Chapter 15

RAY OPTICS

A SINGLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

1. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm below the surface, the radius of this circle (in cm) is –

(a) $36\sqrt{5}$ (b) $4\sqrt{5}$

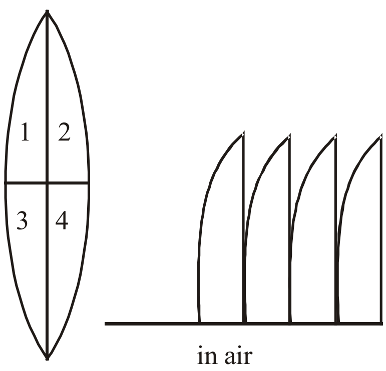
(c) $36\sqrt{7}$ (d) $36/\sqrt{7}$

2. A mango tree is at the bank of river and one of the branch of tree extends over the river. A tortoise lives in river. A mango falls just above the tortoise. The acceleration of the mango falling from tree appearing to the tortoise is (Refractive index of water is 4/3 and the tortoise is stationary)

(a) g (b) 3g/4

(c) 4g/3 (d) None of these

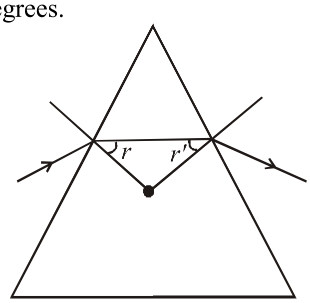
3. The given lens is broken into four parts and rearranged as shown. If the initial focal length is f then after rearrangement the equivalent focal length is –



(a) f (b) $f/2$

(c) $f/4$ (d) $4f$

4. r and r' denote the angles inside an equilateral prism, as usual, in degrees.

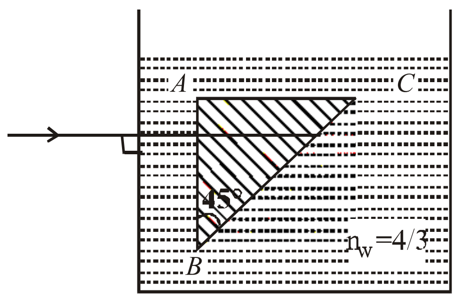


Consider that during some time interval from $t = 0$ to $t = t$, r' varies with time as $r' = 10 + t^2$. During this time r will vary as (assume that r and r' are in degree)

(a) $50 - t^2$ (b) $50 + t^2$

(c) $60 - t^2$ (d) $60 + t^2$

5. A triangular prism of glass is inside water. A ray, incident normally, on one of the faces, is totally reflected from face BC. Then the minimum refractive index of glass is –

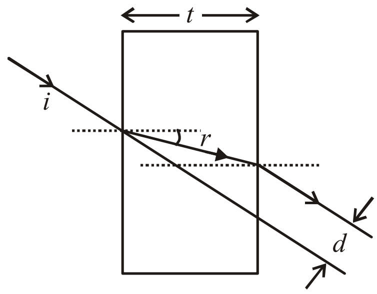


(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{5}{3}$

(c) $\frac{2\sqrt{2}}{5}$ (d) $\frac{4\sqrt{2}}{3}$

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ

6. A ray of light is incident on a thick slab of glass (thickness t) as shown below. The emergent ray is parallel to the incident ray but displaced sideways by a distance d. If the angles are small then d is:



(a) $t(1-i/r)$ (b) $r\,t(1-i/r)$

(c) $i\,t\left(1-\frac{r}{i}\right)$ (d) $t\left(1-\frac{r}{i}\right)$

7. An object is moving with speed v_0 towards a spherical mirror with radius of curvature R, along the central axis of the mirror. The speed of the image with respect to the mirror is (U is the distance of the object from mirror at any given time t):

(a) $\left(\frac{R}{U-2R}\right)v_0^2$ (b) $-\left(\frac{R}{R-2U}\right)^2 v_0$

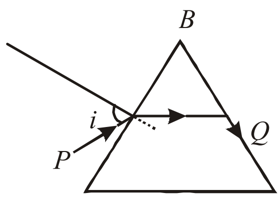
(c) $-\left(\frac{R}{2U-2R}\right)^2 v_0$ (d) $\left(\frac{R}{2U-2}\right)v_0^2$

8. A point source of light is placed at a depth of h below the surface of water of refractive index μ. A floating opaque disc is placed on the surface of water so that light from the sources is not visible from the surface. The minimum diameter of the disc is

(a) $2h/(\mu^2-1)^{1/2}$ (b) $2h(\mu^2-1)^{1/2}$

(c) $h/[2(\mu^2-1)^{1/2}]$ (d) $h(\mu^2-1)^{1/2}$

9. A ray of light PQ is incident at angle i on a prism face. (See figure) After 2 refractions it leaves the prism at a grazing angle.

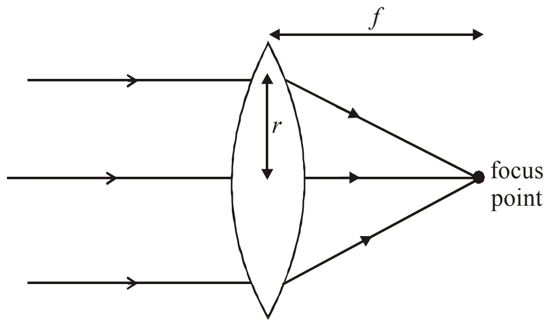


If μ is the refractive index and B is the refractive index and B is the refracting angle of the prism, the refracting index (μ) is:

(a) $\left[1 \left\{\frac{\sin i \quad \cos B}{\sin B}\right\}^2\right]^{\frac{1}{2}}$ (b) $\frac{\cos i \sin B}{\cos B}$

(c) $\frac{\cos i \quad \cos B^{\;2}}{\sin B}$ (d) $\frac{\sin i \cos B}{\sin B}$

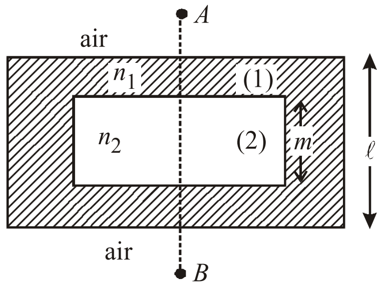
10. On the earth a child focuses the sun light on a screen, using a convex lens of focal length f and radius of aperture r. What is the intensity of light at the focus point (S = solar constant)



(a) $\frac{Sr^2d^2}{2R^2f^2}$ (b) $\frac{Sr^2d^2}{4R^2f^2}$

(c) $\frac{Sr^2d^2}{R^2f^2}$ (d) $\frac{2Sr^2d^2}{R^2f^2}$

11. In a thick glass slab of thickness ℓ and refractive index n_1 a cuboidal cavity of thickness m is carved as shown in the figure and is filled with liquid of $R.I.$ n_2 ($n_1 > n_2$). The ratio of ℓ/m, so that shift produced by this slab is zero when an observer A observes an object B with paraxial rays is

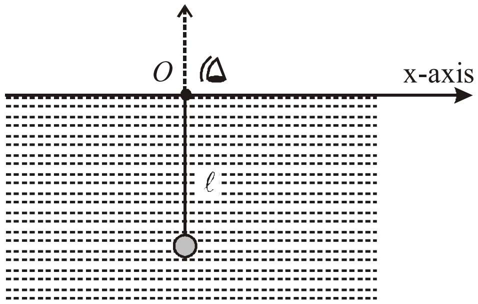


(a) $\frac{n_1-n_2}{n_2-1}$ (b) $\frac{n_1-n_2}{n_2(n_1-1)}$

(c) $\frac{n_1-n_2}{n_1-1}$ (d) $\frac{n_1-n_2}{n_1(n_2-1)}$

MARK YOUR RESPONSE	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ
	11. ⓐⓑⓒⓓ				

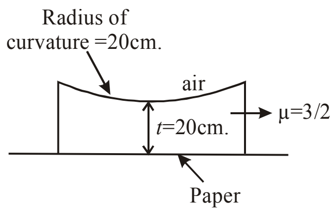
12. A pendulum of length ℓ is free to oscillate in vertical plane above point O. An observer is viewing the bob of the pendulum directly from above. The pendulum is performing small oscillations in water (refractive index is μ) about its equilibrium position. The equation of trajectory of bob as seen by observer is



(a) $\mu^2 x^2 + y^2 = \ell^2$ (b) $\frac{x^2}{\ell^2} \quad \frac{y^2}{\mu^2 \ell^2} \quad 1$

(c) $x^2 \quad y^2 \quad \left(\frac{\ell}{\mu}\right)^2$ (d) $\frac{x^2}{\ell^2} \quad \frac{y^2}{(\ell/\mu)^2} \quad 1$

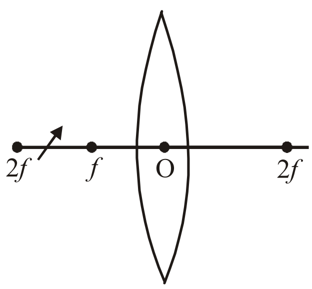
13. A planoconcave lens is placed on a paper on which a flower is drawn.



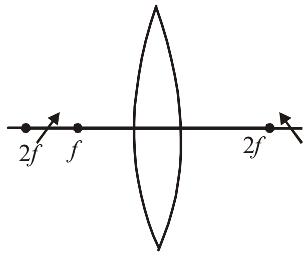
How far above its actual position does the flower appear to be ?

(a) 10 cm. (b) 15 cm.
(c) 50 cm. (d) None of these

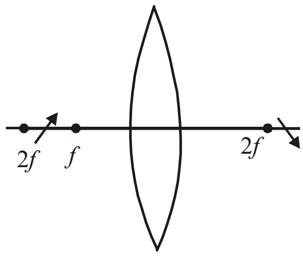
14. The figure shows a straight small object kept in front of a convex lens as shown in the figure. Which among the given options shows the right image of the object?



