New

SURE SHOT QUESTIONS 2026

Chapter – 09 (Questions)

Ray Optics and Optical Instruments

➢ Questions

1. (a) 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,

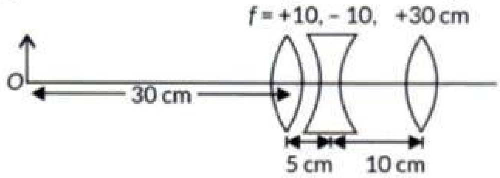
(b) Using mirror formula, explain why does a convex mirror always produce a virtual image. [Delhi 2016]

2. An object is placed 30 cm in front of a plano – convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed.

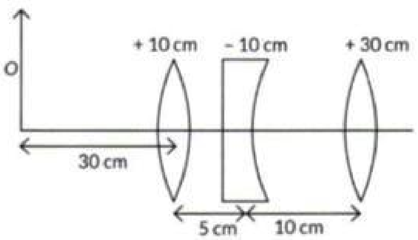
3. (a) Using the ray diagram for a system of two lenses of focal lengths f_1 and f_2 in contact with each other, show that the two lens system can be regarded as equivalent to a single lens of focal length f, where $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$.

Also write the relation for the equivalent power of the lens combination.

(b) Determine the position of the image formed by the lens combination given in the figure.



Three lenses of focal lengths +10 cm, -10 cm and +30 cm are arranged coaxially as in the figure given below. Find the position of the final image formed by the combination. [2/5, Delhi 2019]

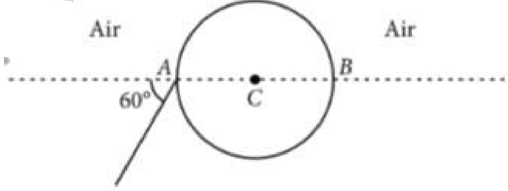


4. An astronomical telescope has an objective lens of focal length 20 m and eyepiece of focal length 1 cm.

(a) Find the angular magnification of the telescope.

(b) If the telescope is used to view the Moon, find the diameter of the image formed by the objective lens. Given the diameter of the Moon is 3.5×10^6 m and radius of lunar orbit is 3.8×10^8 m.

5. A ray of light falls on a transparent sphere with centre C as shown in the figure. The ray emerges from the sphere parallel to the line AB. Find the angle of refraction at A if refractive index of the material of the sphere is $\sqrt{3}$.



6. When a convex lens of focal length 30 cm is in contact with a concave lens of focal length 20 cm, find out if the system is converging or diverging.

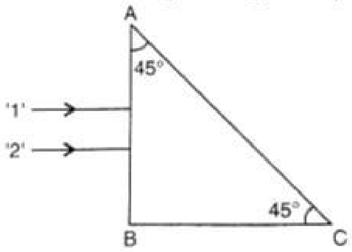
7. The radius of curvature of a convex mirror is 30 cm. it forms an image of an object which is half the size of the object. Find the separation between the object and the image.

8. A convex lens ($n = 1.52$) has a focal length of 15.0 cm in air. Find its focal length when it is immersed in liquid of refractive index 1.65. What will be the nature of the lens?

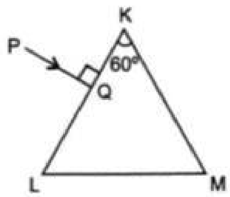
9. An object is kept 20 cm in front of a concave mirror of radius of curvature 60 cm. Find the nature and position of the image formed.

10. An object is kept in front of a concave mirror of focal length 15 cm. The image formed is real and three times the size of the object. Calculate the distance of the object from the mirror.

11. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism.

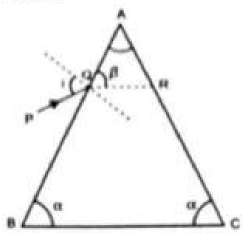


12. A triangular prism of refracting angle 60^0 is made of a transparent material of refractive index $2/\sqrt{3}$. A ray of light is incident normally on the face KL as shown in the figure. Trace the path of the ray as it passes through the prism and calculate the angle of emergence and angle of deviation.



13. Under what conditions does the phenomenon of total internal reflection take place? Draw a ray diagram showing how a ray of light deviates by 90^0 after passing through a right-angled isosceles prism.

