Ray Optics and Optical Instruments

1. Assertion (A) and Reason (R) type questions. Two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below. (2024)

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

Assertion (A): Plane and convex mirrors cannot produce real images under any circumstance.

Reason (R): A virtual image cannot serve as an object to produce a real image.

Ans. (D) Assertion (A) is false and Reason (R) is also false.

2. Monochromatic light of frequency 5.0×10^{14} Hz travels from air into a medium with refractive index 1.5. Find the wavelength of (i) reflected light, and (ii) refracted light at the interface of the two media. (2024)

Ans. Finding the wavelength of

(i) Reflected Light

(ii) Refracted Light

(i) $v = \upsilon \lambda$

$3 \times 10^8 = 5 \times 10^{14} \times \lambda$

$\lambda = 600$ nm or 6×10^{-7}m

(ii)

$$\lambda_{medium} = \frac{\lambda_{air}}{\mu}$$

$$\lambda_{medium} = \frac{600\,nm}{1.5}$$

$$= 400 \text{ nm or } 4 \times 10^{-7} \text{m}$$

3. A plano-convex lens of focal length 16 cm is made of a material of refractive index 1.4. Calculate the radius of the curved surface of the lens. (2024)

Ans. Calculating the radius of the curved surface

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

$$\frac{1}{16} = (1.4 - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right)$$

$$\frac{1}{16} = 0.4 \times \frac{1}{R}$$

$$R = 16 \times 0.4$$

$$R = 6.4 \text{ cm}$$

4. An object is placed 30 cm in front of a concave mirror of radius of curvature 40 cm. Find the (i) position of the image formed and (ii) magnification of the image.

(2024)

Ans. Finding the

(i) position of the image formed

(ii) magnification of the image

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

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

On solving

v = - 60 cm

$$\text{(ii) } m = -\frac{v}{u}$$

$$= -\left(\frac{-60}{-30}\right)$$

$$= -2$$

5. A lens is a transparent medium bounded by two surfaces, with one or both surfaces being spherical. The focal length of a lens is determined by the radii of curvature of its two surfaces and the refractive index of its medium with respect to that of the surrounding medium. The power of a lens is reciprocal of its focal

length. If a number of lenses are kept in contact, the power of the combination is the algebraic sum of the powers of the individual lenses. (2024)

(i) A double-convex lens, with each face having same radius of curvature R, is made of glass of refractive index n. Its power is :

(A) 2 (n - 1)/R

(B) (2n - 1)/R

(C) (n - 1)/2R

(D) (2n - 1)/2R

Ans. (A) 2 (n - 1)/R

(ii) A double-convex lens of power P, with each face having same radius of curvature, is cut into two equal parts perpendicular to its principal axis. The power of one part of the lens will be :

(A) 2P

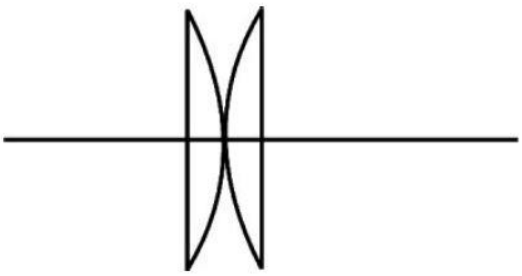
(B) P

(C) 4P

(D) P/2

Ans. (D) P/2

(iii) The above two parts are kept in contact with each other as shown in the figure. The power of the combination will be :



(A) P/2

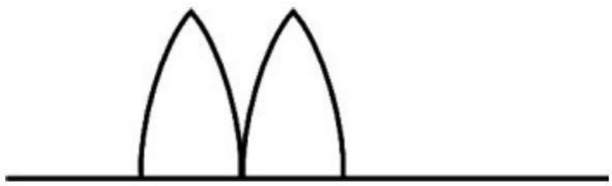
(B) P

(C) 2P

(D) P/4

Ans. (B) P

(iv) A double-convex lens of power P, with each face having same radius of curvature, is cut along its principal axis. The two parts are arranged as shown in the figure. The power of the combination will be :



(A) Zero

(B) P

(C) 2P

(D) P/2

Ans. (C) 2P

(v) Two convex lenses of focal lengths 60 cm and 20 cm are held coaxially in contact with each other. The power of the combination is :

(A) 6·6 D

(B) 15 D

(C) 1/15 D

(D) 1/80 D

Ans. (A) 6·6 D

6. (i) A resistor and a capacitor are connected in series to an ac source $v = v_m \sin \omega t$. Derive an expression for the impedance of the circuit.

(ii) When does an inductor act as a conductor in a circuit ? Give reason for it.

(iii) An electric lamp is designed to operate at 110 V dc and 11 A current. If the lamp is operated on 220 V, 50 Hz ac source with a coil in series, then find the inductance of the coil. (2024)

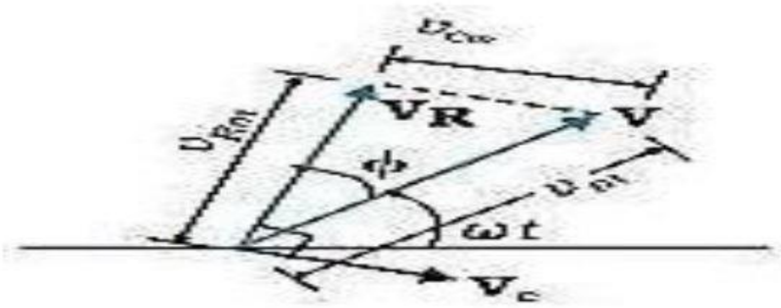
Ans.

(i) Deriving expression for impedance

(ii) Reason

(iii) Inductance of coil

(i)



$V_C + V_R = V$

$$v_m^2 = v_{rm}^2 + v_{cm}^2$$

$$v_{rm} = i_m R$$

$$v_{cm} = i_m X_c$$

$$v_m^2 = (i_m R)^2 + (i_m X_c)^2$$

$$= i_m^2 \left[R^2 + X_c^2\right]$$

$$\Rightarrow i_m = \frac{v_m}{\sqrt{R^2 + X_c^2}}$$

$$\Rightarrow \text{Impedance } Z = \sqrt{R^2 + X_c^2}$$

(ii) For direct current (dc), an inductor behaves as a conductor.

As $X_L = \omega L = 2\pi \nu L$

For dc $\nu = 0 \Rightarrow X_L = 0$

Alternatively: -

Induced emf $(\varepsilon) = -L dI/dt$

For dc; $dI = 0 \Rightarrow \varepsilon = 0$

(iii) $R = 110/11 = 10\ \Omega$

$$i_{rms} = \frac{v_{rms}}{\sqrt{R^2 + X_L^2}} = \frac{220}{\sqrt{100 + X_L^2}}$$

$$11 = \frac{220}{\sqrt{100 + X_L^2}}$$

$$\sqrt{100 + X_L^2} = \frac{220}{11} = 20\Omega$$

Squaring both sides:

$$\Rightarrow 100 + X_L^2 = 400$$

$$\Rightarrow X_L^2 = 300 \Rightarrow X_L = 10\sqrt{3}\,\Omega$$

$$X_L = 2\pi fL \Rightarrow 10\sqrt{3} = 2\pi \times 50 \times L$$

$$L = \frac{\sqrt{3}}{10\pi} H$$

7. (i) Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer.

(ii) A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy ? Explain.

(iii) A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V. Calculate :

(1) The output voltage across the secondary coil

(2) The current in the primary coil if the current in the secondary coil is 2·0 A.

(2024)

Ans. (i) Labelled diagram of step – up transformer

Describing working principle

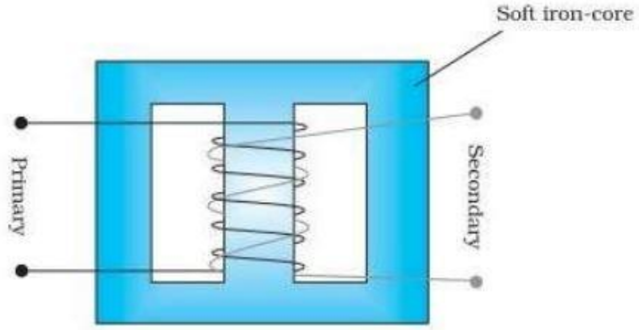
Three causes

(ii) Explanation

(iii) (1) Output voltage across secondary coil

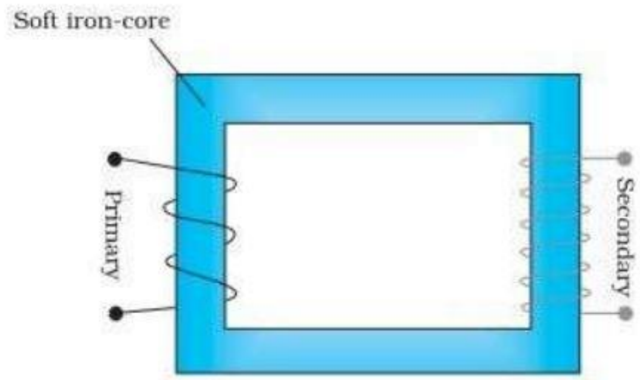
(2) Current in primary coil

(i)



(a)

OR



(b)

The working principle of transformer is mutual induction.

When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it.

Causes of energy losses (Any three)

(a) Flux leakage

(b) Resistance of the windings

(c) Eddy currents

(d) Hysteresis

(ii) No

Current changes correspondingly. So, the input power is equal to the output power.

(iii)

(1)

$$\frac{V_s}{V_P} = \frac{N_s}{N_P}$$

$$V_s = \frac{N_s}{N_P} \times V_P = \frac{3000}{200} \times 90$$

$$V_s = 1350\,V$$

(2)

$$\frac{I_P}{I_s} = \frac{N_s}{N_P}$$

$$I_P = \frac{3000}{200} \times 2 = 30 \text{ A}$$

Previous Years' CBSE Board Questions

9.2 Reflection of Light by Spherical Mirrors

Focal Length of Spherical Mirrors

LA (5 marks)

1. Define the term 'focal length of a mirror'. With the help of a ray diagram, obtain the relation between its focal length and radius of curvature. *(2020)*

The Mirror Equation

(b) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain. *(Delhi 2014)* Ap

LA (5 marks)

9. An object is placed in front of a concave mirror. It is observed that a virtual image is formed. Draw the ray diagram to show the image formation and hence derive the mirror equation $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$. *(3/5, 2020)*

10. (a) Draw a ray diagram to show image formation

VSA (1 mark)

2. When an object is placed between f and $2f$ of a concave mirror, would the image formed be (i) real or virtual and (ii) diminished or magnified?
(Delhi 2015C) U

SA I (2 marks)

3. An object is kept 20 cm in front of a concave mirror of radius of curvature 60 cm. Find the nature and position of the image formed. *(2020)*

4. An object is kept in front of a concave mirror of focal length 15 cm. The image formed is real and three times the size of the object. Calculate the distance of the object from the mirror. *(AI 2019)*

5. Use the mirror equation to show that an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$. *(Delhi 2015)*

SA II (3 marks)

6. A concave mirror produces a two times enlarged virtual image of an object kept 10 cm away from the mirror.
   (a) Find the focal length of the mirror.
   (b) By how much distance the object be displaced and in what direction, in order to get two times enlarged real image of the object? *(2020)*

7. (a) Calculate the distance of an object of height h from a concave mirror of radius of curvature 20 cm, so as to obtain a real image of magnification 2. Find the location of image also.
   (b) Using mirror formula, explain why does a convex mirror always produce a virtual image.
(Delhi 2016) Ap

8. (a) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.
   when the concave mirror produces a real, inverted and magnified image of the object.
   (b) Obtain the mirror formula and write the expression for the linear magnification. *(4/5, 2018)* An

9.3 Refraction

SA II (3 marks)

11. Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light. *(2/3, AI 2017)* Ap

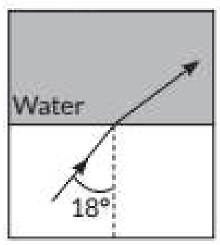
9.4 Total Internal Reflection

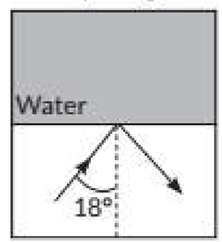
MCQ

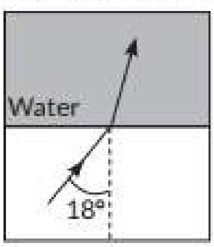
Here, question 12 (i) to (v) is a case study base question of 5 marks.

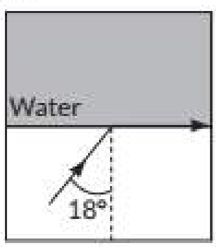
12. A ray of light travels from a denser to a rarer medium. After refraction, it bends away from the normal. When we keep increasing the angle of incidence, the angle of refraction also increases till the refracted ray grazes along the interference of two media. The angle of incidence for which it happens is called critical angle. If the angle of incidence is increased further the ray will not emerge and it will be reflected back in the denser medium. This phenomenon is called total internal reflection of light.

(i) A ray of light travels from a medium into water at an angle of incidence of 18°. The refractive index of the medium is more than that of water and the critical angle for the interface between the two media is 20°. Which one of the following figures best represents the correct path of the ray of light?

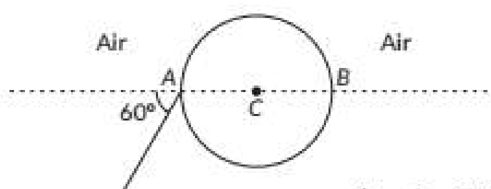
(a) 

(b) 

(c) 

(d) 

(ii) A point source of light is placed at the bottom



(Foreign 2014) U

SA I (2 marks)

of a tank filled with water, of refractive index μ, to a depth d. The area of the surface of water through which light from the source can emerge, is:

(a) $\frac{\pi d^2}{2(\mu^2-1)}$ (b) $\frac{\pi d^2}{(\mu^2-1)}$

(c) $\frac{\pi d^2}{\sqrt{2}\sqrt{\mu^2-1}}$ (d) $\frac{2\pi d^2}{(\mu^2-1)}$

(iii) For which of the following media, with respect to air, the value of critical angle is maximum?

(a) Crown glass (b) Flint glass

(c) Water (d) Diamond

(iv) The critical angle for a pair of two media A and B of refractive indices 2.0 and 1.0 respectively is:

(a) 0° (b) 30° (c) 45° (d) 60°

(v) The critical angle of pair of a medium and air is 30°. The speed of light in the medium is:

(a) 1×10^8 m s^{-1} (b) 1.5×10^8 m s^{-1}

(c) 2.2×10^8 m s^{-1} (d) 2.8×10^8 m s^{-1}

(Term II 2021-22)

SA I (2 marks)

13. How does the refractive index of a transparent medium depend on the wavelength of incident light used? Velocity of light in glass is 2×10^8 m/s and in air is 3×10^8 m/s. If the ray of light passes from glass to air, calculate the value of critical angle.

(Foreign 2015) Ap

LA (5 marks)

14. Under what conditions is the phenomenon of total internal reflection of light observed ? Obtain the relation between the critical angle of incidence and the refractive index of the medium.

(3/5, Delhi 2019) Ap

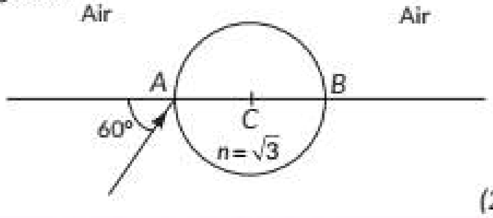
9.5 Refraction at Spherical Surfaces and by Lenses

Refraction at Spherical Surfaces

VSA (1 mark)

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

16. A ray of light falls on a transparent sphere of $n=\sqrt{3}$ at an angle of incidence 60° with the diameter AB of the sphere having centre C. The ray emerges from the sphere parallel to the line AB. Find the angle of emergence.



(2021)

Refraction by a Lens

MCQ

17. A window is provided in the middle of a wall. Its image is obtained on the opposite wall at a distance 'd' from it using a lens. If the window and its image are of the same size, then the focal length of the lens used is

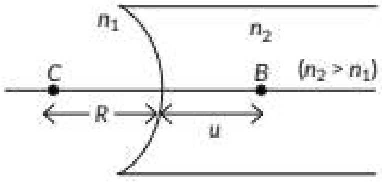
(a) $+\frac{d}{4}$ (b) $+\frac{d}{2}$ (c) $-\frac{d}{4}$ (d) $-\frac{d}{2}$

(2020)

Here, question 18 (i) to (v) is a case study base question of 5 marks.

18. Two transparent media of refractive indices n_1 and n_2 are separated by a spherical transparent surface. The rays of light incident on the surface get refracted into the medium on the other side. The laws of refraction are valid at each point of the spherical surface. A lens is a transparent optical medium bounded by two surfaces, at least one of which should be spherical. The focal length of a lens is determined by the radii of curvature (R_1 and R_2) of its two surfaces and the refractive index(n) of the medium of the lens with respect to the surrounding medium. Depending on R_1 and R_2 a lens behaves as a diverging or a converging lens. The ability of a lens to diverge or converge a beam of light incident on it define its power.

(i) An object is placed at the point B as shown in the figure. The object distance (u) and the image distance (v) are related as



(a) $\frac{1}{v}-\frac{1}{u}=\left(\frac{n_2-n_1}{n_1}\right)\frac{1}{R}$ (b) $\frac{1}{v}-\frac{1}{u}=\left(\frac{n_1-n_2}{n_2}\right)\frac{1}{R}$

(c) $\frac{n_2}{v}-\frac{n_1}{u}=\frac{(n_2-n_1)}{R}$ (d) $\frac{n_1}{v}-\frac{n_2}{u}=\frac{(n_1-n_2)}{R}$

(ii) A point object is placed in air at a distance 'R' in front of a convex spherical refracting surface of radius of curvature R. If the medium on the other side of the surface is glass, then the image is

(a) real and formed in glass.
(b) real and formed in air.
(c) virtual and formed in glass.
(d) virtual and formed in air.

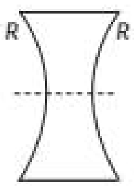
(iii) An object is kept at $2F$ in front of an equi-convex lens. The image formed is

(a) real and of the size of the object.
(b) virtual and of the size of the object.
(c) real and enlarged.
(d) virtual and diminished.

(iv) A thin converging lens of focal length 10 cm and a thin diverging lens of focal length 20 cm are placed coaxially in contact. The power of the combination is

(a) $-5D$ (b) $+5D$ (c) $+15D$ (d) $-15D$

(v) An equi-concave lens of focal length 'f' is cut into two identical parts along the dotted line as shown in the figure. The focal length of each part will be



(a) $\frac{f}{4}$ (b) $\frac{f}{2}$ (c) f (d) $2f$

(Term II 2021-22)

19. A biconvex lens of glass having refractive index 1.47 is immersed in a liquid. It becomes invisible and behaves as a plane glass plate. The refractive index of the liquid is

(a) 1.47 (b) 1.62 (c) 1.33 (d) 1.51

(2020) U

VSA (1 mark)

20. An object approaches a converging lens with a uniform speed of 5 m/s and stops at the focus. How will the image move with respect to the lens? Specify its nature. *(2021)*

21. A biconvex lens made up of glass of refractive index 1.5, forms a real image of an object in air. If the whole set-up were immersed in a liquid of refractive index 1.7, then how will the nature of the image be affected? *(2020)*

23. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason.