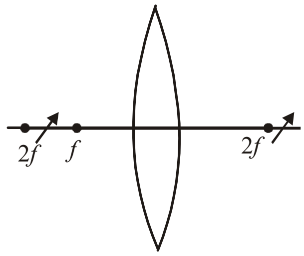
(a)



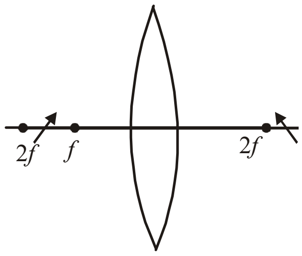
(b)



(c)

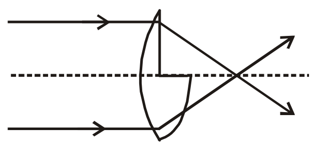


(d)

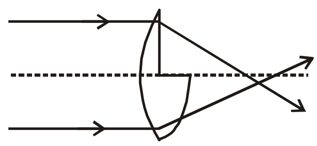


15. Choose the correct ray diagram of a thin equi-convex lens which is cut as shown in the figure.

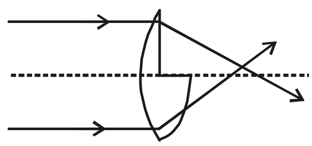
(a)



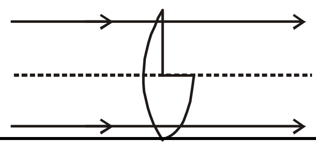
(b)



(c)

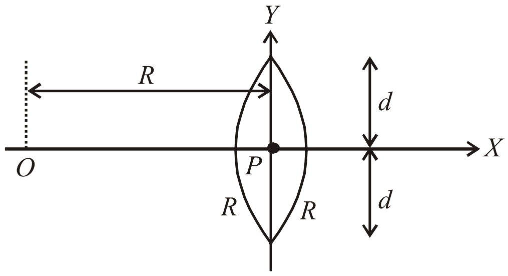


(d)



MARK YOUR RESPONSE	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	

16. A biconvex thin lens of radius of curvature R is made up of variable refractive index μ $2\left(1 \quad \frac{|y|}{d}\right)$. Assume $2d$ R. There are infinite images of the point object O (which is placed at a distance R on the principal axis from the lens as shown in the figure) spreaded over the length

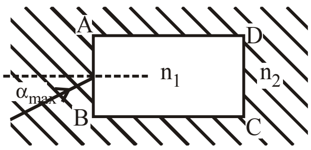


(a) $\frac{R}{5}$ (b) $\frac{2R}{5}$

(c) $\frac{3R}{5}$ (d) $\frac{4R}{5}$

17. The plane surface of a plano-convex lens of focal length 20 cm is silvered. It will behave as
(a) plane mirror
(b) convex mirror of focal length 40 cm
(c) concave mirror of focal length 10 cm
(d) None of these

18. A rectangular glass slab $ABCD$ of refractive index n_1 is immersed in water of refractive index $n_2 (n_1 > n_2)$. A ray of light is incident at the surface AB of the slab as shown. The maximum value of the angle of incidence α_{max} such that the ray comes out only from the other surface CD is given by



(a) $\sin^{-1}\left[\frac{n_1}{n_2}\cos\left(\sin^{-1}\left(\frac{n_2}{n_1}\right)\right)\right]$

(b) $\sin^{-1}\left[n_1\cos\left(\sin^{-1}\left(\frac{1}{n_2}\right)\right)\right]$

(c) $\sin^{-1}\left(\frac{n_1}{n_2}\right)$

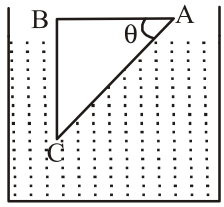
(d) $\sin^{-1}\left(\frac{n_2}{n_1}\right)$

19. A plano convex lens fits exactly into a plano concave lens. Their plane surface are parallel to each other. If the lenses are made of different materials of refractive indices μ_1 & μ_2 and R is the radius of curvature of the curved surface of the lenses, then focal length of combination is

(a) $\frac{R}{\mu_1 - \mu_2}$ (b) $\frac{2R}{\mu_1 - \mu_2}$

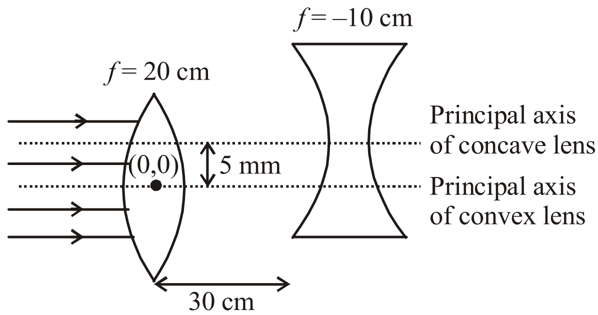
(c) $\frac{R}{2\ \mu_1 - \mu_2}$ (d) $\frac{R}{2 - \ \mu_1 \ \ \mu_2}$

20. A glass prism of refractive index 1.5 is immersed in water (refractive index 4/3). A light beam incident normally on the face AB is totally reflected to reach the face BC, if



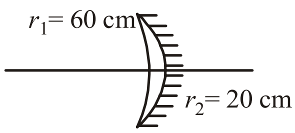
(a) sin θ ≥ 8/9 (b) 2/3 < sin θ ≤ 8/9
(c) sin θ ≤ 2/3 (d) sin θ ≤ 8/9

21.



If the optic axis of convex and concave lenses are separated by a distance 5 mm as shown in the figure. Find the coordinate of the final image formed by the combination if parallel beam of light is incident on lens origin is at the optical centre of convex lens.
(a) (25 cm, 0.5 cm) (b) (25 cm, 0.25 cm)
(c) (25 cm, – 0.5 cm) (d) (25 cm, – 0.25 cm

22. Convex surface of thin concavo – convex lens of refractive index 1.5 is silvered as shown. A small object is kept in air at 30 cm left of the lens on its principal axis. The distance of the final image is



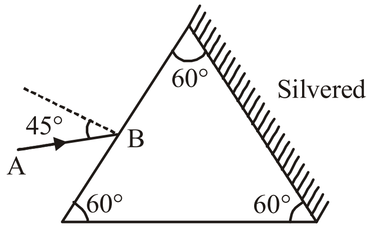
(a) 20 cm (b) 30 cm
(c) 10 cm (d) 15 cm

MARK YOUR RESPONSE					
	16.ⓐⓑⓒⓓ	17.ⓐⓑⓒⓓ	18.ⓐⓑⓒⓓ	19.ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ
	21.ⓐⓑⓒⓓ	22.ⓐⓑⓒⓓ			

23. A concave lens of glass, refractive index 1.5 has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a

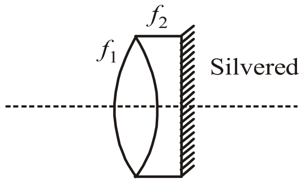
(a) convergent lens of focal length 3.5 R
(b) convergent lens of focal length 3.0 R
(c) divergent lens of focal length 3.5 R
(d) divergent lens of focal length 3.0 R

24. A equilateral prism is made of a transparent material of refractive index $\sqrt{2}$. A ray of light AB is incident at 45° as shown. The net deviation in the path of ray when it comes out of prism is



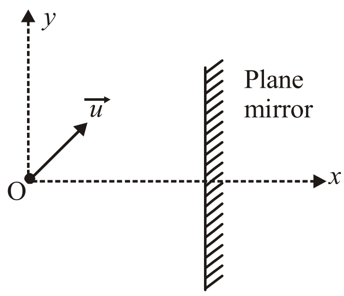
(a) 135° (b) 120°
(c) 30° (d) 150°

25. Two lenses of focal length f_1 = 10 cm and f_2 = – 20 cm are kept as shown. The resultant power of combination will be



(a) –10D (b) 5 D
(c) 0 (d) 10 D

26. A plane mirror is kept parallel to y-axis. A point object is approaching the mirror with velocity $\vec{u} \quad (10\hat{i} \quad 10\hat{j})$ m/s. The magnitude of relative velocity of objective w.r.t image is equal to



(a) $20\sqrt{2}$m/s (b) 20 m/s
(c) $10\sqrt{2}$m/s (d) 10 m/s

27. The maximum deviation produced by a prism of material of refractive index μ is

(a) $\frac{\pi}{2} - 2\sin^{-1}\left(\frac{1}{\mu}\right)$ (b) $\pi - \frac{1}{2}\sin^{-1}\left(\frac{1}{\mu}\right)$

(c) $2\sin^{-1}\left(\frac{1}{\mu}\right)$ (d) $\pi - 2\sin^{-1}\left(\frac{1}{\mu}\right)$

28. A ray of light travelling along the positive z-axis is reflected twice :

(i) for the first time, by a mirror whose normal is along $(\hat{i} \quad \hat{k})$

(ii) for the second time, by a mirror whose normal is along $(\hat{i} \quad \hat{k} \quad \hat{j})$, where the symbols have their usual meanings. The final ray is along

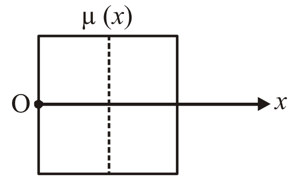
(a) $\hat{j} \quad \hat{k}$ (b) $\hat{k} \quad \hat{i}$

(c) $2\hat{j}+2\hat{k}-\hat{i}$ (d) $(\hat{j}+\hat{k}-2\hat{i})$.

29. A composite glass slab is manufactured so that its refractive index varies along its thickness according to the relation :

$$\mu(x) \quad \left(1 \quad \frac{\alpha x}{t}\right),$$

where t is the thickness of the slab.
The optical path, introduced, by the slab when it is placed in the path of light passing normally through it, is given by



(a) $(1+\alpha)t$ (b) $\left(1 \quad \frac{\alpha}{2}\right)t$

(c) $\frac{t}{1+\alpha}$ (d) $\frac{t}{\alpha}ln(1+\alpha)$

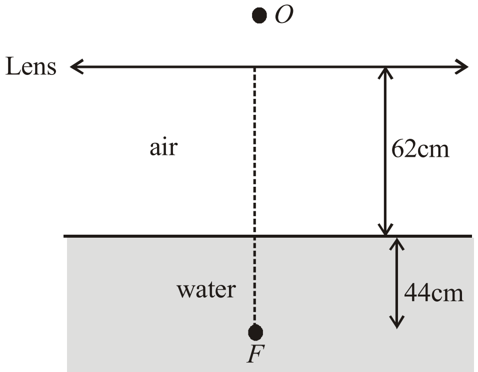
30. A point object is moving with velocity $\vec{u} \quad 2\hat{i} \quad \hat{j}-\hat{k}$ m/s in front of a stationary plane mirror. The magnitude of relative velocity of the image with respect to object is maximum if the normal of the plane mirror will be along

(a) $2\hat{i} \quad \hat{j} \quad \hat{k}$ (b) $-2\hat{i}+\hat{j}-\hat{k}$

(c) $2\hat{i}+\hat{j}-\hat{k}$ (d) $2\hat{i}-\hat{j}-\hat{k}$

MARK YOUR RESPONSE					
	23. ⓐⓑⓒⓓ	24. ⓐⓑⓒⓓ	25. ⓐⓑⓒⓓ	26. ⓐⓑⓒⓓ	27. ⓐⓑⓒⓓ
	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ	30. ⓐⓑⓒⓓ		

31. A stationary observer O looking at a fish F in water ($\mu_w = 4/3$) through a converging lens of focal length 90.0cm. The lens is allowed to fall freely from a height 62.0cm with its axis vertical. The fish and the observer are on the principal axis of the lens. The fish moves up with constant velocity 100 cm/s. Initially it was at a depth of 44.0cm. Find the velocity (in cm/s) with which the fish appears to move with respect to lens to the observer at $t = 0.2$ sec.
(take $g = 10$ m/s^2)

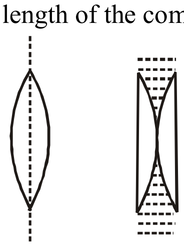


(a) 1475 cm/s (b) 2615 cm/s
(c) 2475 cm/s (d) 2271 cm/s

32. A point object P moves towards a stationary convex mirror with a constant speed v, along the optical axis. The speed of the image
(a) is always less than v
(b) may be greater than, equal to or less than v, depending upon the position of P
(c) is always greater than v
(d) none of these

33. A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refractive indices μ_1 and μ_2 respectively ($\mu_2 > \mu_1 > 1$). The lens will diverge a parallel beam of light if it is filled with
(a) air and placed in air (b) air and immersed in L_1
(c) L_1 and immersed in L_2 (d) L_2 and immersed in L_1

34. A thin convex lens of focal length 10 cm and refractive index 1.5 is cut vertically into two equal pieces. They are placed as shown with a liquid of refractive index 3 between them. What is the focal length of the combination ?



