NCERT SOLUTIONS
CLASS-XII PHYSICS
CHAPTER-9
RAY OPTICS & OPTICAL INSTRUMENTS

Question 1:

A candle which is 2.5 cm in height is placed 27 cm in front of a concave mirror having radius of curvature 36 cm. Find the distance from the mirror at which the screen should be placed to obtain a sharp image? Detail the size and nature of the image.

By how much the screen have to be moved if the candle is moved towards the mirror?

Answer

Height of the candle, h =2.5 cm

Image size=h'

Object distance, u= -27 cm

Radius of the concave mirror, R= -36 cm

Focal length of the concave mirror, f=$\frac{R}{2}$ =-18 cm

Image distance=v

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

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

$=\frac{1}{-18}-\frac{1}{-27}=\frac{-3+2}{54}=-\frac{1}{54}$

$\therefore$v=-54cm

Therefore, the screen should be placed at a distance of 54 cm away from mirror to obtain a sharp image

Magnification of the Image is:

$m=\frac{h'}{h}=-\frac{v}{u}\therefore h'=\frac{-v}{u}\times h$

$=-(\frac{-54}{-27})\times 2.5$=-5cm

The height of the candle's Image Is 5 cm. The image Is inverted and virtual since there is a negative sign.

If we move the candle closer to the mirror the screen will also have to be moved away from the mirror to obtain the image.

Question 2:

A needle which is 4.5cm in size is placed 12cm away from a convex mirror having a focal length of 15cm. Find the location and the magnification of the image. Also find what happens as the needle is moved away from the mirror

Answer :

Size of the needle, h1=4.5 cm

Object distance, u=-12 cm

Focal length of the convex mirror, f= 15 cm

Image distance= v

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

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

$\frac{1}{15}+\frac{1}{12}=\frac{4+5}{60}=\frac{9}{60}$

Therefore

$\frac{60}{9}$=6.7cm

We found that the image of the needle is 6.7 cm away from the mirror and is on the other side of the mirror.

By using the magnification formula:

$m=\frac{h_2}{h_1}=-\frac{v}{u}\,h_2=\frac{-v}{u}\times h_1$

$= \frac{-6.7}{-12} \times \mathbf{4.5}$=+2.5cm

$m = \frac{h_2}{h_1} = \frac{2.5}{4.5}$=0.56

Height of the image is found to be 2.5 cm. The image is erect, virtual and diminished since it shows a positive sign

If we move the needle farther from the mirror the image will also move away from the mirror, and the size of image will also reduce gradually.

Question 3:

Height of a tank containing water is 12.5cm and by using a microscope the apparent depth of needle lying at the bottom is measured to be 9.4cm. Find the refractive index of water? By what distance would the microscope have to be moved to focus again if water is replaced by a liquid of refractive index 1.63 filled up to the same height?

Answer:

Actual depth of the needle in water, h1=12.5cm

Apparent depth of the needle in water, h2 =9.4 cm

Refractive Index of water =μ

The value of μ can be obtained as follows:

$\mu = \frac{h_1}{h_2}$

$\frac{12.5}{9.4}$=1.33

Hence, 1.33 is the refractive index of water.

Now water is replaced by a liquid of refractive index 1.63

The actual depth of the needle remains the same, but its apparent depth changes.

Let x be the new apparent depth of the needle.

$\mu^{\text{‘}} = \frac{h_1}{x}$

Therefore y=$\frac{h_1}{\mu^{\text{‘}}}$

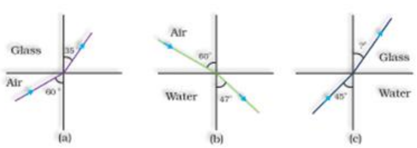
$\frac{12.5}{1.63}$=7.67cm

Hence 7.67cm is the new apparent depth of the needle. We found that the value is less than h_2

Therefore the needle should be moved up to focus again

Distance to be moved to focus=9.4-7.67=1.73cm

Question 4:



Refraction of a ray which is incident at 60° with the normal to a glass-air and water-air interface is shown in the above figures (a) and (b). What will be the angle of refraction in glass when the angle of incidence in 45° with the normal to a water-glass interface(c)

For the glass-air interface:

Angle of incidence, i =60°

Angle of refraction, r=35°

According to Snell's law the refractive index of glass with respect to air is given by:

$\mu_g^a = \frac{sin\ i}{sin\ r}$ ———-(i)

$= \frac{sin\ 60^\circ}{sin\ 35^\circ} = \frac{0.8660}{0.5736} = \mathbf{1.51}$

For the air-water interface:

Angle of incidence, i=60°

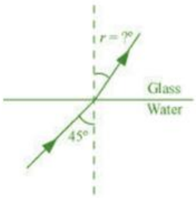
Angle of refraction, r=47°

According to Snell's law the refractive index of water with respect to air is given by:

$$\mu_w^a = \frac{sin\ i}{sin\ r} \qquad \text{——————(ii)}$$
$$= \frac{sin\ 60^\circ}{sin\ 47^\circ} = \frac{0.8660}{0.7314} = 1.184$$

With the help of equations (i) and (ii) the relative refractive index of glass with respect to water can be found:

$$\mu_g^w = \frac{\mu_g^a}{\mu_w^a}$$
$$= \frac{1.51}{1.184} = 1.275$$



Angle of incidence, i= 45°

Angle of refraction= r

r can be calculated from Snells's law=

$$\frac{sin\ i}{sin\ r} = \mu_g^w$$
$$\frac{sin 45^\circ}{sin\ r} = 1.275$$
$$sin\ r = \frac{\frac{1}{\sqrt{2}}}{1.275} = 0.5546$$
$$Therefore\ r = sin^{-1}(0.5546) = 38.68^\circ$$

Therefore, the angle of refraction at the water -glass Interface is 38.68°.