(AI 2014) Ap

SA I (2 marks)

24. Using lens maker's formula, derive the thin lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a biconvex lens. *(2020)*

25. The focal length of an equi-concave lens is 3/4 times of radius of curvature of its surfaces. Find the refractive index of the material of the lens. Under what condition will this lens behave as a converging lens? *(2020)*

26. A screen is placed 80 cm from an object. The image of the object on the screen is formed by a convex lens placed between them at two different locations separated by a distance 20 cm. Determine the focal length of the lens. *(2/5, 2020)* Ev

27. A beam of light converges at a point P. Now a convex lens is placed in the path of the convergent beam at 15 cm from point P. At what point does a beam converge if the convex lens has a focal length 10 cm? *(AI 2019)*

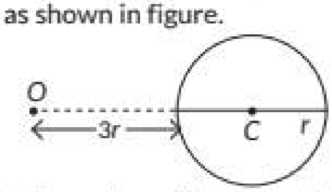
28. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?

(Delhi 2014) An

SA II (3 marks)

29. (a) An object is placed in front of a converging lens. Obtain the conditions under which the magnification produced by the lens is (i) negative and (ii) positive.

(b) A point object is placed at O in front of a glass sphere as shown in figure.



Show the formation of image by the sphere.

(Term II 2021-22)

30. A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm. *(1/3, AI 2017)* Ap

31. A convex lens of focal length 20 cm is placed coaxially

22. A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens? *(Delhi 2015)*

with a convex mirror of radius of curvature 20 cm. The two are kept at 15 cm from each other. A point object lies 60 cm in front of the convex lens. Draw a ray diagram to show the formation of the image by the combination. Determine the nature and position of the image formed. *(AI 2014)*

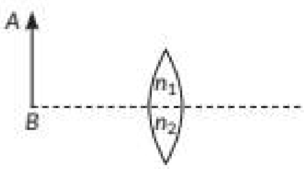
32. A convex lens of focal length 20 cm is placed coaxially with a concave mirror of focal length 10 cm at a distance of 50 cm apart from each other. A beam of light coming parallel to the principal axis is incident on the convex lens. Find the position of the final image formed by this combination.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

33. A convex lens of focal length 20 cm is placed coaxially with a convex mirror of radius of curvature 20 cm. The two are kept 15 cm apart. A point object is placed 40 cm in front of the convex lens. Find the position of the image formed by this combination. Draw the ray diagram showing the image formation. *(AI 2014)* An

LA (4/5 marks)

34. A lens is a transparent optical medium bounded by two surface atleast one of which should be spherical. Considering image formation by a single spherical surface successively at the two surfaces of a lens, lens maker's formula is obtained. It is useful to design lenses of desired focal length using surfaces of suitable radii of curvature. This formula helps us obtain a relation between *u*, *v* and *f* for a lens. Lenses form images of objects and they are used in a number of optical devices, for example microscopes and telescopes.

(i) An object *AB* is kept in front of a composite convex lens, as shown in figure. Will the lens produce one image? If not, explain.



(ii) A real image of an object formed by a convex lens is observed on a screen. If the screen is removed, will the image still be formed? Explain.

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

OR

36. (a) Derive lens maker's formula for a biconvex lens.

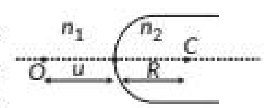
(b) A point object is placed at a distance of 12 cm on the principal axis of a convex lens of focal length 10 cm. A convex mirror is placed coaxially on the other side of the lens at a distance of 10 cm. If the final image coincides with the object, sketch the ray diagram and find the focal length of the convex mirror. *(2020)*

37. (a) Derive the mathematical relation between refractive indices n_1 and n_2 of two media and radius of curvature *R* for refraction at a convex spherical surface. Consider the object to be a point source lying on the principal axis in rarer medium of refractive index n_1 and a real image formed in the denser medium of refractive index n_2. Hence, derive lens maker's formula.

(b) Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed? *(AI 2016)*

38. (a) A point object '*O*' is kept in a medium of refractive index n_1 in front of a convex spherical surface of radius of curvature *R* which separates the second medium of refractive index n_2 from the first one, as shown in the figure.

Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of n_1, n_2 and *R*.



(b) (i) When the image formed above acts as a virtual object for a concave spherical surface separating the medium n_2 from n_1 ($n_2 > n_1$), draw this ray diagram and write the similar (similar to (a)) relation.

(ii) Hence, obtain the expression for the lens maker's formula. *(Delhi 2015)* Ev

39. Draw a ray diagram showing the formation of the image by a point object on the principal axis of a

(iii) Two convex lenses A and B of focal lengths 15 cm and 10 cm respectively are placed coaxially 'd' distance apart. A point object is kept at a distance of 30 cm in front of lens A. Find the value of 'd' so that the rays emerging from lens B are parallel to its principal axis. *(2023)*

35. An object is placed 30 cm in front of a plano-convex lens with its spherical surface of radius of curvature 20 cm. If the refractive index of the material of the lens is 1.5, find the position and nature of the image formed. *(2/5, 2020)* Ev

curvature R_1 and R_2. Show the path of rays due to refraction at first and subsequently at the second surface to obtain the formation of the real image of the object.

Hence obtain the lens-maker's formula for a thin lens.

(b) A double convex lens having both faces of the same radius of curvature has refractive index 1.55. Find out the radius of curvature of the lens required to get the focal length of 20 cm. *(AI 2014C)* Ev

Power of a Lens

MCQ

41. A biconcave lens of power P vertically splits into two identical plano concave parts. The power of each part will be

(a) $2P$ (b) $P/2$ (c) P (d) $P/\sqrt{2}$

(2020) U

VSA (1 mark)

42. What is the power of an equiconvex lens of refractive index n_2 dipped in a liquid of refractive index n_1, where $n_1 < n_2$? *(2021)*

SA II (3 marks)

43. (i) Define SI unit of power of a lens.
(ii) A plano convex lens is made of glass of refractive index 1.5. The radius of curvature of the convex surface is 25 cm.
(a) Calculate the focal length of lens.
(b) If an object is placed 50 cm in front of the lens, find the nature and position of the image formed. *(Term II 2021-22)*

spherical convex surface separating two media of refractive indices n_1 and n_2, when a point source is kept in rarer medium of refractive index n_1. Derive the relation between object and image distance in terms of refractive index of the medium and radius of curvature of the surface.

Hence obtain the expression for lens-maker's formula in the case of thin convex lens. *(Delhi 2014C)*

40. (a) A point object is placed in front of a double convex lens (of refractive index $n = n_2/n_1$ with respect to air) with its spherical faces of radii of

of the lens is 5 D. Calculate the distance of the object and the image from the lens. *(2023)*

45. A lens is a portion of a transparent medium bounded by two surfaces and one of these surfaces is essentially spherical. It is used to converge or diverge the light incident on it. Power of a lens is the measure of its ability to converge or diverge the light incident on it. Power of a lens depends on the refractive index of the material of lens with respect to the surrounding medium and the radii of curvature of its two surfaces.

(a) The power of a convex lens
(i) increases when the lens is dipped in water.
(ii) increases when the wavelength of incident light decreases.
(iii) decreases when another convex lens is placed in contact with it.
(iv) increases when the lens is cut into two identical plano-convex lenses.

(b) The focal length of a concave lens is 40 cm. The power of the lens is
(i) 0.025 D (ii) 2.5 D
(iii) –0.025 D (iv) –2.5 D

(c) The focal length of a concave lens ($\mu_g = 1.5$) in air is 20 cm. What should be the refractive index of the surrounding medium so that the lens behaves as a converging lens of focal length 60 cm?
(i) 1.4 (ii) 1.8 (iii) 1.7 (iv) 1.2

(d) Beams of red light, blue light, yellow light and violet light are incident on a convex lens, one-by-one. Which one of them converges nearest to the lens?
(i) Blue light (ii) Violet light
(iii) Red light (iv) Yellow light

(e) A beam of light coming parallel to the principal axis of a convex lens L_1 of focal length 15 cm is incident on it. Another convex lens L_2 of focal

LA (4/5 marks)

44. The lens maker's formula is useful to design lenses of desired focal lengths using surfaces of suitable radii of curvature. The focal length also depends on the refractive index of the material of the lens and the surrounding medium. The refractive index depends on the wavelength of the light used. The power of a lens is related to its focal length.

Answer the following questions based on the above:

(a) How will the power of a lens be affected with an increase of wavelength of light?

(b) The radius of curvature of two surfaces of a convex lens is R each. For what value of m of its material will its focal length become equal to R?

(c) The focal length of a concave lens of $\mu = 1.5$ is 20 cm in air. It is completely immersed in water of $\mu = \frac{4}{3}$. Calculate its focal length in water.

OR

(c) An object is placed in front of a lens which forms its erect image of magnification 3. The power

length 25 cm is placed coaxially at a distance d from L_1. For the final image to be formed at infinity, the value of d should be :

(i) 10 cm (ii) 15 cm

(iii) 25 cm (iv) 40 cm *(2022 C)*

Combination of Thin Lenses in Contact

SA I (2 marks)

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

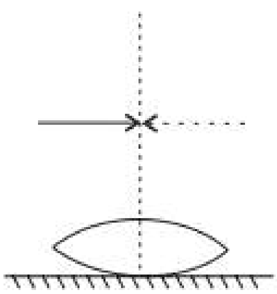
A double convex lens of +5 D is made of glass of refractive index 1.55 with both faces of equal radii of curvature. Find the value of its radius of curvature.

(Foreign 2015) An

SA II (3 marks)

47. A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror

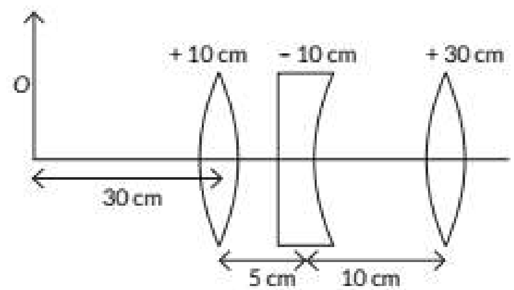
as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle itself. The distance of the needle from the lens is measured to be x. On removing the liquid layer and repeating the experiment, the distance is found to be y. Obtain the expression for the refractive index of the liquid in terms of x and y.



(2018) Cr

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

below. Find the position of the final image formed by the combination.



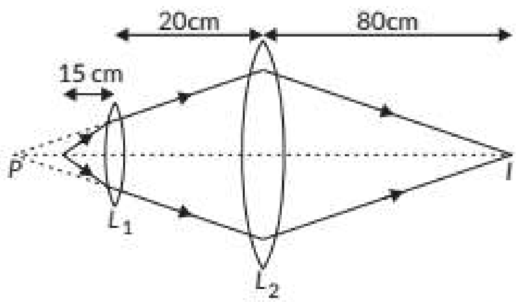
(2/5, Delhi 2019)

50. Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses. *(2/5, AI 2015)*

9.6 Refraction through a Prism

MCQ

51. For a glass prism, the angle of minimum deviation will be smallest for the light of



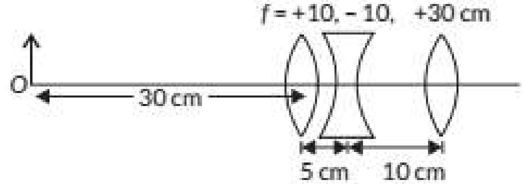
(Foreign 2016) An

LA (5 marks)

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

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

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

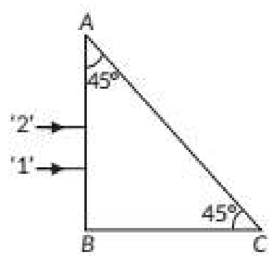


(AI 2019) Ev

OR

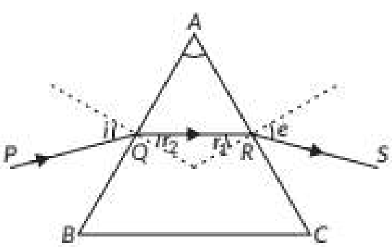
Three lenses of focal lengths +10 cm, –10 cm and +30 cm are arranged coaxially as in the figure given

56. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.33 and 1.45. Trace the path of these rays after entering the prism.



(AI 2014) An

57. Figure shows a ray of light passing through a prism. If the refracted ray QR is parallel to the base BC, show that



(a) red colour (b) blue colour
(c) yellow colour (d) green colour

(2020) U

VSA (1 mark)

52. **Assertion (A) :** The angle of minimum deviation for a prism is lesser for red light than that for blue light.

Reason (R) : The refractive index of the material of a prism for blue light is greater than that for red light.

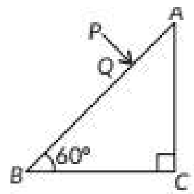
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false. (2021)

53. A ray of light on passing through an equilateral glass prism, suffers a minimum deviation equal to the angle of the prism. The value of refractive index of the material of the prism is _____. (2020)

54. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light? Give reason. (AI 2017)

SA I (2 marks)

55. A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge? Justify your answer.

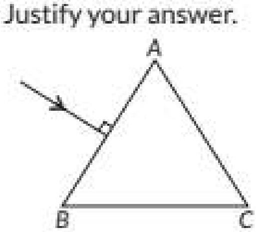


(AI 2016) Ap

61. (a) Plot a graph for angle of deviation as a function of angle of incidence for a triangular prism.

(b) Derive the relation for the refractive index of the prism in terms of the angle of minimum deviation and angle of prism. (AI 2019)

62. The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index $\frac{3}{2}$, placed in water of refractive index $\frac{4}{3}$. Will this ray suffer total internal reflection on striking the face AC? Justify your answer.



(1/3, 2018) An

63. (a) A ray of light incident on face AB

that

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

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

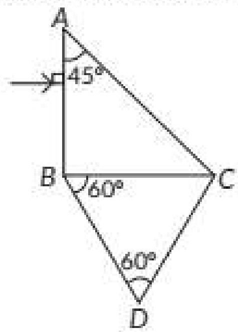
(Foreign 2014)

SA II (3 marks)

58. (a) Write two necessary conditions for total internal reflection.

(b) Two prisms *ABC* and *DBC* are arranged as shown in figure.

The critical angles for the two prisms with respect to air are 41.1° and 45° respectively. Trace the path of the ray through the combination.

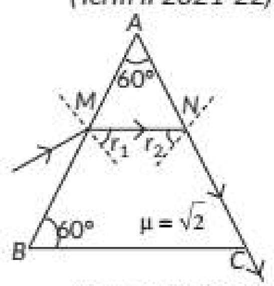


(Term II 2021-22)

59. A ray of light passes through a prism of refractive index $\sqrt{2}$ as shown in the figure. Find :

(i) The angle of incidence ($\angle r_2$) at face *AC*.

(ii) The angle of minimum deviation for this prism.



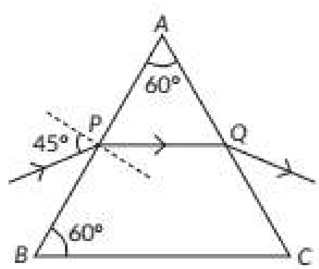
(Term II 2021-22)

60. A ray of light is incident on a prism at an angle of 45° and passes symmetrically as shown in the figure, Calculate.

(a) the angle of minimum deviation,

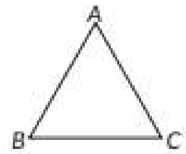
(b) the refractive index of the material of the prism, and

(c) the angle of refraction at the point *P*.



(Term II 2021-22)

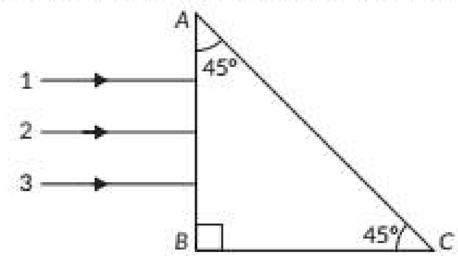
of an equilateral glass prism, shows minimum deviation of 30°. Calculate the speed of light through the prism.



(b) Find the angle of incidence at face *AB* so that the emergent ray grazes along the face *AC*.

(Delhi 2017)

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



(Foreign 2016) An

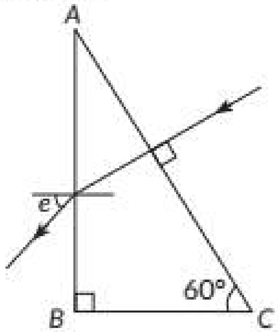
LA (5 marks)

65. (i) Explain the working principle of an optical fibre with the help of a diagram. Mention one use of a light pipe.

(ii) A ray of light is incident at an angle of 60° on one face of a prism with the prism angle $A = 60°$. The ray passes symmetrically through the prism. Find the angle of minimum deviation (δ_m) and refractive index of the material of the prism. If the prism is immersed in water, how will δ_m be affected? Justify your answer. *(2023)*

66. Calculate the angle of emergence (*e*) of the ray of light incident normally on the face *AC* of a glass prism *ABC* of refractive index $\sqrt{3}$. How will the angle of emergence change qualitatively, if the ray of light

emerges from the prism into a liquid of refractive index 1.3 instead of air?

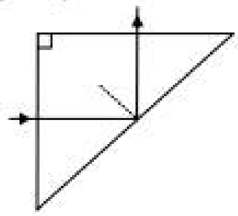


(2020) Ev

67. A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$ of the angle of prism. Calculate the speed of light in the prism. (2/5, AI 2017) Ap

68. (a) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism.

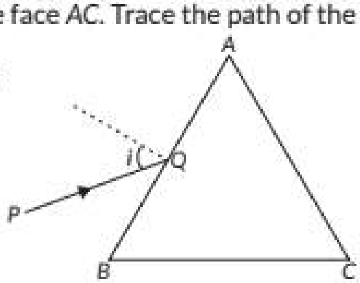
(b) A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in figure. What must be the minimum value of refractive index of glass? Give relevant calculations. (3/5, Delhi 2016)



69. (a) A ray *PQ* of light is incident on the face *AB* of a glass prism *ABC* (as shown in the figure) and emerges out of the face *AC*. Trace the path of the ray. Show that

$\angle i + \angle e = \angle A + \angle \delta$

where δ and e denote the angle of deviation and angle of emergence respectively.



Plot a graph showing the variation of the angle of deviation as a function of angle of incidence. State the condition under which $\angle\delta$ is minimum.

(b) Find out the relation between the refractive index (μ) of the glass prism and $\angle A$ for the case when the angle of prism (A) is equal to the angle of minimum deviation (δ_m). Hence obtain the value of the refractive index for angle of prism $A = 60°$. (AI 2015) Ev

9.7 Optical Instruments

The Microscope

71. A compound microscope is used because a realistic simple microscope does not have _____ magnification. (2020) R

SA I (2 mark)

72. Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and the eyepiece of a compound microscope has short focal lengths? Explain. (Delhi 2017)

73. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece. (AI 2015) Ev

SA II (3 marks)

74. With the help of a ray diagram, show how a compound microscope forms a magnified image of a tiny object, at least distance of distinct vision. Hence derive an expression for the magnification produced by it. (Term II 2021-22)

OR

With the help of a ray diagram, explain the formation of image in a compound microscope when the final image is formed at the near point. Obtain the expression for the magnifying power in this case. (2020)

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

(ii) A small object is placed at a distance of 3.0 cm from a magnifier of focal length 4.0 cm. Find.

(I) the position of the image formed and

(II) the linear magnification produced

(Term II 2021-22)

76. An optical instrument uses an objective lens of power 100 D and an eyepiece of power 40 D. The final image is formed at infinity when the tube length of the instrument is kept at 20 cm.

(a) Identify the optical instrument.

(b) Calculate the angular magnification produced by the instrument. (2020) Ev

77. (a) Draw a ray diagram for the formation of image by a compound microscope.

(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct a compound microscope?

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

VSA (1 mark)

70. In simple microscope, a convex lens of focal length 5 cm is used. Calculate the magnifying power when the objct is placed at the focus of the lens. *(2021)*

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

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

LA (5 marks)

80. (i) Draw a ray diagram to show the working of a compound microscope. Obtain the expression for the expression for the total magnification for the final image to be formed at the near point.

