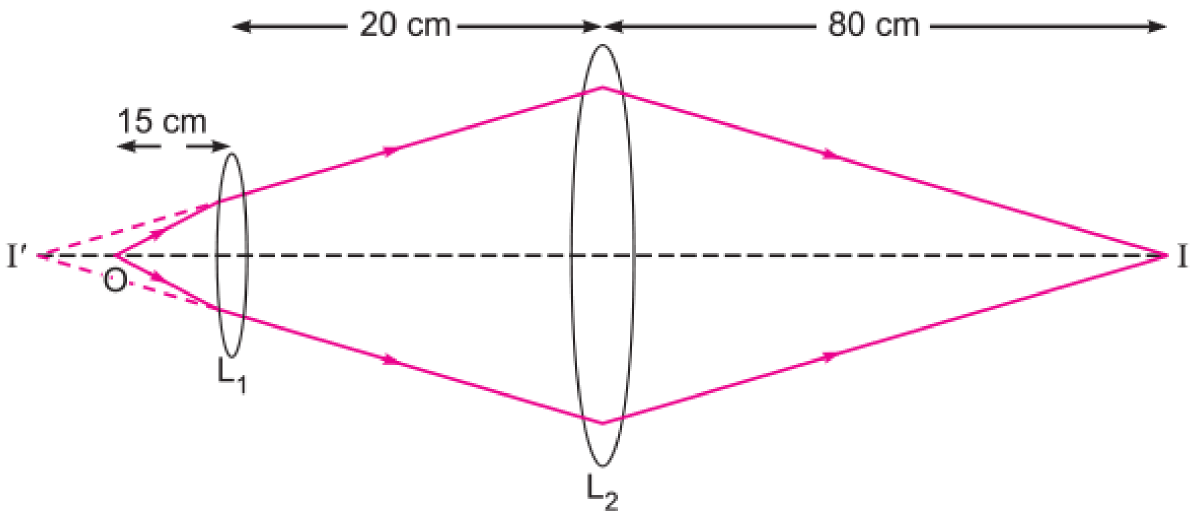
$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} + \frac{1}{-30} = \frac{1}{-10}$$

$$\Rightarrow \quad \frac{1}{v} - \frac{1}{30} = \frac{1}{10} \quad \Rightarrow \quad v = -\ 15\ \text{cm}$$

The lens-mirror combination, therefore, forms a real image I_2 at a distance of 15 cm to the left of the concave mirror or at a distance of 35 cm to the right of the convex lens.

Q. 16. In the following diagram, an object 'O' is placed 15 cm in front of a convex lens L1 of focal length 20 cm and the final image is formed at 'I' at a distance of 80 cm from the second lens L2. Find the focal length of the L2. [CBSE (F) 2016]

Ans.



Let focal length of lens L_2 be x cm

Now, for lens, L_1

u = – 15cm; f = +20 cm; v = ?

Using lens formula

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

$$= \frac{1}{20} + \frac{1}{-15} = \frac{15-20}{300} = \frac{-5}{300} = \frac{-1}{60}$$

$$\Rightarrow v = -60 \text{ cm}$$

⇒ v = –60 cm

i.e., 60 cm from lens in the direction of object.

Now, for lens, L_2

The image formed by lens L_1, will act as object for lens, L_2

u = –60 + (–20) = –80 cm

v = +80 cm (given) and $f = x$ cm

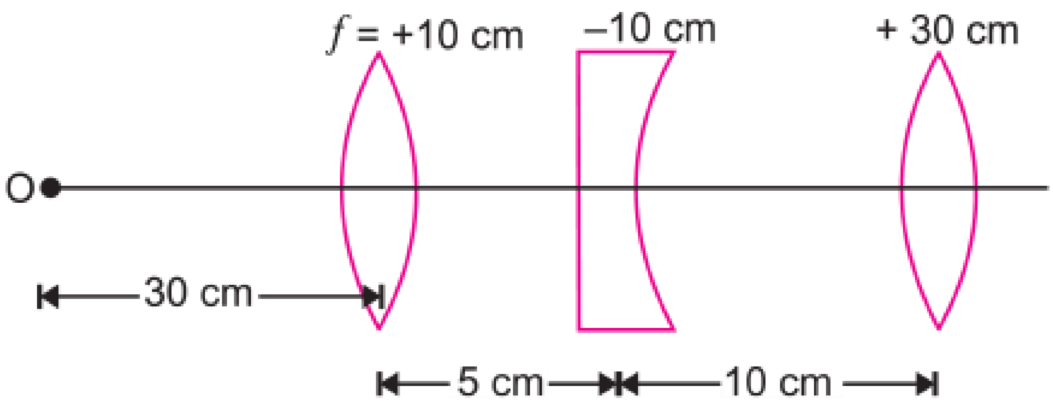
Applying lens formula for lens L_2

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{x} = \frac{1}{80} - \frac{1}{(-80)} = \frac{1}{80} + \frac{1}{80}$$

$$\Rightarrow \quad \frac{1}{x} = \frac{2}{80} \quad \Rightarrow \quad x = 40$$

Hence, focal length of lens L_2 is 40 cm.

Q. 17. Find the position of the image formed of an object 'O' by the lens combination given in the figure. [CBSE (F) 2011]



Ans. For first lens, $u_1 = -30$ cm, $f_1 = +10$ cm

$\therefore$ From lens formula, $\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$

$$\Rightarrow \quad \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{10} - \frac{1}{30} = \frac{3-1}{30}$$

$\Rightarrow v_1 = 15$ **cm**

This means that the image formed by first lens is at a distance of 15 cm to the right of first lens. This image serves as a virtual object for second lens.

For second lens, $f_2 = -10$ cm, $u_2 = 15 - 5 = +10$ cm

$$\therefore \quad \frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} = -\frac{1}{10} + \frac{1}{10} \quad \Rightarrow \quad v_2 = \infty$$

This means that the real image is formed by second lens at infinite distance. This acts as an object for third lens.

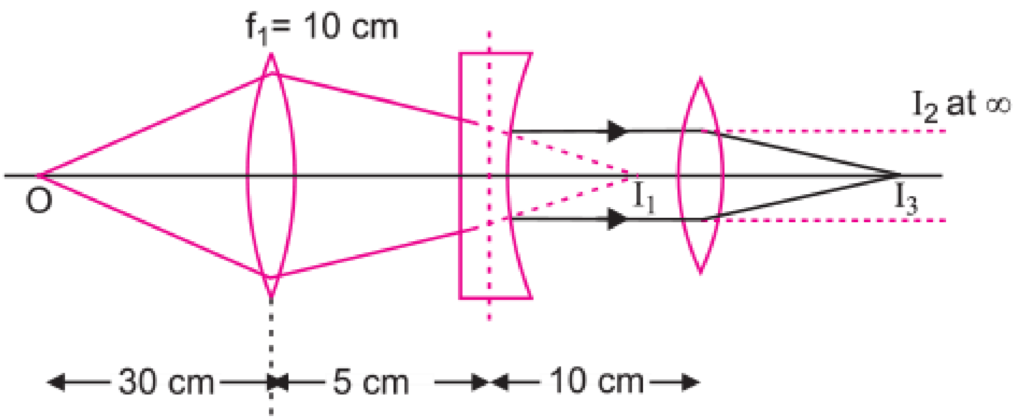
For third lens, $f_3 = +30$ cm, $u_3 = \infty$

From lens formulae, $\frac{1}{v_2} = \frac{1}{f_3} + \frac{1}{u_3} = \frac{1}{30} + \frac{1}{\infty}$

$v_3 = 30$ cm

i.e., final image is formed at a distance 30 cm to the right of third lens.

The ray diagram of formation of image is shown in figure.



Q. 18. Answer the following question: [CBSE (North) 2016]

(i) A screen is placed at a distance of 100 cm from an object. The image of the object is formed on the screen by a convex lens for two different locations of the lens separated by 20 cm. Calculate the focal length of the lens used.

(ii) A converging lens is kept coaxially in contact with a diverging lens - both the lenses being of equal focal length. What is the focal length of the combination?