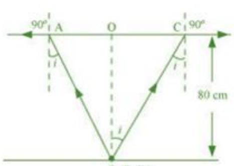
Question 5:

At the bottom of a tank having a depth of 80cm there is a small bulb placed. Find the area of the surface of water through which light can come out of the bulb. Lets consider the bulb to be a point source and refractive index of water is 1.33

Answer :

Actual depth of the bulb in water, d1=80 cm =0.8 m

Refractive Index of water, μ= 1.33



I = Angle of incidence

r =Angle of refraction – 90°

Emergent light is considered as a circle of radius since the bulb is a point source

R=$\frac{AC}{2}$=AO=OB

Using Snell's law, we can write the relation for the refractive index of water as:

$$\mu = \frac{sin\ r}{sin\ i}$$
$$1.33 = \frac{sin\ 90^\circ}{sin\ i}$$
$$Therefore\ i = sin^{-1}(\frac{1}{1.33}) = 48.75^\circ$$

The relation:

tan i=$\frac{OC}{OB} = \frac{R}{d_1}$

Therefore R=$tan\ 48.75^\circ \times 0.8 = 0.91m$

Area of the surface of water=$nR^2 = n(0.91)^2 = 2.61m^2$

$2.61m^2$ is found to be the area of water through which the light from the water can emerge out.

Question 6:

There is a prism which is made of glass of unknown refractive index and a parallel bean of light is incident on the face of the prism. 40° is found to be the angle of minimum deviation. Find the refractive index of the material with which the prism is made. The angle of refraction of prism is 60°. Find the angle of minimum deviation when a parallel beam of light is passed through it when the prism is placed in water. (Refractive index 1.33)

Answer:

Angle of minimum deviation, $\delta_m = 40^\circ$

Angle of the prism, A = 60°

Refractive Index of water, $\mu = 1.33$

Refractive Index of the material= $\mu‘$

The angle of deviation is related to refractive index ($\mu‘$)

$\mu‘$=$\frac{sin\frac{A+\delta m}{2}}{sin\frac{A}{2}}$

=$\frac{sin\frac{60^\circ+40^\circ}{2}}{sin\frac{60^\circ}{2}} = \frac{sin50^\circ}{sin30^\circ}$=1.532

1.532 is the refractive index of the material of the prism

δ_m is the new angle of minimum deviation since the prism is immersed in water.

The relation shows the refractive index of glass with respect to the water:

$$\delta_g^w = \frac{\mu‘}{\mu} = \frac{sin\frac{(A+\delta_m')}{2}}{sin\frac{A}{2}}$$
$$sin\frac{(A+\delta_m')}{2} = \frac{\mu‘}{\mu}sin\frac{A}{2}$$
$$sin\frac{(A+\delta_m')}{2} = \frac{1.532}{1.33} \times sin\frac{60^\circ}{2} = 0.5759$$
$$\frac{(A+\delta_m')}{2} = sin^{-1}0.5759 = 35.16^\circ$$
$$60^\circ + \delta_m' = 70.32^\circ$$
$$Therefore\ \delta_m' = 70.32^\circ - 60^\circ = 10.32^\circ$$

10.32° is the new minimum angle of deviation.

Question 7:

A glass with refractive index 1.55 is used to make double convex lenses with both sides having the same radius of curvature. The focal length is 20cm and hence find the radius of curvature required

Answer:

Refractive Index of glass, $\mu = 1.55$

Focal length of the double-convex lens, f=20 cm

Radius of curvature of one face of the lens=R1

Radius of curvature of the other face of the lens=R2

Radius of curvature of the double-convex lens=R

Therefore $R_1 = R\ and\ R_2 =-R$

Calculate the value of R

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$
$$\frac{1}{20} = (1.55 - 1)\left[\frac{1}{R} + \frac{1}{R}\right]$$
$$\frac{1}{20} = 0.55 \times \frac{2}{R}$$
$$Therefore\ R = 0.55 \times 2 \times 20 = 22cm$$

Hence 22cm is the radius of curvature of the double-convex lens.

Question 8:

At a point P a beam of light converges. A lens can be placed on the way of convergent beam 12 cm from P. Find the point at which the beam converge if the lens is (i)20 cm focal length convex lens and (ii) 16cm focal length concave lens

Answer :

The object is virtual and the image formed is real.

Object distance, u= +12 cm

(i) Focal length of the convex lens, f =20 cm

Image distance=v

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$
$$\frac{1}{v}-\frac{1}{12}=\frac{1}{20}$$
$$\frac{1}{v}=\frac{1}{20}+\frac{1}{12}=\frac{3+5}{60}=\frac{8}{60}$$
$$Therefore\ v=\frac{60}{8}=7.5cm$$

The image will be formed 7.5cm away from the lens, to the right.

(ii)

Focal length of the concave lens, f =-16 cm

Image distance =v

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$
$$\frac{1}{v}=-\frac{1}{16}+\frac{1}{12}$$
$$\frac{-3+4}{48}=\frac{1}{48}$$
$$Therefore\ v=48cm$$

Hence the image is formed to the right 48cm away from the lens

Question 9:

There is a concave lens of focal length 21cm and an object of size 3cm is placed 14cm in front of it. Analyze the image produced by the lens. What will happen if the object is moved further away from the lens?

Answer:

Size of the object, $h_1=3cm$

Object distance, u = -14 cm

Focal length of the concave lens, f = -21 cm

Image distance = v

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$
$$\frac{1}{v}=-\frac{1}{12}-\frac{1}{14}$$
$$\frac{-2-3}{42}=\frac{-5}{42}$$
$$Therefore\ v=-\frac{42}{5}=-8.4cm$$

Hence, the image is formed 8.4cm away and on the other side of the lens. We can understand that the image is virtual and erect from the negative sign.

$$m=\frac{Image\ height(h_2)}{Object\ height(h_1)}=\frac{v}{u}$$
$$Therefore\ h_2=\frac{-8.4}{-14}\times 3=0.6\times 3=1.8cm$$

1.8cm is the height of the image.

The virtual image will move toward the mirror if the object is moved further away from the lens. With increase in object distance the size of the image decreases.

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:

Focal length of the convex lens, f1=30cm

Focal length of the concave lens, f2= -20cm

Focal length of the system of lenses= f

The equivalent focal length of a system of two lenses in contact is given as:

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ $\frac{1}{f} = \frac{1}{30} + \frac{1}{20} = \frac{2-3}{60} = -\frac{1}{60}$

Therefore f=-60cm

Hence, the focal length of the combination of lenses is 60 cm. The negative sign indicates that the system of lenses acts as a diverging lens.

Question 11:

A compound microscope consists of an objective lens of focal length 2.0cm and an eyepiece of focal length 6.25cm 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), and (b) at infinity? What is the magnifying power of the microscope in each case?