(a) –10 cm. (b) –10/4 cm.
(c) –10/3 cm. (d) None

35. The following data are given for a crown glass prism ;
refractive index for violet light $n_v = 1.521$
refractive index for red light $n_r = 1.510$
refractive index for yellow light $n_y = 1.515$
Then the dispersive power of a parallel glass slab made of the same material is
(a) 0.01 (b) 0.03 (c) 0 (d) 0.02

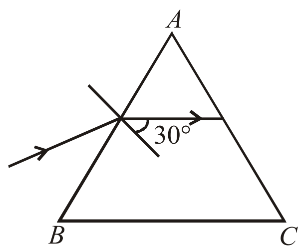
36. The inner surface of a cone coated by a reflecting layer forms a conical mirror. A thin incandescent filament is stretched in the cone along its axis.
Determine the minimum angle α of the cone for which the rays emitted by the filament will be reflected from the conical surface not more than once
(a) 120° (b) 90° (c) 150° (d) 135°

37. Two identical thin planoconvex lenses of refractive index n are silvered, one on the plane side and the other on the convex side. The ratio of their focal lengths is

(a) $\frac{n}{n-1}$ (b) $\frac{n-1}{n}$ (c) $\frac{n\ \ 1}{n}$ (d) n

38. Two converging lenses are mounted at the ends of a tube with a blackened inner lateral surface. The diameters of the lenses are equal to the diameter of the tube. The focal length of one lens is twice that of the other lens. The lenses are at such a distance from each other that parallel light rays incident along the axis of the tube on one lens emerge from the other lens in a parallel beam. When a wide light beam is incident on the lens with the larger focal length, a bright spot of illuminance E_1 is formed on the screen. When the tube is turned through 180°, the bright spot formed on the screen has an illuminance E_2. Determine the ratio of illuminances on the screen.
(a) 1/4 (b) 1/2 (c) 1/8 (d) 1/16

39. In the case of minimum deviation for an equilateral flint glass prism, the angle of refraction is 30° as shown in figure. What should be the angle of refraction of light (for ray incident on surface AB) satisfying the condition of minimum deviation in case of an equilateral crown glass prism?
[Given $\mu_{flint} > \mu_{crown}$]



(a) >30° (b) <30°
(c) 30° (d) information insufficient

MARK YOUR RESPONSE					
	31. ⓐⓑⓒⓓ	32. ⓐⓑⓒⓓ	33. ⓐⓑⓒⓓ	34. ⓐⓑⓒⓓ	35. ⓐⓑⓒⓓ
	36. ⓐⓑⓒⓓ	37. ⓐⓑⓒⓓ	38. ⓐⓑⓒⓓ	39. ⓐⓑⓒⓓ	

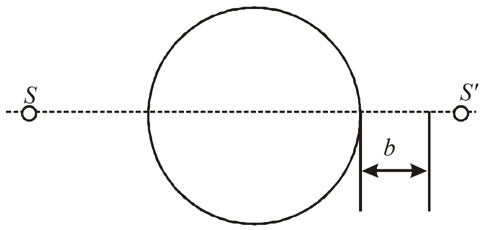
40. A convex lens is in contact with concave lens. The magnitude of the ratio of their focal length is 2/3. Their equivalent focal length is 30 cm. What are their individual focal lengths?

(a) –15, 10 (b) –10, 15
(c) 75, 50 (d) –75, 50

41. A ray of light is incident at an angle α on the boundary separating two transparent media and it refracts. When angle α is increased very slightly, the ray suffers a total internal reflection. The difference between the angles of deviation in two cases is nearly

(a) $90° - \alpha$ (b) $180° - \alpha$
(c) $180° - 2\alpha$ (d) 2α

42. The image of a point source S' lying at a distance b from a transparent sphere is formed by a small diaphragm only by rays close to the optical axis (figure).



Where will the image be after the sphere is cut into two parts perpendicular to the horizontal axis, and the plane surface of the left half is silvered ?

(a) At a distance b from the sphere
(b) At a distance $b/2$ from the sphere.
(c) At a distance $b/3$ from the sphere.
(d) None of these

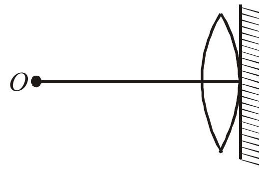
43. Two rays are incident on a spherical mirror of radius $R = 5$ cm. parallel to its optical axis at distances $h_1 = 0.5$ cm. and $h_2 = 3$ cm. Determine the distance Δx (approximately) between the points at which these rays intersect the optical axis after being reflected at the mirror.

(a) 0.2cm. (b) 1.5cm.
(c) 0.6cm. (d) 1.0 cm.

44. In an experiment to determine the focal length (f) of a concave mirror by the u - v method, a student places the object pin A on the principal axis at a distance x from the pole P. The student looks at the pin and its inverted image from a distance keeping his/her eye in line with PA. When the student shifts his/her eye towards left, the image appears to the right of the object pin. Then,

(a) $x < f$ (b) $f < x < 2f$
(c) $x = 2f$ (d) $x > 2f$

45. Behind a thin converging lens having both the surfaces of the same radius 10cm, a plane mirror has been placed. The image of an object at a distance 40cm. from the lens is formed at the same position. What is the refractive index of the lens?

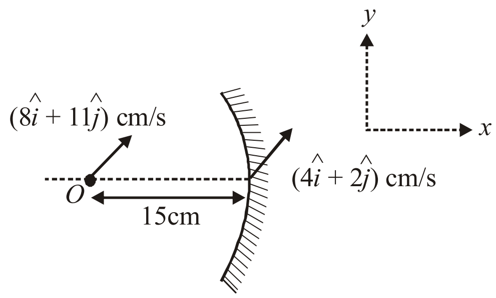


(a) 1.5 (b) 5/3
(c) 9/8 (d) None of these

46. A glass porthole is made at the bottom of a ship for observing sea-life. The hole diameter $D = 40$ cm. is much larger than the thickness of the glass. Determine the area S (approximately) of the field of vision at the sea bottom for the porthole if the refractive index of water is $n_w = 1.4$, and the sea depth is $h = 5$m.

(a) 41m^2 (b) 55m^2 (c) 82m^2 (d) 164m^2

47. A point object is located at a distance 15cm. from the pole of a concave mirror of focal length 10cm on its principal axis is moving with a velocity $(8\hat{i}\ \ 11\hat{j})$ cm/s and velocity of mirror is $(4\hat{i}\ \ 2\hat{j})$ cm/s as shown. If $\vec{v}$ is the velocity of image. Then find the value of $|\vec{v}|$ in (cm/s).



(a) 20 (b) 30 (c) 10 (d) 40

48. I is the image of a point object O formed by spherical mirror, then which of the following statement is incorrect? (Take real or virtual objects at finite distances from pole)

(a) If O and I are on the same side of the principal axis, then they have to be on opposite sides of the mirror
(b) If O and I are on opposite sides of the principal axis, then they have to be on same side of the mirror
(c) If O and I are on opposite sides of the principal axis, then they have to be on opposite sides of the mirror as well
(d) If O is on principal axis, then I has to lie on principal axis only

49. A person walks at a velocity v in a straight line forming an angle α with the plane of a mirror. Determine the velocity v_{rel} at which he approaches his image, assuming that the object and its image are symmetric relative to the plane of the mirror.

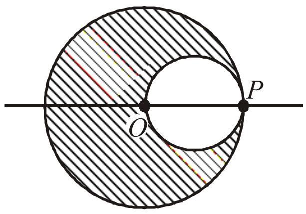
(a) $2v \sin \alpha$ (b) $2v \cos \alpha$
(c) $v \sin \alpha$ (d) $v \cos \alpha$

MARK YOUR RESPONSE	40. ⓐⓑⓒⓓ	41. ⓐⓑⓒⓓ	42. ⓐⓑⓒⓓ	43. ⓐⓑⓒⓓ	44. ⓐⓑⓒⓓ
	45. ⓐⓑⓒⓓ	46. ⓐⓑⓒⓓ	47. ⓐⓑⓒⓓ	48. ⓐⓑⓒⓓ	49. ⓐⓑⓒⓓ

50. A point light source S is outside a cylinder on its axis near the end face (base). Determine the minimum refractive index n of the cylinder material for which none of the rays entering the base will emerge from the lateral surface.

(a) $1/\sqrt{2}$ (b) $\sqrt{2}$ (c) 1/2 (d) 1

51. A transparent sphere of radius R has a cavity of radius $R/2$ as shown in figure. Find the refractive index of the sphere if a parallel beam of light falling on left surface focuses at point P.



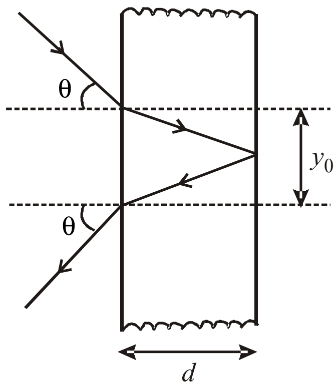
(a) $\mu \quad \frac{3 \quad \sqrt{5}}{2}$ (b) $\mu \quad \frac{3-\sqrt{5}}{2}$

(c) $\mu \quad 3 \quad \sqrt{5}$ (d) $\mu \quad \frac{1 \quad \sqrt{5}}{2}$

52. A point light source is moving with a constant velocity v inside a transparent thin spherical shell of radius R, which is filled with a transparent liquid. If at $t = 0$ light source is at the centre of the sphere, then at what time a thin dark ring will be visible for an observer outside the sphere. The refractive index of liquid with respect to that of shell is $\sqrt{2}$.

(a) $\frac{R}{\sqrt{2}V}$ (b) $\frac{R}{2V}$ (c) $\frac{R}{3V}$ (d) $\frac{R}{\sqrt{3}V}$

53. A ray of light incident from air on a glass plate of refractive index n is partly reflected and partly refracted at the two surfaces of the glass. The displacement y_0 in the figure is



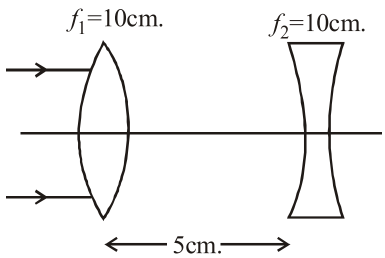
(a) $\frac{2d\sin\theta}{\sqrt{n^2-\sin^2\theta}}$ (b) $\frac{2d\sin\theta}{\sqrt{\sin^2\theta-\frac{1}{n^2}}}$

(c) $\frac{2d\sqrt{n^2-\sin^2\theta}}{\sin\theta}$ (d) None of these

54. Rays of light from Sun falls on a biconvex lens of focal length f and the circular image of Sun of radius r is formed on the focal plane of the lens. Then

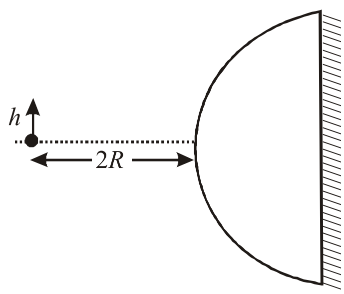
(a) area of image is πr^2 and area is directly proportional of f
(b) area of image is πr^2 and area is directly proportional to f^2
(c) intensity of image increases if f is increased
(d) if lower half of the lens is covered with black paper area will become half