(ii) In a compound microscope an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye-piece has a focal length of 5 cm and the final image is formed at the near point. Find the magnifying power of the microscope. *(2023)*

81. A compound microscope consists of two converging lenses. One of them, of smaller aperture and smaller focal length is called objective and the other of slightly larger aperture and slightly larger focal length is called eye-piece. Both the lenses are fitted in a tube with an arrangement to vary the distance between them. A tiny objects is placed in front of the objective at a distance slightly greater than its focal length. The objective produces the image of the object which acts as an object for the eye-piece. The eye piece, in turn produces the final magnified image.

(I) In a compound microscope the images formed by the objective and the eye-piece are respectively

(a) virtual, real (b) real, virtual
(c) virtual, virtual (d) real, real

(II) The magnification due to a compound microscope does not depend upon

(a) the aperture of the objective and the eye-piece
(b) the focal length of the objective and the eye-piece

(2/3, AI 2017)

78. Draw a ray diagram showing the image formation by a compound microscope. Obtain expression for total magnification when the image is formed at infinity. *(3/5, AI 2015C)*

(V) The focal lengths of objective and eye-piece of a compound microscope are 1.2 cm and 3.0 cm respectively. The object is placed at a distance of 1.25 cm from the objective. If the final image is formed at infinity, the magnifying power of the microscope would be

(a) 100 (b) 150
(c) 200 (d) 250 *(2022 C)*

The Telescope

SA I (2 marks)

82. Why should the objective of a telescope have large focal length and large aperture? Justify your answer. *(Delhi 2017)* U

83. (a) Draw a ray diagram showing the formation of image by a reflecting telescope.

(b) Write two advantages of a reflecting telescope over a refracting telescope. *(AI 2017)*

OR

Draw a schematic arrangement of a reflecting telescope (Cassegrain) showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope. *(Delhi 2016)*

84. A small telescope has an objective lens of focal length 150 cm and eyepiece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment?

If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens? *(AI 2015)*

SA II (3 marks)

85. With the help of a ray diagram explain the working of a reflecting telescope. Mention two advantages of a reflecting telescope over a refracting telescope. *(Term II 2021-22)*

86. (a) (i) Draw a labelled ray diagram showing the formation of the image at infinity by an astronomical telescope.

(c) the length of the tube
(d) the colour of the light used
(III) Which of the following is not correct in the context of a compound microscope?
(a) Both the lenses are of short focal lengths.
(b) The magnifying power increases by decreasing the focal lengths of the two lenses.
(c) The distance between the two lenses is more than $(f_o + f_e)$.
(d) The microscope can be used as a telescope by interchanging the two lenses.
(IV) A compound microscope consists of an objective of 10X and an eye-piece of 20X. The magnification due to the microscope would be
(a) 2 (b) 10 (c) 30 (d) 200

88. Draw a labelled ray diagram of an astronomical telescope in the near point adjustment position.
A giant refracting telescope at an observatory has an objective lens of focal length 15 m and an eyepiece of focal length 1.0 cm. If this telescope is used to view the Moon, find the diameter of the image of the Moon formed by the objective lens. The diameter of the Moon is 3.48×10^6 m, and the radius of lunar orbit is 3.8×10^8 m. *(Delhi 2019)* Ev

89. Draw a ray diagram to show the image formation of a distant object by a refracting telescope. Write the expression for its angular magnification in terms of the focal lengths of the lenses used. State the important considerations required to achieve large resolution and their consequent limitations. *(AI 2019)* Ev

90. (a) Draw a ray diagram depicting the formation of the image by an astronomical telescope in normal adjustment.
(b) You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope? Give reason.

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

(AI 2017) An

91. Which two of the following lenses L_1, L_2, and L_3 will you select as objective and eyepiece for constructing best possible (i) telescope (ii) microscope? Give reason to support your answer.

(ii) A telescope consists of an objective of focal length 150 cm and an eyepiece of focal length 6.0 cm. If the final image is formed at infinity, then calculate.
(I) the length of the tube in this adjustment, and
(II) the magnification produced. *(Term II 2021-22)*

87. What is the difference in the construction of an astronomical telescope and a compound microscope? The focal lengths of the objective and eyepiece of a compound microscope are 1.25 cm and 5.0 cm, respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 when the final image is formed at the near point. *(2020)* Ev

93. (i) Draw a ray diagram for the formation of image of an object by an astronomical telescope, in normal adjustment. Obtain the expression for its magnifying power.
(ii) The magnifying power of an astronomical telescope in normal adjustment is 2.9 and the objective and the eyepiece are separated by a distance of 150 cm. Find the focal lengths of the two lenses. *(2023)*

94. An astronomical telescope has an objective lens of focal length 20 m and eyepiece of focal length 1 cm.
(a) Find the angular magnification of the telescope.
(b) If the telescope is used to view the Moon, find the diameter of the image formed by the objective lens. Given the diameter of the Moon is 3.5×10^6 m and radius of lunar orbit is 3.8×10^8 m. *(2/5, 2020)*

95. Explain two advantages of a reflecting telescope over a refracting telescope. *(1/5, 2018)* U

96. Draw a labelled ray diagram to obtain the real image formed by an astronomical telescope in normal adjustment position. Define its magnifying power.
You are given three lenses of power 0.5 D, 4 D and 10 D to design a telescope.
(i) Which lenses should be use as objective and eyepiece ? Justify your answer.
(ii) Why is the aperture of the objective preferred to be large ? *(AI 2016)* Ev

97. (a) Draw a labelled schematic ray diagram of astronomical telescope in normal adjustment.
(b) Which two aberrations do objectives of refracting telescope suffer from? How are these overcome in reflecting telescope?

Lens	Power (*P*)	Aperture (*A*)
L_1	6 D	1 cm
L_2	3 D	8 cm
L_3	10 D	1 cm

(Delhi 2015C)

LA (5 marks)

92. (i) Draw a ray diagram to show how the final image is formed at infinity in an astronomical refracting telescope. Obtain an expression for its magnifying power.

(ii) Two thin lenses L_1 and L_2, L_1 being a convex lens of focal length 24 cm and L_2 a concave lens of focal length 18 cm are placed coaxially at a separation of 45 cm. A 1 cm tall object is placed in front of the lens L_1 at a distance of 36 cm. Find the location and height of the image formed by the combination. *(2023)*

(Foreign 2016)

98. Draw a ray diagram showing the image formation of a distant object by a refracting telescope. Define its magnifying power and write the two important factors considered to increase the magnifying power.
Describe briefly the two main limitations and explain how far these can be minimized in a reflecting telescope. *(Foreign 2015)*

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

(b) A compound microscope has an objective of focal length 1.25 cm and eyepiece of focal length 5 cm. A small object is kept at 2.5 cm from the objective. If the final image formed is at infinity, find the distance between the objective and the eyepiece. *(Foreign 2014)* Cr

CBSE Sample Questions

9.2 Reflection of Light by Spherical Mirrors

MCQ

1. **Given below are two statements labelled as assertion (A) and Reason (R).**
Assertion (A) : A convex mirror cannot form real images.
Reason (R) : Convex mirror converges the parallel rays that are incident on it.
Select the most appropriate answer from the options given below:
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true. *(2020-21)* R

9.5 Refraction at Spherical Surface and by Lenses

SA I (2 marks)

2. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Justify your answer.

Select the most appropriate answer from the options given below:
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true. *(2020-21)* R

SA II (3 marks)

6. (a) Draw a ray diagram of compound microscope for the final image formed at least distance of distinct vision?

(b) An angular magnification of 30*X* is desired using an objective of focal length 1.25 cm and an eye piece of focal length 5 cm. How will you set up the compound microscope for the final image formed at least distance of distinct vision? *(Term II 2021-22)*

7. (a) Draw a ray diagram of astronomical telescope for the final image formed at infinity.

(b) A small telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. Find the magnifying power of the telescope for viewing distant objects when

(i) the telescope is in normal adjustment,

(2022-23)

3. Write two characteristics of image formed when an object is placed between the optical centre and focus of a thin convex lens. Draw the graph showing variation of image distance v with object distance u in this case. (2020-21)

SA II (3 marks)

4. The focal length of a convex lens made of glass of refractive index (1.5) is 20 cm. What will be its new focal length when placed in a medium of refractive index 1.25? Is focal length positive or negative? What does it signify? (Term II 2021-22) An

9.7 Optical Instruments

MCQ

5. **Given below are two statements labelled as assertion (A) and Reason (R).**

Assertion (A) : A convex lens of focal length 30 cm can't be used as a simple microscope in normal setting.

Reason (R): For normal setting, the angular magnification of simple microscope is $M = D/F$

(ii) the final image is formed at the least distance of distinct vision. (Term II 2021-22)

LA (4 marks)

8. A number of optical devices and instruments have been designed and developed such as periscope, binoculars, microscopes and telescopes utilising the reflecting and refracting properties of mirrors, lenses and prisms. Most of them are in common use. Our knowledge about the formation of images by the mirrors and lenses is the basic requirement for understanding the working of these devices.

(i) Why the image formed at infinity is often considered most suitable for viewing? Explain.

(ii) In modern microscopes multicomponent lenses are used for both the objective and the eyepiece. Why?

(iii) Write two points of difference between a compound microscope and an astronomical telescope.

OR

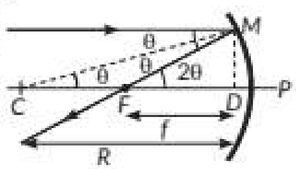
(iii) Write two distinct advantages of a reflecting type telescope over a refracting type telescope. (2022-23)

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. The distance between the principal focus and pole of the mirror is called as focal length.

Let C be the centre of curvature and F be the principal focus of the mirror. Let θ be the angle of incidence and MD be the perpendicular from M on the principal axis.



Then $\angle MCP = \theta$, $\angle MFP = 2\theta$

Now in ΔMCD, $\tan\theta = \frac{MD}{CD}$ and in

ΔMFD, $\tan 2\theta = \frac{MD}{FD}$

$\Rightarrow \frac{MD}{FD} = \frac{2MD}{CD}$ [$\because$ for small θ, $\tan\theta \approx \theta$]

$\Rightarrow FD = \frac{CD}{2} = \frac{R}{2}$ or $f = \frac{R}{2}$

2. When an object is placed between f and $2f$ of a concave mirror, the image formed is real and magnified.

This implies that $v < 0$ so that image is formed on left. Also the above inequality implies

$2f > v$

or $|2f| < |v|$ [$\because$ $2f$ and v are negative]

i.e., the real image is formed beyond $2f$.

6. (a) For virtual image, $m = +2$

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

$u = -10$ cm, $v = -2u = 20$ cm

Using mirror formula

$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$; $\frac{1}{f} = \frac{1}{20} - \frac{1}{10}$

$f = -20$ cm

(b) For real image

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

$v = 2u$

$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$; $-\frac{1}{20} = \frac{1}{2u} + \frac{1}{u}$

$u = -30$ cm

$\therefore$ Displacement of object = 30 – 10 = 20 cm away from mirror.

3. Radius of curvature $R = 60$ cm
focal length $f = 30$ cm

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

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

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

$v = 60$ cm

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

4. $f = -15$ cm, $m = 3$, $u = -x$ cm

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

Using mirror formula,

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

$\Rightarrow$ $x = 10$ cm

$\therefore$ Distance of object from the mirror, $x = 10$ cm.

5. From mirror formula, $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$

Now for a concave mirror, $f < 0$ and for an object on the left of the mirror, $u < 0$

$\therefore$ $2f < u < f$ or $\frac{1}{2f}>\frac{1}{u}>\frac{1}{f}$ or $-\frac{1}{2f}<-\frac{1}{u}<-\frac{1}{f}$

or $\frac{1}{f}-\frac{1}{2f}<\frac{1}{f}-\frac{1}{u}<\frac{1}{f}-\frac{1}{f}$ or $\frac{1}{2f}<\frac{1}{v}<0$

Thus the different parts of the mobile phone are magnified in different proportions because of their different locations from the concave mirror.

(b) One would naturally think that image will be half of the object, but taking the laws of reflection to be true for all points of the mirror, the image will be of the whole object. However, as the area of the reflecting surface has reduced, the intensity of the image will be dim.

Concept Applied

➲ For all points of the mirror, the laws of reflection are

7. (a) Here, $R = -20$ cm, $f = R/2 = -10$ cm
$m = -2$ (image is real)
u = object distance, v = image distance

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

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

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

$\therefore$ $u = -15$ cm

Hence, $v = 2u = -30$ cm

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

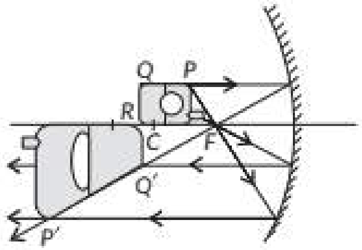
Using mirror formula, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

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

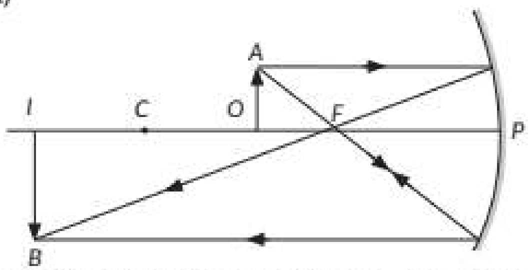
$\therefore$ $v > 0$

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

8. (a) The formation of the image of the cell phone is shown in figure. The part which is at R will be imaged at R and will be of the same size, *i.e.*, $Q'R = QR$. The other end P of the mobile phone is highly magnified by the concave mirror.



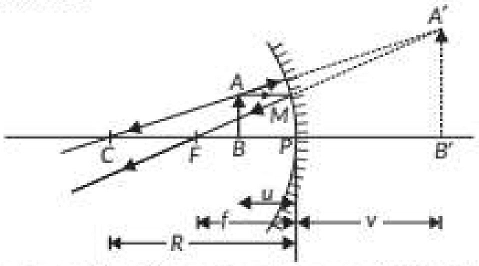
10. (a)



(b) Derivation of mirror formula for a concave mirror: Consider an object AB placed on the principal axis beyond the centre of curvature C of a concave mirror of small aperture, as shown in figure.

true. Therefore, the height of the whole image will be produced.

9. Consider an object AB placed on the principal axis of a concave mirror between its pole P and focus F. As shown in figure, a virtual and erect image $A'B'$ is formed behind the mirror, after reflection from the concave mirror.



Using the cartesian sign convention, we find that

Object distance, $BP = -u$

Image distance, $PB' = v$

Focal length, $FP = -f$

Radius of curvature, $CP = -R = -2f$

Now $\Delta ABC \sim \Delta A'B'C$

$$\therefore \quad \frac{AB}{A'B'} = \frac{CB}{CB'} = \frac{CP-BP}{CP+PB'} = \frac{-2f+u}{-2f+v} \quad \text{... (i)}$$

Also $\Delta MPF \sim \Delta A'B'F$

$$\therefore \quad \frac{MP}{A'B'} = \frac{FP}{FB'} = \frac{FP}{FP+PB'} \quad \text{or} \quad \frac{AB}{A'B'} = \frac{-f}{-f+v} \quad \text{... (ii)}$$

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

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

or $\quad 2f^2 - fu - 2fv + uv = 2f^2 - fv$

or $\quad -fv - fu + uv = 0$

or $\quad uv = fv + fu$

Dividing both sides by $u\,v\,f$, we get

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

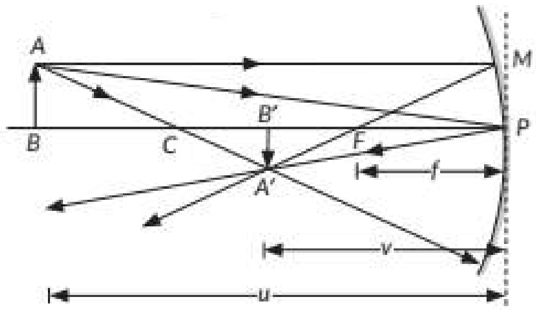
This proves the mirror equation for a concave mirror when it forms a virtual image.

Answer Tips

- When an object is held in front of a concave mirror between the pole P and principal focus F of the mirror, the image formed is virtual, erect and magnified.

This is mirror formula, which is valid for all mirrors.

Linear magnification : The ratio of the height of the image to that of the object is called linear or transverse magnification or just magnification and is denoted by m.



A ray AM from the object travels parallel to the principal axis and after reflection from the mirror it passes through focus F. Another ray AP is incident on the pole P of the mirror and is reflected along PA' in accordance with the laws of reflection so then $\angle APB = \angle B'PA'$. The two reflected rays meet at point A'. Thus A' is the real image of A. The image of any point on AB will lie on a corresponding point of $A'B'$. Hence $A'B'$ is the real image of AB formed by reflection from the concave mirror.

Using cartesian sign convention, we find

Object distance, $BP = -u$

Image distance, $B'P = -v$

Focal length, $FP = -f$

Radius of curvature, $CP = -R = -2f$

Now $\Delta A'B'C \sim \Delta ABC$

$$\therefore \quad \frac{A'B'}{AB} = \frac{CB'}{BC} = \frac{CP-B'P}{BP-CP} = \frac{-R+v}{-u+R} \quad \text{...(i)}$$

As $\angle A'PB' = \angle APB$, therefore,

$\Delta A'B'P \sim \Delta ABP$.

Consequently,

$$\frac{A'B'}{AB} = \frac{B'P}{BP} = \frac{-v}{-u} = \frac{v}{u} \quad \text{...(ii)}$$

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

$$\frac{-R+v}{-u+R} = \frac{v}{u}$$

or $\quad -uR + uv = -vu + vR \quad$ or $\quad vR + uR = 2uv$

Dividing both sides by uvR, we get

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{R}$$

But $R = 2f$

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

(iv) (b) : $\sin C = \frac{1}{\mu}$ or $\sin C = \frac{1}{2} \Rightarrow C = 30°$

(v) (b) : Critical angle, $C = 30°$

$$m = \frac{\text{Height of image}}{\text{Height of object}} = \frac{h_i}{h_o}$$

Also magnification,

$$m = \frac{h_i}{h_o} = -\frac{v}{u}.$$

11. Given : wavelength in air, λ_a = 589 nm
= 5.89×10^{-7} m

Refractive index of water, $\mu_w = 1.33$

∵ speed of light in vacuum, $c = 3 \times 10^8$ m/s

∴ frequency, $\upsilon = \frac{c}{\lambda_a}$

$$= \frac{3\times10^8 \text{ m/s}}{5.89\times10^{-7} \text{ m}} = 5.093\times10^{14} \text{ Hz} \qquad (\because \text{ speed in air} = c)$$

Now, speed of light in water, $v = \frac{c}{\mu_w}$

$$= \frac{3\times10^8 \text{ m/s}}{1.33} \approx 2.2605\times10^8 \text{ m/s}$$

∴ Wavelength in water, $\lambda_w = \frac{v}{\upsilon}$

$$= \frac{\frac{c}{\mu_w}}{\frac{c}{\lambda_a}} = \frac{\lambda_a}{\mu_w} = \frac{5.89\times10^{-7} \text{ m}}{1.33} = 4.43 \times 10^{-7} \text{ m}$$

Thus, for the refracted light

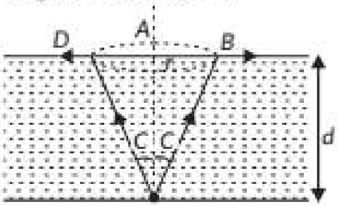
Wavelength, $\lambda_w = 4.43 \times 10^{-7}$ m

Frequency, $\upsilon = 5.09 \times 10^{14}$ Hz and

Speed, $v = 2 \times 10^8$ m/s

12. (i) (a) : Since refractive index of medium is more than that of water, medium is denser than water. Here, light travels from medium (denser) to water (rarer), so it will bends away from the normal. This is correctly shown in (a). Here total internal reflection will not take place because angle of incidence (18°) is less than critical angle (20°).