Answer:

Focal length of the objective lens, f1=2.0 cm

Focal length of the eyepiece, f2=6.25 cm

Distance between the objective lens and the eyepiece, d =15 cm

(a) Least distance of distinct vision, d' = 25 cm

Image distance for the eyepiece, v_2= -25cm

Object distance for the eyepiece= u2

According to the lens formula, we have the relation:

$\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$ $\frac{1}{u_2} = \frac{1}{v_2} - \frac{1}{f_2}$ $\frac{1}{-25} - \frac{1}{6.25} = \frac{-1-4}{25} = \frac{-5}{25}$ $u_2 = -5cm$

Image distance for the objective lens, $v_1 = d + u_2 = I5-5 = 10cm$

Object distance for the objective lens = u_1

$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$ $\frac{1}{u_1} = \frac{1}{v_1} - \frac{1}{f_1}$ $\frac{1}{10} - \frac{1}{2} = \frac{1-5}{10} = \frac{-4}{10}$ $u_1 = -2.5cm$

Hence, the magnifying power of the microscope is 20.

(b) The final Image is formed at infinity.

Therefore image distance for the eyepiece, $v_2 = \infty$

Object distance for the eyepiece=u_2

According to the lens formula, we have the relation:

$\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$ $\frac{1}{\infty} - \frac{1}{u_2} = \frac{1}{6.25}$ $u_2 = -6.25cm$

Image distance for the objective lens, $v_1 = d + u_2 = 15 - 6.25 = 8.75cm$

Object distance for the objective lens=u1

According to the lens formula, we have the relation:

$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$ $\frac{1}{u_1} = \frac{1}{v_1} - \frac{1}{f_1}$ $\frac{1}{8.75} - \frac{1}{2.0} = \frac{2-8.75}{17.5}$ $u_1 = -\frac{17.5}{6.75} = -2.59cm$

Magnitude of the object distance, $|u_1|$=2.59 cm

The magnifying power of a compound microscope is given by the relation:

m=$\frac{v_1}{|u_1|}(\frac{d'}{|u_2|}$

=$\frac{8.75}{2.59} \times \frac{25}{6.25}$=13.51

Hence, the magnifying power of the microscope is 13.51.

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 eyepiece of focal length 2.5cm can bring an object placed at 9.0 mm from the objective in sharp focus. What is the separation between the two lenses? Calculate the magnifying power of the microscope,

Answer:

Focal length of the objective lens, f_o= 8 mm = 0.8 cm

Focal length of the eyepiece, f_e= 2.5 cm

Object distance for the objective lens, u_o = -9.0 mm = -0.9 cm

Least distance of distant vision, d=25 cm

Image distance for the eyepiece, v_e = -d=-25 cm

Object distance for the eyepiece =u_e.

Using the lens formula, we can obtain the value of u_e as:

$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} \frac{1}{-25} - \frac{1}{2.5} = \frac{-1-10}{25} u_e = -\frac{25}{11} = -2.27cm$

We can also obtain the value of the image distance for the objective lens (v) using the lens formula.

$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e} \frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} \frac{1}{-25} - \frac{1}{2.5} = \frac{-1-10}{25} u_e = -\frac{25}{11} = -2.27cm$

The distance between the objective lens and the eyepiece=Ind yo =2.27 – 7.2 = 9.47 cmttUI / id) The magnifying power of the microscope is calculated as:

= —7.2(1 +25 —25)=80 + 10)=88 0.9

Hence, the magnifying power of the microscope is 88.

Question 13:

A small telescope has an objective lens of focal length 144 cm and an eyepiece of focal length 6.0 cm. What is the magnifying power of the telescope? What is the separation between the objective and the eyepiece?
Answer:
Focal length of the objective lens, f_o= 144 cm
Focal length of the eyepiece, f_e= 6.0 cm
The magnifying power of the telescope is given as:
$\frac{f_o}{f_e}$

=$\frac{144}{6}$=24

The separation between the objective lens and the eyepiece is calculated as: $f_o + f_e$=144+6=150cm

Therefore 24 is the magnifying power of the telescope and the separation between the objective lens and the eyepiece is 150cm

Question 14:

(i) A giant refracting telescope at an observatory has an objective lens of focal length 15 m. If an eyepiece of focal length 1.0 cm is used, what is the angular magnification of the telescope?

(ii)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 $3.48 \times 106m$,and the radius of lunar orbit is $3.8 \times 108m$.

Answer:
Focal length of the objective lens, f_o=15m =$15 \times 102cm$
Focal length of the eyepiece, f_e= 1.0 cm
(i) The angular magnification of a telescope is given as:$\alpha \frac{f_o}{f_e}$

=$\frac{15 \times 10^2}{1}$=1500
Hence, the angular magnification of the given refracting telescope is 1500.
(ii) Diameter of the moon, d = $3.48 \times 106m$
Radius of the lunar orbit, r_o= $3.8 \times 108m$
Let d' be the diameter of the image of the moon formed by the objective lens.
The angle subtended by the diameter of the moon is equal to the angle subtended by the image.

$\frac{d}{r_o} = \frac{d'}{f_o}\ \frac{3.48\times10^6}{3.8\times10^8} = \frac{d'}{15}$

Therefore d'= $\frac{3.48}{3.8} \times 10^{-2} \times 15$

$13.74 \times 10^{-2} m = 13.74 cm$

Therefore 13.74cm is the diameter of the moons image formed by the objective lens.

Question 15:
Use the mirror equation to deduce that:
(i) an object placed between f and 2f of a concave mirror produces a real image beyond 2f.
(ii) a convex mirror always produces a virtual image independent of the location of the object.
(iii) the virtual image produced by a convex mirror is always diminished in size and is located between the focus and the pole.
(iv) an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.
[Note: This exercise helps you deduce algebraically properties of images that one obtains from explicit ray diagrams.]
Answer:
(i) For a concave mirror, the focal length (f) is negative.
Therefore f < 0
When the object is placed on the left side of the mirror, the object distance (u) is negative.
Therefore u < 0
For image distance v, we can write the lens formula as:

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

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$————————(i)

The object lies between f and 2f.

Therefore 2f<u<f
$\frac{1}{2f} < \frac{1}{u} < \frac{1}{f}$

$-\frac{1}{2f} < -\frac{1}{u} < -\frac{1}{f}$

$\frac{1}{f} - \frac{1}{2f} < -\frac{1}{f} - \frac{1}{u} < 0$————————(ii)

Using equation (i), we get:

$\frac{1}{2f} < \frac{1}{v} < 0$
$\frac{1}{v}$ is negative, i.e., v is negative.