55. A parallel beam of light falls on two coaxial lens system consisting of a thin converging lens of focal length 10cm. and a thin diverging lens of focal length 5cm. as shown in figure. The beam is also parallel to the principal axis and all the rays in the beam are paraxial. Both lenses are surrounded by air. The intensity of incident light is I_0. If the complete light is transmitted through each lens (that is, there is no absorption of light and neglecting partial reflection at any surface of lens), the intensity of light emergent from diverging lens is



(a) $4 I_0$ (b) I_0 (c) $2 I_0$ (d) $I_0/2$

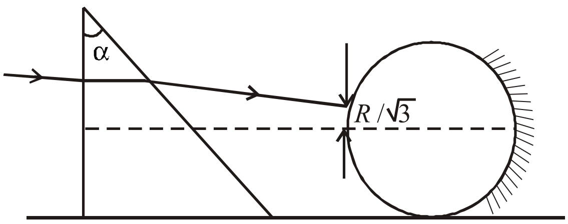
56. A glass hemisphere of radius R and material having refractive index 1.5 is silvered on its flat face as shown in the figure. A small object of height h is located at a distance $2R$ from surface of hemisphere. The final image will form



(a) at a distance of R from silvered surface, on right side
(b) on the object itself
(c) at the hemispherical surface
(d) at a distance of $2R$ from the silvered surface on left side

MARK YOUR RESPONSE	50. ⓐⓑⓒⓓ	51. ⓐⓑⓒⓓ	52. ⓐⓑⓒⓓ	53. ⓐⓑⓒⓓ	54. ⓐⓑⓒⓓ
	55. ⓐⓑⓒⓓ	56. ⓐⓑⓒⓓ			

57. A ray is incident normally on a right angle prism whose refractive index is $\sqrt{3}$ and prism angle $\alpha = 30°$, after crossing prism ray passes through glass sphere. It strikes the glass sphere at $\frac{R}{\sqrt{3}}$ distance from principal axis, as shown in figure sphere is half polished. Find the net angle of deviation of incident ray.

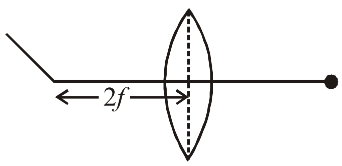


(a) 120° (b) 150°
(c) 90° (d) 180°

58. A prism placed in air made up of flint glass is such that any incident ray on one surface does not emerge from the second surface. Critical angle for flint glass is 36° in air. Then, refracting angle A may be

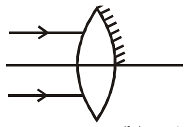
(a) 37° (b) 54°
(c) 71° (d) 73°

59. A small straight rod is placed at an inclination with the optical axis of a thin lens as shown in the figure. The base of the rod is on the optical axis and at a distance $2f$ (f = focal length of the lens) from the lens. The image of the rod would be



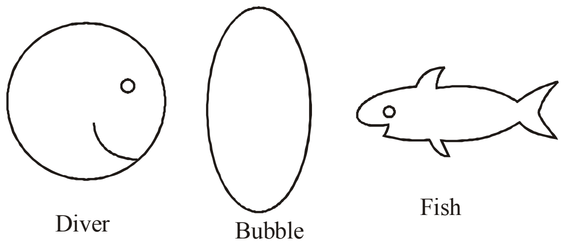
(a) a straight line leaning towards the lens
(b) a straight line leaning away from the lens
(c) a curve leaning towards the lens
(d) a curve leaning away from the lens

60. Half part of the rear surface of a thin equiconvex lens of focal length 40cm and refractive index 1.5 is silvered. If parallel rays are incident on this lens, then the distance between the two focii is



(a) 40 cm (b) 160/3 cm
(c) 200/3 cm (d) none of these

61. A fish sees the smiling face of a scuba diver through a bubble of air between them, as shown. Compared to the face of the diver, the image seen by the fish will be

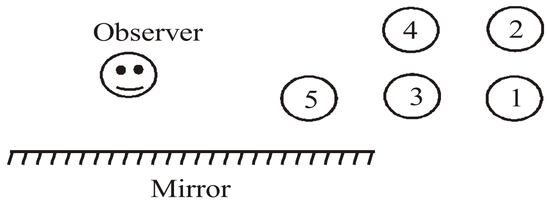


(a) smaller and erect (b) smaller and inverted
(c) larger and erect (d) larger and inverted

62. The width of man's face is 10cm. The distance between the eyes of the man is 4cm. Then the minimum width of plane mirror to see his full face, is

(a) 5 cm (b) 4 cm
(c) 3 cm (d) 10 cm

63. Five spheres are lined up in front of a plane mirror as shown. The observer will be able to see the reflection of



(a) 1 only (b) 5 only
(c) 1 and 3 only (d) 1, 2, 3 and 4 only

64. A scuba diver in an empty swimming pool uses a magnifier (n = 1.25) to enlarge the print on a plastic instruction sheet. If the pool is filled with water (n = 1.33), what happens to the magnification of the print ?

(a) It increases and is greater than one.
(b) It stays the same.
(c) It decreases, but is still greater than one.
(d) It decreases and is less than one

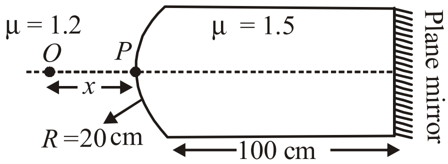
MARK YOUR RESPONSE	57. ⓐⓑⓒⓓ	58. ⓐⓑⓒⓓ	59. ⓐⓑⓒⓓ	60. ⓐⓑⓒⓓ	61. ⓐⓑⓒⓓ
	62. ⓐⓑⓒⓓ	63. ⓐⓑⓒⓓ	64. ⓐⓑⓒⓓ		

B COMPREHENSION TYPE

This section contains groups of questions. Each group is followed by some multiple choice questions based on a paragraph. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

PASSAGE-1

A point object is situated in front of a spherical glass surface as shown in the figure.

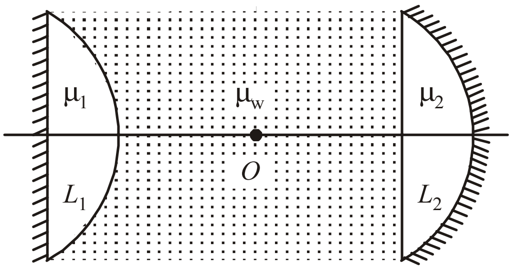


1. The position of image from P when $x = 70$ cm
(a) 70 cm right to P (b) 80 cm left to P
(c) 90 cm left to P (d) 90 cm right to P

2. Position of image from P when $x = 80$ cm
(a) 80 cm right to P (b) 80 cm left to P
(c) 90 cm left to P (d) 70 cm right to P

3. The position of image from P when $x = 90$ cm
(a) 80 cm right to P (b) 90 cm cm left to P
(c) 90 cm right to P (d) 70 cm right to P

PASSAGE-2



A cylindrical tube filled with water ($\mu_w = 4/3$) is closed at its both ends by two silvered plano convex lenses as shown in the figure. Refractive index of lenses L_1 and L_2 are 2.0 and 1.5 while their radii of curvature are 5 cm and 9 cm respectively. A point object is placed somewhere at a point O on the axis of cylindrical tube. It is found that the object and image coincide each other.

4. The position of object w.r.t lens L_1 is
(a) 8 cm (b) 10 cm
(c) 12 cm (d) 14 cm

5. The position of object w.r.t lens L_2 is
(a) 8 cm (b) 10 cm
(c) 12 cm (d) 14 cm

6. The length of the cylindrical tube is
(a) 16 cm (b) 18 cm
(c) 20 cm (d) 22 cm

PASSAGE-3

A curved surface of radius R separates two media of refractive indices μ_1 and μ_2 as shown in figures (A) and (B) respectively.

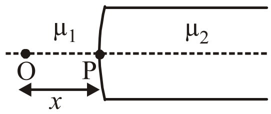


Figure (A)

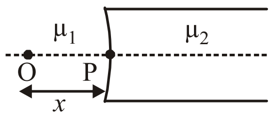


Figure (B)

For a real object a image is virtual if the light rays diverge after refraction and real if they converge or become parallel after refraction.

7. A point object is kept at point O in figure (A) then
(a) real image is formed for all position of object if $\mu_2 > \mu_1$
(b) real image is formed only when $x > R$
(c) real image will form irrespective of μ_1 and μ_2
(d) real image is formed if $x > \dfrac{\mu_1 R}{\mu_2 - \mu_1}$ for $\mu_2 > \mu_1$.

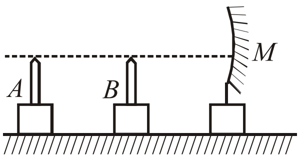
8. If the point object is kept at O at a distance x in figure (A) then
(a) virtual image is formed for any position of O for $\mu_2 < \mu_1$
(b) virtual image can be formed only if $x > R$ and $\mu_2 < \mu_1$
(c) virtual image can be formed only if $x < R$ and $\mu_2 < \mu_1$
(d) virtual image can never be formed.

9. If an object is kept at O at distance x from pole of figure B then
(a) If $\mu_2 < \mu_1$ then virtual image is formed for any value of x
(b) If $\mu_2 < \mu_1$ then virtual image is formed for $x < \dfrac{\mu_1 R}{\mu_1 - \mu_2}$
(c) If $\mu_2 < \mu_1$ then real image is formed for any value of x
(d) If $\mu_2 < \mu_1$ then real image is always formed.

MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	

PASSAGE-4

A concave mirror M is mounted on an optical bench. Two pins A and B are placed on bench such that their tips also lie on the principal axis of the mirror as shown. The image of tip of one tip is formed on the tip of the other pin. Now if pin B is moved 80cm. towards left and pin A is moved 80cm. towards right, image of tip of one pin is again on the tip of the other pin. The magnitude of transverse magnification of the larger image is three. [All the images are formed by paraxial rays].



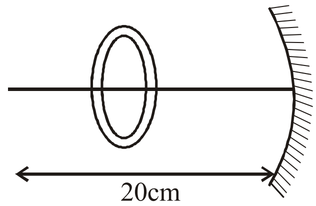
10. The focal length of the mirror is
(a) 30cm. (b) 60cm.
(c) 40 cm. (d) 15 cm.

11. The distance of the nearest pin from pole initially is
(a) 20cm. (b) 60cm.
(c) 80 cm. (d) 40 cm.

12. The magnification of the image of the pin B in second case is
(a) 3 (b) 4.5
(c) 1/4.5 (d) 1/3

PASSAGE-5

A concave mirror of radius of curvature 20cm is shown in the figure. A circular disc of diameter $(1.0 + 0.2t)$ cm is placed on the principal axis of mirror with its plane perpendicular to the principal axis at a distance 15cm from the pole of the mirror.



13. The image formed by the mirror will be in the shape of a
(a) circular disc
(b) elliptical disc with major axis horizontal
(c) elliptical disc with major axis vertical
(d) distorted disc

14. In the above question, the area of the image of the disc at $t = 1$ second is
(a) $1.2\,\pi\,cm^2$ (b) $1.44\,\pi\,cm^2$
(c) $1.52\,\pi\,cm^2$ (d) None of these

15. What will be the rate at which the horizontal radius of image will be changing ?
(a) 0.2 m/s increasing (b) 0.2 cm/s decreasing
(c) 0.4 cm/s increasing (d) 0.4 cm/s decreasing

MARK YOUR RESPONSE	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ
	15. ⓐⓑⓒⓓ				

C REASONING TYPE

In the following questions two Statements (1 and 2) are provided. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct. Mark your responses from the following options :

(a) Both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.
(b) Both Statement-1 and Statement-2 are true and Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is true but Statement-2 is false.
(d) Statement-1 is false but Statement-2 is true.