14. A ray of light incident on the face AB of an isosceles triangular prism makes an angle of incidence (i) and deviates by angle β as shown in the figure. Show that in the position of minimum deviation $\angle\beta = \angle\alpha$. Also find out the condition when the refracted ray QR suffers total internal reflection.

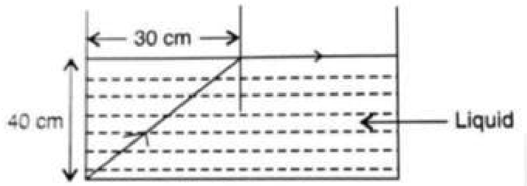


15. State, with the help of a ray diagram, the working principle of optical fibres. Write one important use of optical fibres.

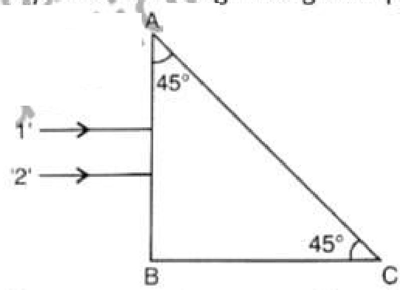
16. A convex lens of focal length 20cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept 15cm apart. A point object is placed 60 cm in front of the convex lens. Draw a ray diagram to show the formation ~~of~~ the image by the combination. Determine the nature and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

17. An object is placed in front of the convex lens made of glass. How does the image distance vary if the refractive index of the medium is increased in such a way that still it remains less than the glass?

18. (i) Define refractive index of a medium.
(ii) In the following ray diagram, calculate the speed of light in the liquid of unknown refractive index.



19. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism.

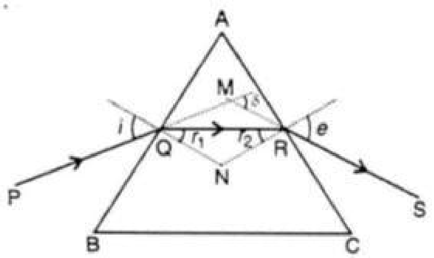


20. (i) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.
(ii) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}th$ of the angle of prism.

21. (i) A point of object is placed on the principal axis of the convex spherical surface of the radius of curvature R, which separates the two media of refractive indices n_1 and n_2 ($n_2 > n_1$). Draw the ray diagram and deduce the relation between the object distance (u), image distance (v) and the radius of curvature (R) for refraction to take place at the convex spherical surface from rarer to denser medium.
(ii) 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.

22.



(i) Draw the ray diagram showing refraction of light through a glass prism and hence obtain the relation between the refractive index μ of the prism , angle of prism and angle of minimum deviation.
(ii) Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = 2$ into the medium of refractive index $\mu_2 = 1$, so that it just grazes along the surface of separation.

23. Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and the eyepiece of a compound microscope has a short focal lengths? Explain.

24. You are given two converging lens 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.

25. Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object. Write the main considerations required in selecting the objective and the eyepiece lenses in order to have large magnifying power and high resolution of the telescope.

26. (i) Draw a labelled ray diagram showing the image formation of a distant object by a refracting telescope. Deduce the expression for its magnifying power when the final image is formed at infinity.

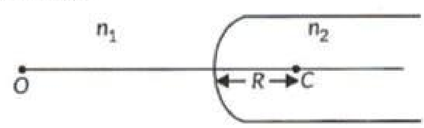
(ii) The sum of focal lengths of the two lenses of a refractive telescope is 105 cm. The focal length of one lens is 20 times that of the other. Determine the total magnification of the telescope when the final image is formed at infinity.

27. (i) State the condition under which a large magnification can be achieved in an astronomical telescope.
(ii) Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope.

28. Why should the objective of a telescope have large focal length and large aperture? Justify your answer.

29. What is the difference in the construction of an astronomical telescope and a compound microscope? The focal lengths of the objective and eyepiece of a compound microscope are 1.25 cm and 5.0 cm, respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 when the final image is formed at the near point.

30. Figure shows a convex spherical surface with centre of curvature C, separating the two media of refractive indices n^ and n2. Draw a ray diagram showing the formation of the image of a point object O lying on the principal axis. Derive the relationship between the object and image distance in terms of refractive indices of the media and the radius of curvature R of the surface.