Ans. (i) For first position of the lens, we have

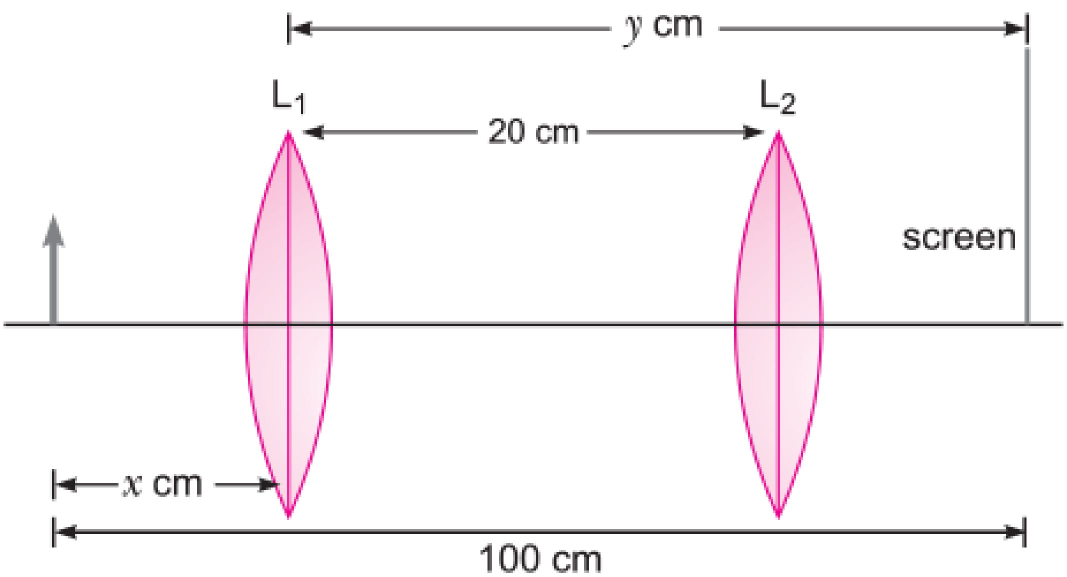
$$\frac{1}{f} = \frac{1}{y} - \frac{1}{(-x)} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{y} + \frac{1}{x} \ldots(i)$$

For second position of lens, we have

$$\frac{1}{f} = \frac{1}{y-20} - \frac{1}{[-(x+20)]}$$

$$\frac{1}{f} = \frac{1}{y-20} + \frac{1}{x+20} \ldots(ii)$$

From (i) and (ii), we have



$$\frac{1}{y} + \frac{1}{x} = \frac{1}{(y-20)} + \frac{1}{(x+20)}$$

$$\frac{x+y}{xy} = \frac{(x+20)+(y-20)}{(y-20)(x+20)}$$

$$\frac{x+y}{xy} = \frac{x+y}{(y-20)(x+20)}$$

∴ $xy = (y-20)(x+20)$

$\Rightarrow \quad xy = xy - 20x + 20y - 400$

$\Rightarrow \quad 20x - 20y = -400$

$\therefore \quad x - y = -20$

Also, $x + y = 100$

On solving, we have

$x = 40$ cm and $y = 60$ cm

$$\therefore \quad \frac{1}{f} = \frac{1}{60} - \frac{1}{-40} = \frac{5}{120} \quad \Rightarrow \quad f = 24\text{cm}$$

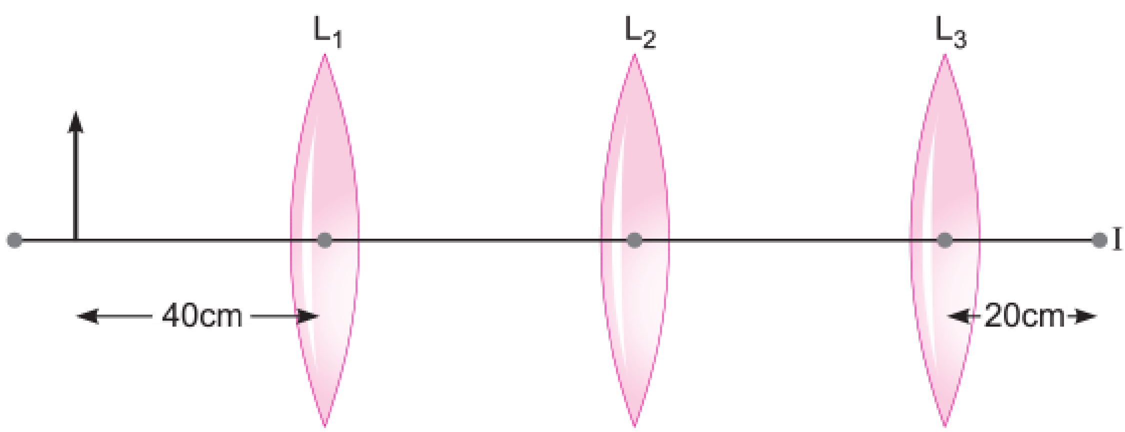
(ii) Let focal length of the combination be f.

$$\therefore \quad \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{f} + \left(-\frac{1}{f}\right)$$

$$\Rightarrow \quad \frac{1}{f} = 0 \quad \Rightarrow f = \text{ infinite.}$$

Q. 19. You are given three lenses L_1, L_2 and L_3 each of focal length 20 cm. An object is kept at 40 cm in front of L1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separations between L_1, L_2 and L_3. [CBSE (AI) 2012]



Given $f_1 = f_2 = f_3 = 20$ cm

For lens L_1, u_1 = – 40 cm

By lens formula $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1} \Rightarrow \frac{1}{v_1} = \frac{1}{20} + \frac{1}{-40} \Rightarrow v_1 = 40 \text{ cm}$

For lens L_3, f_3 = 20 cm, v_3 = 20 cm, u_3 = ?

By lens formula, $\frac{1}{v_3} - \frac{1}{u_3} = \frac{1}{f_3} \Rightarrow \frac{1}{20} - \frac{1}{u_3} = \frac{1}{20}$

$\frac{1}{u_3} = 0 \Rightarrow u_3 = \infty$

Thus lens L_2 should produce image at infinity.

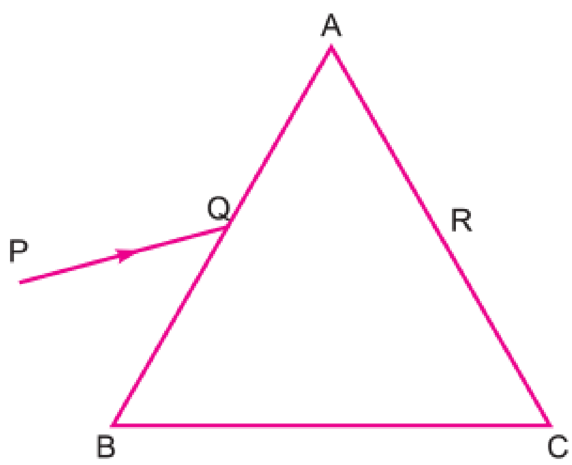
Hence, for L_2, its objective should be at focus. The image formed by lens L_1 is at 40 cm on the right side of lens L_1 which lies at 20 cm left of lens L_2 *i.e.*, focus of lens L_2.

Hence, the distance between L_1 and L_2 = 40 + 20 = 60 cm.

As the image formed by lens L_2 lies at infinity, then the distance between lens L_2 and L_3does not matter.

Hence, the distance between L_2 and L_3 can have any value.

Q. 20. A ray PQ incident on the face AB of a prism ABC, as shown in the figure, emerges from the face AC such that AQ = AR. Draw the ray diagram showing the passage of the ray through the prism. If the angle of the prism is 60° and refractive index of the material of the prism is $\sqrt{3}$, determine the values of angle of incidence and angle of deviation. [*CBSE Panchkula 2015*]



Ans.

$\angle A = 60^o$ and $\mu = \sqrt{3}$

$i + e = A + \delta$

Since QR is parallel to BC hence this is the case of minimum deviation.

$i = e$

$2i = 60 + \delta$

$2r = 60 \Rightarrow r = \frac{60}{2} = 30^o$

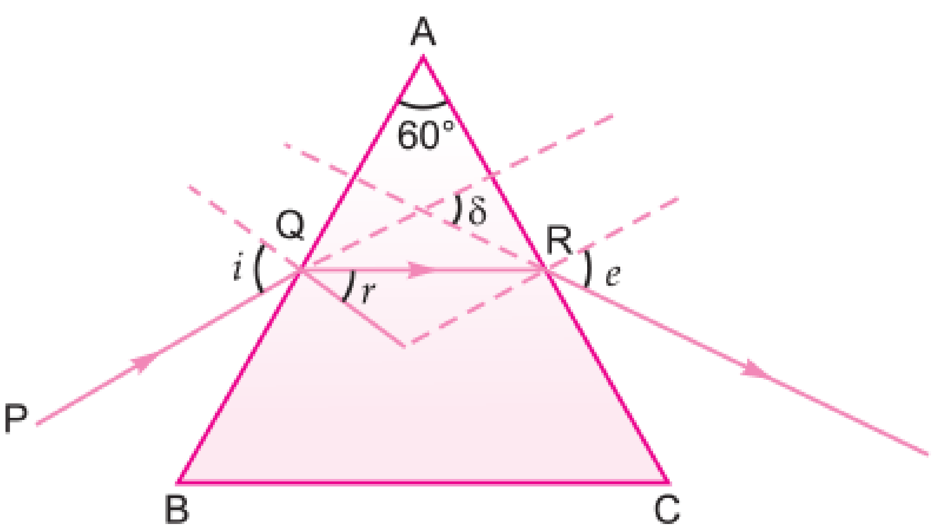
$\mu = \frac{\sin i}{\sin r}$

$\sqrt{3} = \frac{\sin i}{\sin 30^o}$

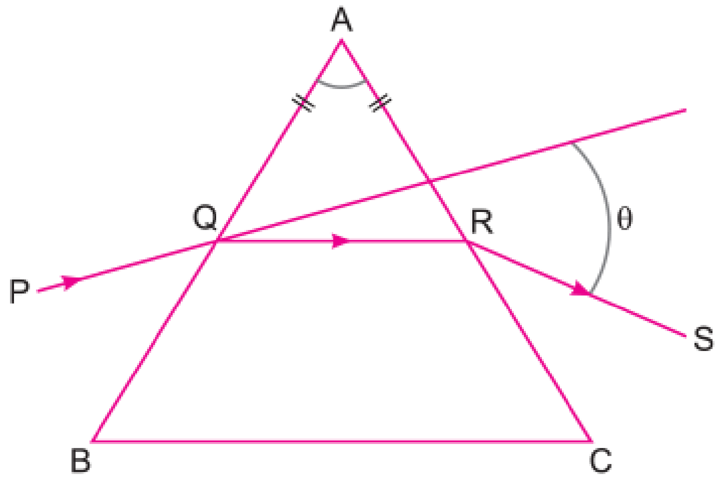
$\sin i = \frac{\sqrt{3}}{2} \Rightarrow \angle i = 60^o$