(ii) (b) : Light rays passes through the surface if,



$$\mu = \frac{1}{\sin C}$$

Also, $\sin C = \frac{r}{\sqrt{r^2+d^2}}$

$$\frac{1}{\mu} = \frac{r}{\sqrt{r^2+d^2}} \Rightarrow r^2+d^2 = \mu^2 r^2$$

$$\Rightarrow d^2 = (\mu^2-1)r^2 \text{ or } r^2 = \frac{d^2}{\mu^2-1}$$

Area, $A = \pi r^2 = \frac{\pi d^2}{\mu^2-1}$

(iii) (c) : Refractive index is minimum for water. Thus, water with respect to air has maximum critical angle.

$$\mu = \frac{1}{\sin C} = \frac{1}{\sin 30^\circ} \Rightarrow \mu = 2$$

Also, $\mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu} = \frac{3\times10^8}{2} = 1.5\times10^8 \text{ m s}^{-1}$

13. (i) The refractive index of a transparent medium is inversely proportional to the wavelength of incident light. The relationship between the two is given by

$$\mu = \frac{\lambda_0}{\lambda}$$

where

μ = Refractive index of medium

λ_0 = Wavelength of incident light in vacuum

λ = Wavelength of incident light in medium

(ii) Given :

Velocity of light in air, $v_a = 3 \times 10^8$ m/s

Velocity of light in glass, $v_g = 2 \times 10^8$ m/s

The refractive index of glass is given by, $\mu_g = \frac{c}{v_g}$

where c is speed of light in vacuum.

The refractive index of air is given by, $\mu_a = \frac{c}{v_a}$

∴ The refractive index of glass w.r.t. air will be

$${}^a\mu_g = \frac{\mu_g}{\mu_a} \Rightarrow {}^a\mu_g = \frac{v_a}{v_g} = \frac{3\times10^8}{2\times10^8} = 1.5$$

We know ${}^a\mu_g = \frac{1}{\sin C}$

where C is the critical angle for the interface

∴ $\frac{1}{\sin C} = 1.5 \Rightarrow \sin C = \frac{1}{1.5}$

⇒ $C = \sin^{-1}(0.66) \Rightarrow C = 41.3^\circ$

∴ Critical angle, $C = 41.3^\circ$

14. Essential conditions for total internal reflection :

(i) Light should be travel from a denser medium to a rarer medium.

(ii) Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.

Relation between refractive index and critical angle

When $i = C$, $r = 90^\circ$

From Snell's law, $\mu_b \sin C = \mu_a \sin 90^\circ = \mu_a \times 1$

$$\frac{\mu_b}{\mu_a} = \frac{1}{\sin C};\ {}^a\mu_b = \frac{1}{\sin C}$$

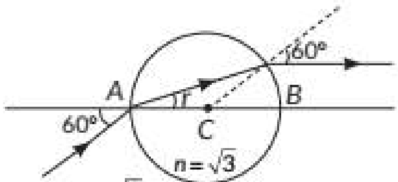
15. From Snell's law, we have : $\frac{\sin(i)}{\sin(r)} = \mu$

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

Now, $\sin(r) = \frac{\sin(i)}{\mu} \Rightarrow \sin(r) = \frac{\sin(60^\circ)}{\sqrt{3}} = \frac{1}{2} \Rightarrow r = \sin^{-1}\left(\frac{1}{2}\right)$

∴ $r = 30^\circ$

16. $n=\frac{\sin i}{\sin r}$



$\sqrt{3}=\frac{\sin 60^\circ}{\sin r}$; $\sin r=\frac{1}{2}$

$r = 30^\circ$

Now, $\frac{1}{\sqrt{3}}=\frac{\sin 30^\circ}{\sin e}$; $\sin e=\sqrt{3}\times\frac{1}{2}=\frac{\sqrt{3}}{2}$

$e = 60^\circ$

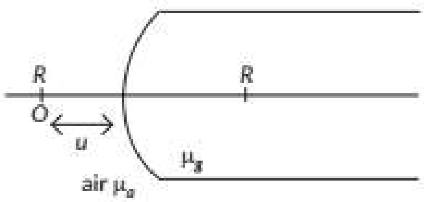
17. (a): $\frac{d}{4}$, as image at $2F$ formed of same size.

Here, $4F = d \Rightarrow F = d/4$

18. (i) : (d) For the spherical refracting surface,

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

(ii) : (d)



If v is the image distance

$$\frac{\mu_g}{v}-\frac{\mu_a}{-R}=\frac{\mu_g-\mu_a}{R} \quad \text{or} \quad \frac{\mu_g}{v}+\frac{1}{R}=\frac{\mu_g}{R}-\frac{1}{R}$$

$$\Rightarrow \quad \frac{\mu_g}{v}=\frac{1}{R}(\mu_g-2) \quad \Rightarrow \quad \frac{\mu_g}{v}=\frac{1}{R}(1.5-2)=-\frac{1}{2R}$$

$$\Rightarrow \quad v=-2\times\frac{3}{2}R=-3R$$

Therefore, virtual image will be formed in the air.

(iii) (a) : If an object is kept at $2F$ from an equi-convex lens, then image will be real, inverted and of same size as object.

(iv) (b) : $f_1 = 10$ cm, $f_2 = -20$ cm

If two lens are kept in contact.

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{10}-\frac{1}{20} \Rightarrow f = +20\text{ cm}$$

$$P=\frac{100}{f(\text{cm})}=\frac{100}{20}=+5\text{D}$$

(v) (c) : If the lens is cut along the horizontal line as shown in figure, then focal length (f) of each part will remains same,

Since, $\frac{1}{f}=(\mu-1)\left(\frac{2}{R}\right)$

19. (a) : 1.47

20. The image moves away with increasing speed from the lens. Image is real, inverted and larger than the object.

21. When convex lens (μ = 1.5) is immersed in a liquid (μ = 1.7), the lens behaves like a concave lens, then the nature of image will be virtual.

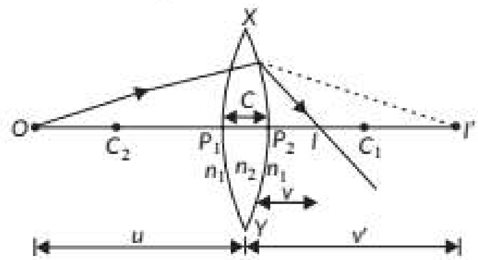
the given lens becomes positive. Hence, it behaves as a convex lens.

Concept Applied

- Focal length of a lens and nature of lens depends on the medium surrounding the lens.

23. The lens will act as a diverging lens as the refractive index of water is greater than that of lens.

24.



For refraction at spherical surface XP_1Y, object is at O and image is at I'.

So, object distance is u and image distance is v'. Also, ray of light is travelling from rarer medium (n_1) to denser medium (n_2).

$$\text{So, } \frac{n_2-n_1}{R_1}=\frac{n_2}{v'}-\frac{n_1}{u} \qquad \text{...(i)}$$

For refraction at spherical surface XP_2Y, point I' behaves as virtual object and image is formed at I. Also, ray of light is travelling from denser medium (n_2) to rarer medium (n_1)

$$\frac{n_2-n_1}{R_2}=\frac{n_2}{v'}-\frac{n_1}{v} \qquad \text{...(ii)}$$

Subtracting equation (ii) from (i), we get

$$\frac{1}{v}-\frac{1}{u}=\left(\frac{n_2-n_1}{n_1}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \qquad \text{...(iii)}$$

When the object is at infinity, light rays incident on lens are parallel and are converged at common point on principal axis known as principal focus F of lens.

So, when $u = -\infty$ then $v = +f$ (focal length)

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

This is the lens maker formula when the lens of glass of refractive index n_2 is placed in any medium of refractive index n_1.

From eqn. (iii) and (iv)

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

This is thin lens formula.

25. Given $f=\frac{-3R}{4}$,

From lens-maker's formula,

22. Focal length of a concave lens is negative.

Using lens maker's formula, $\frac{1}{f}=\left(\frac{\mu_l}{\mu_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

Here, $\mu_l = 1.5$, $\mu_m = 1.65$

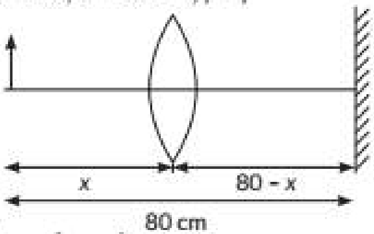
Also, $\frac{\mu_l}{\mu_m} < 1$, so $\left(\frac{\mu_l}{\mu_m}-1\right)$ is negative and focal length of

$\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \Rightarrow \frac{1}{\frac{-3R}{4}}=(\mu-1)\left[\frac{1}{-R}-\frac{1}{R}\right]$

$\frac{4}{3R}=\frac{2(\mu-1)}{R} \Rightarrow \mu=\frac{5}{3}$

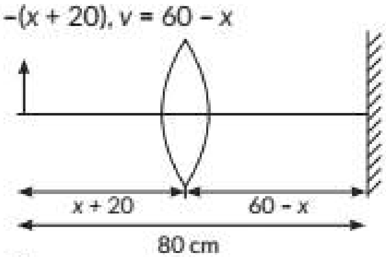
It will behave as a converging lens if $(\mu - 1) < 0$ or $\mu < 1$.

26. Case I : $u = -x$, $v = 80 - x$, $f = f$



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

Case II : $u = -(x + 20)$, $v = 60 - x$



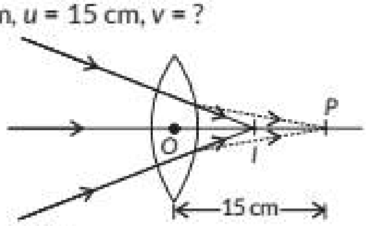
$\frac{1}{f}=\frac{1}{60-x}+\frac{1}{x+20}$ ...(ii)

From (i) and (ii)

$\frac{1}{80-x}+\frac{1}{x}=\frac{1}{60-x}+\frac{1}{x+20} \Rightarrow x=30 \text{ cm}$

$\therefore \quad \frac{1}{f}=\frac{1}{80-30}+\frac{1}{30} \Rightarrow f=18.75 \text{ cm}$

27. $f = 10$ cm, $u = 15$ cm, $v = ?$



Using lens formula,

$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ or, $\frac{1}{v}=\frac{1}{u}+\frac{1}{f}=\frac{1}{15}+\frac{1}{10}=\frac{5}{30}$

$v = 6$ cm

Answer Tips

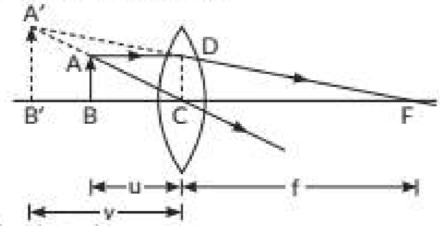
- When the image formed is real, the magnification is negative.

Thus, image formed is real.

(ii) Magnification produced is positive –

As $\Delta ABC \sim \Delta A'B'C$

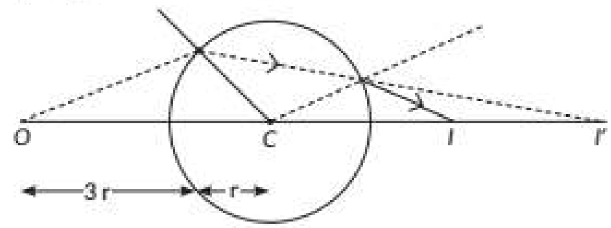
$\frac{A'B'}{AB}=\frac{CB'}{CB}$



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

Thus, image formed is virtual.

(b)



30. Given : $\mu = 1.55$, $f = 20$ cm

$|R_1| = |R_2| = R$ (let)

For double convex lens as $R_1 > 0$ and $R_2 < 0$

So, $R_1 = R$ and $R_2 = -R$

Using lens maker's equation,

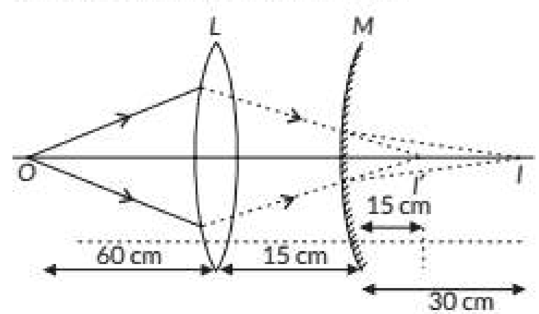
$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$, we get

$\frac{1}{20}=(1.55-1)\left(\frac{1}{R}+\frac{1}{R}\right) \Rightarrow \frac{1}{20}=0.55\times\frac{2}{R}$

$\Rightarrow \quad R = 0.55 \times 2 \times 20 \text{ cm} = 22 \text{ cm}$

$\therefore \quad$ The radius of curvature is 22 cm.

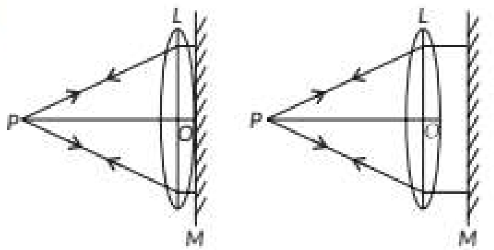
31.



For the convex lens,

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

28.



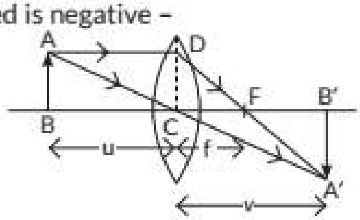
(a) (b)

From figure, focal length of lens = OP = 20 cm

29. (a) Converging lens means convex lens.

(i) Magnification produced is negative –

As $\Delta ABC \sim \Delta A'B'C$



$$\frac{A'B'}{AB}=\frac{CB'}{CB}$$

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

32. Let us first locate the image of the point object S formed by the convex lens. Here

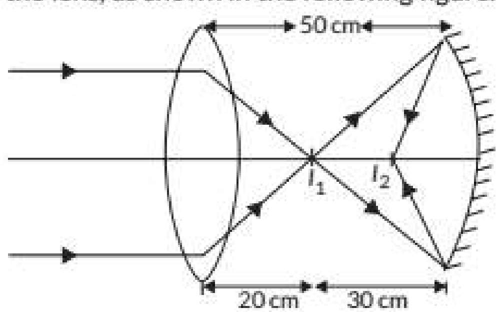
$u = -\infty$ cm and f = 20 cm

From the lens formula, we have: $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\Rightarrow \quad \frac{1}{v}=\frac{1}{20}$

$\therefore \quad v = +20$ cm

The positive sign shows that the image is formed to the right of the lens, as shown in the following figure.



The image I_1 is formed in front of the mirror and hence, acts as a real source for the mirror. The concave mirror forms the image I_2. For the concave mirror, $u = -30$ cm and $f = -10$ cm

Using mirror formula,

$$\frac{1}{v'}+\frac{1}{-30}=\frac{1}{-10} \Rightarrow \frac{1}{v'}=\frac{1}{-10}+\frac{1}{30}=\frac{-3+1}{30}$$

$v' = -15$ cm

Hence, the final image is formed at I_2 at a distance of

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \text{ gives } v = +30 \text{ cm}$$

For the convex mirror

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

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \text{ gives } v = +30 \text{ cm}$$

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

The final image formed is a virtual image.

Commonly Made Mistake

- Sign conventions should be kept in mind to avoid mistakes. Distance should always be measured from the centre of the lens or mirror.

Commonly Made Mistake

- Convex mirrors diverge the reflected rays, convex lenses converge the refracted ray. Also, concave mirrors converge the reflected rays, concave lenses diverge the reflected rays.

34. (i) No, as there are two refractive indices, so lens has two focal lengths and thus two images are formed.

(ii) Yes, the real image is still formed at the same point in space.

(iii) f = 20 cm, $R_1 = R$, $R_2 = -R$, $\mu_g = 1.55$

$$\frac{1}{f}=(\mu_g-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right);\ \frac{1}{20}=(1.55-1)\left(\frac{1}{R}+\frac{1}{R}\right)=\frac{0.55\times 2}{R}$$

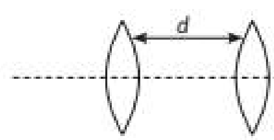
$R = 0.55 \times 2 \times 20 = 22$ cm

OR

(iii) f_A = 15 cm, f_B = 10 cm

u_A = 30 cm

For convex lens A



$$\frac{1}{v_A}-\frac{1}{u_A}=\frac{1}{f_A}$$

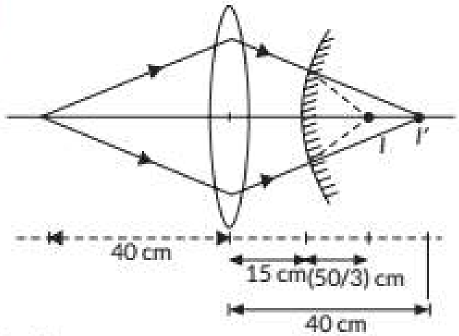
$$\frac{1}{v_A}+\frac{1}{30}=\frac{1}{15}$$

$$\frac{1}{v_A}=\frac{1}{15}-\frac{1}{30}=\frac{1}{30} \Rightarrow v_A = 30 \text{ cm}$$

For concave lens B

15 cm from the concave mirror.

33.



For the lens

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

$u = -40$ cm, $f = +20$ cm. This gives $v = +40$ cm

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

$\therefore \quad u = (+40 - 15)$ cm = 25 cm

Also $f=+\frac{20}{2}\text{ cm}=+10\text{ cm}$

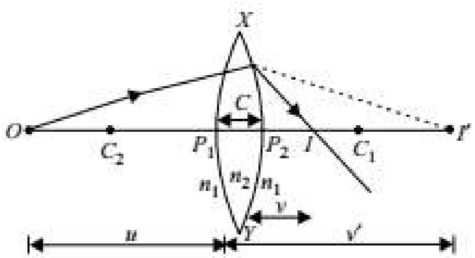
From $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

We get $v=\frac{50}{3}\text{cm} \simeq 16.67\text{ cm}$

The final image is, therefore formed at a distance of $16.67\text{ cm}\left(=\frac{50}{3}\text{cm}\right)$ to the right of the convex mirror.

(at a distance of 31.67 cm $\left(=\frac{95}{3}\text{cm}\right)$ to the right of the convex lens.

36. (a)



For refraction at spherical surface XP_1Y, object is at O and image is at I'.

So, object distance is u and image distance is v'. Also, ray of light is travelling from rarer medium (n_1) to denser medium (n_2).

So, $\frac{n_2-n_1}{R_1}=\frac{n_2}{v'}-\frac{n_1}{u}$ ...(i)

For refraction at spherical surface XP_2Y, point I' behaves as virtual object and image is formed at I. Also, ray of light is travelling from denser medium (n_2) to rarer medium (n_1)

$\frac{n_2-n_1}{R_2}=\frac{n_2}{v'}-\frac{n_1}{v}$ ...(ii)

$u_B=-(d-30), v_B=\infty$

$\frac{1}{\infty}+\frac{1}{d-30}=\frac{1}{10}$

$d = 40$ cm

35. For plano-convex lens, $R_1 = \infty$ and $R_2 = -20$ cm

Given that, $\mu = 1.5$

Using lens maker's formula,

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

or $f = 40$ cm

Given that, $u = 30$ cm

Using lens formula,

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

or $v = -120$ cm

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

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

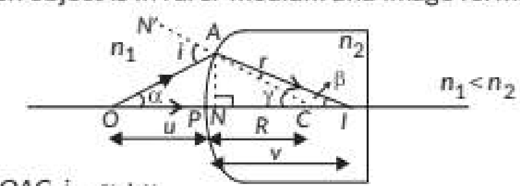
Thus, image is enlarge by four times the size of the object

Answer Tips

- Focal length of a convex lens, $\frac{1}{f}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$ where f is the focal length, μ is the refractive index of the material of the lens, R_1 and R_2 are radii of curvatures.