1. **Statement - 1 :** When light travels from denser to rarer medium the critical angle of incidence have different values for different wavelengths of light.
Statement - 2 : Refractive index of a medium varies with wavelength of light.

2. **Statement - 1 :** Keeping a point object fixed, if a plane mirror is moved, the image will also move.
Statement - 2 : In case of a plane mirror, distance of object and its image is equal from any point on the mirror.

3. **Statement - 1 :** It is not possible to see a virtual image by eye.
Statement - 2 : The rays that seem to emanate from a virtual image do not in fact emanate from the image.

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ		

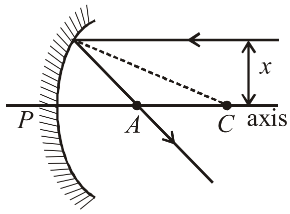
4. **Statement - 1 :** Position of image approaches focus of a lens, only when object approaches infinity.

Statement - 2 : Paraxial rays incident parallel to principal axis intersect at the focus after refraction from lens.

5. **Statement - 1 :** A lens L (shown in the figure), kept in surrounding medium X, has a power $+10D$. If the same lens is kept in a surrounding medium Y, its power is found to be $+12.5D$. Also if the same lens is placed in a surrounding medium Z, its power is now measured to be $-3.5D$, then $\mu_z > \mu_x > \mu_y$.

Statement - 2: In different surroundings, power of a given lens has different values but the same sign.

6. **Statement - 1 :** As the distance x of a parallel ray from axis increases, angle of incidence decreases.



Statement - 2 : As x increases, the distance of point of intersection of the reflected ray with axis from pole decreases.

MARK YOUR RESPONSE	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ		

D MULTIPLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE OR MORE is/are correct.

1. A certain mirror placed at the origin has $\hat{i}$ as the normal vector to its reflecting surface. The mirror begins to translate with a velocity $\hat{i} \quad \hat{j} \quad \hat{k}$ at t = 0, at the same time an object which was initially at $\hat{i} \quad \hat{j}$ starts moving with a velocity $(\hat{i} \quad \hat{j})$ m/s. Now choose the correct options.

   (a) Initial position of the image will be $-\hat{i} \quad \hat{j}$

   (b) The velocity of the image will be $\hat{i} \quad \hat{j}$

   (c) The velocity of the image relative to the object will be zero

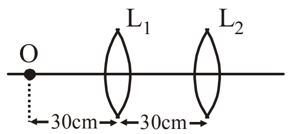
   (d) The velocity of the image relative to the mirror will be $-\hat{k}$.

2. A lens of focal length 'f' is placed in between an object and screen at a distance 'D' apart. The lens forms two real images of the object on the screen for two of its different positions, a distance 'x' apart. The two real images have magnifications m_1 and m_2 respectively $(m_1 > m_2)$.

   (a) $f \quad \frac{x}{m_1 - m_2}$ (b) $m_1 m_2 = 1$

   (c) $f \quad \frac{D^2 - x^2}{4D}$ (d) $D \geq 4f$.

3. Two thin convex lenses are separated as shown. The focal length of lens L_1 is 15 cm and that of lens L_2 is 30 cm. An object is placed at distance 30 cm from lens L_1. The location of image formed finally will be at



   (a) infinity

   (b) 15 cm behind the lens L_1

   (c) optical centre of lens L_2

   (d) 60 cm away from object

4. Which of the following quantities related to a lens depend on the colour/wavelength of the incident light ?

   (a) Focal length (b) Power

   (c) Image distance (d) Chromatic aberration

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	

5. Remote objects are viewed through a converging lens with a focal length F = 9 cm. placed at a distance a = 36cm. in front of the eye. Assume that the radius r of the pupil is approximately 1.5 mm. Choose the correct options

(a) The minimum radius of the screen that should be placed behind the lens so that the entire field of view is covered is 0.5mm.

(b) The minimum radius of the screen that should be placed behind the lens so that the entire field of view is covered is 1.0 mm.

(c) The screen must be placed in the plane S with its centre at point B.

(d) The screen must be placed perpendicular to the plane S with its centre at point B.

6. Let us suppose that a person seating opposite to you at the table wears glasses. Choose the correct options if you wish to determine whether he is short sighted or long-sighted ? Naturally, being a polite person, you would not ask him to let you try his glasses and in general would make no mention of them.

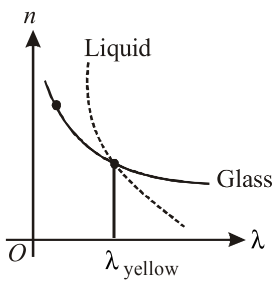
(a) Behind a diverging lens, the eye will look smaller.

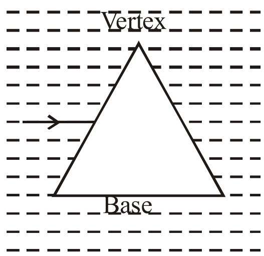
(b) Relative to other parts of the face : if visible contour of the face is displaced inwards, the lenses are diverging, and your companion is short-sighted.

(c) Relative to other parts of the face : if visible contour of the face is displaced outwards, the lenses are converging, and the person is long-sighted.

(d) Behind a converging lens, the eye will look larger.

7. A glass prism is immersed in a hypothetical liquid. The curves showing the refractive index n as a function of wavelength λ for glass and liquid are as shown in the figure. When a ray of white light is incident on the prism parallel to the base





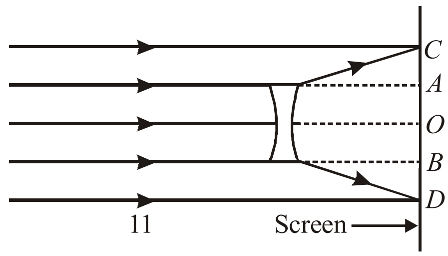
(a) yellow ray travels without deviation

(b) blue ray is deviated towards the vertex

(c) red rays is deviated towards the base

(d) there is no dispersion

8. A concave lens is placed in the path of a uniform parallel beam of light falling on a screen as shown. Then



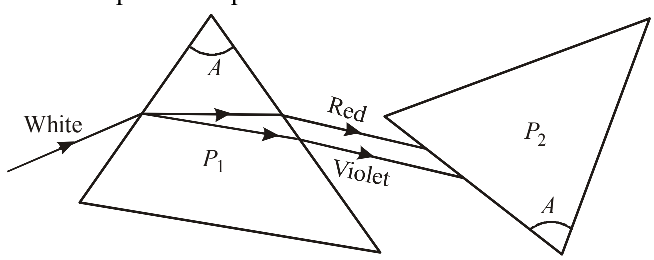
(a) intensity of light will be the same everywhere on the screen

(b) intensity in region AB will be smaller than what it would be in the absence of the lens

(c) in the region AC and BD, the intensity will be smaller than what it would be in the absence of the lens

(d) in the region AC and BD, the intensity will be greater than what it would be in the absence of the lens

9. P_1 and P_2 are identical prisms arranged as shown in figure. A ray of white light incident on face of P_1 undergoes dispersion and falls on one face of P_2. The facing surfaces of the prisms are parallel to each other. Then



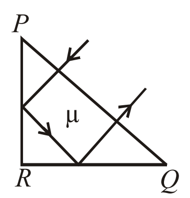
(a) light emerging from P_2 will be white

(b) in the light emerging from P_2 dispersion will be greater

(c) the direction of light emerging from P_2 will be parallel to the direction of ray incident on P_1

(d) the ray emerging from P_2 will be white even if prisms P_1 and P_2 have identical geometry but different material

10. A right-angled prism is made up of a material of refractive index μ. It is desired that a light ray incident normally on PQ emerges parallel to the incident direction after suffering two total internal reflections. In which of the following conditions is this possible ?



(a) $\mu \quad \sqrt{2}$ (b) $\mu \geq 2/\sqrt{3}$

(c) $\mu = 1.3$ (d) never possible.

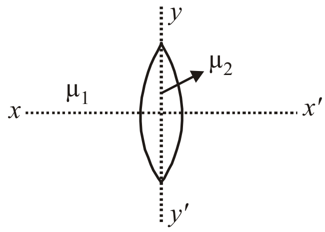
MARK YOUR RESPONSE	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ
	10. ⓐⓑⓒⓓ				

E MATRIX-MATCH TYPE

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labeled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column -I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example:
If the correct matches are A–p, s and t; B–q and r; C–p and q; and D–s and t; then the correct darkening of bubbles will look like the given.

	p	q	r	s	t
A	●	q	r	●	●
B	p	●	●	s	t
C	●	●	r	s	t
D	p	q	r	●	●

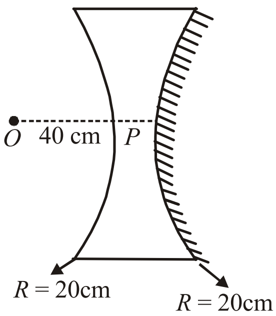
1. A convex lens of refractive index μ_2 is kept in a medium of refractive index μ_1 as shown.



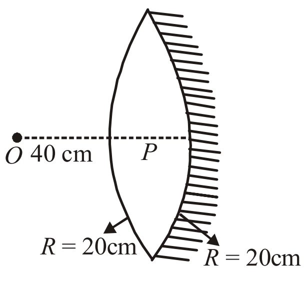
Column I	Column II
(A) On increasing value of μ_1 lens will be	(p) $\lvert f \rvert$ increases and converging
(B) If μ > μ	(q) $\lvert f \rvert$ may decrease or increase and lens will be diverging
(C) When lens is cut into two parts along *yy*', then for any one part	(r) $\lvert f \rvert$ increases and nature of lens remains unchanged
(D) μ is increased but μ < μ_2	(s) $\lvert f \rvert$ increases then decreases

2. Refractive index of lenses is 3/2. Then the final position of the image from the pole is

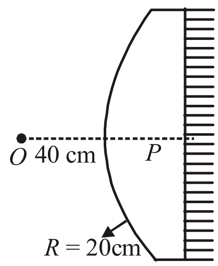
Column-I **Column -II**

(A)


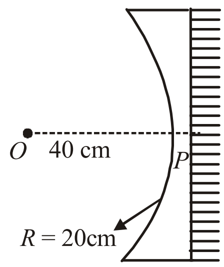
(p) 40/7 cm, left to P

(B)


(q) 40/9 cm, right to P

(C)


(r) 40/3 cm, right to P

(D)


(s) 40 cm, left to P

MARK YOUR RESPONSE

1.

	p	q	r	s
A	p	q	r	s
B	p	q	r	s
C	p	q	r	s
D	p	q	r	s

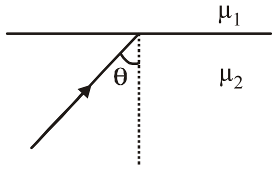
2.

	p	q	r	s
A	p	q	r	s
B	p	q	r	s
C	p	q	r	s
D	p	q	r	s

3. A mirror faces the negative x-axis. (Normal to its reflecting surfaces is $-\hat{i}$), while a particle starts moving such that its image is formed in the mirror. At a certain instant the velocity of the particle is $3\hat{i}\quad 4\hat{j}\quad 5\hat{k}$ and that of the mirror is $\hat{i}-\hat{j}\quad \hat{k}$. Now match the following :

Column I	**Column II**
(A) Magnitude of relative velocity of the image w.r.t. mirror	(p) $\sqrt{42}$
(B) Magnitude of relative velocity of image w.r.t. object	(q) $\sqrt{45}$
(C) Magnitude of relative velocity of object w.r.t. mirror.	(r) 4
(D) Absolute velocity of the image w.r.t. ground	(s) $\sqrt{43}$

4. A ray of light strikes at the boundary separating two media at angle θ. μ_1 and μ_2 are refractive indices of media with $(\mu_2 > \mu_1)$.