Substitute in (i), we have

$120 = 60 + \delta \Rightarrow \delta = 60°$



Q. 21. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in the figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle of prism A = 60° and refractive index of material of prism is $\sqrt{3}$, calculate angle θ. [CBSE North 2016]



Ans. Given, AQ = AR, we have

QR || BC

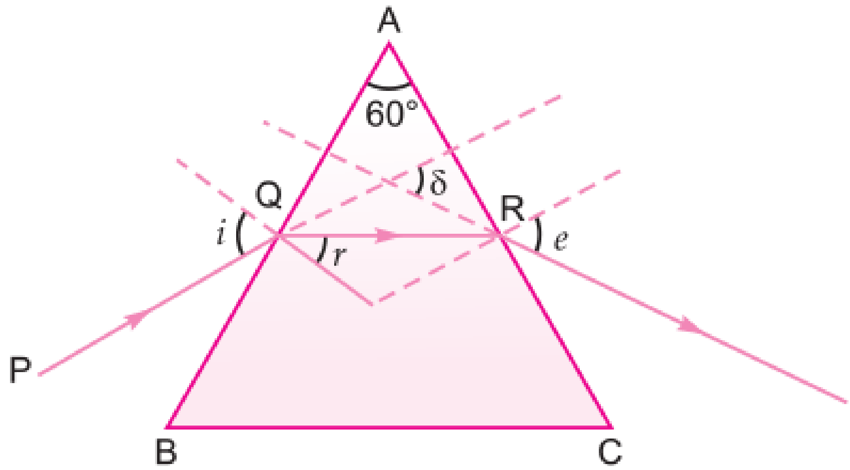
At the minimum deviation, the refracted ray inside the prism becomes parallel to its base.

∴ θ is the angle of minimum deviation.

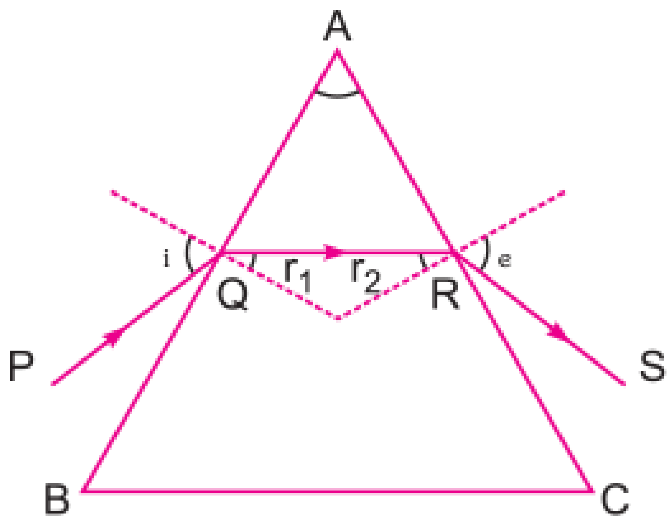
$$\mu = \frac{\sin\left(\frac{A+\theta}{2}\right)}{\sin\left(\frac{A}{2}\right)} \quad \Rightarrow \quad \sqrt{3} = \frac{\sin\left(\frac{60^o+\theta}{2}\right)}{\sin\ 30^o}$$

$$\sin\left(\frac{60^o+\theta}{2}\right) = \frac{\sqrt{3}}{2} \quad \Rightarrow \quad \sin\left(\frac{60^o+\theta}{2}\right) = \sin\ 60^o$$

$$\frac{60^o+\theta}{2} = 60^o \quad \Rightarrow \quad \theta = 60^o$$



Q. 22. Figure shows a ray of light passing through a prism. If the refracted ray QR is parallel to the base BC, show that [CBSE (F) 2014]



(i) $r_1 = r_2 = A/2$,

(ii) angle of minimum deviation, $D_m = 2i - A$.

Ans. (i) We know that

$r_1 + r_2 = A$

Since QR is parallel to BC

So, $r_1 = r_2$ and $i = e$

Therefore, $2r_1$ or $2r_2 = A$ $\Rightarrow$ $r_1 = r_2 = A / 2$

(ii) D_m = Deviation at the first face + Deviation of the second face

$= (i - r_1) + (e - r_2) = (i + e) - (r_1 + r_2)$

$= 2i - A \qquad (\because i = e)$

Q. 23. A compound microscope uses an objective lens of focal length 4 cm and eyepiece lens of focal length 10 cm. An object is placed at 6 cm from the objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of the microscope. [CBSE (AI) 2011]

Ans.

Given $f_o = 4$ cm, $f_e = 10$ cm

$\mu_o = -6$ cm

Magnifying power of microscope

$$M = -\frac{|v_o|}{|u_o|}\left(1 + \frac{D}{f_e}\right)$$

From lens formula $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$$= \frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o} = \frac{1}{4} - \frac{1}{6} = \frac{3-2}{12}$$

$\Rightarrow \quad v_o = 12$ cm

$$\therefore \qquad m = -\frac{12}{6}\left(1 + \frac{25}{10}\right) = -2 \times 3.5 = -7$$

Negative sign shows that the image is inverted.

Length of microscope $L = | v_o | + | u_e |$

For eye lens $\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e}$

$$= \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = -\frac{1}{25} - \frac{1}{10} \quad (v_e = D = -25 \text{ cm}, u_e = ?)$$

$$\Rightarrow \qquad u_e = -\frac{50}{7} (\text{cm}) = -7.14$$

$$\therefore \qquad L = |v_o| + |u_e| = 12 + 7.14 = 19.14 \text{ cm}$$

Q. 24. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece. [CBSE Allahabad 2015]

Ans. The magnification due to the objective lens

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

If the object is close to focus of the objective lens then

$u_o = f_o$ and $v = L$ (L = distance between two lenses)

$$m_o = \frac{L}{f_o}$$

If the final image is at the near point, then magnification due to eye lens is

$$m_e = \left(1 + \frac{D}{f_e}\right)$$

$$M = m_o \times m_e = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

Use f_o = 1.25 cm and f_e =5 cm

$$30 = \frac{L}{1.25}\left(1 + \frac{25}{5}\right)$$

$$30 = \frac{L}{1.25} \times 6 \qquad \Rightarrow \quad L = \frac{30 \times 1.25}{6} = 6.25\,\text{cm}$$

Separation between two lenses is 6.25 cm.

Q. 25. The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece. [CBSE Delhi 2014]

Ans.

Here, $m = -20$, $m_e = 5$, $v_e = -20$ cm

For eyepiece, $m_e = \frac{v_e}{u_e}$

$$\Rightarrow \quad 5 = \frac{-20}{u_e} \quad \Rightarrow \quad u_e = \frac{-20}{5} = -\ 4 \text{ cm}$$

Using lens formula,

$$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \quad \Rightarrow \quad -\frac{1}{20} + \frac{1}{4} = \frac{1}{f_e}$$

$$\Rightarrow \quad \frac{-1+5}{20} = \frac{1}{f_e} \quad \Rightarrow \quad f_e = 5 \text{ cm}$$

Now, total magnification

$$m = m_e \times m_o$$

$$-20 = 5 \times m_o \qquad \Rightarrow m_o = -4$$

$$-20 = 5 \times m_o \qquad \Rightarrow m_o = -4$$

Also $|v_o| + |u_e| = 14$

$$|v_o| + |-4| = 14$$

$$v_o = 14 - 4 = 10 \text{ cm}$$

$$m_o = 1 - \frac{n_o}{f_o} \qquad \Rightarrow \quad -4 = 1 - \frac{10}{f_o}$$

$$-5 = -\frac{10}{f_0} \qquad \Rightarrow \qquad f_0 = 2 \text{ cm.}$$

Q. 26. A small telescope has an objective lens of focal length 150 cm and eyepiece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment? If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens?
[CBSE Allahabad 2015]