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

2f>v

-v>-2f
Therefore, the image lies beyond 2f.
(ii) For a convex mirror, the focal length (f) is positive.
Therefore f > 0
When the object is placed on the left side of the mirror, the object distance (u) is negative.
Therefore u < 0
For image distance v, we have the mirror formula:

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

Usig eqn (ii), we can conclude that:

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

v>0

Thus, the image is formed on the back side of the mirror.
Hence, a convex mirror always produces a virtual image, regardless of the object distance.
(iii) For a convex mirror, the focal length (f) is positive.
Therefore f > 0
When the object is placed on the left side of the mirror, the object distance (u) is negative,
Therefore u < 0
For image distance v, we have the mirror formula:

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

But we have u<0

Therefore $\frac{1}{v} > \frac{1}{f}$

v<f
Hence, the image formed is diminished and is located between the focus (f) and the pole.
(iv) For a concave mirror, the focal length (f) is negative.

Therefore f < 0

When the object is placed on the left side of the mirror, the object distance (u) is negative.
Therefore u < 0
It is placed between the focus (f) and the pole.

Therefore f>u>0

$\frac{1}{f} < \frac{1}{u} < 0$

$\frac{1}{f} - \frac{1}{u} < 0$
For image distance v, we have the mirror formula:

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

Therefore $\frac{1}{v} < 0$

v>0
The image is formed on the right side of the mirror. Hence, it is a virtual image.
For u < 0 and v > 0, we can write:

$\frac{1}{u} > \frac{1}{v}$

v>u
Magnification, m=$\frac{v}{u}$> 1
Hence, the formed image is enlarged.

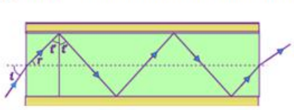
Question 16:
A small pin fixed on a table top is viewed from above from a distance of 50 cm. By what distance would the pin appear to be raised if it is viewed from the same point through a 15 cm thick glass slab held parallel to the table? Refractive index of glass = 1.5. Does the answer depend on the location of the slab?
Answer:
Actual depth of the pin, d = 15 cm
Apparent dept of the pin =d'
Refractive index of glass,μ=1.5
Ratio of actual depth to the apparent depth is equal to the refractive index of glass, i.e.

$\mu = \frac{d}{d'}$

Therefore d'=$\frac{d}{\mu}$

$\frac{15}{1.5}$=10cm
The distance at which the pin appears to be raised =d'-d=15-10=5cm
For a small angle of incidence, this distance does not depend upon the location of the slab.

Question 17:
(i) Figure below shows a cross-section of a 'light pipe' made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made of a material of refractive index 1.44. What is the range of the angles of the incident rays with the axis of the pipe for which total reflections inside the pipe take place, as shown in the figure.
(ii) What is the answer if there is no outer covering of the pipe?



Answer:
(i) Refractive index of the glass fibre,

Refractive index of the outer covering of the pipe, μ_2= 1.44
Angle of incidence = i
Angle of refraction = r
Angle of incidence at the interface = i'
The refractive index (μ) of the inner core − outer core interface is given as:

$\mu = \frac{\mu_2}{\mu_1} = \frac{1}{sini'}\ sini' = \frac{\mu_1}{\mu_2} = \frac{1.44}{1.68} = 0.8571$

$Therefore\ i' = 59^\circ$

For the critical angle, total internal reflection (TIR) takes place only when i>i', i.e., i $> 59^\circ$

Maximum angle of reflection, $r_{max} = 90^\circ - i' = 90^\circ - 59^\circ = 31^\circ$

Let, i_{max} be the maximum angle of incidence.

The refractive index at the air − glass interface, $\mu_1 = 1.68$

$\mu_1 = \frac{sini_{max}}{sinr_{max}}$

1.68 sin 31°

1.68×0.5150=0.8652

Therefore $i_{max} = sin^{-1}0.8652 = 60^\circ$

Thus, all the rays incident at angles lying in the range 0 < i <60° will suffer total internal reflection.

(ii) If the outer covering of the pipe is not present, then:

Refractive index of the outer pipe, μ_1=Refractive index of air=1

For the angle of incidence i =90°, we can write Snell's law at the air − pipe interface as:

$\frac{sini}{sinr} = \mu_2 = 1.68$

$sinr = \frac{sin90^\circ}{1.68} = \frac{1}{1.68}$ $r = sin^{-1}(0.5932) = 36.5^\circ$

Therefore $i' = 90^\circ - 36.5^\circ = 53.5^\circ$

Since i'>r, all incident rays will suffer total internal reflection.

Question 18:

Answer the following questions:

(i) You have learnt that plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances? Explain.

(ii) 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?

(iii) 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?

(iv) Does the apparent depth of a tank of water change if viewed obliquely? If so, does the apparent depth increase or decrease?

(v) The refractive index of diamond is much greater than that of ordinary glass. Is this fact of some use to a diamond cutter?

Answer:

(i) Yes

Plane and convex mirrors can produce real images as well. If the object is virtual, i.e., if the light rays converging at a point behind a plane mirror (or a convex mirror) are reflected to a point on a screen placed in front of the mirror, then a real image will be formed.

(ii) No

A virtual image is formed when light rays diverge. The convex lens of the eye causes these divergent rays to converge at the retina. In this case, the virtual image serves as an object for the lens to produce a real image.

(iii) The diver is in the water and the fisherman is on land (i.e., in air). Water is a denser medium than air. It is given that the diver is viewing the fisherman. This indicates that the light rays are travelling from a denser medium to a rarer medium. Hence, the refracted rays will move away from the normal. As a result, the fisherman will appear to be taller.

(iv) Yes; Decrease

The apparent depth of a tank of water changes when viewed obliquely. This is because light bends on travelling from one medium to another. The apparent depth of the tank when viewed obliquely is less than the near-normal viewing.

(v) Yes

The refractive index of diamond (2.42) is more than that of ordinary glass (1.5). The critical angle for diamond is less than that for glass. A diamond cutter uses a large angle of incidence to ensure that the light entering the diamond is totally reflected from its faces. This is the reason for the sparkling effect of a diamond.

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:

Distance between the object and the image, d = 3 m

Maximum focal length of the convex lens =f_{max}

For real images, the maximum focal length is given as:

$f_{max} = \frac{d}{4}$

$\frac{3}{4} = 0.75m$
Hence, for the required purpose, the maximum possible focal length of the convex lens is 0.75 m.