Column I	**Column II**
(A) When $\theta \quad \sin^{-1}\left(\frac{\mu_1}{\mu_2}\right)$ then deviation in the path of ray is	(p) $\frac{\pi}{2}-\sin^{-1}\left(\frac{\mu_1}{\mu_2}\right)$
(B) Maximum deviation in the path of ray for refraction at boundary	(q) $\pi-2\sin^{-1}\left(\frac{\mu_1}{\mu_2}\right)$
(C) Maximum deviation in the path of ray for reflection at the boundary	(r) Zero
(D) Deviation in the path at grazing angle of incidence	(s) $\sin^{-1}\left(\frac{\mu_2}{\mu_1}\sin\theta\right)-\theta$

5.

Column I	**Column II**
(A) Rainbow	(p) Refraction
(B) Mirage	(q) Dispersion
(C) Twinkling of stars	(r) Scattering
(D) Blue sky	(s) Total internal reflection

6. In column I, some optical instruments are mentioned, while in column II, the description about nature of image they can form for real objects are given. Match the entries of column I with the entries of column II.

Column I	**Column II**
(A) Concave mirror	(p) Real, erect
(B) Convex mirror	(q) Virtual, magnified
(C) Diverging lens	(r) Real, diminished
(D) Converging lens	(s) Virtual, diminished

MARK YOUR RESPONSE

3.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

4.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

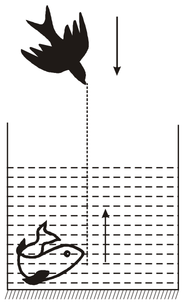
5.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

6.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

7. A bird in air is diving vertically over a tank with speed 6 cm/s. Base of the tank is silvered. A fish in the tank is rising upward along the same line with speed 4 cm/s [Take $\mu_{water} = 4/3$]



	Column I		**Column II**
(A)	Speed of the image of fish formed after reflection from the mirror as seen by the bird	(p)	12
(B)	Speed of image of bird relative to the fish looking upwards	(q)	4
(C)	Speed of image of bird relative to the fish looking downwards in the mirror.	(r)	9
(D)	Speed of image of bird relative to fish looking upwards in the mirror.	(s)	3

8. Match the following for light ray.

	Column I		**Column II**
(A)	In reflection from denser medium	(p)	Amplitude may change
(B)	In refraction into denser medium	(q)	Phase changes
(C)	In reflection from rarer medium	(r)	No phase change
(D)	In refraction into rarer medium	(s)	Velocity decreases

9. Match the columns :

	Column I		**Column II**
(A)	Object is between optic centre and 1st principal focus in a diverging lens	(p)	Image is inverted
(B)	Object is between optic centre and 1st principal focus of a converging lens	(q)	Image is erect
(C)	Object is between optic centre and 2nd principal focus of a diverging lens	(r)	Image is of greater size than the object
(D)	Object is between optic centre and 2nd principal focus of a converging lens	(s)	Image is of smaller size than the object
		(t)	Image is real

MARK YOUR RESPONSE

7.

	p	q	r	s
A	p	q	r	s
B	p	q	r	s
C	p	q	r	s
D	p	q	r	s

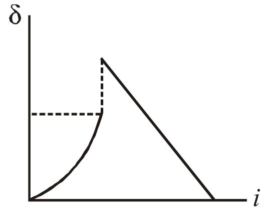
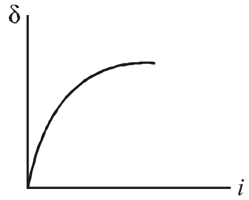
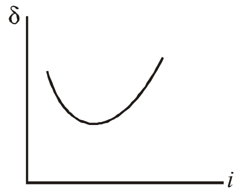
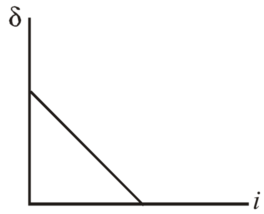
8.

	p	q	r	s
A	p	q	r	s
B	p	q	r	s
C	p	q	r	s
D	p	q	r	s

9.

	p	q	r	s	t
A	p	q	r	s	t
B	p	q	r	s	t
C	p	q	r	s	t
D	p	q	r	s	t

10. Match the entries of column I with the entries of column II, which describes the angle of deviation of ray with angle of incidence.

Column I		**Column II**	
(A)	A ray is falling on a plane smooth mirror	(p)	
(B)	A ray is going from a rarer to denser medium	(q)	
(C)	A ray is going from a denser to rarer medium	(r)	
(D)	A ray is falling on a prism	(s)	

11. Light rays are incident on devices which may cause either reflection or refraction or both. The natures of the incident light and the devices are described in column I. Some possible results of this on the rays are given in column II. Match the columnd correctly.

Column I		**Column II**	
(A)	A ray of white light is incident on one face of an equilateral glass prism	(p)	Divergent beam
(B)	A ray of white light is incident at an angle on a thick glass sheet	(q)	Total internal reflection
(C)	A ray of white light passes from an optically denser medium to an optically rarer medium	(r)	Lateral shift
(D)	A parallel beam of monochromatic light passes symmetrically through a glass lens.	(s)	Dispersion
		(t)	Refraction

MARK YOUR RESPONSE

10.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

11.

	p	q	r	s	t
A	(p)	(q)	(r)	(s)	(t)
B	(p)	(q)	(r)	(s)	(t)
C	(p)	(q)	(r)	(s)	(t)
D	(p)	(q)	(r)	(s)	(t)

12. Match the columns correctly.

	Column I		**Column II**
(A)	Concave mirror, real object	(p)	Real image
(B)	Convex mirror, real object	(q)	Virtual image
(C)	Concave lens, real object	(r)	Magnified image
(D)	Convex lens, real object	(s)	Diminished image
		(t)	Same size

13. A real object is kept in front of a lens. The object is a linear extended object with its length perpendicular to the optic axis of lens. With reference to different cases of image formation by lenses, match the columns correctly.

	Column I		**Column II**
(A)	The image has a magnification –2.5	(p)	Image is virtual
(B)	Magnification of the image is +0.5	(q)	Image is real
(C)	Length of image is the same as that of object	(r)	Power of lens is positive
(D)	Length of image is four times the length of the object	(s)	Power of lens is negative

MARK YOUR RESPONSE

12.

	p	q	r	s	t
A	(p)	(q)	(r)	(s)	(t)
B	(p)	(q)	(r)	(s)	(t)
C	(p)	(q)	(r)	(s)	(t)
D	(p)	(q)	(r)	(s)	(t)

13.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

F

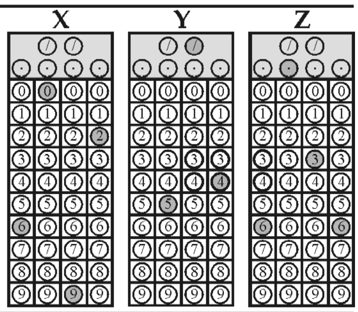
NUMERIC/INTEGER ANSWER TYPE

The answer to each of the questions is either numeric (eg. 304, 40, 3010, 3 etc.) or a fraction (2/3, 23/7) or a decimal (2.35, 0.546).

The appropriate bubbles below the respective question numbers in the response grid have to be darkened.

For example, if the correct answers to question X, Y & Z are 6092, 5/4 & 6.36 respectively then the correct darkening of bubbles will look like the following.

For single digit integer answer darken the extreme right bubble only.

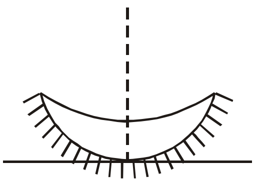


1. A ray of light is incident at an angle of 60° on one face of prism which has an angle of 30°. The ray emerging out of the prism makes an angle of 30° with the incident ray. Calculate the refractive index of the material of the prism.

2. An object is placed 21 cm in front of a concave mirror of radius of curvature 10 cm. A glass slab of thickness 3 cm and refractive index 1.5 is then placed close to the mirror in the space between the object and the mirror.
Find the image distance (in cm) of the final image formed. (You may take the distance of the near surface of the slab from the mirror to be 1 cm).

3. A telescope has an objective of focal length 50 cm and an eye piece of focal length 5 cm. The least distance of distinct vision is 25 cm. The telescope is focussed for distinct vision on a scale 200 cm away from the objective. Calculate the separation (in cm) between the objective and the eye-piece.

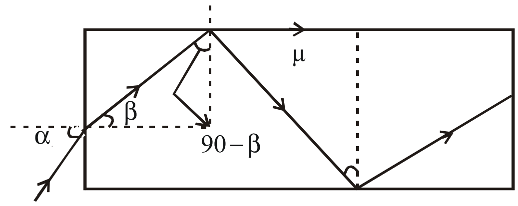
4. The convex surface of a thin concavo-convex lens of glass of refractive index 1.5 has a radius of curvature 20 cm. The concave surface has a radius of curvature 60 cm. The convex side is silvered and placed on a horizontal surface.



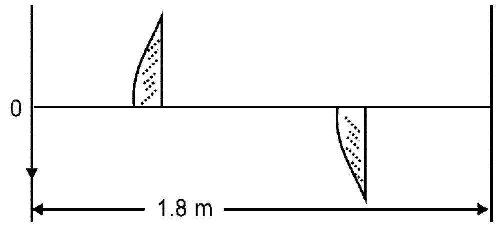
At what distance (in metre) should a pin be placed on the optic axis such that its image is formed at the same place? Calculate your answer in cm.

5. A plano convex lens has a thickness of 4 cm . When placed on a horizontal table, with the curved surface in contact with it, the apparent depth of the bottom most point of the lens is found to be 3 cm. If the lens is inverted such that the plane face is in contact with the table, the apparent depth of the centre of the plane face is found to be 25/8 cm. Find the focal length (in cm) of the lens.

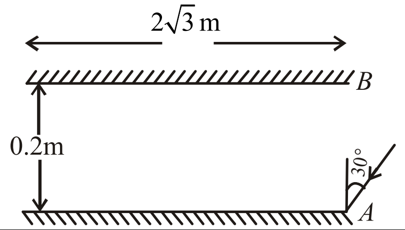
6. Light is incident at an angle α on one planar end of a transparent cylindrical rod of refractive index μ. Determine the least value of μ so that the light entering the rod does not emerge from the curved surface of rod irrespective of the value of α.