Ans. If the telescope is in normal adjustment, i.e., the final image is at infinity.

$$M = \frac{f_o}{f_e}$$

Since $f_o = 150 \text{ cm}, \ f_e = 5 \text{ cm}$

$$\therefore \qquad M = \frac{150}{5} = 30$$

If tall tower is at distance 3 km from the objective lens of focal length 150 cm. It will form its image at distance v0 So,

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

$$\frac{1}{150 \text{ cm}} = \frac{1}{v_o} - \frac{1}{(-3 \text{ km})}$$

$$\frac{1}{v_o} = \frac{1}{1.5 \ m} - \frac{1}{3000 \ m}$$

$$v_o = \frac{3000 \times 1.5}{3000 - 1.5} = \frac{4500}{2998.5} = 1.5 \ m$$

$$\text{Magnification,} \quad m_o = \frac{I}{O} = \frac{h_i}{h_o} = \frac{v_o}{u_o}$$

$$\frac{h_i}{100 \ m} = \frac{1.5 \ m}{3 \text{ km}} = \frac{1.5}{3000}$$

$$h_i = \frac{1.5 \times 100}{3000} = \frac{1}{20} \ m$$

$$h_i = 0.05 \ m$$

Q. 27. An object is placed 40 cm from a convex lens of focal length 30 cm. If a concave lens of focal length 50 cm is introduced between the convex lens and the image formed such that it is 20 cm from the convex lens, find the change in the position of the image.
[CBSE Chennai 2015] [HOTS]

Ans. For the convex lens, $f_1 = +30$ cm and object distance $u_1 = -40$ cm, therefore,

$$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1}$$

$$\frac{1}{+30} = \frac{1}{v_1} - \frac{1}{-40}$$

$$\frac{1}{v_1} = \frac{1}{30} - \frac{1}{40} = \frac{1}{120}$$

$\Rightarrow v_1 = +\ 120$ cm, a real image is formed.

On introducing a concave lens, $f_2 = -\ 50$ cm

And $u_2 = 120 - 20 = +\ 100$ cm from the concave lens

$$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2} \qquad\qquad \frac{1}{-50} = \frac{1}{v_2} - \frac{1}{+100}$$

$$\therefore \qquad \frac{1}{v_2} = -\frac{1}{50} + \frac{1}{100} = -\frac{1}{100}$$

$$v_2 = -\ 100 \text{ cm}$$

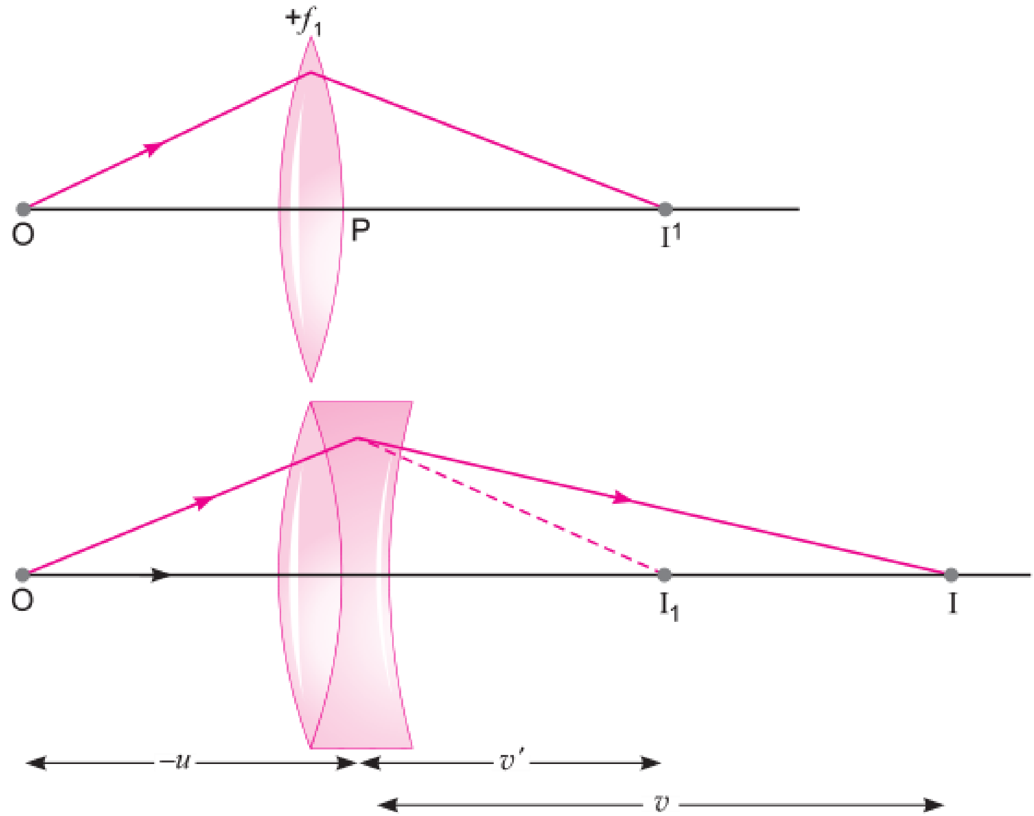
A virtual image is formed at the distance of 100 cm from the concave lens.

The change in position between the real image and the virtual image is 100 cm + 100 cm= + 200 cm

To the left of its original position.

Q. 28. A convex lens of focal length f_1 is kept in contact with a concave lens of focal length f_2. Find the focal length of the combination. [CBSE (AI) 2013]

Ans.



+f_1
O
P
I^1
O
I_1
I
$-u$
v'
v

For convex lens of focal length $(+ f_1)$

$$+\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u} \qquad ...(i)$$

For concave lens of focal length $(- f_2)$

$$-\frac{1}{f_1} = \frac{1}{v} - \frac{1}{v'} \qquad ...(ii)$$

Adding equation (i) and (ii)

$$\frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u} \qquad ...(iii)$$

For an equivalent lens (using lens formula)

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}, \text{ where } f \text{ is the focal length of combination.} \qquad ...(iv)$$

From equation (iii) and (iv),

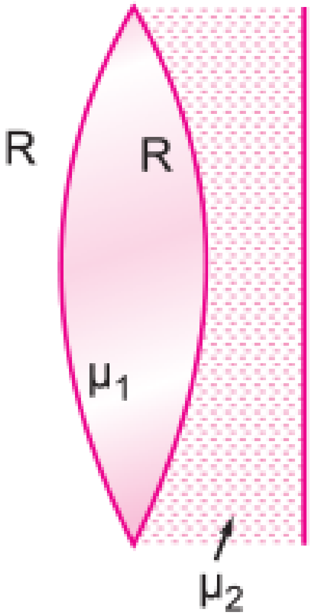
$$\frac{1}{f} = \frac{1}{f_1} - \frac{1}{f_2}$$

Q. 29. A biconvex lens with its two faces of equal radius of curvature R is made of a transparent medium of refractive index μ1. It is kept in contact with a medium of refractive index μ_2 as shown in the figure.

(a) Find the equivalent focal length of the combination.

(b) Obtain the condition when this combination acts as a diverging lens.

(c) Draw the ray diagram for the case $\mu_1 > (\mu_2 + 1)/2$, when the object is kept far away from the lens. Point out the nature of the image formed by the system. [CBSE Patna 2015] [HOTS]



Ans. (a) If refraction occurs at first surface

$$\frac{\mu_1}{v_1} - \frac{1}{u} = \frac{(\mu_1 - 1)}{R} \qquad \ldots(i)$$

If refraction occurs at second surface, and the image of the first surface acts as an object

$$\frac{\mu_2}{v} - \frac{u_1}{v_1} = \frac{\mu_2 - \mu_1}{-R} \qquad \ldots(ii)$$

On adding equation (i) and (ii), we get

$$\frac{\mu_2}{v} - \frac{1}{u} = \frac{2\mu_1 - \mu_2 - 1}{R}$$

If rays are coming from infinity, *i.e.,* $u = -\infty$ then $v = f$

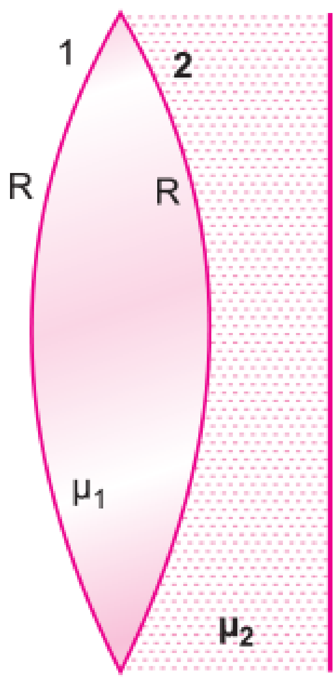
$$\frac{\mu_2}{f} + \frac{1}{\infty} = \frac{2\mu_1 - \mu_2 - 1}{R} \qquad \Rightarrow f = \frac{\mu_2 R}{2\mu_1 - \mu_2 - 1}$$