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:

Distance between the image (screen) and the object, D = 90 cm
Distance between two locations of the convex lens, d = 20 cm
Focal length of the lens = f
Focal length is related to d and D as:

$$f = \frac{D^2 - d^2}{4D}$$

$= \frac{90^2-(20^2)}{4\times90} = \frac{770}{36} = 21.39cm$
Therefore, the focal length of the convex lens is 21.39 cm.

Question 21:

(i) Determine the 'effective focal length' of the combination of the two lenses in Exercise 9.10, if they are placed 8.0 cm apart with their principal axes coincident. Does the answer depend on which side of the combination a beam of parallel light is incident? Is the notion of effective focal length of this system useful at all?

(ii) An object 1.5 cm in size is placed on the side of the convex lens in the arrangement (a) above. 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:

Focal length of the convex lens, f_1 = 30 cm
Focal length of the concave lens, f_2 = −20 cm
Distance between the two lenses, d = 8.0 cm
(i) When the parallel beam of light is incident on the convex lens first:
According to the lens formula, we have:

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

Where,
u_1= Object distance
v_1= Image distance

$$\frac{1}{v_1} = \frac{1}{30} - \frac{1}{\infty} = \frac{1}{30}$$

Therefore $v_1 = 30cm$
The image will act as a virtual object for the concave lens.
Applying lens formula to the concave lens, we have:

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

Where,
u_2=Object distance
= (30 − d) = 30 − 8 = 22 cm
v_2= Image distance

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

Therefore $v_2 = -220cm$

The parallel incident beam appears to diverge from a point that is $(220 - \frac{d}{2} = 220 - 4)216cm$ from the centre of the combination of the two lenses.
When the parallel beam of light is incident, from the left, on the concave lens first:
According to the lens formula, we have:

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

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

Where,
u_2=Object distance = −∞

v_2=Image distance

$$\frac{1}{v_2} = \frac{1}{-20} + \frac{1}{-\infty} = -\frac{1}{20}$$

Therefore $v_2 = -20cm$
The image will act as a real object for the convex lens.
Applying lens formula to the convex lens, we have:

$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$
Where,
u_1= Object distance
= −(20 + d) = −(20 + 8) = −28 cm
v_1= Image distance

$\frac{1}{v_1} = \frac{1}{30} + \frac{1}{-28} = \frac{14-15}{420} = \frac{-1}{420}$

Therefore $v_2 = -420cm$

Hence, the parallel incident beam appear to diverge from a point that is (420 − 4) 416 cm from the left of the centre of the combination of the two lenses.
The answer does depend on the side of the combination at which the parallel beam of light is incident. The notion of effective focal length does not seem to be useful for this combination.
(ii) Height of the image, h_1 = 1.5 cm
Object distance from the side of the convex lens, u_1 = -40 cm
$|u_1| = 40cm$

According to the lens formula:

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

v_1= Image distance

$\frac{1}{v_1} = \frac{1}{30} + \frac{1}{-40} = \frac{4-3}{120} = \frac{1}{120}$

Therefore $v_1 = 120cm$

Magnification, m=$\frac{v_1}{|u_1|} = \frac{120}{40} = 3$
Hence, the magnification due to the convex lens is 3.
The image formed by the convex lens acts as an object for the concave lens.
According to the lens formula:

$\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$
Where,
u_2= Object distance
= +(120 − 8) = 112 cm.

v_2=Image distance

$\frac{1}{v_2} = \frac{1}{-20} + \frac{1}{112} = \frac{-112+20}{2240} = \frac{-92}{2240}$

Therefore $v_2 = \frac{-2240}{92}$

Magnification, m'=$|\frac{v_2}{u_2}| = \frac{2240}{92} \times \frac{1}{112} = \frac{20}{92}$

Hence, the magnification due to the concave lens is $\frac{20}{92}$.
The magnification produced by the combination of the two lenses is calculated as:

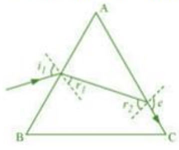
$m \times m'$
The magnification of the combination is given as:

$\frac{h_2}{h_1} = 0.652$

$h_2 = h_1 \times 0.652$
Where,
h_1= Object size = 1.5 cm
h_2 = Size of the image
Therefore $h_2 = 0.652 \times 1.5 = 0.98cm$

Hence, the height of the image is 0.98 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:
The incident, refracted, and emergent rays associated with a glass prism ABC are shown in the given figure.



Angle of prism, Therefore A = 60°
Refractive index of the prism, μ= 1.524
i_1= Incident angle
r_1= Refracted angle
r_2= Angle of incidence at the face AC
e= Emergent angle = 90°
According to Snell's law, for face AC, we can have:

$\frac{sine}{sinr_2} = \mu\ sinr_2 = \frac{1}{\mu} \times sin\ 90^\circ$

=$\frac{1}{1.524} = 0.6562$

Therefore $r_2 = sin^{-1}0.6562 = 41^\circ$

Therefore $r_1 = A - r_2 = 60 - 41 = 19^\circ$
It is clear from the figure that angle A=$r_1 + r_2$
According to Snell's law, we have the relation:

$\mu = \frac{sini_1}{sinr_1}\ sini_1 = \mu sinr_1$

=$1.524 \times sin19^\circ$=0.496

Therefore $i_1 = 29.75^\circ$

Therefore the angle of incidence is 29.75°
Question 23:
You are given prisms made of crown glass and flint glass with a wide variety of angles. Suggest a combination of prisms which will
(i) deviate a pencil of white light without much dispersion,
(ii) disperse (and displace) a pencil of white light without much deviation.
Answer:
(i) Place the two prisms beside each other. Make sure that their bases are on the opposite sides of the incident white light, with their faces touching each other. When the white light is incident on the first prism, it will get dispersed. When this dispersed light is incident on the second prism, it will recombine and white light will emerge from the combination of the two prisms.
(ii) Take the system of the two prisms as suggested in answer (a). Adjust (increase) the angle of the flint-glass-prism so that the deviations due to the combination of the prisms become equal. This combination will disperse the pencil of white light without much deviation.
Question 24:
For a normal eye, the far point is at infinity and the near point of distinct vision is about 25cm 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:
Least distance of distinct vision, d = 25 cm
Far point of a normal eye, d' = ∞
Converging power of the cornea,
Least converging power of the eye-lens, $P_c = 40D$
To see the objects at infinity, the eye uses its least converging power.
Power of the eye-lens, P = $P_c + P_e = 40 + 20 = 60D$