37. (a) Refraction at convex spherical surface :

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



In ΔOAC, $i = \alpha + \gamma$

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

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

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

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

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

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

$\beta\approx\tan\beta=\frac{AN}{NI}\approx\frac{AN}{PI}$; $\gamma\approx\tan\gamma=\frac{AN}{NC}\approx\frac{AN}{PC}$

On using them in equation (i), we get

Subtracting equation (ii) from (i), we get

$$\frac{1}{v}-\frac{1}{u}=\left(\frac{n_2-n_1}{n_1}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(iii)$$

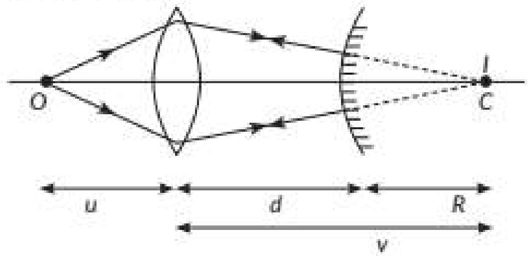
When the object is at infinity, light rays incident on lens are parallel and are converged at common point on principal axis known as principal focus F of lens.

So, when $u = -\infty$ then $v = +f$ (focal length)

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

This is the lens maker formula when the lens of glass of refractive index n_2 is placed in any medium of refractive index n_1.

(b) The final image formed by the combination is coinciding with the object itself. Therefore rays from the object are retracing their path after refraction from the lens and reflection from the mirror. The refracted rays are therefore, falling normally on the mirror. Thus, the image of the convex lens should form at the centre of curvature of the convex mirror.



Using lens formula,

$$\frac{1}{v}-\frac{1}{(-12)}=\frac{1}{10} \Rightarrow \frac{1}{v}=\frac{1}{10}-\frac{1}{12}=\frac{1}{60} \Rightarrow v = 60 \text{ cm}$$

Radius of curvature, $R = v - d$

$\therefore \quad R = 60 - 10 = 50$ cm

$\therefore \quad$ Focal length, $f=\frac{R}{2}=25$ cm

So, $\alpha \approx \tan\alpha=\frac{AN}{NO} \approx \frac{AN}{PO}$; $\beta \approx \tan\beta=\frac{AN}{NI} \approx \frac{AN}{PI}$

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

On using them in equation (i), we get

$$(n_2-n_1)\frac{AN}{PC}=n_1\frac{AN}{PO}+n_2\frac{AN}{PI} \text{ or } \frac{n_2-n_1}{PC}=\frac{n_1}{PO}+\frac{n_2}{PI} \quad ...(ii)$$

where, $PC = +R$, radius of curvature

$PO = -u$, object distance

$PI = +v$, image distance

So $\frac{n_2-n_1}{R}=\frac{n_1}{-u}+\frac{n_2}{v}$ ...(iii)

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

$$(n_2-n_1)\frac{AN}{PC}=n_1\frac{AN}{PO}+n_2\frac{AN}{PI} \text{ or } \frac{n_2-n_1}{PC}=\frac{n_1}{PO}+\frac{n_2}{PI} \quad ...(ii)$$

where, $PC = +R$, radius of curvature

$PO = -u$, object distance

$PI = +v$, image distance

So $\frac{n_2-n_1}{R}=\frac{n_1}{-u}+\frac{n_2}{v}$ ...(i)

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

(b) $R = 20$ cm, $n_2 = 1.5$, $n_1 = 1$, $u = -100$ cm

$\frac{n_2}{v}-\frac{n_1}{u}=\frac{n_2-n_1}{R}$ or $\frac{1.5}{v}+\frac{1}{100}=\frac{1.5-1}{20}$

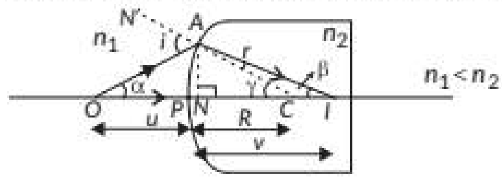
or $\frac{1.5}{v}=\frac{0.5}{20}-\frac{1}{100}=\frac{1}{40}-\frac{1}{100}=\frac{3}{200}$

or $v=\frac{200}{3}\times 1.5 = 100$ cm

So, a real image is formed on the other side, 100 cm away from the surface.

38. (a) Refraction at convex spherical surface :

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



In ΔOAC, $i = \alpha + \gamma$

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

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

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

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

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

where, $PC = +R$, radius of curvature

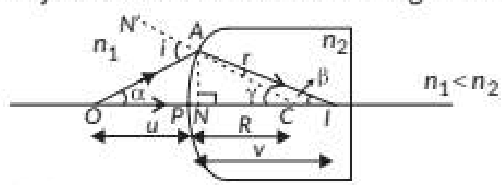
$PO = -u$, object distance; $PI = +v$, image distance

So $\frac{n_2-n_1}{R}=\frac{n_1}{-u}+\frac{n_2}{v}$ ...(i)

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

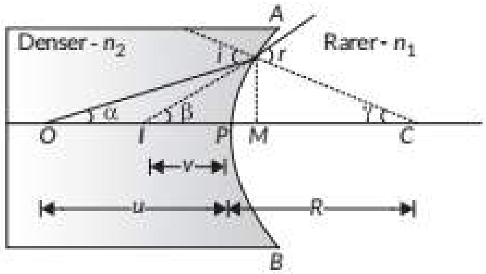
40. (a) Refraction at convex spherical surface :

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



In ΔOAC, $i = \alpha + \gamma$

(b) (i)



Relationship between the object distance and image distance in terms of n_1, n_2 and R for a concave spherical surface.

$$\frac{n_1}{v'}-\frac{n_2}{v}=\frac{n_1-n_2}{R'} \quad \text{...(iv)}$$

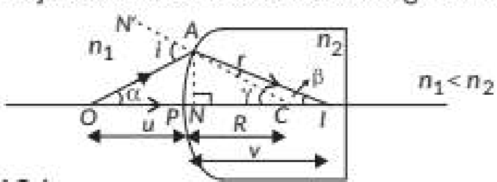
(ii) Adding eq. (iii) and (iv)

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

or $\frac{1}{v'}-\frac{1}{u}=(n_{21}-1)\left[\frac{1}{R}-\frac{1}{R'}\right]$ or $\frac{1}{f}=(n_{21}-1)\left[\frac{1}{R}-\frac{1}{R'}\right]$

where $n_{21} = n_2/n_1$

39. Refraction at convex spherical surface :
When object is in rarer medium and image formed is real.



In ΔOAC, $i = \alpha + \gamma$
and in ΔAIC, $\gamma = r + \beta$ or $r = \gamma - \beta$

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

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

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

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

So, $\alpha\approx\tan\alpha=\frac{AN}{NO}\approx\frac{AN}{PO}$; $\beta\approx\tan\beta=\frac{AN}{NI}\approx\frac{AN}{PI}$

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

On using them in equation (i), we get

$(n_2-n_1)\frac{AN}{PC}=n_1\frac{AN}{PO}+n_2\frac{AN}{PI}$ or $\frac{n_2-n_1}{PC}=\frac{n_1}{PO}+\frac{n_2}{PI}$ ...(ii)

43. (i) SI unit of power of a lens is dioptre (D). One dioptre of power of a lens is described as the unit of measurement of the optical power of a lens equivalent to the reciprocal of focal length (f).

$1\text{ D} = 1\text{ m}^{-1}$

(ii) Given, radius of curvature of convex surfaces = 25 cm
Refractive index = 1.5

(a) Focal length of lens, $f=\frac{R}{(\mu-1)}$

$f=\frac{-25}{(1.5-1)}=\frac{-25}{0.5}=-50$ cm

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

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

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

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

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

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

$\beta\approx\tan\beta=\frac{AN}{NI}\approx\frac{AN}{PI}$; $\gamma\approx\tan\gamma=\frac{AN}{NC}\approx\frac{AN}{PC}$

On using them in equation (i), we get

$(n_2-n_1)\frac{AN}{PC}=n_1\frac{AN}{PO}+n_2\frac{AN}{PI}$ or $\frac{n_2-n_1}{PC}=\frac{n_1}{PO}+\frac{n_2}{PI}$ ...(ii)

where, $PC = +R$, radius of curvature
$PO = -u$, object distance
$PI = +v$, image distance

So $\frac{n_2-n_1}{R}=\frac{n_1}{-u}+\frac{n_2}{v}$ ...(i)

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

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

Here $f = 20$ cm, $\mu = 1.55$, $R_1 = -R_2 = R$

$\therefore \frac{1}{20}=(1.55-1)\left(\frac{1}{R}+\frac{1}{R}\right)$ or $\frac{1}{20}=0.55\times\frac{2}{R}$

or $R = 0.55 \times 2 \times 20 = 22$ cm.

41. (b) For bi-concave lens, $\frac{1}{F}=(\mu-1)\left[\frac{1}{-R}-\frac{1}{R}\right]=\frac{-2(\mu-1)}{R}$

For plano-concave lens, $\frac{1}{F'}=(\mu-1)\left[\frac{1}{-R}-\frac{1}{\infty}\right]=\frac{-(\mu-1)}{R}$

$\Rightarrow F'=2F \Rightarrow P'=\frac{P}{2}$

42. $P=\frac{1}{f}=\left(\frac{\mu_L}{\mu_s}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$\mu_L = n_2$, $\mu_s = n_1$

$P=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{R}-\frac{1}{-R}\right)=\left(\frac{n_2-n_1}{n_1}\right)\left(\frac{2}{R}\right)$

$$\frac{1}{f_w}=\left(\frac{3/2}{4/3}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\left(\frac{9}{8}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad \text{...(iv)}$$

Equation (iii) ÷ (iv),

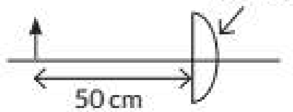
$$\frac{-\frac{1}{20}}{\frac{1}{f_w}}=\frac{\left(\frac{1}{2}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}{\left(\frac{1}{8}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)};\ -\frac{f_w}{20}=\frac{8}{2}$$

$f_w = -80$ cm

So, focal length of concave lens is – 80 cm in water.

(b) $u = -50$ cm

From lens formula, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$



$\Rightarrow \frac{1}{v}=\frac{1}{f}+\frac{1}{u}=\frac{1}{-50}-\frac{1}{50}=\frac{-2}{50}=\frac{-1}{25} \Rightarrow v = -25$ cm

Image formed is real and inverted.

44. (a) As we know that, refractive index decrease with an increase in wavelength of light. Therefore, focal length of lens will be increased with increasing wavelength of light.

Focal length $\propto \frac{1}{\text{power}} \propto$ wavelength

So, power $\propto \frac{1}{\text{wavelength}}$

As we increase the wavelength of light, the power of lens will decrease.

(b) The radius of curvature of two surfaces of a convex lens = R

The refractive index of material μ, the focal length becomes R.

So, len's maker formula,

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

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

So, $\frac{1}{R}=(\mu-1)\left[\frac{2}{R}\right]$; $\mu-1=\frac{1}{2} \Rightarrow \mu=\frac{3}{2}$

(c) Focal length of a concave lens = -20 cm

refractive index of concave lens, $\mu_1 = 1.5$ or $\frac{3}{2}$

immersed in water, $\mu_2=\frac{4}{3}$

Focal length in air,

$$\frac{1}{f}=(\mu_1-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(i)$$

Focal length in water,

$$\frac{1}{f_w}=\left(\frac{\mu_1}{\mu_2}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(ii)$$

Put the respective values

$$-\frac{1}{20}=\left(\frac{3}{2}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(iii)$$

OR

(c) An object is placed in front of lens which forms its erect image of magnification, $m = 3$.

The power of lens, $P = 5$D

Magnification, $m=\frac{v}{u}=3$ or $v = +3u$ ...(i)

The focal length of lens, $f=\frac{1}{P}=\frac{100}{5}$ cm $=+20$ cm

Lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$\Rightarrow \frac{1}{3u}-\frac{1}{u}=\frac{1}{20} \Rightarrow \frac{1-3}{3u}=\frac{1}{20} \Rightarrow \frac{-2}{3u}=\frac{1}{20}$ or $u=\frac{-40}{3}$ cm.

$u=\frac{40}{3}$ cm $\left(\text{object is } \frac{40}{3} \text{ cm away in front of lens.}\right)$

$v=3u=-3\times\frac{40}{3}$ cm $=-40$ cm

$v = -40$ cm (image formed at a distance of 40 cm on same side as object)

45. (a) (ii) When wavelength decreases, the power increases.

(b) (iv) $P=\frac{100}{-40}=-2.5$D

(c) (iv) $\mu_g = 1.5$, $f_1 = 20$ cm, $f_2 = 60$ cm

$$\frac{1}{f_1}=(\mu_g-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right); \frac{1}{20}=(1.5-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(1)$$

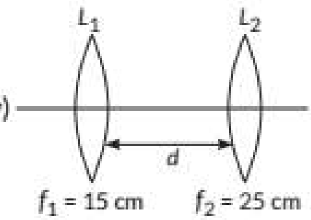
$$\frac{1}{f_2}=\left(\frac{\mu_g-1}{\mu}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right); \frac{1}{60}=\left(\frac{1.5-1}{\mu}\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \quad ...(2)$$

From (i) and (2)

$\frac{1}{60}=\left(\frac{\mu_g}{\mu}-1\right)\frac{1}{10}$; $\frac{1}{6}=\frac{1.5}{\mu}-1$; $\mu = 1.2$

(d) (ii) Angle of deviation is more for violet colour, so violet colour coverages nearest to the lens.

(e) (iv)



$u_1 = \infty$, $f_1 = 15$ cm

$\frac{1}{f_1}=\frac{1}{v_1}-\frac{1}{u_1} \Rightarrow \frac{1}{15}=\frac{1}{v_1}-\frac{1}{\infty}$

$v_1 = 15$ cm

Now for L_2: $u_2 = -(d-15)$, $v_2 = \infty$, $f_2 = 25$ cm

$$\frac{1}{25}=\frac{1}{\infty}+\frac{1}{d-15}$$

$25 = d - 15; d = 40$ cm

46. The focal length of original equi-convex lens is f. Let the focal length of each part after cutting be F.

Here, $\frac{1}{f}=\frac{1}{F}+\frac{1}{F} \Rightarrow \frac{1}{f}=\frac{2}{F} \Rightarrow f=\frac{F}{2} \Rightarrow F=2f$

Power of each part will be given by

$$P=\frac{1}{F} \Rightarrow P=\frac{1}{2f}$$

From lens maker is formula, we have

$$P=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

where P = Power of lens = +5 D
μ = Refractive index of the lens = 1.55
R_1 = Radius of curvature of first face (+ve)
R_2 = Radius of curvature of second face (−ve)
Given : $R_1 = R_2 = R$

$$\Rightarrow 5=(1.55-1)\left(\frac{1}{R}-\frac{1}{-R}\right) \Rightarrow 5=(1.55-1)\left(\frac{2}{R}\right)$$

$$\Rightarrow 5=0.55\left(\frac{2}{R}\right) \Rightarrow R=\frac{0.55\times 2}{5} \Rightarrow R=0.22\,\text{m}$$

The radius of curvature of the lens is 22 cm.

47. Clearly, equivalent focal length of equi-convex lens and water lens, $f = x$
Focal length of equi-convex lens $f_1 = y$
Focal length f_2 of water lens is given by

$$\frac{1}{f_2}=\frac{1}{f}-\frac{1}{f_1}=\frac{1}{x}-\frac{1}{y}=\frac{y-x}{xy} \text{ or } f_2=\frac{xy}{y-x}$$

The water lens formed between the plane mirror and the equi-convex lens is a plano-concave lens. For this lens,
$R_1 = -R$ and $R_2 = \infty$
Using lens maker's formula,

$$\frac{1}{f_2}=(\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right] \text{ or } \frac{y-x}{xy}=(\mu-1)\left[\frac{1}{-R}-\frac{1}{\infty}\right]$$

$$\text{or } \mu-1=\frac{(x-y)R}{xy} \text{ or } \mu=1+\frac{(x-y)R}{xy}.$$

Concept Applied

- A plano-concave lens is a convex lens in which one surface is plane and other is concave. Radius of curvature for plane mirror is infinite and concave lens is equal to $-R$

48. As per the figure,
The image formed by lens L_1 is at P. Therefore, using lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$
As per the parameters given in the question
$v = -60$ cm
Now, this image is acting as an object for the lens L_2. We can again use the lens formula and other parameters given in the question and question figure to find the focal length of lens L_2.

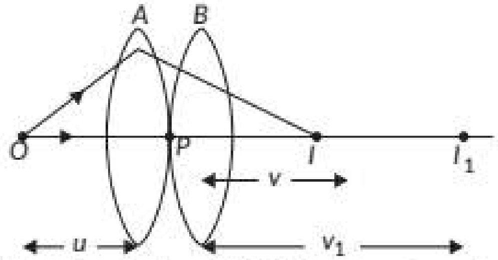
$$\frac{1}{v_{L_2}}-\frac{1}{u_{L_2}}=\frac{1}{f_{L_2}}$$

Here, $u_{L_2} = v + (-20) = -60 - 20 = -80$ cm
$v_{L_2} = 80$ cm

$$\frac{1}{80}-\frac{1}{(-80)}=\frac{1}{f_{L_2}}$$

$f_{L_2} = 40$ cm
So, the focal length of the lens L_2 = 40 cm.

49. (a)



An object is placed at point O. The lens A produces an image at I_1 which serves as a virtual object for lens B which produces final image at I.
Given, the lenses are thin. The optical centres (P) of the lenses A and B coincide with each other.
For lens A, we have

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

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

Adding equations (i) and (ii),

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

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

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

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

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

(b) For lens L_1 : $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$
where, $f = +10$ cm

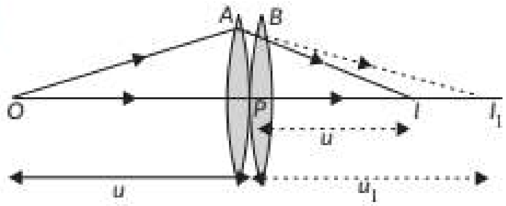
$$\frac{1}{v_1}=\frac{1}{10}-\frac{1}{30}; \frac{1}{v_1}=\frac{3-1}{30}=\frac{2}{30} \Rightarrow v_1=15\,\text{cm}$$

For lens L_2 :
$v_1 = 15$ cm, $u = 10$ cm, $f = -10$ cm
Position of final image,

$u = -15$ cm, $f_{L_1} = 20$ cm

So, the image distance will be

$$\frac{1}{v} - \frac{1}{(-15)} = \frac{1}{20}$$

50. 

Consider two lenses placed close to each other. The focal lengths of lens A and B is f_1 and f_2 respectively.

For lens A,

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

For lens B,

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \quad \text{...(ii)}$$

Adding (i) and (ii),

$$\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2}; \quad \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

Since $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ then, $\frac{1}{f_T} = \frac{1}{f_1} + \frac{1}{f_2}$ $\left(\because P = \frac{1}{f}\right)$

$$P_T = \frac{1}{f_1} + \frac{1}{f_2}\ ; P_T = P_1 + P_2$$

51. (a) : $\delta = (\mu - 1)A$, since red is having smallest refractive index compared to other colours, it has the smallest angle of minimum deviation.

52. (A) $\delta_{m(Red)} < \delta_{m(Blue)}$

$\mu_{Blue} < \mu_{Red}$

So, assertion is correct and reason is correct explanation of assertion.

