NCERT Solutions for Class 12 Physics

Chapter 9 Ray Optics and Optical Instruments

Question 1.
A small candle 2.5 cm in size is placed 27 cm in front of a concave mirror of a radius of curvature of 36 cm. At what distance from the mirror should a screen be placed in order to receive a sharp image? Describe the nature and size of the image. If the candle is moved closer to the mirror, how would the screen have to be moved?

Answer:
Here, h = 2.5 cm, u = − 27 cm, R = − 36 cm.

Since $f = \dfrac{R}{2}$. Therefore, $f = \dfrac{-36}{2} = -18 \text{cm}$

(i) Using mirror formula

$\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$, we get

$\dfrac{1}{v} = \dfrac{1}{f} - \dfrac{1}{u} = -\dfrac{1}{18} + \dfrac{1}{27} = -\dfrac{1}{54}$

or $\quad v = -54 \text{ cm} \quad$ (Position of image)

Thus, the screen should be placed at a distance of 54 cm in front of the concave mirror.

(ii) Using, $\dfrac{h'}{h} = -\dfrac{v}{u}$, we get

$h' = -\left(\dfrac{v}{u}\right)h = -\left(\dfrac{-54\,\text{cm}}{-27\,\text{cm}}\right) \times 2.5\,\text{cm}$

$= -5.0 \text{ cm}$

Thus, size of image is 5.0 cm.

Nature of image : Real, inverted and magnified. When the position of the object (i.e. candle) is moved closer to the concave mirror, the distance of the image moves away from the screen till the distance of the candle from the concave mirror is less than 18 cm. Hence, the screen has to be moved away from the concave mirror. When the distance of the candle is less than 18 cm from the concave mirror, a virtual and magnified image of the candle is formed behind the mirror. This image is not obtained on the screen.

Question 2.
A 4.5 cm needle is placed 12 cm away from a convex mirror of focal length 15 cm. Give the location of the image and magnification. Describe what happens as the needle is moved farther from the mirror.

Answer:
Here, h_1 = 4.5 cm, μ = − 12 cm, f= 15 cm

Using $\dfrac{1}{u}+\dfrac{1}{v}=\dfrac{1}{f}$, we get

or $\quad \dfrac{1}{v}=\dfrac{1}{f}-\dfrac{1}{u}$ or $\dfrac{1}{v}=\dfrac{1}{15}+\dfrac{1}{12}=\dfrac{4+5}{60}$

$\Rightarrow \quad \dfrac{1}{v}=\dfrac{9}{60}$ or $v=\dfrac{60}{9}$ cm

$v = 6\cdot7$ cm

Thus, the image is formed at 6·7 cm behind the mirror.

As magnification $m=\dfrac{h'}{h}=-\dfrac{v}{u}$, we get,

$\dfrac{h'}{4\cdot5}=\dfrac{-\dfrac{60}{9}}{-12}=\dfrac{5}{9}$

$\therefore \quad h'=\dfrac{5\times4\cdot5}{9}=2\cdot5$ cm (Size of image)

Thus, the image is virtual, erect and diminished. As we move the needle away from the mirror, the image goes on decreasing in size and moves towards the principal focus on the other side.

Question 3.
A tank is filled with water to a height of 12.5 cm. The apparent depth of the needle lying at the bottom of the tank is measured by a microscope to be 9.4 cm. What is the refractive index of water ? If water is replaced by a liquid of refractive index 1.63 up to the same height, by what distance would the microscope have to be moved to focus on the needle again ? (C.B.S.E. 2009)
Answer:
Here, real depth = 12.5 cm, Apparent depth = 9.4 cm

Using, $\dfrac{\text{Real depth}}{\text{Apparent depth}}={}^{a}n_w$, we get,

$\dfrac{12\cdot5}{9\cdot4}={}^{a}n_w$ or ${}^{a}n_w=1\cdot33$

If water is replaced by liquid, then ${}^{a}n_l=1\cdot63$

So apparent depth $=\dfrac{\text{real depth}}{{}^{a}n_l}=\dfrac{12\cdot5}{1\cdot63}=7\cdot66$ cm

$\therefore$ Distance through which the microscope has to be moved
$= 9\cdot4 - 7\cdot66 = 1\cdot74$ cm

Question 4.
The following figures (a) and (b) show refraction of an incident ray in air at 60° with the normal to glass-air and water-air interface, respectively. Predict the angle of refraction of an incident ray in water at 45° with the normal to a water-glass interface [Fig. (c)]

(a)

(b)

(c)
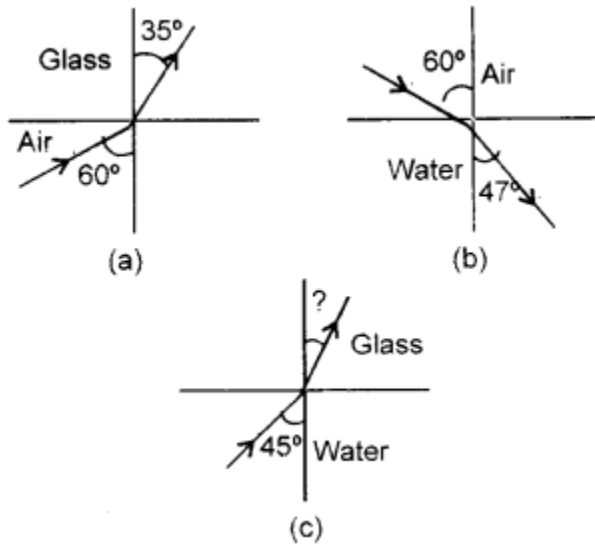
Answer:

From fig. (a),

$$^a n_g = \frac{\sin 60°}{\sin 35°} \qquad \left(\because n = \frac{\sin i}{\sin r} \right)$$

$$= \frac{\sqrt{3}/2}{0\cdot5736} = 1\cdot51$$

From fig (b),

$$^a n_w = \frac{\sin 60°}{\sin 41°} = \frac{\sqrt{3}/2}{0\cdot6561} = 1\cdot32$$

$$^w n_g = \frac{^a n_g}{^a n_w} = \frac{\sin i}{\sin r} = \frac{1\cdot51}{1\cdot32} = 1\cdot14$$

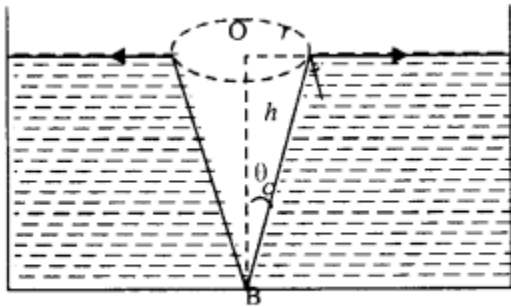$$\Rightarrow \quad \frac{\sin 45°}{\sin r} = 1\cdot14$$

or $$\quad \sin r = \frac{1}{\sqrt{2} \times 1\cdot14} = 0\cdot6203$$

$$\Rightarrow \quad r = \sin^{-1} 0\cdot6203 = 38°21'$$

Question 5.
A small bulb is placed at the bottom of a tank containing water to a depth of 80 cm. What is the area of the surface of water through which light from the bulb can emerge out ? Refractive index of water is 1.33 (consider the bulb to be a point source).
Answer:

Here, $h = 80$ cm, $n = 1.33$

The light rays from the bulb B, which fall on the surface of water at an angle equal to critical angle (θ_c), grazes on the surface of water and the rays of light which fall on the surface of water at an angle greater than θ_c are totally internally reflected back into the water. The rays of light images emerges out of water through a circular patch of radius r.