Power of the eye-lens is given as:

P=$\frac{1}{Focal\ length\ of\ the\ eye\ lens\ (f)}$

$f = \frac{1}{P}\ \frac{1}{60D}$

$\frac{100}{60} = \frac{5}{3}cm$
To focus an object at the near point, object distance (u) = −d = −25 cm
Focal length of the eye-lens = Distance between the cornea and the retina = Image distance
Hence, image distance, $v = \frac{5}{3}$
According to the lens formula, we can write:

$\frac{1}{f'} = \frac{1}{v} + \frac{1}{u}$
Where,

f'=focal length

$\frac{1}{f'} = \frac{3}{5} + \frac{1}{25} = \frac{15+1}{25} = \frac{16}{25}cm^{-1}$

Power $P' = \frac{1}{f'} \times 100$

$P' = \frac{16}{25} \times 100 = 64D$

Therefore Power of the eye-lens = 64 − 40 = 24 D
Hence, the range of accommodation of the eye-lens is from 20D to 24D

Question 25:

Does the human eye partially lose its ability of accommodation when it undergoes short-sightedness (myopia) or long sightedness (hypermetropia)? If not, what might cause these defects of vision?

Soln: The eye-lens is normally accommodated by a person undergoing through myopia or hypermetropia. When the eye-balls get elongated from front to back is when Myopia starts occuring. Hypermetropia, on the other hand occurs when the eye-balls get shortened. When the eye-lens loses its ability of accommodation, the defect is called presbyopia.

Question 26:

Spectacles of power −1.0 dioptre is being used by a person suffering from myopia for distant vision. He also needs to use separate reading glass of power + 2.0 dioptres when he turns old. Explain what may have happened.

Soln: The myopic person uses a spectacle of power, P = -1.0 D

Focal length of the given spectacles, f = $\frac{1}{P}$ = $\frac{1}{-1\times10^{-2}}$

= -100 cm

Hence, 100 cm is the far point of the person. He might have a normal near point of 25 cm. The objects placed at infinity produce virtual images at 100 cm, when spectacles are being used. He is able to see the objects placed between 100 cm and 25 cm when he uses the ability of accommodation of the eye-lens.

During old age, the person uses reading glasses of power, P’ = +2 D

Old age decreases the ability of accommodation. This defect is called presbyopia. As a result, he is unable to see clearly the objects placed at 25 cm.

Question 27:

A person looking at a cloth with a pattern consisting vertical and horizontal lines is able to see the vertical lines more distinctly than the horizontal ones. What is this defect due to? How is such a defect of vision corrected?

Soln : In the described situation, the person is not able to see horizontal lines clearly, whereas the vertical lines are distinctly visible. This may be due to the disfunctioning of the refracting system (cornea and eye-lens) of the eye in the same way in different planes. This defect is called astigmatism. The curvature in the person’s eye is enough in the vertical plane. However, the curvature in the horizontal plane is insufficient. Hence, sharp images of the vertical lines are formed on the retina, but horizontal lines appear blurred. This defect can be corrected by using cylindrical lenses.

Question 28:

A child with normal near point (25 cm) reads a book with small size print using a magnifying glass: a thin convex lens of focal length 5 cm.

(a) What would be the shortest and the longest distance at which the lens should be placed from the page so that the book can be read easily when viewing through the magnifying glass?

(b) What is the max and the mini angular magnification (magnifying power) possible using the above given simple microscope?

Soln: (a) Focal length of the magnifying glass, f = 5 cm

Distance vision has the least distance, d = 25 cm

Closest object distance = u

Image distance, v = -d = -25 cm

According to the lens formula, we have:

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

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

$= \frac{1}{-25} - \frac{1}{5}$

$= \frac{-v}{25}$

Therefore, u = $\frac{-25}{6}$

= -4.167 cm

Hence, the closest distance at which the person can read the book is 4.167 cm.

For the object at the longest distance (u'), the image distance (v') = ∞

According to the lens formula, we have:

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

$\frac{1}{u'} = \frac{1}{\infty} - \frac{1}{5}$

$= -\frac{1}{5}$

Therefore, u' = -5 cm

Hence, the farthest distance at which the person can read the book is 5 cm.

(b) Maximum angular magnification is given by the relation:

$\alpha_{max} = \frac{d}{|u|}$

$= \frac{25}{\frac{25}{6}}$

= 6

Minimum angular magnification is given by the relation:

$= \alpha_{max} = \frac{d}{|u'|}$

$= \frac{25}{5}$

= 5

Question 29:

A large card divided into squares each of size 1 mm^2 is being viewed from a distance of 9 cm through a magnifying glass (converging lens has a focal length of 9 cm) held close to the eye. Determine:

(a) the magnification produced by the lens? How much is the area of each square in the virtual image?

(b) the angular magnification (magnifying power) of the lens?

(c) Is the magnification in (a) equal to the magnifying power in (b)? Explain.

Answer 9.29:

(a)Area of each square, A = 1 mm^2

Object distance, u = −9 cm

Focal length of a converging lens, f = 10 cm

The lens formula for the image distance v, can be written as:

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

$\frac{1}{10} = \frac{1}{v} + \frac{1}{9}$

$\frac{1}{v} = -\frac{1}{90}$

Therefore, v = -90 cm

Magnification, m = $\frac{v}{u}$

$= \frac{-90}{-9}$

= 10

Therefore, area of each square in the virtual image = (10)^2 A

= 10^2 x 1 = 100 mm^2

= 1 cm^2

(b) The lens has a magnifying power of = $\frac{d}{|u|}$

$= \frac{25}{9}$

= 2.8

(c) The magnification in (a) is not the same as the magnifying power in (b).

the magnification magnitude is $(|\frac{v}{u}|)$ and the magnifying power is $\left(\frac{d}{|u|}\right)$.

The two quantities will be equal when the image is formed at the near point (25 cm).

Question 30:

(a)Determine the distance in which the lens should be held from the figure in Exercise 9.29 in order to view the squares distinctly with the maximum possible magnifying power?

(b)Determine the magnification in the following situation?

(c) Find if the magnifying power is equal to magnification?