53. Refractive index, $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

$$= \frac{\sin\left(\dfrac{60+60}{2}\right)}{\sin\left(\dfrac{60}{2}\right)} = \frac{\sin 60^\circ}{\sin 30^\circ} = \frac{\sqrt{3}}{2} \times \frac{2}{1} = \sqrt{3}$$

[$\because$ prism is equilateral]

54. $\because$ $\lambda_{red} > \lambda_{violet}$ and $\lambda \propto \dfrac{1}{\mu}$

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

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

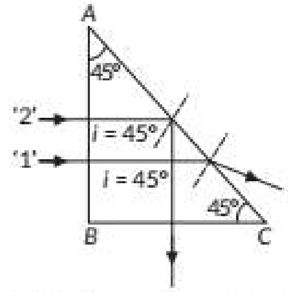
$\angle i$ on face AC is 30° which is less than $\angle i_c$. Hence, the ray will get refracted at the face AC.

56. Critical angle for ray '1' : $\mu_1 = \dfrac{1}{\sin C_1}$

$$\sin C_1 = \frac{1}{\mu_1} = \frac{1}{1.33} = 0.75 \Rightarrow C_1 \approx 48^\circ$$

Critical angle for ray '2' : $\mu_2 = \dfrac{1}{\sin C_2}$

$$\sin C_2 = \frac{1}{\mu_2} = \frac{1}{1.45} = 0.69 \Rightarrow C_2 \approx 43^\circ$$



Both the rays will fall on the side AC with angle of incidence, i equal to 45°. Critical angle of ray '1' is greater than i. Hence, it will emerge from the prism as shown in the figure.

Critical angle of ray '2' is less than i. Hence, it will be internally reflected as shown in the figure.

Concept Applied

- Conditions for total internal reflection are (i) Light should travel from an optically denser medium to a rarer medium (ii) Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.

57. (i) When QR is parallel to the base BC, we have

$i = e \Rightarrow r_1 = r_2 = r$

We know that, $r_1 + r_2 = A \Rightarrow r + r = A$

$\therefore$ $r = A/2$

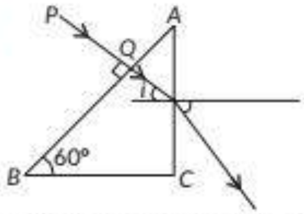
(ii) Also, we have $A + \delta = i + e$

Substituting, $\delta = \delta_m$ and $i = e$

$\therefore \mu_{red} < \mu_{violet}$

$$\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\frac{A}{2}} \quad \therefore (\delta_m)_{violet} > (\delta_m)_{red}$$

55.

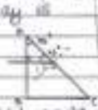


Ray will emerge from the face *AC*

As $\sin i_c = 1/\mu$

Here $\sin i_c = 1/1.5 = 0.67$, $i_c = 42°$

• For interface AC
Now ray incident on AC is parallel to line BC
Hence angle on incidence of ray is
= 90 - 45° = 45°



This angle is greater than the critical angle of the prism ABC wrt air (i_c = 41°), hence the ray will get total internally reflected with angle of reflection = 45°. Thus the reflected ray would be parallel to AB and perpendicular to BC

• For interface BC
As angle of incidence is zero, angle of refraction is also zero and hence deviation is also zero.

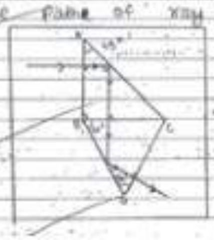
• For interface BD
The incident light is perpendicular to BC hence its angle of incidence = 90° - (90-60)°
= 60°

Again this angle is greater than the critical angle of prism BCD wrt air (i_c = 41°). Hence ray will get total internally reflected with angle of reflection = 60°. Now from the above figure, using geometry we find that the reflected wave is perpendicular to CD.

• For interface CD
As angle of incidence is zero, the wave will emerge out of CD into air with zero angle of refraction.

Hence the path of ray is :

Ans :



$A + \delta_m = i + i$

$\therefore \quad \delta_m = 2i - A$

58.

(a) Two necessary conditions for total internal reflection are:
• Light should travel from optically denser to optically rarer medium.
• Angle of incidence of light should be greater than the critical angle for the given pair of media
For eg: If light is travelling from medium n_1 to medium n_2 ($n_1 > n_2$)
$\sin i > \sin C = \frac{n_2}{n_1} = n_{21}$

(b) • For interface AB
As angle of incidence is zero, angle of refraction is also zero, hence ray will pass undeviated from the interface AB

(c) $\mu = \frac{\sin i}{\sin r}$; $\sin r = \frac{\sin 45°}{\sqrt{2}} = \frac{1}{2}$ or $r = 30°$

Angle of refraction at point $P = 30°$

61. (a) If graph is plotted between angle of incidence i and angle of deviation δ, it is found that the angle of deviation δ first decreases with increase in angle of incidence i and then becomes minimum 'δ_m' when $i = e$ and then increases with increase in angle of incidence i.

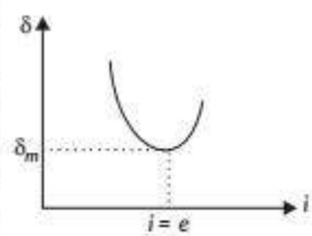
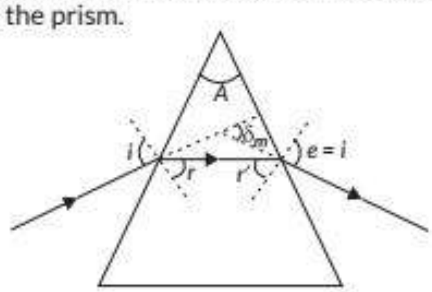


Figure shows the path of a ray of light suffering refraction through a prism of refracting angle '*A*'.

(b) At minimum deviation, the inside beam travels parallel to base of the prism.



$i = e$

$r = r'$

$\delta_m = (i + e) - (r + r')$

$\delta_m = 2i - 2r$ ...(i)

Also $r + r' = A = 2r$ ...(ii)

So, angle of incidence using equation (i)

$$i = \frac{A + \delta_m}{2}, \text{ angle of refraction } r = \frac{A}{2}$$

[Topper's Answer, 2022]

59. (i) Emergent light ray is parallel to face AC, so r_2 is the critical angle.

$$\mu = \frac{1}{\sin r_2} \text{ or } \sin r_2 = \frac{1}{\sqrt{2}} \text{ or } \angle r_2 = 45^\circ$$

(ii) For prism, $\mu = \sin\frac{[(A+\delta_m)/2]}{\sin A/2}$

$$\sqrt{2} = \frac{\sin[30^\circ + \delta_m/2]}{\sin 30^\circ} \Rightarrow \sin\left(30^\circ + \frac{\delta_m}{2}\right) = \frac{1}{\sqrt{2}}$$

$$\Rightarrow 30^\circ + \frac{\delta_m}{2} = 45^\circ \Rightarrow \delta_m = 30^\circ$$

Angle of minimum deviation $= 30^\circ$

60. Here, $A = 60^\circ$, $i = 45^\circ$

(a) Angle of minimum deviation,

$\delta_m = 2i - A = 2 \times 45^\circ - 60^\circ = 30^\circ$

(b) Refractive index, $\mu = \dfrac{\sin\frac{(A+\delta_m)}{2}}{\sin\left(\frac{A}{2}\right)}$

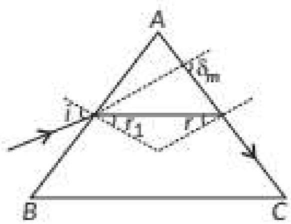
$$\mu = \frac{\sin(45^\circ)}{\sin(30^\circ)} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \sqrt{2}$$

Given : $A = 60^\circ$, $\delta_m = 30^\circ$

$$\mu = \frac{\sin 45^\circ}{\sin 30^\circ} = \frac{1}{\sqrt{2}} . 2 \Rightarrow \mu = \sqrt{2}$$

$$\because \quad \mu = \frac{c}{v} \Rightarrow v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.414} = 2.12 \times 10^8 \text{ m s}^{-1}$$

(b) $\sin i_C = \dfrac{1}{\mu} = \dfrac{1}{\sqrt{2}}$



$i_C = r = 45^\circ$

$A = r_1 + r$

$\Rightarrow$ $r_1 = 15^\circ$

$\dfrac{\sin i}{\sin r_1} = \sqrt{2}$

$\sin i = \sqrt{2} \sin 15^\circ = \dfrac{(\sqrt{3}-1)}{2\sqrt{2}} \times \sqrt{2}$

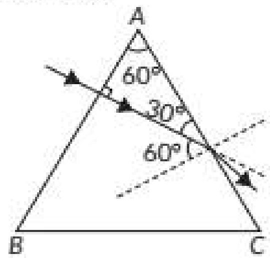
$\sin i = \dfrac{\sqrt{3}-1}{2}$; $i = \sin^{-1}\left(\dfrac{\sqrt{3}-1}{2}\right)$

Now refractive index of the material of prism

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

where A is the refracting angle of the prism and $A = 60^\circ$ for an equiangular prism.

62. Critical angle for the given pair of media



$$\theta_c = \sin^{-1}\left(\frac{\mu_w}{\mu_g}\right)$$

$$= \sin^{-1}\left(\frac{4/3}{3/2}\right) = \sin^{-1}\left(\frac{8}{9}\right)$$

$$\sin\theta_c = \frac{8}{9} = 0.89$$

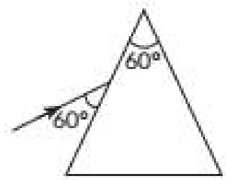
Now, $\sin 60^\circ = \dfrac{\sqrt{3}}{2} = 0.86$

On face AC, angle of incidence is less than that of critical angle, so there will be no total internal reflection.

63. (a) The refractive index of the material of prism,

$$\mu = \frac{\sin\left[\frac{A+\delta_m}{2}\right]}{\sin\frac{A}{2}}$$

(ii) Given, $i = 60^\circ$



$\angle A = 60$

Angle of minimum deviation

$\delta_m = 2i - \angle A$

$= 2 \times 60^\circ - 60^\circ = 60^\circ$

Refractive index of material of prism

$$\mu = \frac{\frac{(A+\delta_m)}{2}}{\sin\left(\frac{A}{2}\right)};\ \mu = \frac{\sin\left(\frac{60^\circ+60^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)} = \frac{\sin 60^\circ}{\sin 30^\circ};\ \mu = \frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}} = \sqrt{3}$$

If prism is immersed in water, the relative refractive index will decrease. Thus, the angle of minimum deviation will also decrease.

66. From snell's law, $\dfrac{\sin i}{\sin r} = \dfrac{\mu_2}{\mu_1}$

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

$\mu_p \sin 30^\circ = \mu_a \sin e$

64. Critical angle for

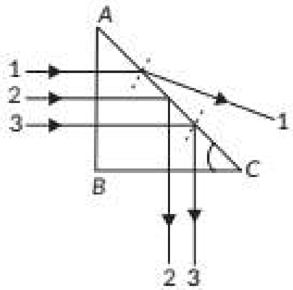
(i) For ray 1, $\sin c_1 = \frac{1}{1.39} = 0.7194$ or $c_1 = 46°$

(ii) For ray 2, $\sin c_2 = \frac{1}{1.47} = 0.6802$ or $c_2 = 43°$

(iii) For ray 3,

$\sin c_3 = \frac{1}{1.52} = 0.6802$

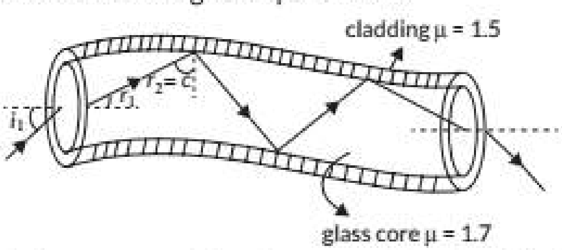
or $c_3 = 41°$



As angle of incidence $i = 45°$ of ray 1 on face AC is less than its critical angle of 46°, so ray 1 will emerge out of face AC.

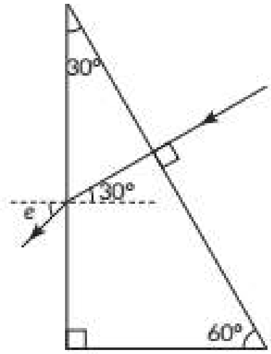
65. (i) Optical fibre is made up of very fine quality glass or quartz of refractive index about 1.7. A light beam incident on one end of an optical fibre at appropriate angle refracts into the fibre and undergoes repeated total internal reflections.

This is because the angle of incidence is greater than critical angle. The beam of light is received at other end of fibre with nearly no loss in intensity. To send a complete image, the image of different portion is send through separate fibres and thus a complete image can be transmitted through an optical fibre.



Light pipes are used in a large variety of applications. Because of its ability of transmit up to 80% of emitted light, it is useful for a broad range of application including security equipment, medical devices and communications equipment.

68. (a) (i) If graph is plotted between angle of incidence i and angle of deviation δ, it is found that the angle of deviation δ first decreases with increase in angle of incidence i and then becomes minimum 'δ_m' when $i = e$ and then increases with increase in angle of incidence i. Figure shows the path of a ray of light suffering refraction through a prism of refracting angle 'A'.



$\sqrt{3} \times \frac{1}{2} = \sin e$ [$\because \mu_{air} = 1$] or $e = 60°$

when the ray of light emerges into a liquid of $\mu_L = 1.3$,

$\Rightarrow \mu_p \sin 30° = \mu_L \sin e$

$\sqrt{3} \times \frac{1}{2} = 1.3 \times \sin e \Rightarrow e = \sin^{-1}\left(\frac{\sqrt{3}}{2 \times 1.3}\right) \simeq 41.78°$

Thus, the angle of emergence decreases.

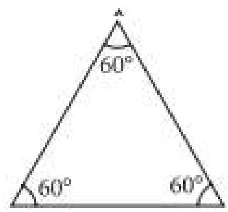
67. For equilateral prism $A = 60°$

For minimum angle of deviation,

$i + e = A + \delta_m$

$2i = A + \delta_m$

$\frac{2 \times 3A}{4} = A + \delta_m$

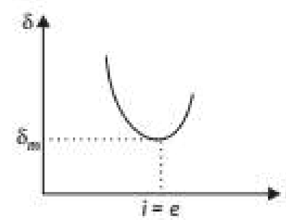


$\delta_m = \frac{3A}{2} - A = \frac{A}{2}$ $\because \mu = \frac{\sin\left(\frac{A + \frac{A}{2}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$\Rightarrow \mu = \frac{\sin\left(\frac{3A}{4}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin 45°}{\sin 30°} = \frac{0.7071}{0.5} = 1.414$

$\mu = 1.414$

$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.414} = 2.1216 \times 10^8 \text{ m s}^{-1}$



Concept Applied

- At minimum deviation, there is only one angle of incidence *i.e.*; when $\delta = \delta_{min}$, $i_1 = i_2$.

∴ Total deviation produced in the ray in passing through the prism is

$\delta = \delta_1 + \delta_2 = (i_1 - r_1) + (e - r_2) = (i_1 + e) - (r_1 + r_2)$ ...(i)

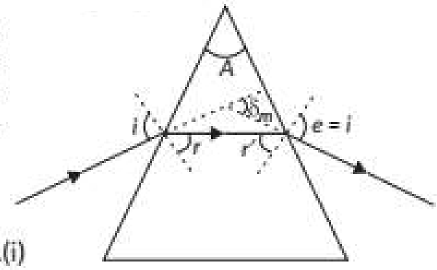
From figure, Sum of angle of ΔAQR is 180°, *i.e.*;

$A + (90° - r_1) + (90° - r_2) = 180°$

$A = (r_1 - r_2)$

From equation (i), $\delta = (i_1 + e) - A$ or $\delta + A = (i_1 + i_2)$

(ii) At minimum deviation, the inside beam travels parallel to base of the prism.



$i = e$

$r = r'$

$\delta_m = (i + e) - (r + r')$

$\delta_m = 2i - 2r$ ...(i)

Also $r + r' = A = 2r$ ...(ii)

So, angle of incidence using equation (i)

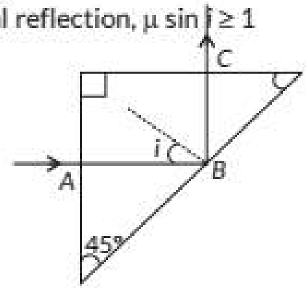
$$i = \frac{A+\delta_m}{2}, \text{ angle of refraction } r = \frac{A}{2}$$

Now refractive index of the material of prism

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

where A is the refracting angle of the prism and $A = 60°$ for an equiangular prism.

(b) At point B, for total internal reflection, $\mu \sin i \geq 1$



$$\mu \geq \frac{1}{\sin i}$$

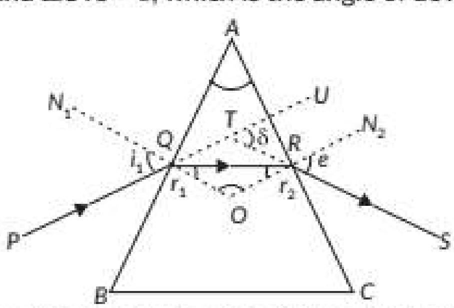
$$\mu \geq \frac{1}{\sin 45°} = \sqrt{2}$$

$(\because i = 45°)$

$\therefore \quad \mu \geq \sqrt{2}$

$\mu_{min} = \sqrt{2}$

69. (a) A ray of light PQ is incident on the face AB of the prism ABC at $\angle i_1$. It is refracted along QR at $\angle r_1$ bending towards the normal N_1O. The refracted ray QR is incident at $\angle r_2$ on face AC of the prism. It bends away from normal N_2O and emerge along RS at $\angle e$. In passing through the prism, ray PQ suffers two refractions and has turned through and $\angle UTS = \delta$, which is the angle of deviation.



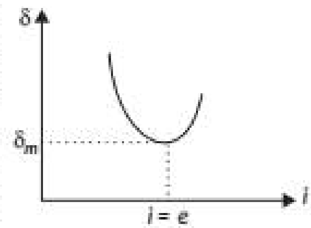
At the face AB, the angle of incidence is i_1 and angle of refraction is r_1. So the deviation at this surface is

$$\delta_1 = i_1 - r_1 \text{ (clockwise)}$$

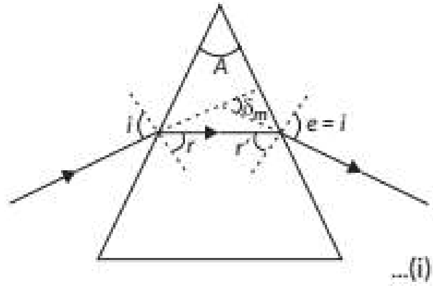
At the second face AC, the angle of incidence is r_2 and angle of refraction is e. So the deviation at this surface is

$$\delta_2 = e - r_2 \text{ (clockwise)}$$

If graph is plotted between angle of incidence i and angle of deviation δ, it is found that the angle of deviation δ first decreases with increase in angle of incidence i and then becomes minimum 'δ_m' when $i = e$ and then increases with increase in angle of incidence i. Figure shows the path of a ray of light suffering refraction through a prism of refracting angle 'A'.



(b) At minimum deviation, the inside beam travels parallel to base of the prism.



$i = e$

$r = r'$

$\delta_m = (i + e) - (r + r')$

$\delta_m = 2i - 2r$ ...(i)

Also $r + r' = A = 2r$ ...(ii)

So, angle of incidence using equation (i)

$$i = \frac{A+\delta_m}{2}, \text{ angle of refraction } r = \frac{A}{2}$$

Now refractive index of the material of prism

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

where A is the refracting angle of the prism and $A = 60°$ for an equiangular prism.

For, $A = 60°, \delta_m = 60°$

$$\mu = \frac{\sin\left(\frac{60+60}{2}\right)}{\sin\frac{60}{2}} = \frac{\sin 60°}{\sin 30°} = \frac{\sqrt{3}/2}{1/2} \quad \text{or} \quad \mu = \sqrt{3}$$

70. $f = 5$ cm, $D = 25$ cm

$$\text{M.P.} = \frac{D}{f} = \frac{25}{5} = 5$$

71. A compound microscope is used because a realistic simple microscope does not have large magnification.

72. The magnification of compound microscope when the final image is formed at infinity,

$$M = \frac{L}{f_0}\left(\frac{D}{f_e}\right)$$

Both the objective and the eyepiece of a compound microscope has short focal length so as to produce large magnifying power as,

$$M = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

Concept Applied

- Magnification of the compound microscope is inversely proportional to the focal length of the objective lens and focal length of the eye-piece.