Now, $\tan \theta_c = \dfrac{r}{h}$ or $r = h \tan \theta_c$ ...(i)

Since $\sin \theta_c = \dfrac{1}{n}$, $\therefore \cos \theta_c = \sqrt{1 - \sin^2 \theta_c} = \sqrt{1 - \dfrac{1}{n^2}}$

$$= \sqrt{\dfrac{n^2 - 1}{n}}$$

Hence, $\tan \theta_c = \dfrac{\sin \theta_c}{\cos \theta_c} = \dfrac{1}{\sqrt{n^2 - 1}}$

$\therefore$ eqn. (i) becomes, $r = \dfrac{h}{\sqrt{n^2 - 1}} = \dfrac{80 \text{ cm}}{\sqrt{(1 \cdot 33)^2 - 1}}$

$$= \dfrac{80 \text{ cm}}{0 \cdot 88} = 90 \cdot 9 \text{ cm}$$

Therefore, area of surface of water through which light from the bulb can emerge out, $A = \pi r^2 = 3 \cdot 14 \times (90 \cdot 9)^2$
$= 2 \cdot 6$ m^2

Question 6.
A prism is made of glass of unknown refractive index. A parallel beam of light is incident on a face of the prism. By rotating the prism, the angle of minimum deviation is measured to be 40°. What is the refractive index of the material of the prism ? If the prism is placed in water (refractive index 1.33), predict the new angle of minimum deviation of a parallel beam of light. The refracting angle of the prism is 60°.
Answer:

Here, $A = 60°$, $\delta_m = 40°$

Using $^a n_g = \dfrac{\sin \dfrac{A+\delta_m}{2}}{\sin \dfrac{A}{2}}$; we get

$$^a n_g = \dfrac{\sin \dfrac{60° + 40°}{2}}{\sin \dfrac{60°}{2}} = \dfrac{\sin 50°}{\sin 30°} = \dfrac{0 \cdot 7660}{0 \cdot 5000}$$

$$= 1 \cdot 53$$

When the **prism is placed in water,** then

$$^\omega n_g = \dfrac{^a n_g}{^a n_\omega} = \dfrac{1 \cdot 53}{1 \cdot 33} = 1 \cdot 15$$

$$\therefore {}^\omega n_g = \dfrac{\sin \dfrac{A+\delta_m}{2}}{\sin \dfrac{A}{2}} \Rightarrow 1 \cdot 15 = \dfrac{\sin \dfrac{60° + \delta_m}{2}}{\sin \dfrac{60°}{2}}$$

or $\sin \dfrac{60° + \delta_m}{2} = 1 \cdot 15 \sin 30° = 1 \cdot 15 \times 0 \cdot 5$

$$= 0 \cdot 5750$$

$$\therefore \dfrac{60° + \delta_m}{2} = \sin^{-1} 0 \cdot 5750 = 35°6'$$

or $60° + \delta_m = 70°12'$ or $\delta_m = 10°12'$

Question 7.
Double-convex lenses are to be manufactured from a glass of refractive index 1.55, with both faces of the same radius of curvature. What is the radius of curvature required if the focal length is to be 20 cm ?
Answer:
Here, n = 1.55, R_1 = R and R_2 = − R, f= 20 cm Using lens maker formula, we get

Here, $n = 1.55$, $R_1 = R$ and $R_2 = -R$, $f = 20$ cm
Using lens maker formula, we get

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

$$\therefore \quad \frac{1}{20} = (1.55-1)\left[\frac{1}{R} - \left(-\frac{1}{R}\right)\right] = 0.55 \times \frac{2}{R}$$

or $\quad R = \frac{1.10}{1} \times 20 = 22$ cm

Question 8.

A beam of light converges to a point P. A lens is placed in the path of the convergent beam 12 cm from P. At what point does the beam converge if the lens is (a) a convex lens of focal length 20 cm, (b) a concave lens of focal length 16 cm?

Answer:

(a) When a convex lens is placed in the path of light converging at P, the beam converges at P_t. Thus, point P acts as virtual object for the convex lens.
Now, $u = 12$ cm, $f = 20$ cm.
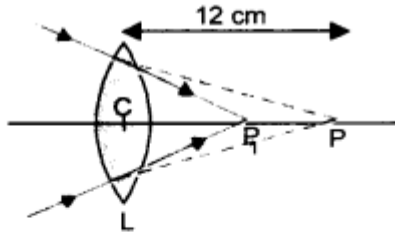
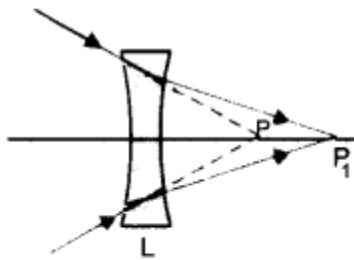Using $\dfrac{1}{f} = -\dfrac{1}{u} + \dfrac{1}{v}$, we get

$$\dfrac{1}{v} = \dfrac{1}{f} + \dfrac{1}{u} \quad \text{or} \quad \dfrac{1}{v} = \dfrac{1}{20} + \dfrac{1}{12}$$

or $\qquad \dfrac{1}{v} = \dfrac{3+5}{60} = \dfrac{8}{60} = \dfrac{2}{15}$

$\therefore \qquad v = \dfrac{15}{2} = 7 \cdot 5 \text{ cm}$

Thus, the beam converges at a distance of 7.5 cm from the convex lens.

(b) For a concave lens, the image formation is as shown.

Here, $u = 12$ cm, $f = -16$ cm

Using $\quad -\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$, we get

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

or $\dfrac{1}{v} = -\dfrac{1}{16} + \dfrac{1}{12} = \dfrac{-3+4}{48}$ or $v = 48$ cm

Question 9.
An object of size 3.0 cm is placed 14 cm in front of a concave lens of focal length 21 cm. Describe the image produced by the lens. What happens if the object is moved farther from the lens?
Answer:

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Using $-\dfrac{1}{u}+\dfrac{1}{v}=\dfrac{1}{f}$, we get

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

or

$$\dfrac{1}{v}=-\dfrac{1}{21}-\dfrac{1}{14}=\dfrac{-2-3}{42}=\dfrac{-5}{42}$$

$$\therefore \quad v=-\dfrac{42}{5}=-8.4\ \text{cm}$$

Also, the magnification, $m=\dfrac{h'}{h}=\dfrac{v}{u}$

$$\Rightarrow \quad \dfrac{h'}{3.0}=\dfrac{-8.4}{-14}=0.6 \text{ or } h'=1.8\ \text{cm}$$

Thus, the image is virtual, erect, diminished and is formed on the same side of the lens at a distance of 8.4 cm from the lens. If the object is moved away from the lens, the image moves towards the principal focus and goes on decreasing in size.

Question 10.
What is the focal length of a convex lens of focal length 30 cm in contact with a concave lens of focal length 20 cm? Is the system a converging or a diverging lens? Ignore thickness of the lenses.
Answer:
Here, f_1 = 30 cm and f_2 = -20 cm
For the combination of two thin lenses, the focal length of the combination is given by

$$\dfrac{1}{F}=\dfrac{1}{f_1}+\dfrac{1}{f_2}=\dfrac{1}{30}+\dfrac{1}{(-20)}=\dfrac{2-3}{60}$$

$$=-\dfrac{1}{60} \text{ or } F=-60\ \text{cm}$$

Since the focal length of the system of lens is negative, therefore, the combination behaves as a diverging lens.