(*b*) If the combination behave as a diverging system then $f < 0$. This is possible only when

$$2\mu_1 - \mu_2 - 1 < 0$$

$$\Rightarrow \quad 2\mu_1 < \mu_2 + 1$$

$$\Rightarrow \quad \mu_1 < \frac{(\mu_2 + 1)}{2}$$



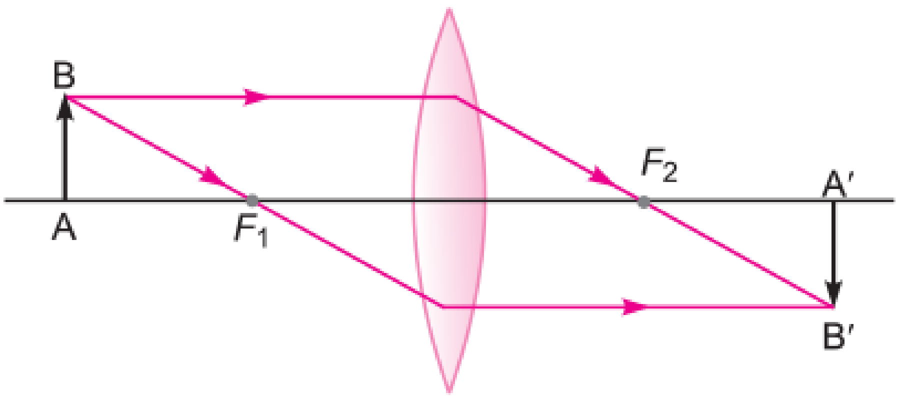
(c) If the combination behaves as a converging lens then $f > 0$. It is possible only when

$2\mu_1 - \mu_2 - 1 > 0$

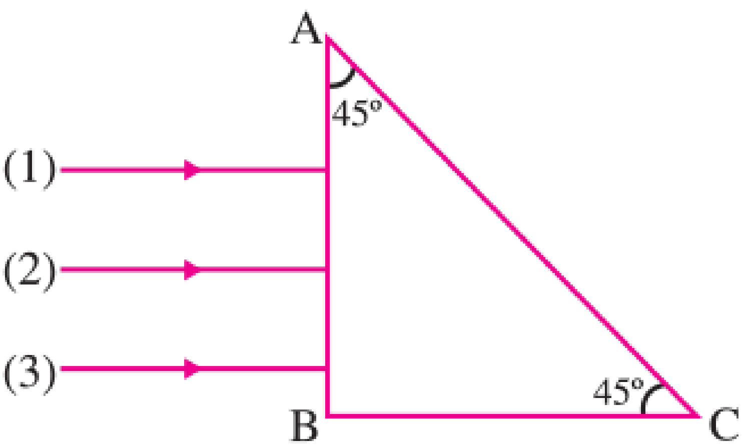
$\Rightarrow \quad 2\mu_1 - > \mu_2 + 1$

$\Rightarrow \quad \mu_1 > \frac{(\mu_2+1)}{2}$

Nature of the image formed is real.



Q. 30. Three rays (1, 2, 3) of different colours 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. [CBSE (F) 2016] [HOTS]



Ans. The ray incident perpendicularly on side AB, so it will pass out normally through AB

On face AC, i = 45°

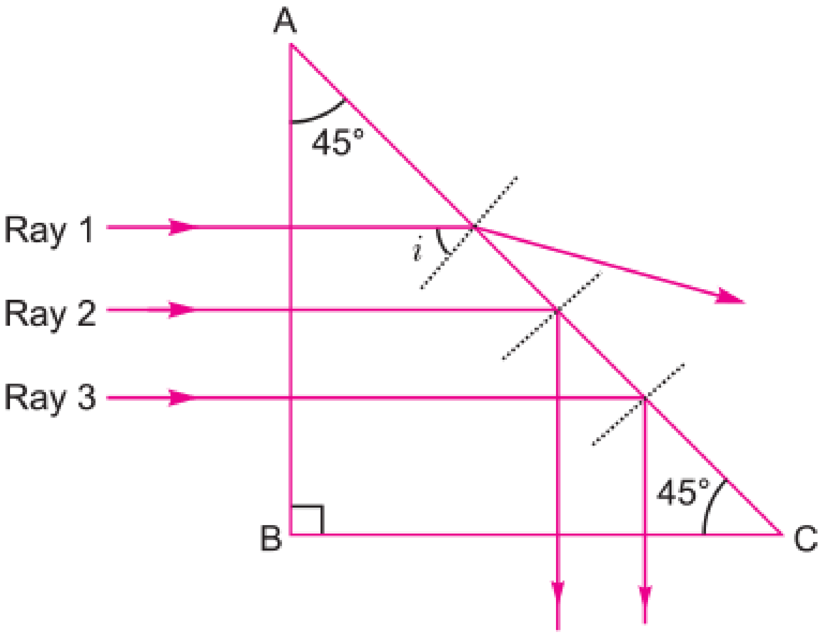
For Total Internal Reflection,

Angle of incidence > critical angle

45° > c

Taking sin both sides

sin 45° > sin c



$$\Rightarrow$$

$$\frac{1}{\sqrt{2}} > \frac{1}{\mu} \qquad \left[\because c = \sin^{-1}\left(\frac{1}{\mu}\right)\right]$$

$$\Rightarrow \sqrt{2} < \mu \qquad \Rightarrow \quad 1.414 < \mu$$

Hence, ray 2, 3 will undergo TIR and path of ray will be as shown.

Ray 1 is refracted from AC.

Q. 31. A ray of light incident on one of the faces of a glass prism of angle 'A' has angle of incidence 2A. The refracted ray in the prism strikes the opposite face which is silvered, the reflected ray from it retracing its path. Trace the ray diagram and find the relation between the refractive index of the material of the prism and the angle of the prism. [CBSE Chennai 2015] [HOTS]

Ans. From Snell's law

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin 2A}{\sin r} \qquad \ldots(i)$$

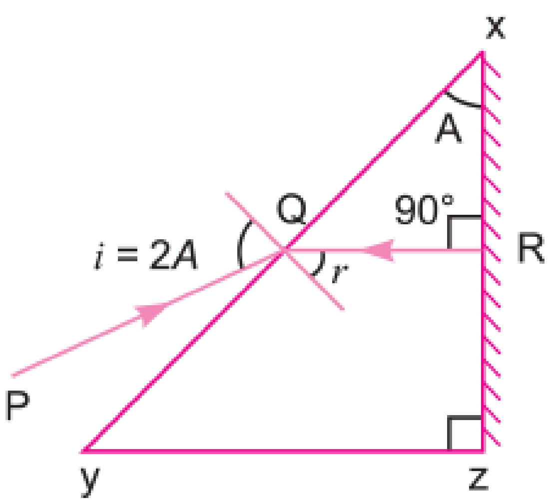
In ΔXQR, $\quad (90^\circ - r) + A + 90^\circ = 180^\circ$

or $\quad r = A \qquad \ldots(ii)$

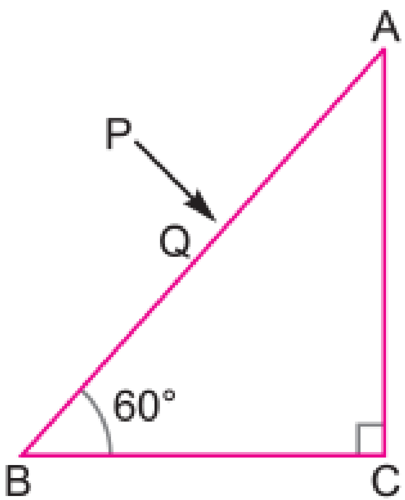
From Eq. (i) and (ii), we get

$$\mu = \frac{\sin 2A}{\sin A} = 2 \cos A$$

$\therefore \qquad A = \cos - 1\ (\mu / 2)$



Q. 32. A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge? Justify your answer. [CBSE Central 2016] [HOTS]



Ans.

For face AB, $\angle i = 0°$, $\therefore \angle r = 0°$, the ray will pass through AB undeflected

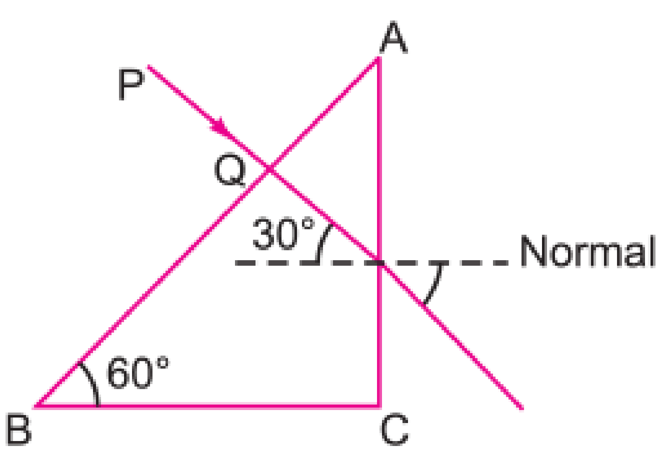
Now, at face AC

Here, $i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$

$= \sin^{-1}\left(\frac{2}{3}\right) = \sin^{-1}(0.66)$

$\angle i$ on face AC is 30° which is less than $\angle i_c$. Hence, the ray get refracted.