73. Maximum magnification of a compound microscope is

$$m=\frac{v_0}{u_0}\left[1+\frac{D}{f_e}\right]$$

So, for m to be 30,

$$30=\frac{v_0}{u_0}\left[1+\frac{25}{5}\right] \text{ or } 30=\frac{v_0}{u_0}[6]$$

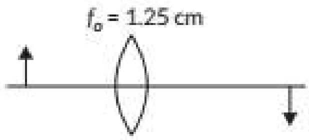
$v_0 = 5u_0$ ... (i)

For objective of focal length 1.25 cm,

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

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

$$\frac{1+5}{5u_o}=\frac{1}{1.25}$$



$5u_o = +7.5$ cm or $u_o = 1.5$ cm. So, $v_o = +7.5$ cm

Now u_e for required magnification,

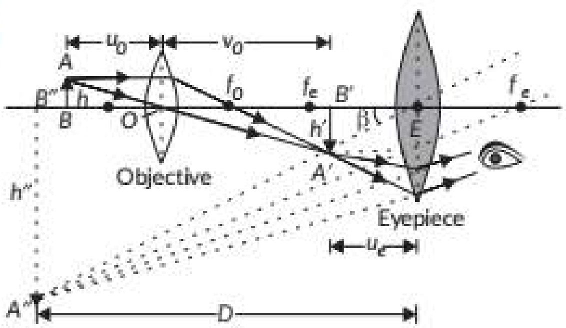
$$\frac{1}{v_e}-\frac{1}{u_e}=\frac{1}{f_e} \text{ or } \frac{1}{-25}-\frac{1}{-u_e}=\frac{1}{5}$$

$$\frac{1}{u_e}=\frac{1}{5}+\frac{1}{25}=\frac{5+1}{25} \text{ or } u_e=\frac{25}{6}\text{ cm}$$

Hence, separation between two lenses should be

$$v_o+u_e=7.5\text{ cm}+\frac{25}{6}\text{ cm}=11.67\text{ cm}$$

74.



Compound microscope consists of two convergent lenses of short focal lengths and apertures arranged co-axially. Lens (of focal length f_o) facing the object is known as objective or field lens while the lens (of focal length f_e) facing the eye, is known as eye-piece or ocular. The objective has a smaller aperture and smaller focal length than eye-piece. Magnifying power of a compound microscope

$m = m_o \times m_e$

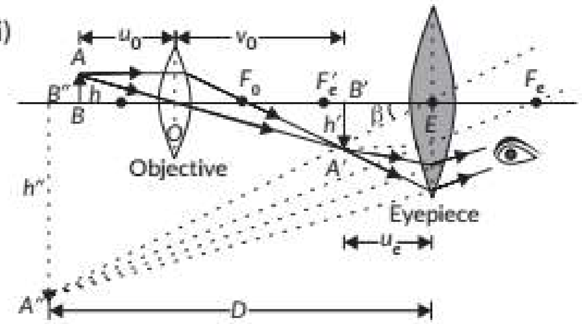
If α is the angle subtended at the eye by the object when it is at least distance of distinct vision from eye.

$$m=\frac{\beta}{\alpha}=\frac{\tan\beta}{\tan\alpha}=\frac{h'/u_e}{h/D}=\frac{h'}{h}\cdot\frac{D}{u_e}=m_o m_e$$

As the eyepiece acts as a simple microscope, so

$$m_e=\frac{D}{u_e}=1+\frac{D}{f_e} \quad \therefore m=\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)$$

75. (i)



(ii) Object distance, $u = -3$ cm

Focal length, $f = 4$ cm

(I) If v is the image distance, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

$$\frac{1}{v}=\frac{1}{4}-\frac{1}{3}=\frac{3-4}{12} \Rightarrow v=-12\text{ cm}$$

(II) Linear magnification, $m=\frac{v}{u}=\frac{-12}{-3}=4$

76. (a) $P_o = 100$ D, $\therefore f_o = 1$ cm, $P_E = 40$ D,

$\therefore$ $f_E = 2.5$ cm.

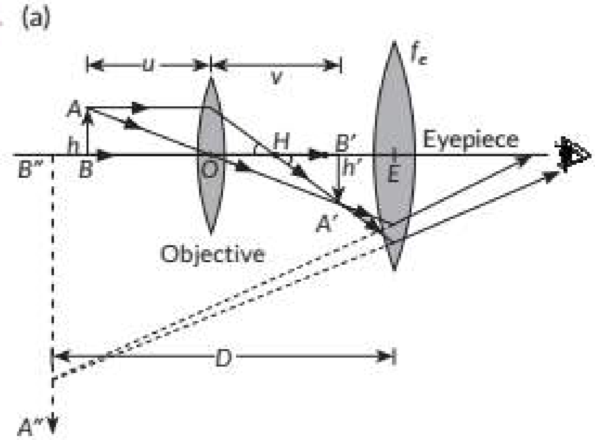
Since $f_o < f_E$, the instrument is a compound microscope.

(b) Magnification, $m=\frac{L}{f_0}\left(\frac{D}{F_E}\right)=\frac{20}{1}\left(\frac{25}{2\cdot5}\right)=200$

Commonly Made Mistake

- Common mistake that students do in such questions is using the formula for image at infinity in place of formula for image at minimum distance of distinct vision.

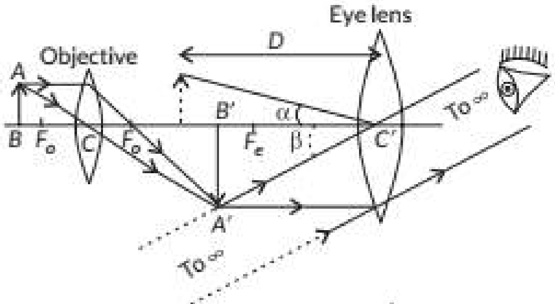
77. (a)



(b) For constructing compound microscope, L_3 should be used as objective and L_2 as eyepiece because both the lenses of microscope have short focal lengths and the focal length of objective lens should be smaller than the eyepiece lens.

78. When image is formed at infinity the magnifying

Here, $m_o = \frac{h'}{h} = \frac{v_o}{u_o}$



Magnification due to objective, $m_0 = \frac{L}{-f_0}$

Angular magnification due to eyepiece, $m_e = \frac{D}{f_e}$

Total magnification when the final image is formed at infinity,

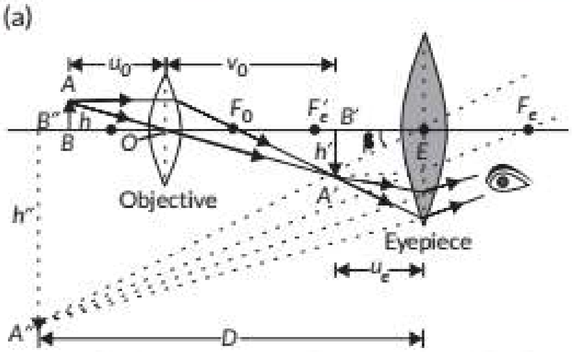
$m = m_0 \times m_e = -\frac{L}{f_0} \times \frac{D}{f_e}$

Obviously, magnifying power of the compound microscope is large when both f_0 and f_e are small.

Concept Applied

- When lenses are used in combination, each lens magnifies the image formed by the free coding lens.

79. (a)



(b) Separation between eye-piece and the objective,
$L = 14$ cm, $m = -20$, $m_e = 5$, $D = 20$ cm, $f_o = ?$, $f_e = ?$
Magnification of eye-piece when image is formed at the least distance for clear vision.

$m_e = \left(1 + \frac{D}{f_e}\right) \Rightarrow 5 = \left(1 + \frac{20}{f_e}\right) \Rightarrow 4 = \frac{20}{f_e} \Rightarrow f_e = 5$ cm

Net magnification of the compound microscope when image is formed at the least distance for clear vision.

$m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \Rightarrow -20 = -\frac{14}{f_o}\left(1 + \frac{20}{5}\right)$

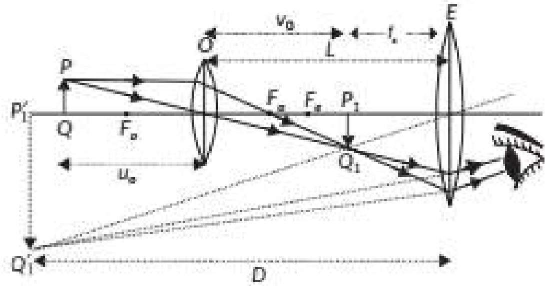
$\Rightarrow 10 = \frac{7}{f_o}(5) \Rightarrow f_o = \frac{35}{10} = 3.5$ cm

power of compound microscope is given by

$M = \frac{-L}{f_0} \times \frac{D}{f_e}$

object is known as objective or field lens while the lens (of focal length f_e) facing the eye, is known as eye-piece or ocular. The objective has a smaller aperture and smaller focal length than eye-piece. Magnifying power of a compound microscope

$$M = m_o \times m_e$$



When the final image is formed at infinity (normal adjustment),

$$M = -\frac{L}{F_0}\left(\frac{D}{f_e}\right)$$

Length of tube, $L = v_o + f_e$
When the final image is formed at least distance of distinct vision,

$$M = -\frac{L}{F_0}\left(1 + \frac{D}{f_e}\right)$$

where u_o and v_o represent the distance of object and image from the objective lens, f_e is the focal length of an eye lens.

Length of the tube, $L = v_o + \left(\frac{f_e D}{f_e + D}\right)$

(ii) $u_0 = -1.5$ cm, $f_0 = 1.25$ cm, $f_e = 5$ cm, $v_e = D$

$M = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$

$L = v_0 + f_e$

$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0} \Rightarrow \frac{1}{1.25} = \frac{1}{v_0} + \frac{1}{1.5}$

$\frac{1}{v_0} = \frac{1}{1.25} - \frac{1}{1.5} = \frac{1.5 - 1.25}{1.5 \times 1.25} = \frac{0.25}{1.5 \times 1.25}$

$v_0 = 7.5$ cm; so, $L = 7.5 + 5 = 12.5$ cm

$M = \frac{12.5}{1.25}\left(1 + \frac{25}{5}\right) = 60$

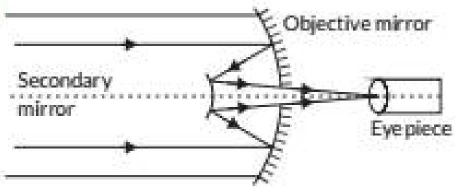
81.

I. (a) real, virtual
II. (b) the aperture of the objective and the eye-piece
III. (c) The microscope can be used as a telescope by interchanging the two lenses

Answer Tips

- Find the focal length of the objective and the eye-piece of the compound microscope and use the formula of total magnification of the compound microscope when image is formed at the least distance of distinct vision.

80. (i) Compound microscope : It consists of two convergent lenses of short focal lengths and apertures arranged co-axially. Lens (of focal length f_o) facing the

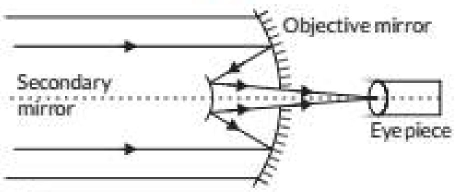
83. 

Advantages :

(i) It is free from chromatic aberration.

(ii) Its resolving power is greater than refracting telescope due to larger aperture of mirror.

OR



Advantages :

(i) It is free from chromatic aberration.

(ii) Its resolving power is greater than refracting telescope due to larger aperture of mirror.

84. Magnifying power of telescope in normal adjustment

$$m = -\frac{f_o}{f_e} = -\frac{150}{5} = -30 \quad \text{... (i)}$$

Height of image for a 100 m tall tower 3 km away, formed by objective lens

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o} \Rightarrow \frac{1}{v_o} - \frac{1}{-3000} = \frac{1}{1.5}$$

$$\frac{1}{v_o} = \frac{1}{1.5} - \frac{1}{3000} = \frac{2998.5}{4500}$$

$$\Rightarrow v_o = \frac{4500}{2998.5} \text{ m}$$

[Topper's Answer, 2022]

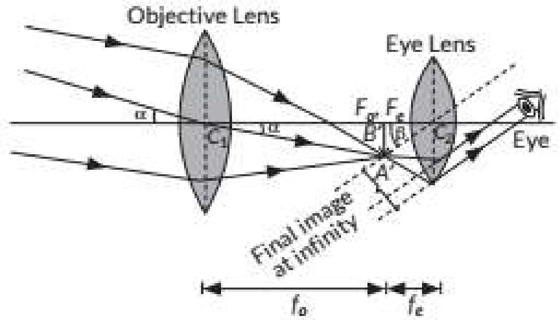
82. Objective of a telescope is a convex lens of large focal length and a large aperture. It faces the distant object and forms bright image of the distant objects. The aperture of the objective is taken large so that it can gather sufficient amount of light from the distant objects.

Advantages :

(i) It is free from chromatic aberration.

(ii) Its resolving power is greater than refracting telescope due to larger aperture of mirror.

86. (a) (i) When final image is formed at infinity :



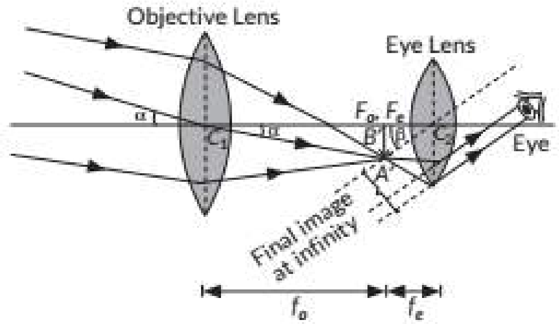
(ii) f_o = 150 cm, f_e = 6 cm

(I) Length of tube when image is formed at infinity

$= f_o + f_e = 150 + 6 = 156$ cm

(II) Magnification $= \frac{f_o}{f_e} = \frac{150}{6} = 25$

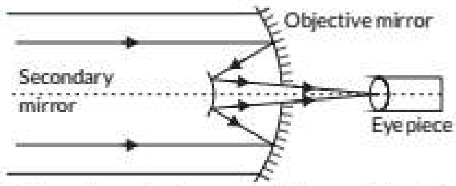
87. Construction for astronomical telescope.



Also, $\frac{h_I}{h_o}=\frac{v_o}{u_o} \Rightarrow \frac{h_I}{100}=\frac{4500}{2998.5}\times\frac{1}{-3000}$

$h_I=-\frac{150}{2998.5}$ m = -0.05 m = -5 cm

85.

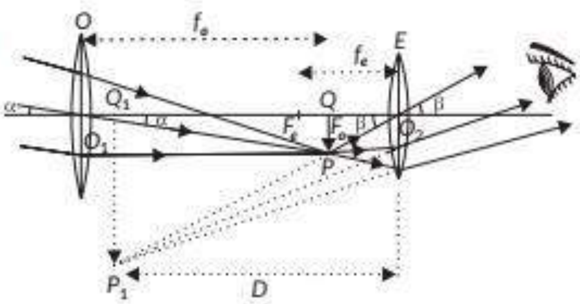


Reflecting type telescope : It consists of a large primary concave parabolic shape mirror having a hole at its centre. Another secondary convex mirror before the focus of primary mirror forms the image at convenient position for observer.

The parallel rays from astronomical object are reflected by primary concave mirror and then are further reflected by convex mirror before getting focussed at eye piece. Eyepiece removes the defects from the image and also acts as magnifier.

The magnifying power of reflecting type telescope is given by, $M=+\frac{f_0}{f_e}$

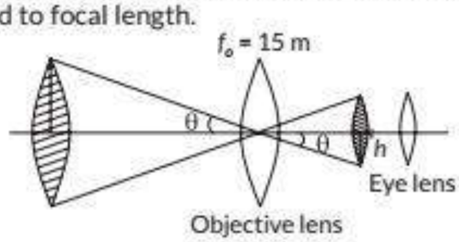
88.



Here, f_o = 15 m = 1500 cm and f_e = 1.0 cm. Angular magnification by the telescope in normal adjustment

$m=\frac{f_o}{f_e}=\frac{1500\text{ cm}}{1.0\text{ cm}}=1500$

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



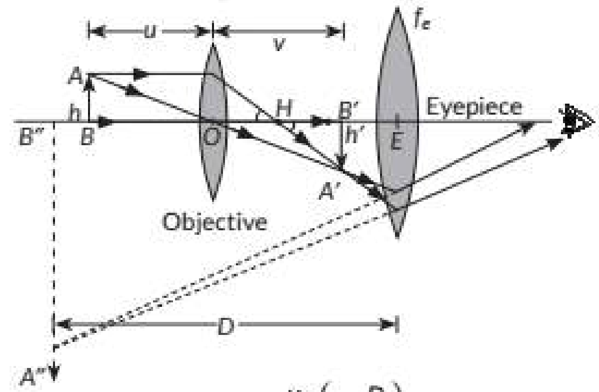
i.e., Radius of moon $R_m=\frac{3.5}{2}\times10^6$ m

$R_m = 1.74\times10^6$ m

Distance of object = Radius of lunar orbit

$R_0 = 3.8\times10^8$ cm

Construction for compound microscope :



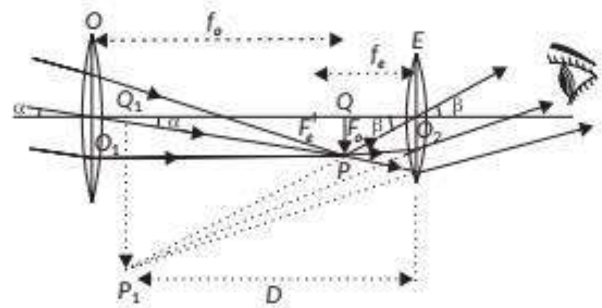
Angular magnification, $m=\frac{v_0}{u_0}\left(1+\frac{D}{fe}\right)$

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

From lens formula,

$\frac{1}{f_0}=\frac{1}{v_0}-\frac{-1}{(-u_0)} \Rightarrow \frac{1}{1.25}=\frac{u_0+v_0}{v_0u_0}$ ...(ii)

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

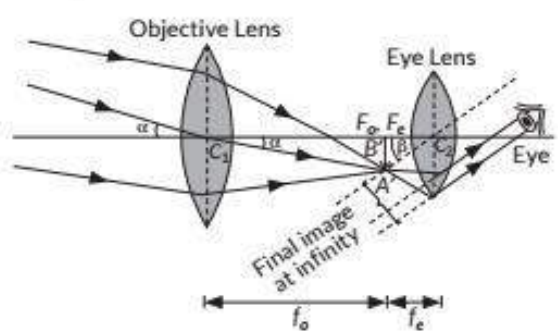


Magnification, $M=-\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$

Resolving power of telescope, $R=\frac{a}{1.22\lambda}$

$R\propto a$ and $R\propto\frac{1}{\lambda}$

90. (a)



(b) For a telescope, lens L_1 is chosen as objective, as its aperture and focal lengths is the largest. The lens L_3 is

Distance of image for objective lens is the focal length of objective lens, $f_0 = 15$ m

Radius of image of moon by objective lens can be calculated.