Question 11.
A compound microscope consists of an objective lens of focal length 2-0 cm and an eye-piece of focal length 6.25 cm separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at (a) the least distance of distinct vision (25 cm), (b) infinity ? What is the magnifying power of the microscope in each case? (C.B.S.E. 2008)
Answer:
Here, f_n =2.0 cm, f = 6.25 cm,
Distance between object lens and eye piece = 15 cm (a) For the formation of image at the least distance of distinct vision,

$$v_e = -25 \text{ cm} \; ; \quad u_e = ?$$

Using, $-\dfrac{1}{u_e} + \dfrac{1}{v_e} = \dfrac{1}{f_e}$, we have

or $\qquad \dfrac{1}{u_e} = \dfrac{1}{v_e} - \dfrac{1}{f_e}$

$$= -\dfrac{1}{25} - \dfrac{1}{6.25} = -\dfrac{1}{5}$$

or $\qquad u_e = -5 \text{ cm}$

Negative sign tells that the object for the objective lens lies to the left of the lens.

∴ Distance of the image from the objective lens,

$$v_o = 15 - 5 = 10 \text{ cm}$$

Using $-\dfrac{1}{u_o} + \dfrac{1}{v_o} = \dfrac{1}{f_o}$, we get

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

$$= \dfrac{1}{10} - \dfrac{1}{2} = -\dfrac{4}{10}$$

∴ $\qquad u_o = -\dfrac{10}{4} \quad \text{or} \quad u_o = -2 \cdot 5 \text{ cm}$

Magnifying power,

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

$$= \frac{10}{-(-2\cdot5)}\left(1 + \frac{25}{6\cdot25}\right)$$

$$[\because D = 25 \text{ cm}]$$

$$= 4(5) = 20$$

(b) When the final image is formed at infinity.

Here, $v_o = \infty$, $f_e = 6.25$ cm

Using $-\dfrac{1}{u_e} + \dfrac{1}{v_e} = \dfrac{1}{f_e}$, we get

$$\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = -\frac{1}{6.25}$$

or $u_e = -6.25$ cm

Distance between objective and eye piece = 15 cm

Therefore, $v_o = 15 + u_e = 15 - 6.25 = 8.75$ cm

Using, $-\dfrac{1}{u_o} + \dfrac{1}{v_o} = \dfrac{1}{f_o}$, we get

$$\frac{1}{u_o} = \frac{1}{v_o} - \frac{1}{f_o} = \frac{1}{8.75} - \frac{1}{2} = \frac{-6.75}{17.5}$$

or $u_o = -2\cdot59$ cm

Question 12.

A person with a normal near point (25 cm) using a compound microscope with objective of focal length 8.0 mm and an eye-piece of focal length 2.5 cm can bring an object placed 9.0 mm from the objective in sharp focus. What is the separation between the two lenses ? How much is the magnifying power of the microscope?

Answer:

Here f_o = 8·0 mm = 0·80 cm ; f_e = 2·5 cm

$\quad\quad$ D = 25 cm, v_e = $-$D = $-$25 cm

$\quad\quad$ u_o = $-$9·0 mm = $-$0·90 cm

Linear magnification of the eye lens is given by

$$m_e = \frac{v_e}{u_e} = 1 + \frac{D}{f_e}$$

$$\Rightarrow \frac{-25}{u_e} = 1 + \frac{25}{2\cdot5} = 11$$

$$\therefore \quad u_e = -\frac{25}{11} \text{cm}$$

Using $\quad -\dfrac{1}{u_o} + \dfrac{1}{v_o} = \dfrac{1}{f_o}$ for objective lens we get

$$-\frac{1}{-0\cdot90} + \frac{1}{v_o} = \frac{1}{0\cdot80}$$

or $\quad \dfrac{1}{v_o} = \dfrac{1}{0\cdot8} - \dfrac{1}{0\cdot9} = \dfrac{0\cdot9 - 0\cdot8}{0\cdot72}$

$$\therefore \quad v_o = \frac{0\cdot72}{0\cdot1} \text{cm} = 7\cdot2 \text{ cm}$$

∴ Separation between two lenses

$$= |u_e| + |v_o| = \frac{25}{11} + 7\cdot2$$

$$= 2\cdot27 + 7\cdot2 = 9\cdot47 \text{ cm}$$

Magnifying power

$$M = \frac{v_o}{-u_o}\left(1 + \frac{D}{f_e}\right) = \frac{7\cdot2}{0\cdot9}\left(1 + \frac{25}{2\cdot5}\right) = 88$$

Question 13.
A small telescope has an objective lens of focal length 144 cm and an eye-piece of focal length 6.0 cm. What is the magnifying power of the telescope? What is the separation between the objective and the eye-piece?
Answer:

Here, focal length of objective lens, f_o = 144 cm Focal

Focal length of eye-piece, f_e = 6·0 cm

Therefore, using $m = \dfrac{f_o}{f_e}$, we get $m = \dfrac{144}{6\cdot0} = 24$

Also, the distance between objective and eye-piece is

$$= f_o + f_e = 144 + 6 = 150 \text{ cm}$$

Question 14.
(a) A giant refracting telescope at an observatory has an objective lens of focal length 15m. If an eye-piece of focal length 1.0 cm is used, what is the angular magnification of the telescope ?
(b) If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens ? The diameter of the moon is 3.48 x 10^6m and the radius of the lunar orbit is 3.8 x 10^8m. (C.B.S.E. 2008, 2011)
Answer:

Here, f_o = 15 cm, f_e = 1 cm
(a) Angular magnification,

$$m = \dfrac{f_o}{f_e} = \dfrac{1500}{1} = 1500$$

(b) Let D be the diameter of moon's image

Then $\dfrac{D}{1500}$

$$= \dfrac{\text{Diameter of moon}}{\text{Radius of Lunar orbit}} = \dfrac{3\cdot48 \times 10^6 \times 100}{3\cdot8 \times 10^8 \times 100}$$

or $$D = 1500 \times \dfrac{3\cdot48}{380} = 13\cdot7 \text{ cm}$$

Question 15.
Use the mirror equation to deduce that
(a) an object placed between f and 2f of a concave mirror produces a real image beyond 2f.
(b) a convex mirror always produces a virtual image independent of the location of the object.
(c) the virtual image produced by a convex mirror is always diminished in size and is located between the focus and the pole.
(d) an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image. (C.B.S.E. 2011)
Answer:

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(a) For a concave mirror, the mirror formula is given by

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad \text{or} \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} \qquad \qquad \dots(i)$$

where both f and u are negative $i.e.$ $f < 0$ and $u < 0$

Then, for an object between f and $2f$, we have

$$2f < u < f \quad \text{or} \quad \frac{1}{2f} > \frac{1}{u} > \frac{1}{f}$$

Multiplying by -1, the inequality becomes

$$-\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f} \quad \text{or} \quad \frac{1}{f} - \frac{1}{2f} < \frac{1}{f} - \frac{1}{u} < \frac{1}{f} - \frac{1}{f}$$

Using equation (i), we have

$$\frac{1}{2f} < \frac{1}{v} < 0$$

It means that if v is negative, the image formed is real and beyond $2f$.