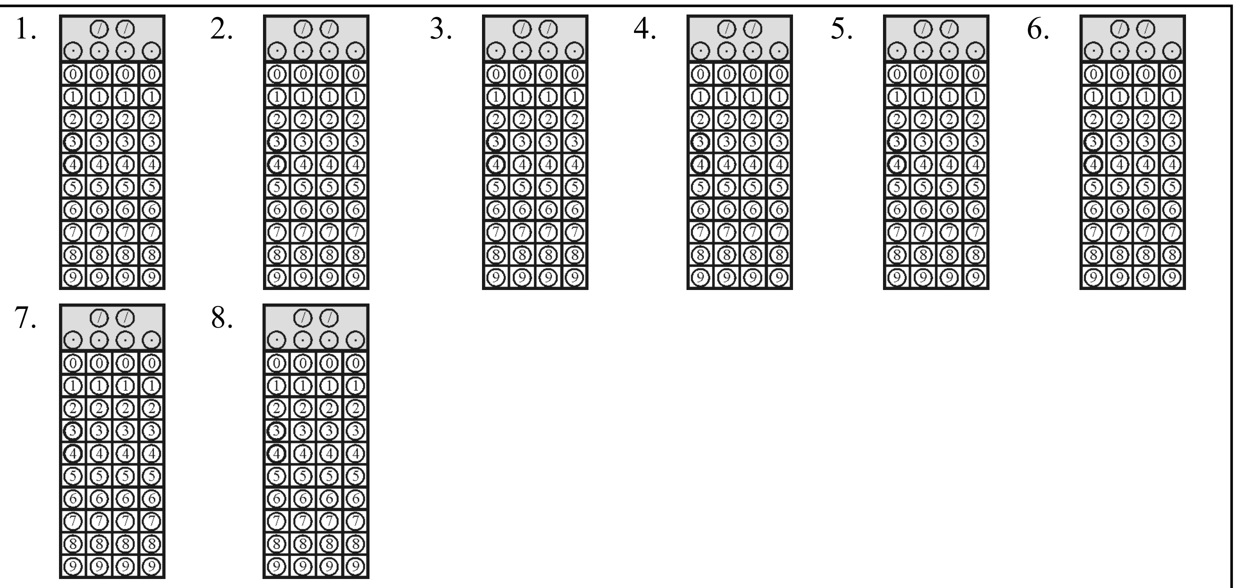
7. A thin plano-convex lens of focal length f is split into two halves: one of the halves is shifted along the optical axis . The separation between object and image planes is 1.8 m. The magnification of the image formed by one of the half-lenses is 2. Find the focal-length of the lens (in m).



8. Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle of 30° at a point just inside one end of A. The plane of incidence coincides with plane of the figure. Find the maximum number of times the ray undergoes reflections (including the first one) before it emerges out.



MARK YOUR RESPONSE



Answerkey

A SINGLE CORRECT CHOICE TYPE

1	(d)	**7**	(b)	**13**	(a)	**19**	(a)	**25**	(d)	**31**	(c)	**37**	(a)	**43**	(c)	**49**	(a)	**55**	(a)	**61**	(a)
2	(c)	**8**	(a)	**14**	(b)	**20**	(a)	**26**	(b)	**32**	(a)	**38**	(d)	**44**	(b)	**50**	(b)	**56**	(b)	**62**	(c)
3	(b)	**9**	(a)	**15**	(c)	**21**	(b)	**27**	(d)	**33**	(d)	**39**	(c)	**45**	(c)	**51**	(a)	**57**	(d)	**63**	(a)
4	(a)	**10**	(c)	**16**	(d)	**22**	(c)	**28**	(c)	**34**	(c)	**40**	(a)	**46**	(c)	**52**	(a)	**58**	(d)	**64**	(d)
5	(d)	**11**	(b)	**17**	(c)	**23**	(a)	**29**	(b)	**35**	(d)	**41**	(a)	**47**	(a)	**53**	(a)	**59**	(c)		
6	(c)	**12**	(d)	**18**	(a)	**24**	(d)	**30**	(c)	**36**	(a)	**42**	(a)	**48**	(c)	**54**	(b)	**60**	(b)		

B COMPREHENSION TYPE

1	(c)	**3**	(d)	**5**	(a)	**7**	(d)	**9**	(b)	**11**	(d)	**13**	(a)	**15**	(a)
2	(a)	**4**	(b)	**6**	(b)	**8**	(a)	**10**	(a)	**12**	(d)	**14**	(b)		

C REASONING TYPE

1	(a)	**2**	(d)	**3**	(d)	**4**	(d)	**5**	(c)	**6**	(d)

D MULTIPLE CORRECT CHOICE TYPE

1	(a, b, c, d)	**3**	(c, d)	**5**	(a, c)	**7**	(a, b, c)	**9**	(a, c)
2	(a, b, c, d)	**4**	(a, b, c, d)	**6**	(a, b, c, d)	**8**	(b, d)	**10**	(a, b, c)

E MATRIX-MATCH TYPE

1. **A-s; B-q; C-r; D-p**

2. **A-q; B-p; C-s; D-r**

3. **A-q; B-r; C-q; D-p**

4. **A-s; B-p; C-q; D-r**

5. **A-p, q, s; B-p, s; C-p; D-r**

6. **A-q, r; B-s; C-s; D-q, r**

7. **A-r, B-s; C-p; D-q**

8. **A-p, q; B-p, r, s; C-p, r; D-p, r**

9. **A-q, r, t; B-q, r; C-q, s; D-q, s, t**

10. **A-s; B-q; C-p; D-r**

11. **A-p, q, s, t; B-r, t; C-p, q, s, t; D-p, q, t**

12. **A-p, q, r, s, t; B-q, s; C-q, s; D-p, q, r, s, t**

13. **A-q, r; B-p, s; C-q, r; D-p, q, r**

F NUMERIC/INTEGER ANSWER TYPE

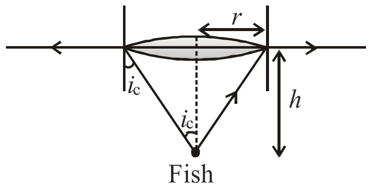
1	1.73	**2**	7.67	**3**	70.8	**4**	15	**5**	75	**6**	1.41	**7**	0.4	**8**	30

Solutions

A SINGLE CORRECT CHOICE TYPE

1. **(d)** $\sin i_c \quad \frac{1}{\mu} \quad \frac{r}{\sqrt{r^2 \quad h^2}}$

Using $h = 12$ cm, $\mu = 4/3$



We get $\frac{36}{\sqrt{7}}$ cm.

2. **(c)** $\frac{x}{1} = \frac{x_{rel}}{\mu} \Rightarrow x_{rel} = \mu x$

$$\Rightarrow \frac{d^2 x_{rel}}{dt^2} = \mu^2 \frac{d^2 x}{dt^2} \Rightarrow a_{rel} = \mu g$$

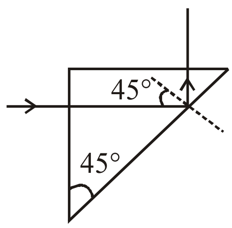
3. **(b)** Cutting a lens in transverse direction doubles their focal length i.e. $2f$.
Using the formula of equivalent focal length,

$$\frac{1}{f} \quad \frac{1}{f_1} \quad \frac{1}{f_2} \quad \frac{1}{f_3} \quad \frac{1}{f_4}$$

We get equivalent focal length as $f/2$.

4. **(a)** In a prism : $r + r' = A \Rightarrow r = A - r'$
$\therefore \; r = 60° - (10 + t^2) = 50 - t^2$

5. **(d)**



For T.I.R. $45° > C$

$\therefore \sin 45 \quad \sin C$

$\therefore \; \frac{1}{\sqrt{2}} \quad \frac{4/3}{n}$

$\therefore \; n \quad \frac{4\sqrt{2}}{3}$

6. **(c)** The lateral displacement is given by

$$d = \frac{t}{\cos r}\sin(i - r)$$

For small angle i, angle r is also small, and so
$d = t\,(i - r) = t\,i\,(1 - r/i)$

7. **(b)** For concave mirror

$$\frac{2}{R} \quad \frac{1}{v} \quad \frac{1}{u}$$

or $\frac{2}{-R} \quad \frac{1}{v} \quad \frac{1}{-u}$

$\therefore \; \frac{1}{v} = \frac{1}{U} - \frac{2}{R} \quad \frac{R - 2U}{UR}$

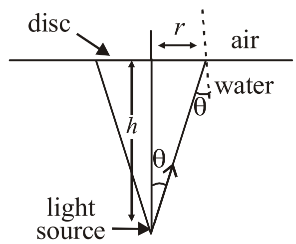
or $v = \left[\frac{RU}{R - 2U}\right]$

In spherical mirror, image velocity

$$v_i = -\left[\frac{v^2}{u^2}\right] v_0 = -\left[\frac{RU}{R - 2U}\right]^2 \frac{v_0}{U^2}$$

$$= -\left[\frac{R}{R - 2U}\right]^2 v_0$$

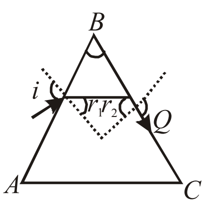
8. **(a)** The figure shows incidence from water at critical angle θ_c for the limiting case.



Now, $\sin\theta_c = 1/\mu$ so that $\tan\theta_c = 1/(\mu^2 - 1)^{1/2}$ which is also equal to r/h where r is the radius of the disc.
Therefore, diameter of the disc is
$2r = 2h \tan\theta_c$.

9. **(a)** A ray of light incident on face AB will just suffer internal reflection at the other face BC. If it gets incident on face BC at critical C angle for the material of the prism. If critical angle for material is C, then

$$\sin C \quad \frac{1}{\mu} \qquad \ldots(i)$$



Now, for prism we have

$r_1 + r_2 = B$ or $r_1 + C = B$

$r_1 = B - C$

At face AB, $\mu = \dfrac{\sin i}{\sin r_1}$

$$\mu \quad \frac{\sin i}{\sin(B-C)} \quad \frac{\sin i}{\sin B \cos C - \cos B \sin C}$$

$$\mu \quad \frac{\sin i}{\sin B\sqrt{1-\sin^2 C} - \cos B \sin C}$$

Using relation (i), we get

$$\mu \quad \frac{\sin i}{\sin B\sqrt{1-\frac{1}{\mu^2}} - \cos B.\left(\frac{1}{\mu}\right)}$$

$$\sin i = \mu\left[\left(\sqrt{1-\frac{1}{\mu^2}}\right)\sin B - \cos B\left(\frac{1}{\mu}\right)\right]$$

$$\sin i \quad \cos B \quad \mu\left(\sqrt{1-\frac{1}{\mu^2}}\right)\sin B$$

$$\frac{\sin i \quad \cos B}{\sin B} = \sqrt{\mu^2 - 1}$$

$$\text{or} \quad \mu^2 \quad 1 \quad \left(\frac{\sin i \quad \cos B}{\sin B}\right)^2$$

$$\mu \quad \left[1 \quad \left\{\frac{\sin i \quad \cos B}{\sin B}\right\}^2\right]^{1/2}$$

10. **(c)** Image radius $(r_1) \quad \dfrac{Rf}{d}$

Power collected by rays = $(S)\,\pi r^2$

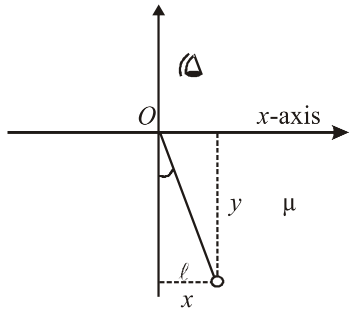
Intensity at focus = $\dfrac{(S)\pi r^2}{\pi\left(\frac{Rf}{d}\right)^2} \quad \dfrac{Sr^2 d^2}{R^2 f^2}$

11. **(b)** Shift $= (\ell - m)\left(1 - \dfrac{1}{n_1}\right) + m\left(1 - \dfrac{1}{n_2}\right) \quad 0$

12. **(d)** For a small oscillations the eye is almost vertically above the bob.