SURE SHOT QUESTIONS 2026

Chapter – 09 (Solutions)

Ray Optics and Optical Instruments

➢ Solutions

1. Ans. (a) Here, R = -20 cm, f = R/2 = -10 cm

$m=-2$ (image is real)

u = object distance, v = image distance

$m=-\frac{v}{u}\Rightarrow v=2u$

Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\frac{1}{2u}+\frac{1}{u}=\frac{1}{-10}\Rightarrow\frac{3}{2u}=\frac{1}{-10}$

$\therefore\quad u=-15cm$

Hence, v = 2u = -30 cm

(b) For convex mirror: $f>0, u<0$

Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{f}-\frac{1}{(-u)}\Rightarrow\frac{1}{v}=\frac{1}{f}+\frac{1}{u}\Rightarrow v=\frac{f\times u}{f+u}$

$\therefore\quad v>0$

This implies that image of object placed in front of a convex mirror is always formed behind the mirror which is virtual in nature.

2. Ans. For plano -convex lens, $R_1=\infty$ and

$R_2=-20cm$

Given that, $\mu=1.5$

Using lens maker's formula,

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=(1.5-1)\left[\frac{1}{\infty}-\frac{1}{(-20)}\right]=\frac{1}{40}$$

Or f = 40 cm

Given that, u = 30 cm

Using lens formula,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\ or\ \frac{1}{v}-\left(\frac{1}{-30}\right)=\frac{1}{40}\ or\ \frac{1}{v}=-\frac{1}{120}$$

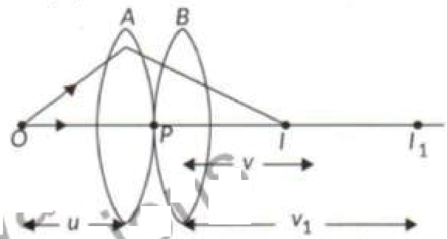
Or $v=-120cm$

$\therefore$ The image is formed at 120 cm on the same side as the object. So, the image is virtual and erect.

Magnification, $m=-\frac{v}{u}=\frac{-(-120)}{30}=4$

Thus, image is enlarge by four times the size of the object

3. Ans. (a)



An object is placed at point O. The lens A produces an image at I_1 which serves as a virtual object for lens B which produces final image at I.

Given, the lenses are thin. The optical centres (P) of the lenses A and B coincide with each other.

For lens A, we have

$$\frac{1}{v_1}-\frac{1}{u}=\frac{1}{f_1}\qquad\text{.............(i)}$$

For lens B, we have $\frac{1}{v}-\frac{1}{v_1}=\frac{1}{f_2}$ ....(ii)

Adding equations (i) and (ii),

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

If two lenses are considered as equivalent to a single lens of focal length f, then

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\qquad\text{.............(iv)}$$

From equation (iii) and equation (iv), we can write

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

(b) For lens $L_1:\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

Where, $f=+10cm$

$$\frac{1}{v_1}=\frac{1}{10}-\frac{1}{30};\ \frac{1}{v_1}=\frac{3-1}{30}=\frac{2}{30}\Rightarrow v_1=15cm$$

For lens L_2 :

$$v_1=15cm,\ u=10cm,\ f=-10cm$$

Position of final image,

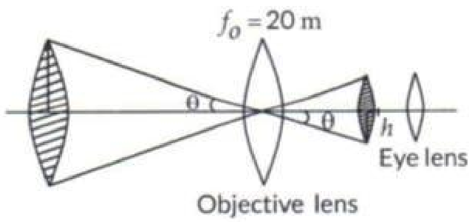
$$\frac{1}{v_2}=\frac{1}{f}+\frac{1}{u}=\frac{1}{10}-\frac{1}{10}\Rightarrow\ v_2=\infty$$

∴ For third lens L_3 object is at infinity, hence final image is formed at focus of L_3 at a distance of 30 cm.