(b) For a convex mirror, using the mirror formula

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} \quad \text{where } f > 0 \text{ and } u < 0 \text{ we find that } v \text{ is}$$

always positive $i.e.$ the image lies on the right of the mirror and is thus a virtual image.

(c) The magnification of mirror,

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

For a convex mirror f is positive whereas u is negative. Therefore $f - u$ is always greater than f

$i.e.$ $\quad f - u > f \qquad \therefore \qquad m < 1$ $i.e.,$ the image is diminished

(d) For a concave mirror, $f < 0, u < 0$

$$u < 0$$

$\therefore$ For an object placed in between pole and principal focus,

$$f < u < 0 \quad \Rightarrow \quad \frac{1}{f} - \frac{1}{u} > 0$$

But using mirror formula, $\dfrac{1}{v} = \dfrac{1}{f} - \dfrac{1}{u}$, we find, $\dfrac{1}{v} > 0$

i.e. v is positive and lies to the right of pole.

$\Rightarrow$ the image is virtual. Also, magnification,

$$m = -\dfrac{v}{u} = \dfrac{v}{|u|}$$

Since $\dfrac{1}{v} < \dfrac{1}{|u|}$ i.e., $v > |u|$

$\therefore$ m is positive and greater than 1. So, the image is enlarged.

Question 16.
A small pin fixed on the table top is viewed from above from a distance of 50 cm. By what distance would the pin appear to be raised if it is viewed from the same point through a 15 cm thick glass slab held parallel to the table?
Refractive index of glass = 1.5. Does the answer depend upon the location of the slab?
Answer:
Here, t = 15 cm, n = 1.5
The lateral displacement

$$x = t\left[1 - \dfrac{1}{n}\right]$$

i.e. $x = 15\left(1 - \dfrac{1}{1\cdot5}\right) = 15 \times \dfrac{0\cdot5}{1\cdot5} = 5 \text{ cm}$

For small angles of incidence, the answer does not depend upon the location of the slab.

Question 17.
(a) Following figure shows a cross-section of a 'light pipe' made of glass fibre of refractive index 1.68. The outer covering of the pipe is made of material of refractive index 1.44. What is the range of the angles of incident rays with the axes of the pipe for which the total internal reflection inside the pipe take place as shown in the figure ?
(b) What is the answer if there is no outer covering of pipe ?
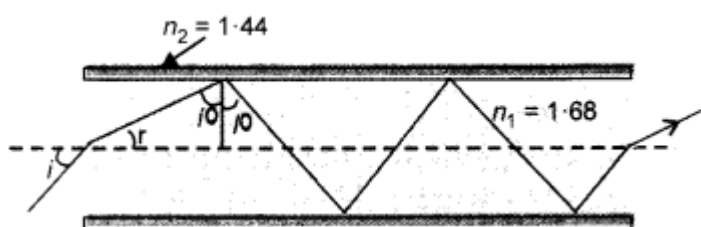
Answer:

(a) The maximum value of the acceptance angle $i = \theta_a$ is given by $\sin \theta_a = \sqrt{n_1^2 - n_2^2}$, where n_1 is the refractive index of core and n_2 that of the cladding.

Here $n_1 = 1 \cdot 68$ and $n_2 = 1 \cdot 44$

$\therefore \quad \sin \theta_a = \sqrt{(1 \cdot 68)^2 - (1 \cdot 44)^2} = \sqrt{0 \cdot 7488} = 0 \cdot 8653$

$\Rightarrow \quad \theta_a = 59°55' \gg 60°$

Therefore, the range of angle of incidence is $0 < i < 60°$

(b) In case there is no outer coating, then $n_2 = 1$ (for air)

$\therefore$ critical angle for reflection

$$\theta_c = \sin^{-1}\left(\frac{1}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.68}\right) = 36°32'$$

Now for $\quad i = 90°, \quad \dfrac{\sin i}{\sin r} = n_1$

$\Rightarrow \quad \dfrac{\sin 90°}{\sin r} = 1 \cdot 68 \quad$ or $\quad r = 36°32'$

$\therefore$ Using $r + i = 90° \Rightarrow i = 90° - r$
$\qquad\qquad\qquad = 90° - 36°32' \quad = 53°28'$

Clearly, $\quad i > i'_c \, (36°32')$

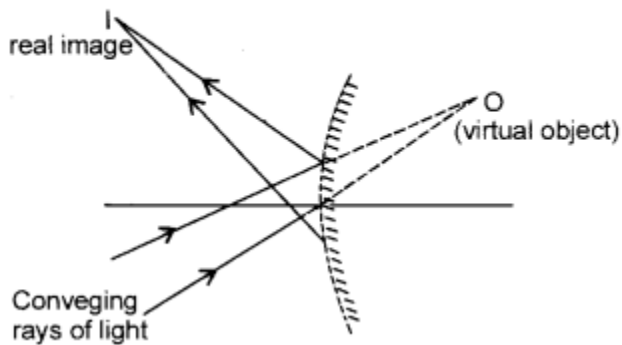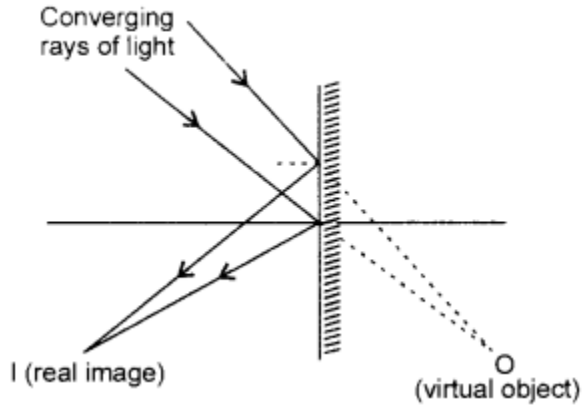Therefore all incident rays in the range 0 to 90° suffer total internal refletion.

Question 18.
Answer the following questions:
(a) You have learned that plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances ? Explain.
(b) A virtual image, we always say, cannot be caught on a screen. Yet when we 'see' a virtual image, we are obviously bringing it on to the 'screen' (i.e., the retina) of our eye. Is there a contradiction?
(c) A diver under water, looks obliquely at a fisherman standing on the bank of a lake, would the fisherman look taller or shorter to the diver than what he actually is ?
(d) Does the apparent depth of a tank of water change if viewed obliquely ? If so, does the apparent depth increase or decreases
(e) The refractive index of diamond is much greater than that of ordinary glass. Is this fact of some use to a diamond cutter ?

Answer:
(a) Yes. They can produce real images if the object is a virtual object as shown in figure.

Converging rays of light

I (real image)   O (virtual object)

I real image   O (virtual object)

Conveging rays of light

(b) here is no contradiction in this case. The virtual image of the object acts as an object for the convex lens of our eye and the lens of our eye make a real image of this object on the ratina.