And, applying Snell's law at face AC

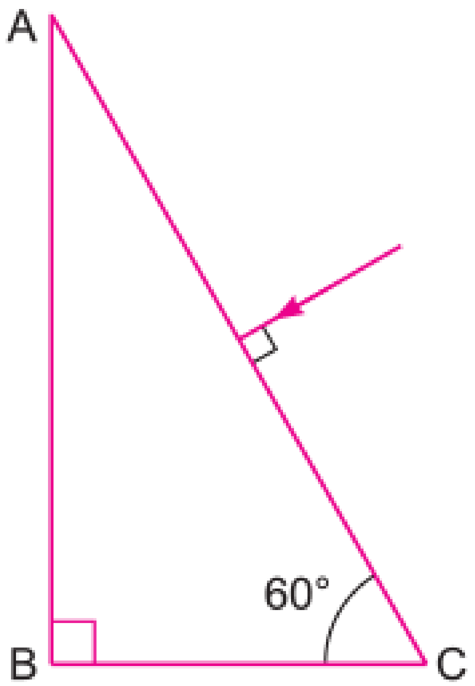


$$\sin 30^\circ \times \frac{3}{2} = \sin r \times 1$$

$$\Rightarrow \quad \sin r = \frac{1}{2} \times \frac{3}{2} \quad \Rightarrow \quad r = \sin^{-1}\left(\frac{3}{4}\right) = \sin^{-1}(0.75)$$

And, clearly $r > i$, as ray passes from denser to rarer medium.

Q. 33. Trace the path of a ray of light passing through a glass prism (ABC) as shown in the figure. If the refractive index of glass is $\sqrt{3}$, find out of the value of the angle of emergence from the prism. [CBSE (F) 2012] [HOTS]



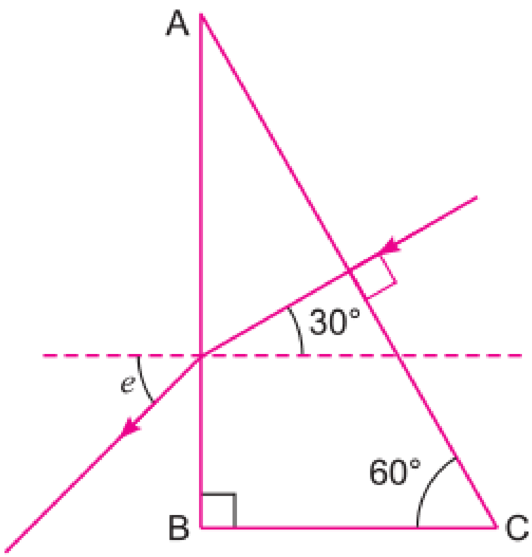
Ans.

Given $n_g = \sqrt{3}$

$i = 0$

At the interface AC,

By Snell's Law



$$\frac{\sin\ i}{\sin\ r} = \frac{n_g}{n_a}$$

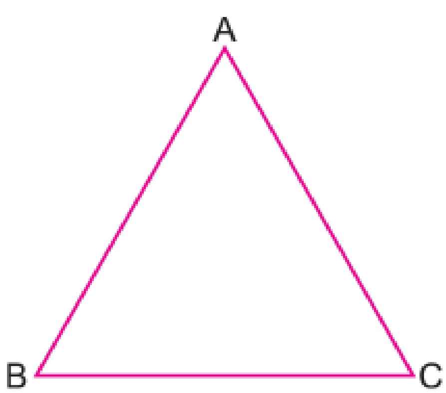
But $\sin\ i = \sin\ 0^\circ = 0$, hence $r = 0$

At the interface AB, $i = 30^\circ$

Applying Snell's Law

$$\frac{\sin\ 30^\circ}{\sin\ e} = \frac{n_a}{n_g} = \frac{1}{\sqrt{3}} \quad \Rightarrow \quad \sin\ e = \sqrt{3}\ \sin 30^\circ \quad \Rightarrow \quad e = 6$$

Q. 34. (i) A ray of light incident on face AB of an equilateral glass prism, shows minimum deviation of 30°. Calculate the speed of light through the prism.



(ii) Find the angle of incidence at face AB so that the emergent ray grazes along the face AC. [CBSE Delhi 2017] [HOTS]

Ans.

i. Here $A = 60°$, $\delta_m = 30°$

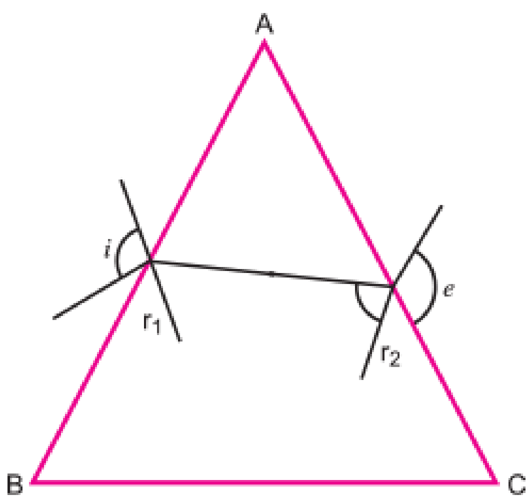
We know that

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \frac{\sin\ 45°}{\sin 30°} = \sqrt{2}$$

Also $\mu = \frac{c}{v} \Rightarrow v = \frac{3\times10^8}{\sqrt{2}}\ m/s$

$= 2.122 \times 10^8$ m/s

ii.



At face AC, let the angle of incidence be r_2. For grazing ray, $e = 90°$

$\Rightarrow \quad \mu = \frac{1}{\sin r_2} \quad \Rightarrow \quad r_2 = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$

Let angle of refraction at face AB be r_1. Now $r_1 + r_2 = A$

$\therefore \quad r_1 = A - r_2 = 60° - 45° = 15°$

Let angle of incidence at this face be i

$\mu = \frac{\sin i}{\sin r_1} \quad \Rightarrow \quad \sqrt{2} = \frac{\sin i}{\sin 15°}$

$\therefore \quad i = \sin^{-1}\left(\sqrt{2}.\sin 15°\right)$

Q. 35. (i) For a glass prism ($\mu = \sqrt{3}$) the angle of minimum deviation is equal to the angle of the prism. Find the angle of the prism.

(ii) Draw ray diagram when incident ray falls normally on one of the two equal sides of a right angled isosceles prism having refractive index $\mu = \sqrt{3}$
[CBSE South 2016] [HOTS]

Ans.

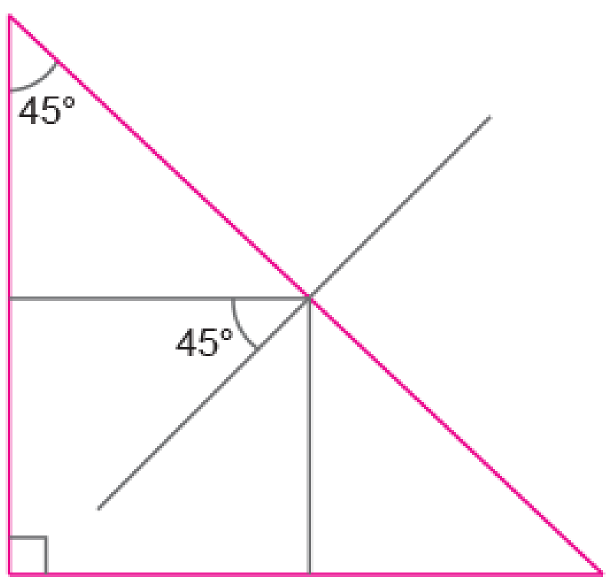
(i) At minimum deviation $\mu = \frac{\sin\left[\frac{(A+\delta m)}{2}\right]}{\sin\left(\frac{A}{2}\right)}$

Given $\delta_m = A$

$$\therefore \qquad \mu = \frac{\sin A}{\sin \frac{A}{2}} = \frac{2 \sin \frac{A}{2} \cos \frac{A}{2}}{\sin \frac{A}{2}} = 2 \cos \frac{A}{2}$$

$$\therefore \qquad \cos \frac{A}{2} = \frac{\sqrt{3}}{2} \text{ or } \frac{A}{2} = 30$$

$\Rightarrow A = 60°$



$$(ii) \quad \mu = \sqrt{3} = \frac{1}{\sin\ i_c} \qquad \Rightarrow \qquad \sin i_c = \frac{1}{\sqrt{3}}$$

Alternatively,

$$\sin c = \frac{1}{\sqrt{3}} \text{ which is less than } \frac{1}{\sqrt{2}}$$

$$\therefore \qquad \text{Angle of incidence} > i_c$$

Total internal reflection takes place.