4. Ans. (a) Angular magnification,

$$m=\frac{f_0}{f_e}=\frac{2000cm}{1.0cm}=2000$$

(b) The image of the moon by the objective lens formed on its focus only the as the moon in nearly at infinite distance as compared to focal length.



i.e., Radius of moon $R_m=\frac{3.5}{2}\times10^6\,m$

$$R_m=1.75\times10^6\,m$$

Distance of object = Radius of lunar orbit

$$R=3.8\times10^8\,m$$

Distance of image for objective lens is the focal length of objective lens, $f_0=20m$

Radius of image of moon by objective lens can be calculated, as,

$$\tan\theta=\frac{R_m}{R_0}=\frac{h}{f_0}$$

$$h=\frac{R_m\times f_0}{R_0}=\frac{1.75\times10^6\times20}{3.8\times10^8}=9.21\times10^{-2}m$$

Diameter of the image of the moon,

$$=2h=18.42\times10^{-2}m=18.42cm$$

5. Soln. From Snell's law, we have: $\frac{\sin(i)}{\sin(r)}=\mu$

At A, $i=60^0;\ \mu=\sqrt{3}$

Now, $\sin(r)=\frac{\sin(i)}{\mu}$

$$\Rightarrow\quad \sin(r)=\frac{\sin(60^0)}{\sqrt{3}}=\frac{1}{2}$$

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

$$\therefore\quad r=30^0$$

6. Soln. $f_1=f_{convex}=30cm$

$$f_2=f_{concave}=-20cm$$

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

$$=\frac{1}{30}-\frac{1}{20}$$

$$=\frac{2-3}{60}$$

$$\frac{1}{f}=-\frac{1}{60}[\therefore \text{concave(diverging) lens}]$$

7. Ans. Focal length of convex mirror = + 15 cm

Magnification, $m=\frac{\text{height of image }(h_i)}{\text{height of object }(h_0)}$

$$m=\frac{(h_i)}{(h_0)}=\frac{1}{2}$$

Also, $m=\frac{-v}{u}=\frac{1}{2}\Rightarrow u=-2v$

By mirror formula, we have

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}\ \Rightarrow\ \frac{1}{v}-\frac{1}{2v}=\frac{1}{f}\ \Rightarrow\ \frac{1}{2v}=\frac{1}{15}\ \Rightarrow\ v=7.5\text{ cm}$$

∴ $u=-15$ cm

So, separation between the object and image

= 15 + 7.5 = 22.5 cm

8. Ans. Refractive index of convex lens, n = 1.52

Focal length of lens, f = 15.0 cm.

According to Lens Makers formula.

$$\frac{1}{f}=({}^a\mu_g-1).\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\frac{1}{15}=(1.52-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]\quad ...(i)$$

After dipping in liquid of refractive index, $n = 1.65$

$$\frac{1}{f_w} = \left(\frac{^a\mu_g}{^a\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{1.52}{1.65} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{1.52 - 1.65}{1.65}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(ii)}$$

Dividing equation (i) by (ii)

$$\frac{\frac{1}{15}}{\frac{1}{f_w}} = \frac{(0.52)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}{\left(\frac{-0.13}{1.65}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

$$\frac{1}{15} \times \frac{f_w}{1} = \frac{-0.52 \times 1.65}{0.13}$$

$$f_w = \frac{-0.52 \times 1.65 \times 15}{0.13}$$

$f_w = -99$ cm

So, after dipping in liquid, the convex lens behaves like a concave lens.

9. Ans. Radius of curvature R = 60 cm

Focal length f = 30 cm

By Mirror formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{F}$

4 = -20 cm, f = -30 cm (concave mirror)

$$\frac{-1}{20} + \frac{1}{v} = \frac{-1}{30} \Rightarrow \frac{1}{v} = \frac{1}{20} - \frac{1}{30} = \frac{10}{600}$$

$$v = 60 cm$$

Thus image formed is virtual, erect and magnified in nature.

10. Ans. f = -15 cm, m = 3, u = -x cm

$$m = -\frac{v}{u} = 3 \text{ or } v = -3u = 3x$$

Using mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}; \frac{1}{3x} + \frac{1}{-x} = \frac{1}{-15} \text{ or}, -\frac{2}{3x} = \frac{1}{-15}$$

$$\Rightarrow \quad x = 10 cm$$

∴ Distance of object from the mirror, x = 10 cm.