Explain.

Answer 9.30:

(a)When the image is formed at the near point, we get the maximum possible magnification.

So, Image distance, v = −d = −25 cm

Focal length, f = 10 cm

Object distance = u

According to the lens formula, we have:

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

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

$= \frac{1}{-25} - \frac{1}{10} = -\frac{7}{50}$

Therefore, u = $\frac{-50}{7}$

= – 7.14 cm

Hence, the lens should be kept 7.14 cm away in order to view the squares distinctly.

(b) Magnification = $\left|\frac{v}{u}\right|$

$= \frac{25}{\frac{50}{7}} = 3.5$

(c) Magnifying power = $\frac{d}{u}$

$= \frac{25}{\frac{50}{7}}$

= 3.5

Therefore, the magnifying power is equal to the magnitude of magnification since the image is formed at the near point (25 cm).

Question 31:

The virtual image of each square in the figure is to have an area of 6.25 mm^2. Find out, what should be the distance between the object in Exercise 9.30 and the magnifying glass?If the eyes are too close to the magnifier, would you be able to see the squares distinctly?

Answer 9.31:

Area of the virtual image of each square, A = 6.25 mm^2

Area of each square, A_0 = 1 mm^2

Hence, the linear magnification of the object can be calculated as:

m = $\sqrt{\frac{A}{A_o}}$

$= \sqrt{\frac{6.25}{1}}$

= 2.5

But m = $\frac{Imagedistance(v)}{Objectdistance(u)}$

Therefore, v = mu

= 2.5u ………… (1)

The magnifying glass has a focal length of, f = 10 cm

According to the lens formula, we have the relation:

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

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

$= \frac{1}{u}\left(\frac{1}{2.5} - \frac{1}{1}\right)$

$= \frac{1}{u}\left(\frac{1-2.5}{2.5}\right)$

Therefore, u = $-\frac{1.5\times10}{2.5}$ = -6 cm

And v = 2.5u

= 2.5 x 6

= -15 cm

The virtual image cannot be seen by the eyes distinctly, because the image is formed at a distance of 15 cm, which is less than the near point (i.e. 25 cm) of a normal eye.

Question 32:

Answer the following questions:

(a) An object subtends an angle at the eye which is equal to the angle subtended at the eye by the virtual image that is produced by a magnifying glass. Does the magnifying glass provide angular magnification? Explain.

(b)A person's eyes are very close to the lens when he is viewing through a magnifying glass. Does angular magnification change if the eye is moved back?

(c) The focal length of the lens is inversely proportional to the magnifying power of a simple microscope. Why don't we achieve greater and greater magnifying power by using a convex lens of smaller and smaller focal length?

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

(e) Our eyes should be positioned not on the eyepiece but a short distance away from it for best viewing, when viewing from a compound microscope. Explain why? How much should be that short distance between the eye and eyepiece?

Answer 9.32: (a) The angular size of the image is equal to the angular size of the object, but still the angular size of image is equal to angular size of the object. The objects placed closer than the least distance of distinct vision (i.e., 25 cm) can be viewed through a magnifying glass. A closer object causes a larger angular size. A magnifying glass provides angular magnification. The object cannot be placed closer to the eye, without magnification. With magnification, the object can be placed much closer to the eye.

(b) Yes, the angular magnification changes. The angular magnification decreases a little, when the distance between the eye and a magnifying glass is increased. This is because the angle subtended at the eye is slightly less than the angle subtended at the lens. Image distance does not have any effect on angular magnification.

(c) Making lenses having very small focal lengths is not easy. Spherical and chromatic aberrations are produced by a convex lens having a very small focal length. Thus, the focal length of a convex lens cannot be decreased by a greater amount.

(d) A compound microscope produces an angular magnification of $\left[\left(\frac{25}{f_e}\right)+1\right]$

where,

f_e = focal length of the eyepiece

It can be inferred that if f_e is small, then angular magnification of the eyepiece will be large.

The angular magnification of the objective lens of a compound microscope is given as

$\frac{1}{(|u_o|f_o)}$

Where, u_o = object distance for the objective lens

f_o = focal length of the objective

The magnification is large when $u_o > f_o$. In the case of a microscope, the object is kept close to the objective lens. Hence, the object distance is very little. Since, u_o is small, f_o will be even smaller. Therefore, f_e and f_o are both small in the given condition.

(e)We are unable to collect much refracted light when we place our eyes too close to the eyepiece of a compound microscope. As a result, there is substantial decrement in the field of view. Hence, the clarity of the image gets blurred. The eye-ring attached to the eyepiece gives the best position for viewing through a compound microscope. The precise location of the eye depends on the separation between the objective lens and the eyepiece.

Question 33:

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

Answer 9.33: Focal length of the objective lens, = 1.25 cm

Focal length of the eyepiece, fe = 5 cm

Least distance of distinct vision, d = 25 cm

Angular magnification of the compound microscope = 30X

Total magnifying power of the compound microscope, m = 30

The angular magnification of the eyepiece is given by the relation:

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

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

= 6

The angular magnification of the objective lens (mo) is related to me as:

$m_o m_e = m$

$m_o = \frac{m}{m_e}$

= $\frac{30}{6}$

= 5

We also have the relation:

$m_o = \frac{Image distance for the objecive lens (v_o)}{Object distance for the objective lens (-u_o)}$ $5 = \frac{v_o}{-u_o}$

Therefore, $v_o = -5u_o$ .... (1)

Applying the lens formula for the objective lens:

$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$ $\frac{1}{1.25} = \frac{1}{-5u_o} - \frac{1}{u_o}$

= $\frac{-6}{5u_o}$

Therefore, $u_o = \frac{-6}{5} \times 1.25$

= -1.5 cm

And $v_o = -5u_o$

= -5 x (-1.5)

= 7.5 cm

The object should be placed 1.5 cm away from the objective lens to obtain the desired magnification.

Applying the lens formula for the eyepiece:

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

Where,

v_e = Image distance for the eyepiece = -d = -25 cm

u_e = Object distance for the eyepiece

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

= $\frac{-1}{25} - \frac{1}{5}$

= $\frac{-6}{25}$

Therefore, u_e = -4.17 cm

Separation between the objective lens and the eyepiece = $|u_e| + |v_o|$

= 4.17 + 7.5

= 11.67 cm

Therefore, the separation between the objective lens and the eyepiece should be 11.67 cm.