(c) Let AB be the fisherman standing on the bank of the lake. The rays of light from the head of the fisherman bends towards the normal on refraction at the interface separating water and air. The refracted rays appear to come from point B' instead of point B for the fish. Thus, for a diver the height of the fisherman is AB' which is greater than his actual height AB.
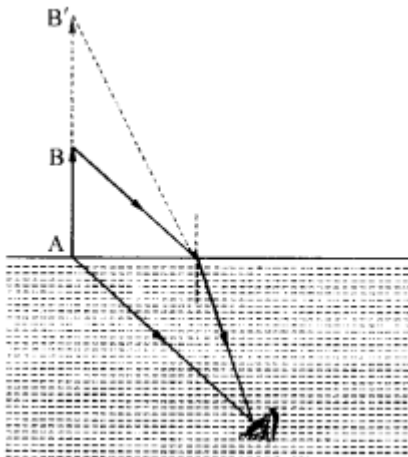
(d) The apparent depth of a pond of water decreases when viewed obliquely. This is due to the refraction of light from the surface of water.
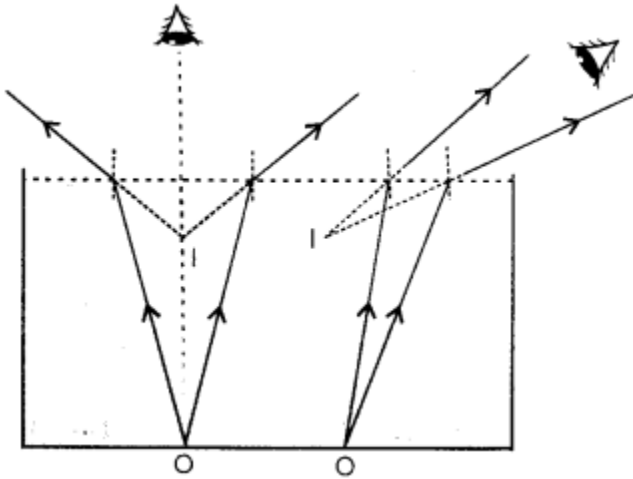
Question 19.
The image of a small electric bulb fixed on the wall of a room is to be obtained on the opposite wall 3 m away by means of a large convex lens. What is the maximum possible focal length of the lens required for the purpose ?

Answer:
The minimum distance between a real object and its real image formed by a convex lens of focal length/is given by L = 4f

Question 20.
A screen is placed 90 cm from an object. The image of the object on the screen is formed by a convex lens at two different locations separated by 20 cm. Determine the focal length of the lens.

Answer:
Let O be the position of object and I is the position of image when lens is at L_1 and then at L_2
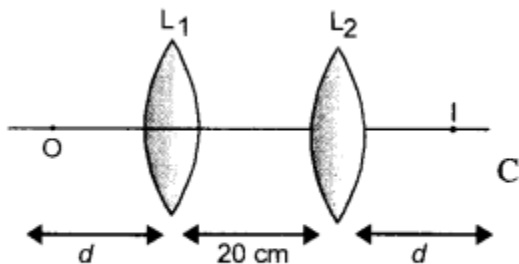
Now $d + 20 + d = 90$ or $d = 35$ cm

When lens is at L_1, then $u = -d = -35$cm, $v = 20 + d = 55$ cm

Using $\dfrac{1}{-u} + \dfrac{1}{v} = \dfrac{1}{f}$, we get

$$\frac{1}{f} = \frac{1}{35} + \frac{1}{55} = \frac{18}{385}$$

or $\qquad f = \dfrac{385}{18} = 21.4$ cm

Question 21.
(a) Determine the effective focal length of the combination of the two lenses in the question 910 if they are placed 8.0 cm apart with their principal axes coincident. Does the answer depend on which side a beam of parallel light is incident ? Is the notion of effective focal length of this

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system useful at all ?

(b) An object 1.5 cm in size is placed on the side of the convex lens in the above arrangements. The distance between the object and the convex lens is 40 cm. Determine the magnification produced by the two-lens system, and the size of the image.

Answer:

(a) As $-\dfrac{1}{u_1}+\dfrac{1}{v_1}=\dfrac{1}{f_1}$ we have $-\dfrac{1}{-\infty}+\dfrac{1}{v}=\dfrac{1}{30}$ i.e.

$v_1 = 30$ cm

This image formed by convex lens appears as an object placed at 30 – 8 cm = 22 cm from the convex lens on the right hand side.

∴ Using $-\dfrac{1}{u_2}+\dfrac{1}{v_2}=\dfrac{1}{f_2}$, we have,

$$-\dfrac{1}{22}+\dfrac{1}{v_2}=\dfrac{1}{-20}$$

i.e.

$$\dfrac{1}{v_2}=\dfrac{-1}{20}+\dfrac{1}{22}=\dfrac{-11+10}{220}=\dfrac{-1}{220}$$

∴ $v_2 = -220$ cm

⇒ The parallel beam of light appears to diverge from $(220 - 8) = 212$ cm from the convex lens from the left.
Now let the parallel beam of light fall on the concave lens after which the convex lens is placed at 8 cm.

Then $\dfrac{-1}{u_1} + \dfrac{1}{v_1} = \dfrac{1}{f_1} \quad \Rightarrow \quad \dfrac{-1}{-\infty} + \dfrac{1}{v_1} = \dfrac{1}{-20}$

or $\qquad v_1 = -20$ cm

⇒ the image is formed -20 cm to the left of concave length and ∴ it is $20 + 8 = 28$ cm to the left of convex lens.

Again, $-\dfrac{1}{u_2} + \dfrac{1}{v_2} = \dfrac{1}{f_2} \quad \Rightarrow \quad \dfrac{-1}{-28} + \dfrac{1}{v_2} = \dfrac{1}{30}$

i.e. $\quad \dfrac{1}{v_2} = \dfrac{1}{30} - \dfrac{1}{28} = \dfrac{14-15}{420} = \dfrac{-1}{420}$

i.e. $\quad v_2 = -420$ cm

⇒ the light appears to diverge from a point at 420 cm to the left of convex lens.
Clearly the answer depends upon the side of incidence so the notion of effective focal length is not useful in this case.

(b) Using $-\dfrac{1}{u_1} + \dfrac{1}{v_1} = \dfrac{1}{f_1}$ we have $\dfrac{1}{40} + \dfrac{1}{v_1} = \dfrac{1}{30}$

i.e. $\quad \dfrac{1}{v_1} = \dfrac{1}{30} - \dfrac{1}{40} = \dfrac{4-3}{120} = \dfrac{1}{120}$

∴ $\qquad v_1 = 120$ cm

∴ Magnification produced by convex lens,

$$m_1 = \frac{v_1}{|u_1|} = \frac{120}{40} \quad \Rightarrow \quad m_1 = 3$$

Now $u_2 = 120 - 8 = 112$ cm(*i.e.* object is to the right of concave lens)

$$f_2 = -20 \text{ cm}$$

$$\therefore \quad -\frac{1}{u_2} + \frac{1}{v_2} = \frac{1}{f_2} \quad \Rightarrow \quad -\frac{1}{112} + \frac{1}{v_2} = \frac{1}{-20}$$

or $\quad \dfrac{1}{v_2} = -\dfrac{1}{20} + \dfrac{1}{112} = \dfrac{-28+5}{560} = \dfrac{-23}{560}$

$$\therefore \quad v_2 = -\frac{560}{23}$$

$\therefore$ magnification produced by concave lens, $m_2 = \dfrac{|v_2|}{u_2}$

$$\Rightarrow \quad m_2 = \frac{\frac{560}{23}}{112} = \frac{5}{23}$$

$\therefore$ Net magnification $m = m_1 \times m_2$

$$= 3 \times \frac{5}{23} = 0 \cdot 65$$

$\therefore$ Size of image $= m \times$ size of object
$$= 0 \cdot 65 \times 1 \cdot 5 = 0 \cdot 98 \text{ cm}$$

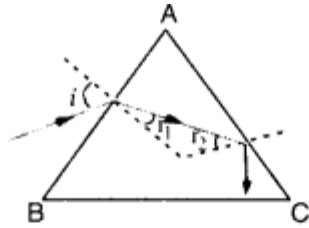**Question 22.**
At what angle should a ray of light be incident on the face of a prism of refracting angle 60° so that it just suffers total internal reflection at the other face ? The refractive index of the material of the prism is 1.524.
Answer:
Let the ray of light be incident on the face AB at angle i so that it is totally internally reflected at

face AC.