11. Soln. At plane AC, the incident angle for ray 1 and ray 2 = 45^0

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

$$1.35 = \frac{1}{\sin C_1}$$

$$\Rightarrow \quad \sin C_1 = \frac{1}{1.35} = 0.74$$

Hence, $C_1 > 45^0 \qquad (\sin 45^0 = 0.707)$

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

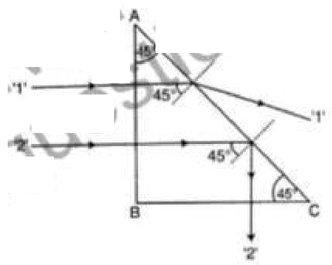
$$1.45 = \frac{1}{\sin C_2}$$

$$\Rightarrow \quad \sin C_2 = \frac{1}{1.45} = 0.689$$

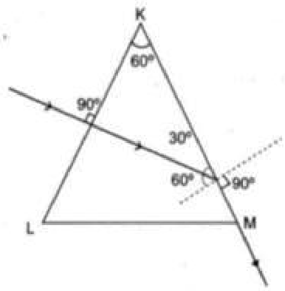
Hence $C_2 < 45^0 \qquad (\sin 45^0 = 0.707)$

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



12. Soln. From diagram it is clear that incidence angle at face KM is 60^0.



Hence, critical angle is also 60^0.

Therefore, incident light ray will not emerge from KM face due to total internal reflection at this face. Hence, it will move along face KM Angle of emergence = 90^0.

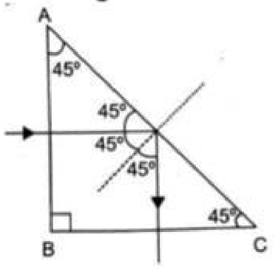
Hence angle of deviation = 30^0 (from fig.)

13. Soln. The phenomenon of total internal reflection occurs when,

1. Angle of incidence is equal or greater than critical angle.

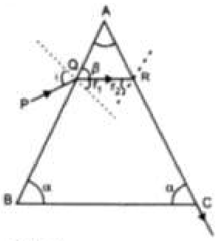
$$i \geq C$$

2. When light travels from more denser medium to less denser medium.
In case of right angle isosceles triangle if light rays fall normally on AB then light incident of face AC with angle of incidence > critical angle.



Hence, total internal reflection will occur with normal to the surface of BC.

14. Soln.



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

(i) Condition for minimum deviation:

1. $A = 180 - 2\alpha$
2. $\dfrac{\sin i}{\sin(90-\beta)} = \mu$

When, $r_1 = r_2 = r >$ critical angle

$r_1 + r_2 = 180 - 2\alpha$

$2r = 180 - 2\alpha \quad [\because r_1 = r_2]$

$r_1 = r = 90 - \alpha$

$\beta = 90 - r_1$

$= 90 - 90 + \alpha$

$\beta = \alpha$

Condition when QR have total internal reflection:

$\angle QRC \geq$ critical angle for the prism

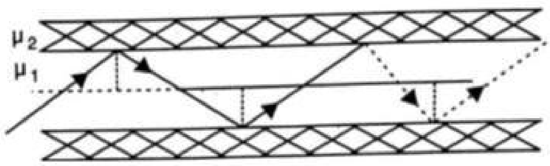
$\angle 180^0 - \beta \geq$ critical angle

Or $\angle 180^0 - \alpha \geq$ critical angle

$\because \quad \angle 180^0 - \alpha = \angle BAC$

$\therefore \quad \angle BAC \geq$ critical angle

15. Soln.



Optical fibre works on principle of total internal reflection. When angle of incidence is greater than Critical angle then incident rays are totally reflected back in same media.

When, $\theta_i > \theta_C$, Total internal reflection occurs and if $\theta_i < \theta_C$, refraction occurs.

Application: Optical fibre are used for communication due to very high bandwidth of media.

16. Soln. Here for convex lens

$u = -60\,cm$

$f = +20\,cm$ (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

$u = 30 - 15 = 15\,cm$

(+ve sign means virtual source)

$f = +10\,cm$ (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 virtual, magnified and erect.