Short Answer Questions – II (OIQ)

Q. 1. An equiconvex lens of focal length 'f' is cut into two identical plane convex lenses. How will the power of each part be related to the focal length of the original lens?

A double convex lens of + 5D is made of glass of refractive index 1.55 with both faces of equal radii of curvature. Find the value of its radius of curvature.

Ans.

$$\text{Power of a lens, } P = \frac{1}{f(\text{ in metre })}$$

After cutting, the power of each part will be half of the power of original lens.

Therefore, focal length = 2f

$\therefore$ Power of each part, $P' = \frac{1}{2f}$

$= P = \frac{1}{f} \quad \Rightarrow \quad 5 = \frac{1}{f}$

$f = \frac{1}{5} m = 20\, cm$

Now, $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Since $R_1 = +R$ and $R_2 = -R$

$\therefore \quad \frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{R}\right)$

$\frac{1}{20} = (1.5 - 1) \times \frac{2}{R} \quad \Rightarrow \quad R = 20\, cm$

Q. 2. Two lenses of power 10 D and –5 D are placed in contact.

(i) Calculate the power of lens combination.

(ii) Where should an object be held from the lens, so as to obtain a virtual image of magnification 2?

Ans.

i. Given $P_1 = 10$ D, $P_2 = -5$ D

Power of Combination, $P = P_1 + P_2 = 10\text{ D} - 5\text{ D} = 5\text{ D}$

ii. Focal length (Convergent lens) $f = \frac{1}{P} = \frac{1}{5}\,m = 0.20\,m = 20$ cm

(Convergent lens)

Magnification $m = \frac{v}{u} = +2 \Rightarrow v = 2u$

From lens formula (u is negative) $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

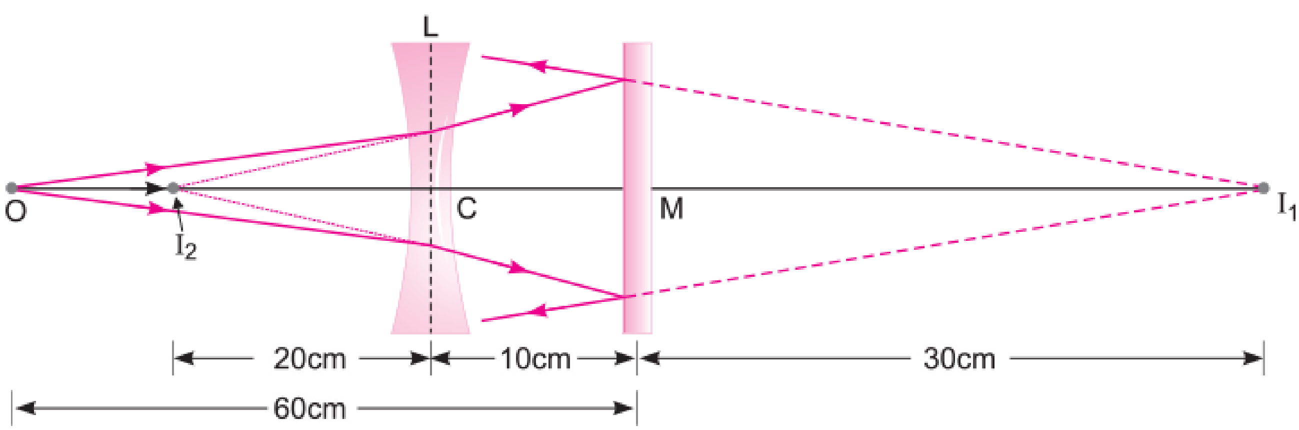
$$\frac{1}{20} = \frac{1}{2u} - \frac{1}{u} \Rightarrow -\frac{1}{2u} = \frac{1}{20} \Rightarrow u = -10\,cm$$

Q. 3. Figure shows a plane mirror M placed at a distance of 10 cm from a concave lens L. A point object is placed at a distance of 60 cm from the lens. The image formed due to refraction by the lens and reflection by the mirror is 30 cm behind the mirror. What is the focal length of this lens?

Ans. The rays coming from O, diverge on passing through concave lens, get reflected from the mirror, would form image at I_1 – such that $MI_1 = MI_2 = 30$ cm

$CI_2 = MI_2 - ML = 30 - 10 = 20$ cm

I_2 is the position of object for plane mirror. Let I_2 also be the position of virtual image of object formed by concave lens alone.



For the lens, $u = -60$ cm, $v = -20$ cm

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

$$\Rightarrow \quad \frac{1}{-20} + \frac{1}{60} = \frac{1}{f} \quad \Rightarrow \quad \frac{3+1}{60} = \frac{1}{f} \quad \Rightarrow \quad f = -30\,cm.$$

Q. 4. The critical angle for a given piece of glass is 45°. Calculate the polarising angle for it. Also calculate the angle of refraction when light is incident on this glass at an angle of incidence equal to i_p . [HOTS]

Ans.

We know $\sin i_c = \frac{1}{\mu}$

$$\mu = \frac{1}{\sin i_c} = \frac{1}{\sin 45^o} = \sqrt{2}$$

According to Brewster's law

$$\tan i_p = \mu = \sqrt{2} \qquad \Rightarrow i_p = \tan^{-1}\sqrt{2} = \tan^{-1}(1.414) \cong 51^\circ\, 40'$$

When light is incident at an angle i_p the corresponding angle of refraction 'r' is given by

$$i_p + r = 90^\circ$$

$$\therefore \quad r = 90^\circ - (51^\circ\, 40') = (38^\circ\, 20')$$

Q. 5. A double convex lens, made from a material of refractive index μ_1, is immersed in a liquid of refractive index μ_2 where $\mu_2 > \mu_1$. What change, if any, would occur in the nature of the lens? [HOTS]

Ans. Focal length of lens (refractive index μ_1) in a liquid of refractive index μ_2 is

$$f_1 = \frac{\mu_1 - 1}{\frac{\mu_1}{\mu_2} - 1} \times f_a$$

$$\text{Given } \mu_2 > \mu_1, \quad i.e., \ \frac{\mu_1}{\mu_2} < 1$$

$$\text{so } f_l = -\frac{\mu_1 - 1}{1 - \frac{\mu_1}{\mu_2}} f_a$$

So the focal length of lens in liquid will be of opposite sign of the focal length of lens in air; i.e., nature of lens will change. Hence, lens would now behave like a diverging (concave) lens.

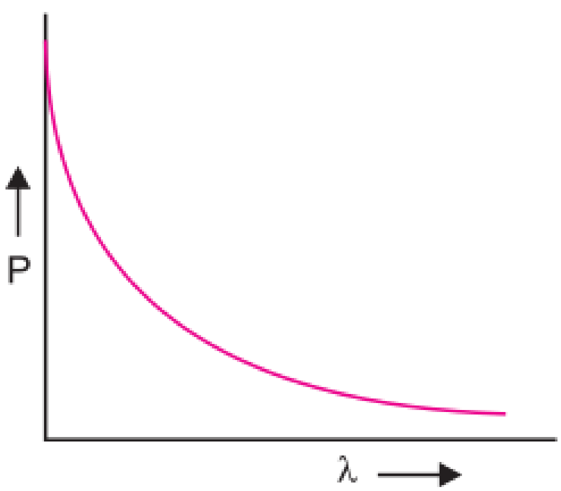
Q. 6. Draw a plot showing the variation of power of a lens with the wavelength of the incident light. [HOTS]

Ans.

Refractive index $= A + \frac{B}{\lambda^2}$, where λ is the wavelength.

Power of a lens $P = \frac{1}{f} = (n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Clearly, power of a lens $\propto (n_g - 1)$. This implies that the power of a lens decreases with increase of wavelength $\left(P \propto \frac{1}{\lambda^2} \text{ nearly}\right)$. The plot is shown in fig. alongside.

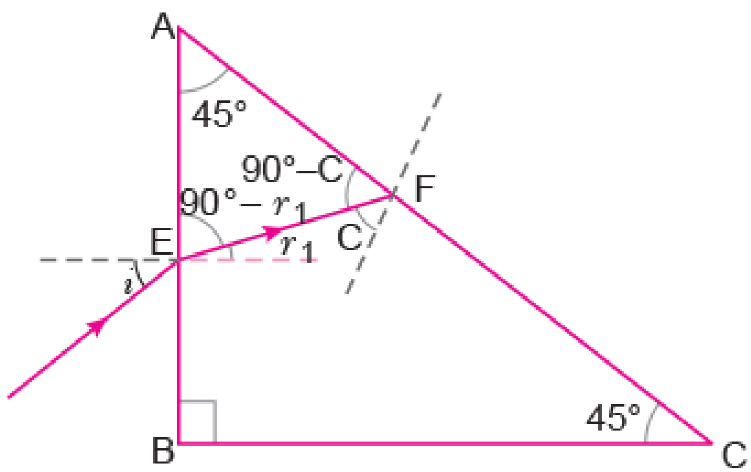


Q. 7. A right angled prism of refractive index n has a plane of refractive index n1 so that n1 < n, cemented to its diagonal face. The assembly is in air. A ray is incident on AB.