For total internal reflection $r_2 \geq \theta_c$

Now $\quad \sin \theta_c = \dfrac{1}{n} = \dfrac{1}{1.524} = 0.6562$

$\therefore \quad \theta_c = 41°$

$\therefore$ for total internal reflection $r_2 = C = 41°$

using $\quad A = r_1 + r_2$, we get $r_1 = A - r_2$

$\qquad\qquad\qquad = 60° - 41° = 19°$

Now using $\quad \dfrac{\sin i}{\sin r_1} = n$, we get $\dfrac{\sin i}{\sin 19°} = 1.524$

or $\quad \sin i = 1.524 \sin 19° = 0.4962$

$\therefore \quad i = \sin^{-1} 0.4962$

$\qquad\qquad = 29°45' \approx 30°$

Question 23.
You are given prism made of crown glass and flint glass with a wide variety of angles. Suggest a combination of prisms which will (a) deviate a pencil of white light without much dispersion (b) disperse (and displace) a pencil of white light without much deviation.
**Answer:**
(a) Angular dispersion produced by two prisms i.e. crown glass and flint glass should be zero in this case

i.e. $(n_{blue} - n_{red})A + (n'_{blue} - n'_{red})A' = 0$

or $A' = \dfrac{-(n_b - n_r)A}{(n'_b - n'_r)}$

$A' < A$ because $(n'_{blue} - n'_{red})$ for flint glass prism is more than $(n_{blue} - n_{red})$ for crown glass.

Thus crown glass prism of larger angle is to be combined with a smaller angled flint glass prism in opposite order as shown in figure.
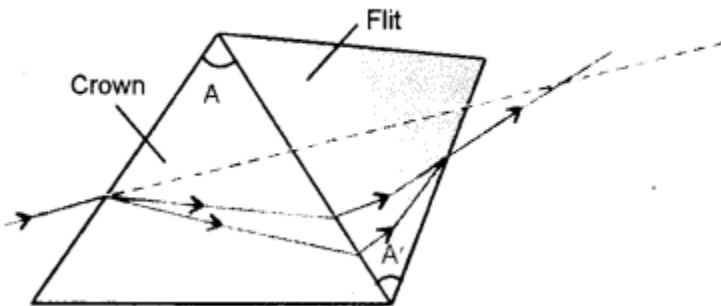
(b) For no deviation,

$$(n - 1)A + (n' - 1)A' = 0$$

or $A' = \dfrac{-(n - 1)A}{(n' - 1)}$

In the combination of prisms, flint glass prism of greater angle may be tried but in any case still this angle will be smaller than the angle of the crown glass prism in opposite order as shown in figure.

Question 24.
For a normal eye, the far point is at infinity and the near point of distinct vision is about 2.5 cm in front of the eye. The cornea of the eye provides a converging power of about 40 dioptres, and the least converging power of the eye lens behind the cornea is about 20 dioptres. From this rough data estimate the range of accommodation {i.e., the range of converging power of the eye-lens) of a normal eye.
Answer:
When the object is placed at infinity, the eye makes use of the least converging power, Therefore, total converging power of cornea and the eye lens = 40 + 20 = 60 dioptre.

Here, $u = -\infty$, $f = \dfrac{1}{P} = \dfrac{1}{60}$ m

Using $-\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$, we get

$$u = -\infty, \quad f = \dfrac{1}{P} = \dfrac{1}{60} \text{ m}$$

$\therefore \dfrac{-1}{-\infty} + \dfrac{1}{v} = 60 \Rightarrow v = \dfrac{1}{60}\text{m} = \dfrac{100}{60}\text{cm}$

or $\quad v = \dfrac{5}{3}$ cm

To focus the object at the near point,

$$u = -25 \text{ cm}; \quad v = \dfrac{5}{3} \text{ cm}$$

Using, $-\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$, we get $\dfrac{1}{f} = \dfrac{-1}{-25} + \dfrac{1}{\frac{5}{3}} = \dfrac{1}{25} + \dfrac{3}{5}$

or $\quad \dfrac{1}{f} = \dfrac{1+15}{25} = \dfrac{16}{25}$

$\therefore$ Power $P = \dfrac{100}{f(cm)}$ dioptre $= \dfrac{100}{25} \times 16 = 64$ dioptre

$\Rightarrow$ Power of eye lens = 64 – 40 = 24 dioptre. Therefore, the rough range of eye lens is 20 to 24 dioptre.

Question 25.
Does short-sightedness (myopia) or long-sightedness (hypermetropia) imply necessarily that the eye has partially lost its ability of accommodation ? If not, what might cause these defects of vision ?
Answer:
No. Myopia may arise due to the elongation of the eye ball and hypermetropia may arise due to the decrease in the size of the eye ball even when the eye has the normal ability of accommodation. There is another defect in the eye called presbyopia similar to hypermetropia. However, the causes of presbyopia and hypermetropia are different. Presbyopia arises in elderly persons and is corrected by using a bi-focal lens.

Question 26.
A myopic person has been using spectacles of power – 1.0 dioptres for distant vision. During old age he also needs to use separate reading glass of power +2 dioptres. Explain what may have happened.
Answer:
For -1.0 dioptre, the far point for eyes is 1 m i.e. 100 cm. The near point is 25 cm. The objects lying at infinity are brought at 100 cm from his eyes using the concave lens and the objects lying in between 25 cm and 100 cm are brought to focus using the ability of accommodation of the eye lens. In the old age, this ability of accommodation is reduced and the near point reaches 50 cm from his eyes.

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Using $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$, we get $-\dfrac{1}{50} + \dfrac{1}{25} = \dfrac{1}{f}$ i.e. $f = 50\,\text{cm}$

and $\qquad P = \dfrac{100}{f} = \dfrac{100}{50} = 2$ dioptre

The person requires glasses of $+2$ dioptre.

Question 27.
A person looking at a mesh of crossed wires is able to see the vertical wires more distinctly than the horizontal wires. What is this defect due to ? How is such a defect of vision corrected ?

Answer:
This is due to the defect of lenses called astigmatism. The defect arises because of the fact that curvature of the eye-lens and the cornea is not same in different planes. This defect is removed by using cylindrical lens with vertical axis.

Question 28.
A man with normal near point (25 cm) reads a book with small print using a magnifing glass: a thin convex lens of focal length 5 cm.
(a) What is the closest and the farthest distance at which he can read the book when viewing through the magnifying glass ?
(b) What is the maximum and minimum angular magnification (magnifying power) possible using the above simple microscope ?

Answer:
(a) To see the object at a closest distance, the image of object should be formed at the least distance of distinct vision.