17. Soln. From the lens maker formula, it is clear that n_{21} decreases then focal length increase.

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \left(\because n_{21} = \frac{n_2}{n_1}\right)$$

Here refractive index of the glass with respect to surrounding material decreases. Hence, focal length increases which will also increase the image distance.

18. Soln. (i) Refractive index of a medium is the ratio of speed of light (c) in free space to the speed of light (v) in that medium.

$$\mu = \frac{c}{v}$$

(ii) $\mu = \frac{c}{v} = \frac{1}{\sin i_c}$

$$= \frac{3\times10^8}{v} = \frac{1}{\frac{30}{50}}$$

$$v = \frac{30}{50}\times 3\times10^8$$

$$= 1.8\times10^8\ m/s$$

19. Soln. At plane AC, the incident angle for ray 1 and ray 2 = 45^0

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

$$1.35 = \frac{1}{\sin C_1}$$

$$\Rightarrow \quad \sin C_1 = \frac{1}{1.35}$$

$$= 0.74$$

Hence, $\quad C_1 > 45^0 \qquad (\sin 45^0 = 0.707)$

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

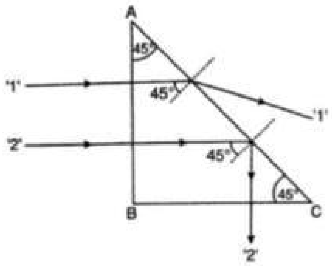
$$1.45 = \frac{1}{\sin C_2}$$

$$\Rightarrow \quad \sin C_2 = \frac{1}{1.45} = 0.689$$

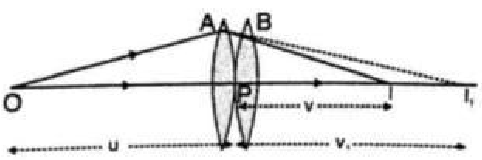
Hence $\quad C_2 < 45^0 \qquad (\sin 45^0 = 0.707)$

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



20. Soln.



(i) Two thin lenses, of focal length f_1 and f_2 are kept in contact. Let O be the position of object and let u be the object distance. The distance of the image (which is at I_1), for the first lens is v_1.

This image serves as object for the second lens.

Let the final image be at I. We then have

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

$$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v_1}$$

Adding, we get

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

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

$$P = P_1 + P_2$$

(ii) At minimum deviation

$$r = \frac{A}{2} = 30^0$$

We are given that, $i = \frac{3}{4}A = 45^0$

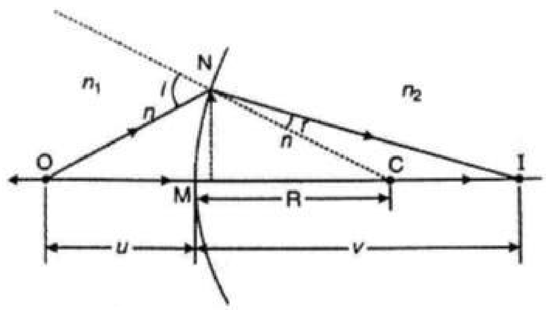
$$\therefore \quad \mu = \frac{\sin 45^0}{\sin 30^0} = \sqrt{2}$$

$\therefore$ Speed of light in the prism = $\frac{c}{\sqrt{2}}$

$$(\cong 2.1 \times 108 ms^{-1})$$

[Award ½ mark if the student writes the formula: $\mu = \frac{sin\left(\frac{A+\delta_m}{2}\right)}{sin\left(\frac{A}{2}\right)}$ but does not do any calculations.]

21. Soln. (i)



For small angles

$$\tan\angle NOM = \frac{MN}{OM}$$

$$\tan\angle NCM = \frac{MN}{NC}$$

And $\quad \tan\angle NIM = \frac{MN}{NC}$

For ΔNOC, i is exterior angle, therefore

$$i = \angle NOM + \angle NCM$$
$$= \frac{MN}{OM} + \frac{MN}{MC}$$

Similarly, $r = \frac{MN}{MC} - \frac{MN}{MI}$

For small angles, Snells law can be written as

$$n_1 i = n_2 r$$

$$\therefore \quad \frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

$$\therefore \quad OM = -u, \quad MI = +v$$
$$MC = +R$$

(using sign convention)

$$\therefore \quad \frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

(ii) Lens Maker's formula is

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$\therefore$ Focal length in an is

$$\frac{1}{20} = (1.6 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

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

Let f' be the focal length of the lens in water

$$\therefore \quad \frac{1}{f'} = \left(\frac{1.6 - 1.3}{1.3}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$= \frac{0.3}{12 \times 1.3}$$
$$or \quad f' = \frac{120 \times 1.3}{3} = 52\,cm$$