(a) Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.

(b) Assuming n = 1.352, calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated.

Ans.



a. $\sin C = \frac{n_1}{n}$

In ΔAEF

$(90 - r_1) + 45 + (90 - C) = 180$

$\Rightarrow r_1 = 45 - C$

$\frac{\sin\ i}{\sin\ r_1} = n \sin i = n \sin r_1 = n \sin(45 - C)$

$= n\ (\sin 45 \cos C - \cos 45 \sin C)$

$= \frac{n}{\sqrt{2}}(\cos C - \sin C)$

$= \frac{n}{\sqrt{2}}\left(\sqrt{[1 - \sin^2 C]}\right) - \sin C = \frac{1}{\sqrt{2}}\left(\sqrt{n^2 - n_1^2}\right) - n_1$

$i = \sin^{-1}\left(\frac{1}{\sqrt{2}}\sqrt{n^2 - n_1^2} - n_1\right)$

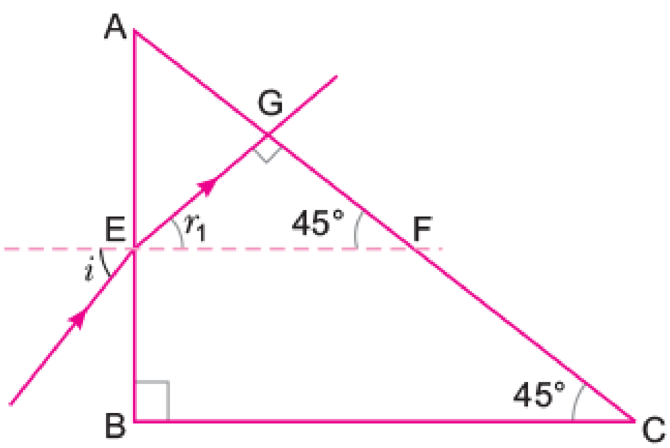
b. From ΔABC

$r_1 + 90^\circ + 45^\circ = 180^\circ \quad \Rightarrow \quad r_1 = 45^\circ$

$\frac{\sin i}{\sin r_1}$

$\sin i = n \sin r_1 = 1.352 \sin 45 = 0.956$

$i = \sin^{-1}(0.956) = 72.58$

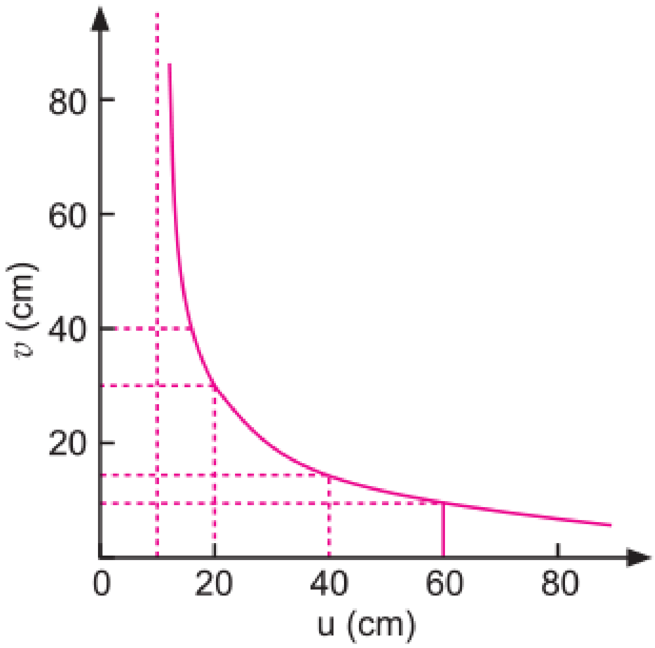


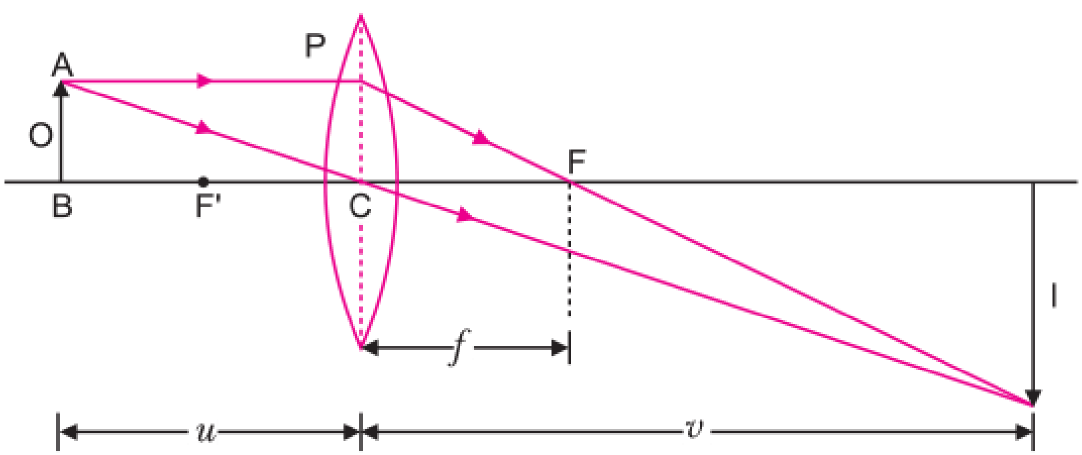
Q. 8. A lens forms a real image of an object. The distance from the object to the lens is u cm and the distance of the image from the lens is v cm. The given graphs shows variation of v with u.

(i) What is the nature of the lens?
(ii) Using the graph, find the focal length of this lens.

Ans. (i) The lens is convex because image formed by the lens is real.

(ii) Focal length : From graph when u = – 40 cm, v = 15 cm.





$$\therefore \qquad \frac{1}{f} = \frac{1}{v} - \frac{1}{u} \qquad\qquad \text{(for a lens)}$$

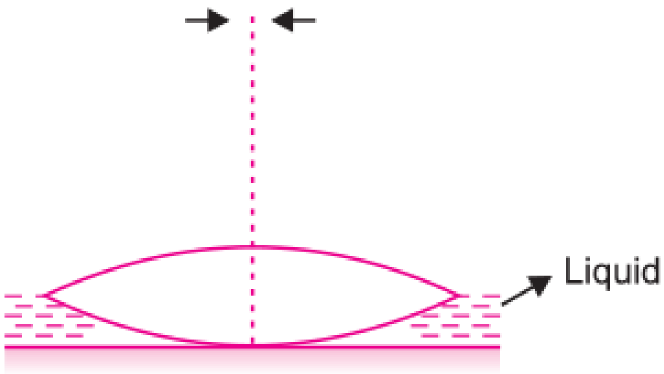
$$= \frac{1}{15} + \frac{1}{40} = \frac{40+15}{40\times 15}$$

$$f = \frac{40\times 15}{55} = \frac{120}{11} \approx \mathbf{11\,cm}$$

Q. 9. (a) An equiconvex lens with radii of curvature of magnitude r each, is put over a liquid layer poured on top of a plane mirror. A small needle, with its tip on the principal axis of the lens, is moved along the axis until its inverted real image coincides with the needle itself. The distance of the needle from the lens is measured to be 'a'. On removing the liquid layer and repeating the experiment the distance is found to be 'b'.

Given that two values of distances measured represent the focal length values in the two cases, obtain a formula for the refractive index of the liquid.

(b) If r = 10 cm, a = 15 cm, b =10 cm, find the refractive index of the liquid. [HOTS]



Ans.

a. (a) The focal length (f_1) of lens is given by

$$\frac{1}{f_1} = (n-1)\left(\frac{1}{r} + \frac{1}{r}\right) = \frac{2(n-1)}{r}$$

Given $f_1 = b$

$$\Rightarrow \frac{1}{b} = \frac{2(n-1)}{r} \Rightarrow b = \frac{r}{2(n-1)}$$

The focal length of liquid lens (plano concave lens) is

$$\frac{1}{f_2} = (n_l - 1)\left(-\frac{1}{r} - \frac{1}{\infty}\right) = -\frac{(n_l - 1)}{r} \Rightarrow f_2 = \frac{r}{(n_l-1)}$$

As glass lens and liquid lens are in contact

$$\therefore \quad \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{b} - \frac{(n_l-1)}{r}$$

Given $f = a$

$$\therefore \quad \frac{1}{a} = \frac{1}{b} - \frac{n_l-1}{r}$$

$$\Rightarrow \frac{n_l-1}{r} = \frac{1}{b} - \frac{1}{a}$$

$$\Rightarrow \quad n_l - 1 = r\left(\frac{1}{b} - \frac{1}{a}\right)$$

Refractive index of liquid,

$$n_l = 1 + \frac{r}{b} - \frac{r}{a}$$

b. $n_l = 1 + \frac{10}{10} - \frac{10}{15} = 1 + 1 - \frac{2}{3} = 2 - \frac{2}{3} = \frac{4}{3} = \mathbf{1.33}$