Using $-\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$ we have $-\dfrac{1}{u} - \dfrac{1}{25} = \dfrac{1}{5}$ i.e. $-\dfrac{1}{u}$

$= \dfrac{1}{5} + \dfrac{1}{25} = \dfrac{5+1}{25} = \dfrac{6}{25}$

$\therefore \qquad u = \dfrac{-25}{6} = -4 \cdot 2\ \text{cm}$

$\Rightarrow$ the object is to be placed at 4.2 cm from the magnifying glass.

Also, to see the object at the farthest point, its image must be formed at infinity,

$$\therefore \quad -\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \quad i.e. \quad -\frac{1}{u}+\frac{1}{-\infty}=\frac{1}{5}$$

i.e. $u = -5$ cm

i.e. the object is to be placed at 5 cm from the magnifying glass.

(b) Angular magnification, $m = \dfrac{D}{|u|}$

$\therefore$ maximum angular magnification $= \dfrac{25}{25/6} = 6$

and minimum angular magnification $= \dfrac{25}{5} = 5$.

Question 29.

A card sheet divided into squares each of size 1 mm^2 is being viewed at a distance of 9 cm through a magnifying glass (a converging lens of focal length 10 cm) held close to eye.
(a) What is the magnification (image size/object size) produced by the lens ? How much is the area of each square in the virtual object ?
(b) What is the angular magnification (magnifying powers) of the lens ?
(c) Is the magnification in
(1) equal to magnifying power in
(2) ? Explain.

Answer:

(a) Using the lens formula, $-\dfrac{1}{u}+\dfrac{1}{v}=\dfrac{1}{f}$ when $f = 10$ cm, $u = -9$ cm, we get

$$\therefore -\frac{1}{-9}+\frac{1}{v}=\frac{1}{10} \quad i.e. \quad \frac{1}{v}=\frac{1}{10}-\frac{1}{9}=\frac{9-10}{90} \quad i.e. \quad v = -90 \text{ cm}$$

Linear magnification $= \dfrac{v}{u} = \dfrac{-90}{-9} = 10$

$\therefore$ Area of each square in the image
$= (1 \text{ mm} \times 10) \times (1 \text{ mm} \times 10) = 100 \text{ mm}^2 = 1 \text{ cm}^2$

(b) Angular magnification $= \dfrac{D}{|u|} = \dfrac{25}{9} \approx 2.8$

(c) Clearly magnification and power magnification are not equal to each other unless the image is located near the least distance of distinct vision, e. v = D.

Question 30.

(a) At what distance should the lens be held from the figure in the above exercise in order to view the squares distinctly with maximum possible magnifying power ?
(b) What is the magnification (image size/object size) in this case ?
(c) Is the magnification equal to magnifying power in this case ? Explain.

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Answer:

(a) The magnifying power is maximum if the image is formed at the least distance of distinct point from the eye, i.e., if v = -25 cm ; Also, f = 10 cm

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

$$i.e., \quad \frac{1}{u} = -\frac{1}{10}-\frac{1}{25} = \frac{-5-2}{50} = \frac{-7}{50}$$

$$\therefore \quad u = -\frac{50}{7} \text{ cm} = -7.14 \text{ cm}$$

(b) Linear magnification $= \dfrac{v}{u} = \dfrac{-25}{-\frac{50}{7}} = 3.5$

(c) Angular magnification $= \dfrac{D}{|u|} = \dfrac{25}{\frac{50}{7}} = 3.5$

=> the linear magnification and magnifying power is equal in this case.

Question 31.

What should be the distance between the object in the previous exercise and the magnifying glass if the virtual image of each square in the figure is to have an area 6.25 mm²? Would you be able to see the squares distinctly with your eyes very close to the magnifier?

Answer:

The new area to be observed = 6.25 mm².

$\therefore$ Length of each side $= \sqrt{6.25} = 2.5$ mm

Now linear magnification

$$= \frac{\text{size of image}}{\text{size of object}} = \frac{v}{u} \Rightarrow \frac{v}{u} = \frac{2.5 \text{ mm}}{1 \text{ mm}} = 2.5 \Rightarrow v = 2.5\,u$$

Now using $\dfrac{1}{f} = -\dfrac{1}{u}+\dfrac{1}{v}$

$$\Rightarrow \quad \frac{1}{10} = -\frac{1}{u}+\frac{1}{2.5\,u} = \frac{-2.5+1}{2.5\,u} = \frac{-1.5}{2.5\,u}$$

$$\Rightarrow \quad u = -6 \text{ cm}$$

Therefore, $v = 2.5\,u = -2.5 \times 6 = -15$ cm

Since $|v| = 15$ cm < 25 cm $i.e.$, the image lies at distance less than the least distance of distinct vision from the eye, it can not be observed distinctly.

Question 32.

Answer the following questions :

(a) The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virutal image produced by a magnifying glass. In what sense then does a magnifying glass provide angular magnification?

(b) In viewing through a magnifying glass, one usually positions one's eyes very close to the lens. Does angular magnification change if the eye is moved back?

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(c) Magnifying power of a simple microscope is inversely proportional to the focal length of the lens. What then stops us from using a convex lens of smaller and smaller focal length and achieving greater and greater magnifying power?

(d) Why must both the objective and the eye-piece of a compound microscope have short focal lengths?

(e) When viewing through a compound microscope, our eyes should be positioned not on the eye-piece but a short distance away from it for best viewing. Why? How much should be that short distance between the eye and eyepiece?

Answer:

(a) When magnifying glass is not used, object to be seen clearly is to be placed at 25 cm. However, while using magnifying glass, object can be placed closer to eye than at 25 cm. The closer object has large angular size than the same object placed at 25 cm. It is in this sense that magnifying glass provides angular magnification.

(b) Yes. The angular magnification decreases slightly because angle subtended at eye is somewhat less than the angle subtended at the lens.

(c) The aberrations like spherical and chromatic aberrations start croping up if the convex lens of smaller and smaller focal length is made.

(d) Angular magnification of eye piece is given by $(1+D/f_e)$ and angular magnification of objective is approximately given by v/f_0. Clearly for better magnification focal length of eye piece f_e and focal length of objective f_e should be small.

(e) If we position our eye very close to the eyepiece, the whole light will not fall on our eye and the field of view will decrease. So we place our eye a short distance away from the eye-piece to collect the large amount of light refracted through the eyepiece to increase the field of view.

Question 33.
An angular magnification (magnifying power) of 30 X is desired using an objective of focal length 1.25 cm and eye piece of focal length 5 cm. How will you set up the compound microscope ?