22. Soln. (i)

From fig $\angle A + \angle QNR = 180^0$ ....(i)

From triangle $\Delta QNR, r_1 + r_2 + QNR 180^0$..............(ii)

Hence from eqn. (i) & (ii)

$$\therefore \angle A = r_1 + r_2$$

The angle of deviation

$$\delta = (i - r_1) + (e - r_2)$$
$$= i + e - A$$

At minimum deviation $i = e$ and $r_1 = r_2$

$$\therefore r = \frac{A}{2}$$
$$and i = \frac{A + \delta_m}{2}$$

Hence, refractive index,

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$$

(ii) From snell's law, $\mu_1 \sin i = \mu_2 \sin r$

Given $\quad \mu_1 = \sqrt{2}, \mu_2 = 1$

And $\quad r = 90^0 (just\ grazing)$

$$\therefore \sqrt{2} \sin i = 1 \times \sin 90^0$$
$$\Rightarrow \sin i = \frac{1}{\sqrt{2}}$$
$$or i = 45^0$$

23. Soln. Magnifying power is defined as the angle subtended at the image to the angle subtended (at the unaided eye) by the object.

Alternatively: Also accept this definition in the form of formula

$$m = m_0 \times m_e = \frac{L}{f_0} \times \frac{D}{f_e}$$

The increase the magnifying power both the objective and eyepiece must have short focal lengths

$$\left(as\ m = \frac{L}{f_0} \times \frac{D}{f_e}\right)$$

24. Soln. Given, $f_0 = 1.25 cm, f_e = 5 cm$ (In microscope, focal length of objective lens should be very small)

Magnification, m= 30,

It we set these lens for minimum distance for distinct vision, then for

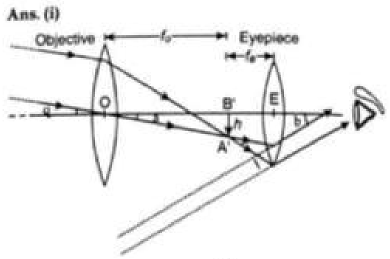
$$m = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$
$$30 = \frac{L}{1.25}\left(1 + \frac{25}{5}\right)$$
$$L = 1.25 \times 30 \times \frac{5}{30}$$
$$L = 5 \times 1.25$$
$$L = 6.25\,cm$$

Hence, distance between two lenses is

$$= f_0 + 6.25 + f_e$$
$$= 1.25 + 6.25 + 5$$
$$= 12.5\,cm$$

This is a required separation between the objective and the eyepiece.

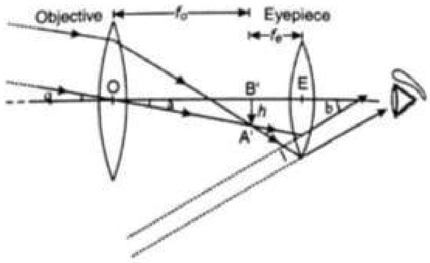
25. Soln.



For a large magnifying power, f_0 should be large and f_e should be small.

For a higher resolution, the diameter of the objective should be large.

26. Soln. (i)



[Note: deduct ½ mark if not labelled]

Magnifying power,

$$m = \frac{\tan\beta}{\tan\alpha} \cong \frac{\beta}{\alpha}$$

$\because$ The angles are small

Final image is formed at infinity when the image A'B' is formed by the objective lens at the focus of the eyepiece,

$$m = \frac{h}{f_e} \times \frac{f_0}{h}$$

$$m = \frac{f_0}{f_e}$$

(ii) Given,

$$f_0 + f_e = 105, f_0 = 20f_e$$
$$20f_e + f_e = 105$$
$$f_e = \frac{105}{21} = 5cm$$
$$f_0 = 20 \times 5 = 100cm$$

$\therefore$ Magnification, $m = \frac{f_0}{f_e} = \frac{100}{5} = 20$

27. Soln. (i) $m = \frac{f_0}{f_e}$

By increasing f_0 or decreasing f_e

(ii) (a) No chromatic aberration.