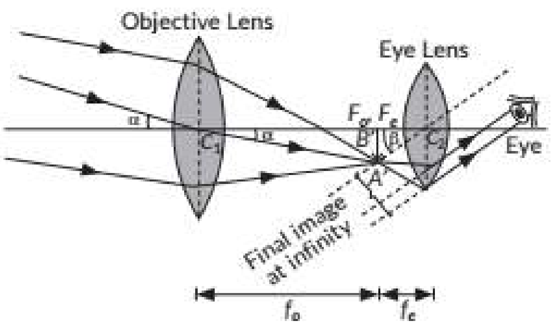
$$\tan\theta = \frac{R_m}{R_0} = \frac{h}{f_o}$$

$$h = \frac{R_m \times f_o}{R_0} = \frac{1.75\times10^6\times20}{3.8\times10^8} = 6.87\times10^{-2}\text{ m.}$$

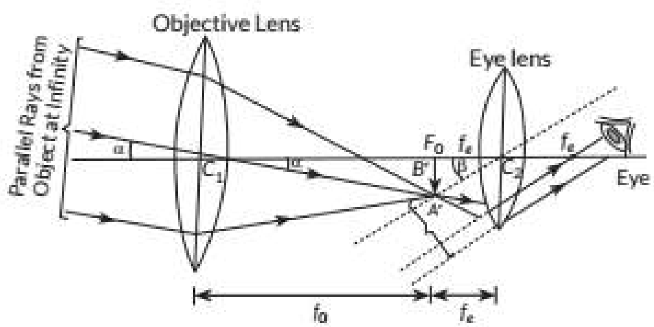
Diameter of the image of the moon,

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

89. When final image is formed at infinity :



When the final image is formed at least distance of distinct vision :



Magnifying power or angular magnification of an astronomical telescope in normal adjustment is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object directly, when the final image and the object, both at infinite distance from the eye.

As the object lies at very huge distance, therefore, angle subtended by the object at C_2 (where eye is held) is almost the same as the angle subtended by the object at C_1 (because C_1 is close to C_2), *i.e.* $\angle A'C_1B' = \alpha$. Rays coming from the final image at infinity make $\angle A'C_2B' = \beta$ on the eye. Therefore, by definition

magnifying power, $m = \frac{\beta}{\alpha}$ ...(i)

chosen as eyepiece as its focal length is smallest.

Answer Tips

- In normal adjustment, the astronomical telescope produces images at infinity so that the image appears large and the distant objects can be seen easily.

91. An astronomical telescope should have an objective of larger aperture and longer focal length while an eyepiece of small aperture and small focal length. Therefore, we will use L_2 as an objective and L_3 as an eyepiece.

For constructing microscope, L_3 should be used as objective and L_1 as eyepiece because both the lenses of microscope should have short focal lengths and the focal length of objective should be smaller than the eyepiece.

92. (i) The course of rays in normal adjustment of telescope is shown in figure. A parallel beam of light from an astronomical object (at infinity) is made to fall on the objective lens of the telescope. It forms a real, inverted and diminished image $A'B'$ of the object. The eye piece is so adjusted that $A'B'$ lies just at the focus of the eye piece. Therefore, a final highly magnified image is formed at infinity. The final image is erect with respect to $A'B'$ and is inverted w.r.t. the object.

For concave lens, $u_2 = 72 - 45 = 27$ cm

$f_2 = -18$ cm

$$\frac{1}{v_2} = \frac{1}{f_2} + \frac{1}{u_2} = -\frac{1}{18} + \frac{1}{27} = \frac{-1}{54} \Rightarrow v_2 = -54\text{ cm}$$

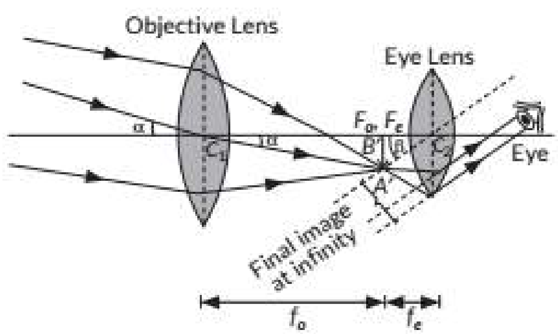
Now, the image formed at a distance, $d = 54 - 45 = 9$ cm

We will get image at a distance of 9 cm infront of convex lens.

Now, height of image is, $m = \frac{h_I}{h_o} = \frac{v}{u}$

$$h_I = \frac{v}{u}\times h_0 = \frac{(-54)}{27}\times1 = -2\text{cm.}$$

93. (i) An astronomical telescope in normal adjustment.



As angles α and β are small, therefore, $\alpha = \tan\alpha$ and $\beta = \tan\beta$,

$$m = \frac{\tan\beta}{\tan\alpha} \qquad ...(ii)$$

In $\Delta A'B'C_2$, $\tan\beta = \frac{A'B'}{C_2B'}$; In $\Delta A'B'C_1$, $\tan\alpha = \frac{A'B'}{C_1B'}$

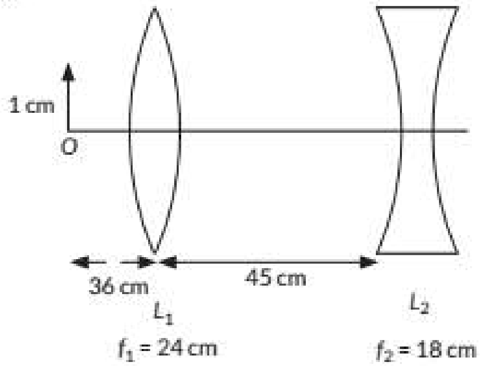
$$m = \frac{A'B'}{C_2B'} \times \frac{C_1B'}{A'B'} = \frac{C_1B'}{C_2B'} \quad \text{or} \quad m = \frac{f_0}{-f_e}$$

where $C_1B' = f_0$ = focal length of objective lens,
$C_2B' = -f_e$ = focal length of eye lens.

Negative sign of m indicates that final image is inverted with respect to the object.

Thus, to increase magnifying power of an astronomical telescope in normal adjustment, focal length of objective lens should be large and focal length of eye lens should be small.

(ii)



Height of object, $h_l = 1$ cm

For convex lens, $u_1 = 36$ cm, $f_1 = 24$ cm

$$\frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{u_1} = \frac{1}{24} - \frac{1}{36} = \frac{1}{72}$$

$v_1 = 72$ cm

It is used to see distant objects.

It consists of two lenses:

Objective of large aperture and large focal length f_o.

Eyepiece of small aperture and short focal length f_e.

Magnifying power: It is the ratio of the angle subtended by the final image at the eye to the angle which the object subtends at the lens, or the eye.

(ii) $M = 2.9$, $L = 150$ cm

$$M = \frac{f_0}{f_e} = 2.9 \qquad ...(i)$$

$L = f_0 + f_e = 150$

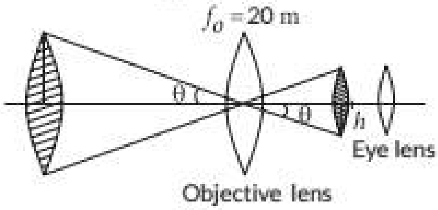
from (i)

$f_e + 2.9 f_e = 150$; $3.9 f_e = 150$; $f_e = 38.5$ cm

$f_0 = 150 - 38.5 = 111.5$ cm

94. (a) Angular magnification, $m = \frac{f_0}{f_e} = \frac{2000 \text{ cm}}{1.0 \text{ cm}} = 2000$

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



i.e., Radius of moon $R_m = \frac{3.5}{2} \times 10^6$ m

$R_m = 1.75 \times 10^6$ m

Distance of object = Radius of lunar orbit

$R_0 = 3.8 \times 10^8$ m

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

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

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

$$h = \frac{R_m \times f_o}{R_0} = \frac{1.75 \times 10^6 \times 20}{3.8 \times 10^8} = 9.21 \times 10^{-2} \text{ m.}$$

Diameter of the image of the moon,

$= 2h = 18.42 \times 10^{-2}$ m = 18.42 cm

95. A concave mirror of large aperture has high gathering power and absorbs very less amount of light than the lenses of large apertures. The final image formed in

Chromatic aberration : The inability of a lens in which image formed by white object is coloured and blurred. This inability of lens to form a clear image is known as chromatic aberration.

Spherical aberration : The inability of a lens to form a point image of an object is called spherical aberration.

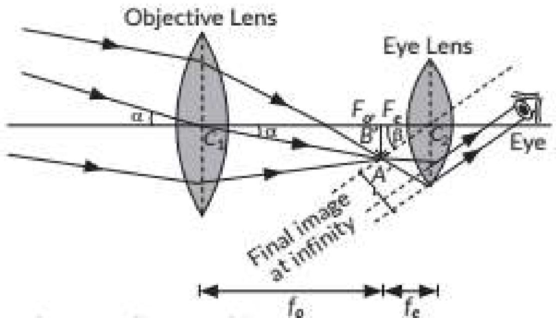
In the reflecting-type telescope, the objective lens is replaced by the concave parabolic mirror of a large aperture required for observing fainter objects.

The use of parabolic mirror makes the resolving power of the telescope high. The parabolic mirrors are free from chromatic and spherical aberrations.

reflecting telescope is very bright. So even very distant or faint stars can be easily viewed.

Due to large aperture of the mirror used, the reflecting telescopes have high resolving power.

96. (a) An astronomical telescope in normal adjustment.



It is used to see distant objects.

It consists of two lenses:

Objective of large aperture and large focal length f_o.

Eyepiece of small aperture and short focal length f_e.

Magnifying power: It is the ratio of the angle subtended by the final image at the eye to the angle which the object subtends at the lens, or the eye.

(i) : For a telescope, power of objective = 0. 5 D

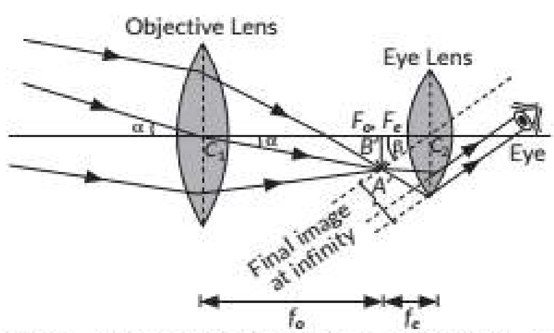
Power of eyepiece = 10 D

This choice would give higher magnification as

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

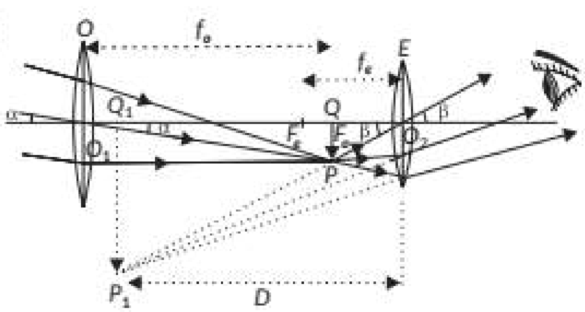
(ii) : Aperture of the objective is preferred to be large so as to have high resolving power and larger light gathering power to obtain brighter image.

97. (a)

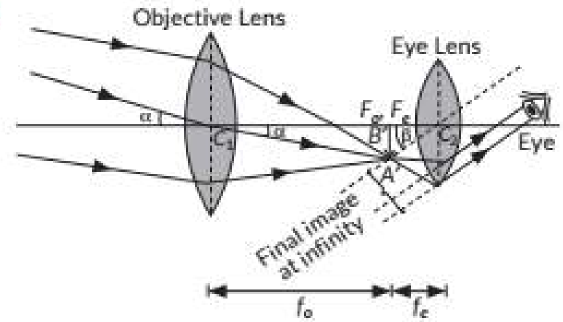


(b) Refracting telescope suffer from chromatic and spherical aberrations.

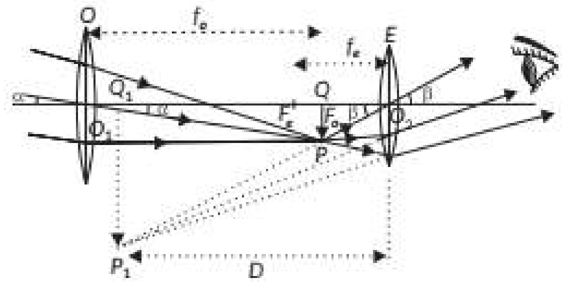
99. (a)



98.



When the final image is formed at least distance of distinct vision :



Magnifying power of refracting telescope (*M*) is defined as the ratio of the angle subtended by the image (β) at the eye to the angle subtended by the distant object at the unaided eye (α).

$$M = \frac{\beta}{\alpha}$$

We can increase the magnifying power of telescope by

(i) Increasing the focal length of the objective.

(ii) Decreasing the focal length of eyepiece.

Two limitations of refractive telescope are:

(i) The lenses used in refractive telescope are expensive.

(ii) The lenses used for making refracting telescope have chromatic aberration and distortions.

They can be minimised by using reflecting type telescope, which use concave mirror rather than a lens for the objective.

Reflecting type telescope has the following advantages :

(i) They are free from chromatic aberration as mirror is used instead of lens.

(ii) There is no problem for mechanical support because weight of mirror is much less than the weight of the lens. It can be supported easily.

Here, f_a = 0.2 m, $^a\mu_g$ = 1.50

$$\therefore \quad \frac{1}{0.2} = (1.50-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow \frac{1}{R_1} - \frac{1}{R_2} = 10 \qquad \textbf{(1)}$$

Consider f_w be the focal length of the lens, when immersed in medium.

$$^w\mu_g = \frac{^a\mu_g}{^a\mu_w} = \frac{1.50}{1.25} = 1.2$$

In order to have a large magnifying power and high resolution of the telescope, its objective lens should have a large focal length and the eyepiece lens should have a short focal length.

(b) Distance between the objective and the eyepiece, $L = v_0 + |u_e|$

To find v_0, we have : $v_0 = \infty$ cm and $f_0 = 1.25$ cm

Now, $\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$ or $v_0 = 2.5$ cm

To find u_e, we have : $v_e = \infty$ and $f_e = 5$ cm

Calculating using the same formula as above, we get : $u_e = -5$ cm

$\therefore$ $L = 2.5 + 5 = 7.5$ cm

CBSE Sample Questions

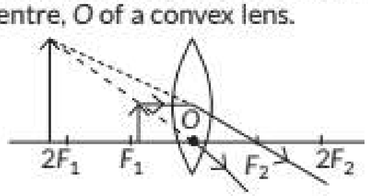
1. (c) : A concave mirror is a converging mirror. Convex mirror is a diverging mirror and can never form a real image **(1)**

2. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow \frac{1}{f} = \left(\frac{\mu_m}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\frac{\mu_m}{\mu_w} = \frac{1.25}{1.33} \Rightarrow \frac{\mu_m}{\mu_w} = 0.98$

The value of $(\mu - 1)$ is negative and 'f' will be negative. So, it will behave like diverging lens. **(2)**

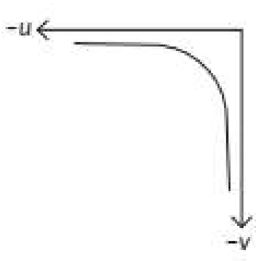
3. When an object is placed between principal focus, F_1 and optical centre, O of a convex lens.



The image formed is

(i) Virtual and erect **(1/2)**

(ii) Enlarged **(1/2)**



(1)

4. Using $\frac{1}{f_a} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Now, $\frac{1}{f_w} = ({}^w\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (1.2 - 1) \times 10 = 2$

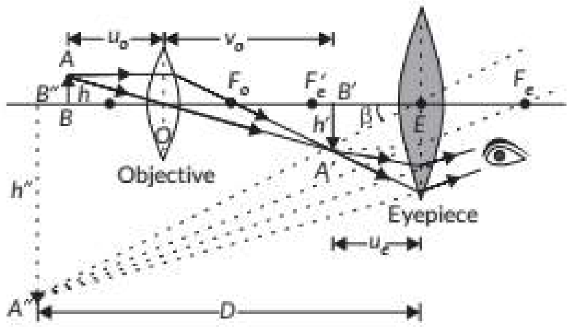
or $f_w = \frac{1}{2} = 0.5\,\text{m} = 50\,\text{cm}$

New focal length is positive. **(1)**

The significance of the positive sign of the focal length is that given convex lens is still converging in the given medium. **(1)**

5. (b) **(1)**

6. (a) For final image to be formed at least distance of distinct vision, magnification,



(1)

(b) For final image to be formed at least distance of distinct vision,

$m = \frac{v_o}{u_o}\left[1 + \frac{D}{f_e}\right]$

So, for m to be 30,

$30 = \frac{v_o}{u_o}\left[1 + \frac{25}{5}\right]$ or $30 = \frac{v_o}{u_o}[6]$

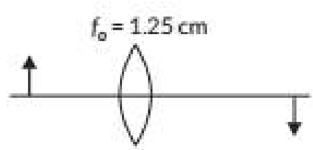
$v_o = 5u_o$ ... (i)

For objective of focal length 1.25 cm,

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

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

$\frac{1+5}{5u_o} = \frac{1}{1.25}$



$5u_o = +7.5$ cm or $u_o = 1.5$ cm. So, $v_o = +7.5$ cm

Now u_e for required magnification

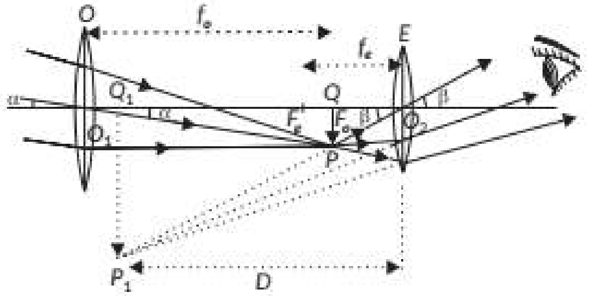
$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$ or $\frac{1}{-25} - \frac{1}{-u_e} = \frac{1}{5}$

$\frac{1}{u_e} = \frac{1}{5} + \frac{1}{25} = \frac{5+1}{25}$ or $u_e = \frac{25}{6}$ cm **(2)**

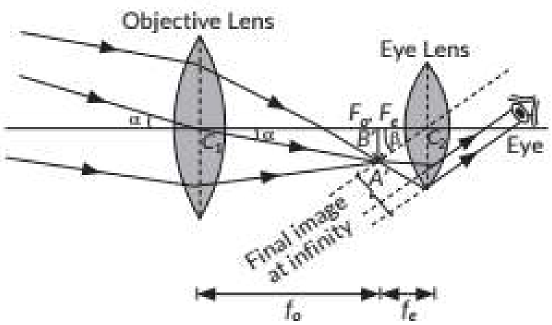
Hence, for final image to formed at least distance of distinct vision, separation between two lenses should be

$$v_o + u_e = 7.5\text{ cm} + \frac{25}{6}\text{ cm} = 11.67\text{ cm}$$

7. (a) For final image to be formed at least distance of distinct vision, magnification,



Ray diagram of astronomical telescope when final image is formed at infinity.



(1)

(b) (i) Given f_o = 140 cm, f_e = 5 cm

When final image is at infinity(normal adjustment),

magnifying power, $m = \frac{-f_o}{f_e} = -\frac{140}{5.0}$ **(1)**

$m = -28$

Negative sign shows that the image is inverted.

(ii) When final image is at the least distance of distinct vision, magnifying power,

$$m = \frac{-f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$= \frac{-140}{5.0}\left(1 + \frac{5.0}{25}\right) = -33.6$$ **(1)**

8. (i) When the image is formed at infinity, we can see it with minimum strain in the ciliary muscles of the eye. **(1)**

(ii) The multi-component lenses are used for both objective and the eyepiece to improve image quality by minimising various optical aberrations in lenses. **(1)**

(iii) (a) The compound microscope is used to observe minute nearby objects whereas the telescope is used to observe distant objects.

(b) In compound microscope, the focal length of the objective is lesser than that of the eyepiece whereas in telescope the focal length of the objective is larger than that of the eyepiece. **(2)**

OR

(iii) The two advantages are :

(a) The image formed by reflecting type telescope is brighter than that formed by refracting telescope.

(b) The image formed by the reflecting type telescope is more magnified than that formed by the refracting type telescope. **(2)**