Question 34:

A small telescope has an objective lens of focal length 140 cm and an eyepiece 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 at infinity)?

(b) the final image is formed at the least distance of distinct vision (25 cm)?

Answer 9.34: Focal length of the objective lens, = 140 cm

Focal length of the eyepiece, fe = 5 cm

Least distance of distinct vision, d = 25 cm

(a)When the telescope is in normal adjustment, its magnifying power is given as:

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

= $\frac{140}{5}$ = 28

(b) When the final image is formed at d, the magnifying power of the telescope is given as:

$\frac{f_o}{f_e}\left[1 + \frac{f_e}{d}\right]$

= $\frac{140}{5}\left[1 + \frac{5}{25}\right]$

= 28[1 + 0.2]

= 28 x 1.2 = 33.6

Question 35:

(a)For a telescope, what is the separation between the objective lens and the eyepiece?

(b) 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?

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

Answer 9.35:

Focal length of the objective lens, fo = 140 cm

Focal length of the eyepiece, fe = 5 cm

(a) In normal adjustment, the separation between the objective lens and the eyepiece = $f_o + f_e$

(a) In normal adjustment, the separation between the objective lens and the eyepiece = $f_o + f_e$

= 140 + 5

= 145 cm

(b) Height of the tower, h1 =100 m

Distance of the tower (object) from the telescope, u = 3Km = 3000 m

The angle subtended by the tower at the telescope is given as:

$\Theta = \frac{h1}{u}$

= $\frac{100}{3000}$

= $\frac{1}{30}$ rad

The angle subtended by the image produced by the objective lens is given as:

$\Theta = \frac{h_2}{f_o}$ = $\frac{h_2}{140}$ rad

Where, h_2 = height of the image of the tower formed by the objective lens

$\frac{1}{30}$ = $\frac{h_2}{140}$

Therefore, h_2 = $\frac{140}{30}$

= 4.7 cm

Therefore, the objective lens forms a 4.7 cm tall image of the tower.

(c) Image is formed at a distance, d = 25cm

The magnification of the eyepiece is given by the realtion:

m = 1 + $\frac{d}{f_e}$

= 1 + $\frac{25}{5}$

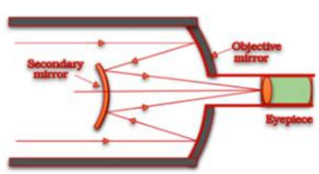
= 1 + 5 = 6

Height of the final image = mh_2 = 6 x 4.7 = 28.2 cm

Hence, the height of the final image of the tower is 28.2 cm.

Question 36:

A Cassegrain telescope uses two mirrors as shown in Fig. 9.33. Such a telescope is built with the mirrors 20 mm apart. If the radius of curvature of the large mirror is 220 mm and the small mirror is 140 mm, where will the final image of an object at infinity be?



Soln: The following figure shows a Cassegrain telescope consisting of a concave mirror and a convex mirror.

Distance between the objective mirror and the secondary mirror, d = 20 mm

Radius of curvature of the objective mirror, R_1 = 220 mm

Hence, focal length of the objective mirror, f_1 = $\frac{R_1}{2}$ = 110 mm

Radius of curvature of the secondary mirror, r_1 = 140 mm

Hence, focal length of the secondary mirror, f_2 = $\frac{R_2}{2}$

= $\frac{140}{2}$

= 70 mm

The image of an object placed at infinity, formed by the objective mirror, will act as a virtual object for the secondary mirror.

hence, the virtual object distance for the secondary mirror, u = f_1 – d

= 110 – 20

= 90 mm

Applying the mirror formula for the secondary mirror, we can calculate image distance (v) as:

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f_2}$

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

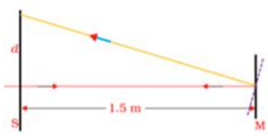
$= \frac{1}{70} - \frac{1}{90} = \frac{2}{630}$

Therefore, v = $\frac{630}{2}$ = 315 mm

Hence, the final image will be formed 315 mm away from the secondary mirror.

Question 37:

Light incident normally on a plane mirror attached to a galvanometer coil retraces backwards as shown in Fig. 9.36. A current in the coil produces a deflection of 3.5° of the mirror. What is the displacement of the reflected spot of light on a screen placed 1.5 m away?



Soln: Angle of deflection, θ = 3.5°

Distance of the screen from the mirror, D = 1.5 m

The reflected rays get deflected by an amount twice the angle of deflection i.e.,

2θ = 7.0°

The displacement (d) of the reflected spot of light on the screen is given as:

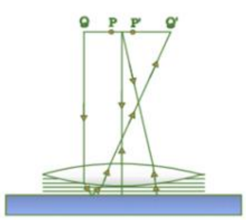
$\tan 2\Theta = \frac{d}{1.5}$

Therefore, d = 1.5 x tan7^{o} = 0.184 m = 18.4 cm

Hence, the displacement of the reflected spot of light is 18.4 cm.

Question 38:

Figure 9.37 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 the liquid?



Soln: Focal length of the convex lens, f1 = 30 cm

The liquid acts as a mirror. Focal length of the liquid = f2

Focal length of the system (convex lens + liquid), f = 45 cm

For a pair of optical systems placed in contact, the equivalent focal length is given as:

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

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

$= \frac{1}{45} - \frac{1}{30}$

$= -\frac{1}{90}$

Therefore, f_2 = -90 cm

Let the refractive index of the lens be and the radius of curvature of one surface be R. Hence, the radius of curvature of the other surface is –R.

of curvature of the other surface is −R.

R can be obtained using the relation : $\frac{1}{f_1} = (\mu_1 - 1)(\frac{1}{R} + \frac{1}{-R})$

$\frac{1}{30}$ = (1.5 – 1) $\left(\frac{2}{R}\right)$

Therefore, R = $\frac{30}{1}$

R = 30 cm

Let μ_2 be the refractive index of the liquid.

Radius of curvature of the liquid on the side of the plane mirror = ∞ Radius of curvature of the liquid on the side of the lens, R = −30 cm

The value of μ_2 can be calculated using the relation:

$\frac{1}{f_2} = (\mu_2 - 1)\left[\frac{1}{-R} - \frac{1}{infinity}\right]$

μ_2 – 1 = $\frac{1}{3}$

Therefore, μ_2 = 1.33

Hence, the refractive index of the liquid is 1.33 .