(b) No spherical aberration.

(c) Mechanical advantage – low weight, easier to support.

(d) Mirrors are easy to prepare.

(e) More economical.

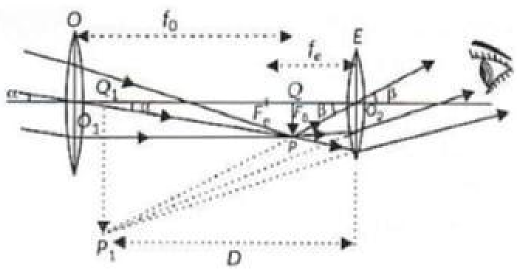
28. Soln. Large focal length : to increase magnifying power

$$\left(\because\ m = \frac{f_0}{f_e}\right)$$

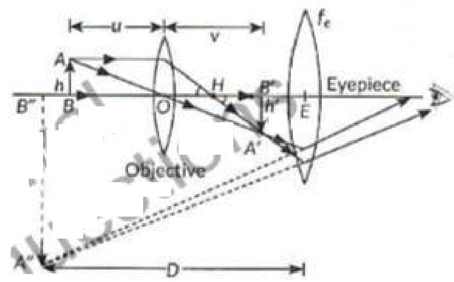
Large aperture: to increase resolving power

$$\left(\because\ RP = \frac{2a}{1.22\lambda}\right)$$

29. Soln. Construction for astronomical telescope.



Construction for compound microscope:



Angular magnification, $m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$

$$\Rightarrow \quad 30 = \frac{v_0}{u_0}\left(1 + \frac{25}{5}\right)$$

$$\Rightarrow \quad v_0 = 5u_0 \qquad ....(i)$$

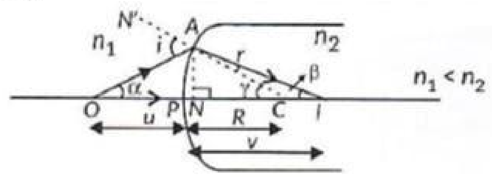
From lens formula,

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{-1}{(-u_0)} \Rightarrow \frac{1}{1.25} = \frac{u_0 + v_0}{v_0 u_0} \qquad ......(ii)$$

Substituting (i) in (ii), $u_0 = 1.5$ cm

30. Soln. Refraction at convex spherical surface, see figure.

When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$

And in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

$\therefore$ By Snell's law ${}^1n_2 = \frac{\sin i}{\sin r} = \frac{i}{r} = \frac{\alpha+\gamma}{\gamma-\beta}$

Or $\frac{n_2}{n_1} = \frac{\alpha+\gamma}{\gamma-\beta}$ or $n_2\gamma - n_2\beta = n_1\alpha + n_1\gamma$

Or $(n_2 - n_1)\gamma = n_1\alpha + n_2\beta$ ....(i)

As α, β and γ are small and P and N lie close to each other,

So, $\alpha \simeq \tan\alpha = \frac{AN}{NO} \approx \frac{AN}{PO}$

$\beta \approx \tan\beta = \frac{AN}{NI} \approx \frac{AN}{PI}$

$\gamma \approx \tan\gamma = \frac{AN}{NC} \approx \frac{AN}{PC}$

On using them in equation (i), we get

$(n_2 - n_1)\frac{AN}{PC} = n_1\frac{AN}{PO} + n_2\frac{AN}{Pl}$

Or $\frac{n_2 - n_1}{PC} = \frac{n_1}{PO} + \frac{n_2}{Pl}$ ....(ii)

Where, PC = +R, radius of curvature

PQ = -u, object distance

$Pl = +v$, image distance

So $\frac{n_2 - n_1}{R} = \frac{n_1}{-u} + \frac{n_2}{v}$ or $\frac{n_2 - n_1}{R} = \frac{n_2}{v} - \frac{n_1}{u}$

This gives formula for refraction at spherical surface when object is in rarer medium.