Answer:
For the image formed at the least distance of distinct vision, the magnifying power is given by

$$m = m_o . m_e$$

Here $m_o = \dfrac{v_o}{-u_o}$ and $m_e = 1 + \dfrac{D}{f_e}$

Using $m_e = 1 + \dfrac{D}{f_e}$, we get, $1 + \dfrac{25}{5} = 6$

$\therefore$ $m = m_o . m_e$ i.e. $m_o = \dfrac{m}{m_e} = \dfrac{30}{6} = 5$

Now $m_o = \dfrac{v_o}{-u_o}$ i.e. $\dfrac{v_o}{-u_o} = 5$ i.e. $v_o = -5u_o$

$\therefore$ Using $-\dfrac{1}{u_o} + \dfrac{1}{v_o} = \dfrac{1}{f_o}$, we get,

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$$-\frac{1}{u_o} - \frac{1}{5u_o} = \frac{1}{f_o} \quad \text{or} \quad \frac{-5-1}{5u_o} = \frac{1}{1.25}$$

or

$$u_o = -\frac{6}{5} \times 1.25 = -1.5 \text{ cm}$$

∴

$$v_o = -5u_o = -5 \times (-1.5) = 7.5 \text{ cm}$$

Again using $-\dfrac{1}{u_e} + \dfrac{1}{v_e} = \dfrac{1}{f_e}$, we get

$$-\frac{1}{u_e} + \frac{1}{-25} = \frac{1}{5} \qquad (\because \text{ image is formed at 25 cm)}$$

∴

$$\frac{-1}{u_e} = \frac{1}{5} + \frac{1}{25} = \frac{5+1}{25} = \frac{6}{25}$$

or

$$u_e = -\frac{25}{6} \text{ cm} = -4.17 \text{ cm}$$

∴ $|u_e| = 4.17$ cm

Thus, the distance between the objective and the eyes
lens $= v_o + |u_e| = 7.5 + 4.17 = 11.67$ cm
Also, the position of the object from the objective lens
$= |u_o| = 1.5$ cm

Question 34.

A small telescope has an objective lens of focal length 140 cm and an eye piece of focal length 5.0 cm. What is the magnifying power of the telescope for viewing distant objects when
(a) the telescope is in normal adjustment (i.e.,when the final image is formed at infinity) ?
(b) the final image is formed at the least distance of distinct vision (25 cm) ?

Answer:

(a) In normal adjustment,

$$|m| = \frac{f_o}{|f_e|} = \frac{140}{5} = 28$$

(b) When the image is formed at the least distance of distinct vision,

$$|m| = \frac{f_o}{|f_e|}\left(1+\frac{f_e}{D}\right) = \frac{140}{5}\left(1+\frac{5}{25}\right)$$

$$= 28 \times \frac{6}{5} = 33.6$$

Question 35.

For the telescope described in the last exercise, in 9.34
(a) what is the separation between the objective lens and the eye-piece ?
(b) If this telescope is used to view a 100 m tall tower 3 km away, what is the height of image of the tower formed by objective lens ?

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(c) What is the height of final image of the tower if it is formed at 25 cm ?

Answer:

(a) Since the final image is formed at infinity, the distance between the object lens and the eye-piece is $f_0 + f_e = 140 + 5 = 145$ cm

(b) The angle subtended by the tower is

$$\alpha = \frac{\text{Height of tower}}{\text{Distance of tower}} = \frac{100}{3000} = \frac{1}{30}$$

Also, if h is the size of image formed by the object, then

$$\alpha = \frac{h}{f_o} = \frac{h}{140}$$

$$\therefore \quad \frac{h}{140} = \frac{1}{30} \Rightarrow h = \frac{140}{30} = 4\cdot7 \text{ cm}$$

(c) Angular magnification of eye piece is

$$= \left(1 + \frac{D}{f_e}\right) = 1 + \frac{25}{5} = 6$$

$\therefore$ Height of the final image $= 6h = 6 \times 4\cdot7 = 28\cdot2$ cm

Question 36.

A cassegrain telescope uses two mirrors as shown in figure. Such a telescope is built with mirrors 20 mm apart. If the radius of curvature of large mirror is 220 mm and the small mirror is 140 mm, where will be the final image of an object at infinity be ?
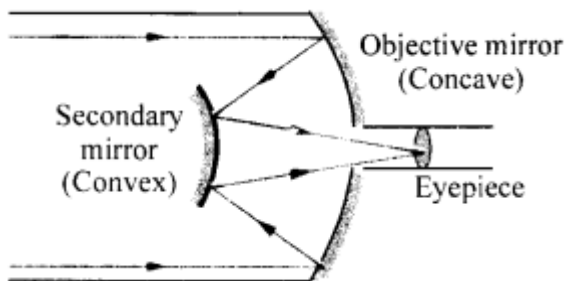
Answer:

$$f_0 = \frac{220}{2} = 110 \text{ mm}$$

Object at infinity will form an image at 110 mm.

This image will act as virtual object for the smaller mirror.

Distance of virtual object for small mirror,
$u = 110 - 20 = 90$ mm

$$f_s = \frac{140}{2} = 70 \text{ mm}$$

Using mirror formula, $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$, we get

$$\frac{1}{v} = \frac{1}{f_s} - \frac{1}{u} = \frac{1}{70} - \frac{1}{90} = \frac{1}{315} \text{ mm}$$

Question 37.

The adjoining figure shows an equiconvex lens (of refractive index 1.50) in contact with a liquid layer on top of a plane mirror. A small needle with its tip on the principal axis is moved along the axis until its inverted image is found at the position of the needle. The distance of the needle from the lens is measured to be 45.0 cm. The liquid is removed and the experiment is repeated. The new distance is measured to be 30.0 cm. What is the refractive index of liquid ?
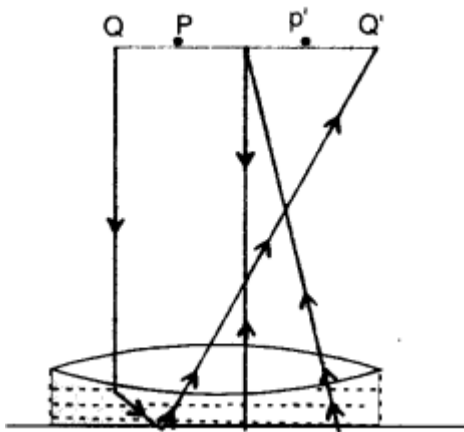
Answer:

In the presence of the liquid, the distance of the needle from the lens is equal to the focal length f of the combination of the convex lens and the piano concave lens formed by the liquid below it i.e. f = 45 cm. Also n = 1.5

In the absence of the liquid, the distance of the needle and the lens is equal to the focal length of the convex lens only i.e. f = 30 cm

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∴ If f_2 is the focal length of plane concave lens formed

by the liquid, then $\dfrac{1}{f_1} + \dfrac{1}{f_2} = \dfrac{1}{f}$

or $\quad \dfrac{1}{f_2} = \dfrac{1}{f} - \dfrac{1}{f_1} = \dfrac{1}{45} - \dfrac{1}{30} = \dfrac{2-3}{90} = \dfrac{-1}{90}$

⇒ $\quad f = -90$ cm

Using the Lens maker's formula,

$$\dfrac{1}{f} = (n-1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right), \text{ we get}$$

$$\dfrac{1}{30} = (1\cdot5 - 1)\left(\dfrac{1}{R} - \left(-\dfrac{1}{R}\right)\right)$$

$$(\because R_1 = R \text{ and } R_2 = -R)$$

$$= 0\cdot5 \times \dfrac{2}{R} = \dfrac{1}{R} \implies R = 30 \text{ cm}$$

For the plano convex lens formed by the liquid

$\quad f_2 = -90$ cm, $n = ?$, $R_2 = \infty$ and $R_1 = -30$ cm

∴ Using $\dfrac{1}{f_2} = (n-1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$, we get,

$$\dfrac{1}{-90} = (n-1)\left(-\dfrac{1}{30} - \dfrac{1}{\infty}\right)$$

i.e. $\quad n - 1 = \dfrac{30}{90} = \dfrac{1}{3}$

i.e. $\quad n = 1 + \dfrac{1}{3} = \dfrac{4}{3} = 1\cdot33$