They y co-ordinate of bob as seen by eye

$$y = -\frac{\ell\cos\theta}{\mu}$$



The x-co-ordinate of bob as seen by eye

$= x = \ell \sin\theta$

The equation of trajectory is $\dfrac{x^2}{\ell^2} \quad \dfrac{y^2}{(\ell/\mu)^2} \quad 1$

13. **(a)** Considering refraction at the curved surface,

$u = -20$, $\mu_2 = 1$

$\mu_1 = 3/2$, $R = +20$

Applying $\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} \quad \dfrac{\mu_2 - \mu_1}{R}$

$\Rightarrow \dfrac{1}{v} - \dfrac{3/2}{-20} = \dfrac{1-3/2}{20} \Rightarrow v = -10$

i.e., 10 cm below the curved surface or 10 cm above the actual position of flower.

14. **(b)** Firstly the image has to be inverted. Secondly as the object point moves from $2f$ to f images moves from $2f$ to infinity on the other side very fast.

(Take three points on the object, find their images, see if they are in a straight line)

15. **(c)**

16. **(d)** For $y = 0$, $\mu = 2$

$\Rightarrow \dfrac{1}{v} - \dfrac{1}{-R} \quad \dfrac{2(2-1)}{R} \Rightarrow v = R$

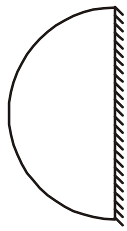
For $y = d$, $\mu = 4$

$\Rightarrow \dfrac{1}{v'} - \dfrac{1}{-R} \quad \dfrac{2(4-1)}{R} \Rightarrow v' \quad \dfrac{R}{5}$

$\therefore$ Spreading $\quad v - v' \quad \dfrac{4R}{5}$

17. **(c)** $\dfrac{1}{f} \quad \mu - 1\left(\dfrac{1}{R} - \dfrac{1}{\infty}\right) \quad (\mu - 1)\left(\dfrac{1}{R}\right)$

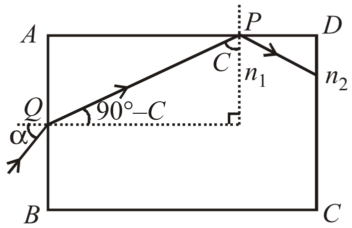
When one surface is silvered



$\dfrac{1}{f_{eq}} \quad \dfrac{-2(\mu-1)}{R}$, $f_{eq} \quad -f/2$

$\Rightarrow$ concave mirror of focal length = 10 cm

18. **(a)** See figure. The ray will come out from CD if it suffers total internal reflection at surface AD, i.e., it strikes the surface AD at critical angle C (the limiting case).



Applying Snell's law at P

$$n_1 \sin C = n_2 \text{ or } \sin C \quad \frac{n_2}{n_1}$$

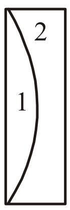
Applying Snell's law at Q

$$n_2 \sin \alpha = n_1 \cos C$$

$$\Rightarrow \sin \alpha \quad \frac{n_1}{n_2} \cos \left\{ \sin^{-1} \left(\frac{n_2}{n_1} \right) \right\}$$

or $\quad \alpha \quad \sin^{-1} \left[\frac{n_1}{n_2} \cos \left\{ \sin^{-1} \left(\frac{n_2}{n_1} \right) \right\} \right]$

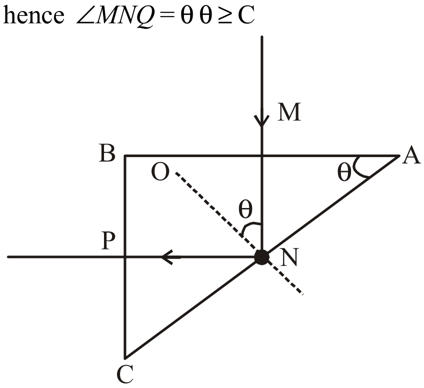
19. **(a)** $\frac{1}{F} \quad \frac{1}{f_1} \quad \frac{1}{f_2}$



$$\frac{1}{F} \quad (\mu_1 - 1)\left(\frac{1}{\infty} \quad \frac{1}{R} \right) \quad (\mu_2 - 1)\left(\frac{1}{-R} - \frac{1}{\infty} \right) \quad \frac{\mu_1 - \mu_2}{R}$$

$$F \quad \frac{R}{\mu_1 - \mu_2}$$

20. **(a)** Since ray MN is incident normally on face AB, hence $\angle MNQ = \theta \; \theta \geq C$



$\sin \theta \geq \sin C$

Now, $\frac{1.5}{4/3} \quad \frac{1}{\sin C}$

or $\sin C \quad \frac{8}{9} \Rightarrow \sin \theta \geq 8/9$

21. **(b)** Refraction at convex lens

$v_1 = 20$ cm

Refraction at concave lens u = – 10 cm

$$\frac{1}{v} - \frac{1}{-10} \quad -\frac{1}{-10} \Rightarrow v = -5 \text{ cm}$$

$$\Rightarrow \text{height} \quad \frac{5\text{mm}}{2} = 2.5 \text{ mm} = 0.25 \text{ cm}$$

Hence co-ordinate of the final image

= (25 cm, 0.25 cm)

22. **(c)** Power of combinations

$$P = 2(\mu - 1)\left(\frac{1}{-60} - \frac{1}{-20} \right) \quad \left(\frac{-1}{-20/2} \right)$$

$$P = \frac{2}{15} \quad \frac{-1}{f}$$

$\therefore$ Resultant focal length

$$f = -\frac{15}{2}$$

$\therefore$ From mirror formula

$$\frac{1}{-30} \quad \frac{1}{v} \quad \frac{1}{f}$$

Solving $v = -10$ cm.

Alternatively

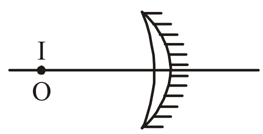
Let x be the distance at which object and image coincide, then

$$\frac{1.5}{-20} - \frac{1}{-x} \quad \frac{1.5 - 1}{-60} \Rightarrow x = 15 \text{ cm}$$

$$\therefore \ f_{eq} \text{ (of the mirror)} = \frac{15}{2} = 7.5 \text{ cm}$$

Now, from mirror formula

$v = -10$ cm.



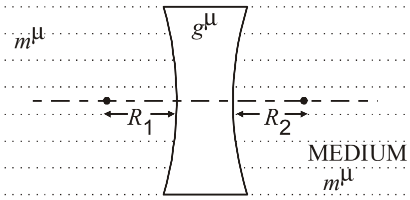
23. **(a)** Use lens maker's formula

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

Now, ${}^{m}_{g}\mu \quad \frac{{}_{g}\mu}{{}_{m}\mu} \quad \frac{1.5}{1.75}$

For concave lens as shown in figure in this case

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



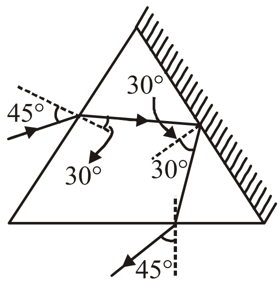
$$\therefore \quad \frac{1}{f} = \left(\frac{1.5}{1.75} - 1\right)\left(-\frac{1}{R} - \frac{1}{R}\right) \quad \frac{0.25 \times 2}{1.75R}$$

$\Rightarrow$ $f = +3.5R$

The positive sign shows that the lens behaves as convergent lens.

24. **(d)** $\delta = (45° - 30°) + (180° - 60°) + (45° - 30°)$

$= 150°$ clockwise.



25. **(d)** $P = 2\left[\frac{100}{10} \quad \frac{100}{-20} \quad 0\right]$

$P = 10$ dioptre.

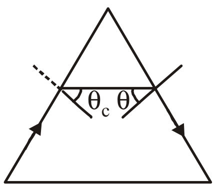
26. **(b)** Velocity of image in mirror

$\vec{v} = -10\hat{i} \quad 10\hat{j}$

$\vec{v}_{rel} = \vec{u} - \vec{v} \quad 20\hat{i}.$

27. **(d)** For maximum deviation

$i_1 = i_2 = 90°$



$$\therefore \quad r_1 = r_2 = \theta_c \quad \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\therefore \quad A = r_1 + r_2 = 2\theta_c$$

$$\delta = \pi - A = \pi - 2\sin^{-1}\left(\frac{1}{\mu}\right).$$

28. **(c)** When an incident ray $\vec{I}$ is reflected by a mirror whose normal is $\vec{N}$, the reflected ray is given by the following

$$\vec{R} = -2\frac{(\vec{I}.\vec{N})\vec{N}}{(\vec{N}.\vec{N})} \quad \vec{I}$$

Using this expression twice, we get the result.

$$\vec{R} \quad \frac{2\hat{j} + 2\hat{k} - \hat{i}}{3}.$$

29. **(b)** The optical path of light passing through the slab is given by

$$\Delta = \int_0^t \mu\, dx = \int_0^t \left(1 \quad \frac{\alpha x}{t}\right) dx = t\left(1 \quad \frac{\alpha}{2}\right)$$

30. **(c)** The magnitude of the velocity of the image will be same as that of the object. The difference will be maximum when the velocity of the image is opposite to that of object. The velocity must be along normal to the mirror.

31. **(c)** At $t = 0.2$ sec,

velocity of lens $v_1 = gt = 2$ m/s (downwards)

$\therefore$ For lens the fish appears to approach with a speed of

$$2 + \left(1 \times \frac{3}{4}\right) \quad \frac{11}{4} \text{m/s}$$

At a distance $\left[42 \quad \frac{24}{(4/3)}\right] \quad 60\text{cm}.$

$\therefore$ Image of fish from lens,

$$V \quad \frac{-60 \times 90}{-60 \quad 90} \quad -180\text{cm}.$$

$\therefore$ Velocity of image w.r.t. lens

$$= \left(\frac{V^2}{U^2}\right)\frac{dU}{dt} = \left(\frac{-180}{-60}\right)^2 \times \frac{11}{4}$$

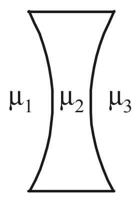
$$\frac{99}{4}\text{m/s} \quad 2475 \text{ cm/s}$$

32. **(a)** Image speed $= -\left(\frac{v^2}{u^2}\right)\frac{du}{dt}$

For convex mirror $\left|\frac{v}{u}\right| \quad 1$

$\therefore$ Image speed is always less than v.

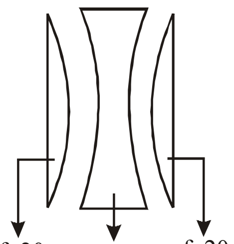
33. **(d)** $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$



If $\mu_2 > \mu_1$, the concave lens maintains its nature otherwise the nature of the lens will be reversed.

So, the lens should be filled with L_2 and immerse in L_1.

34. **(c)** $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; $R = 10$ cm.



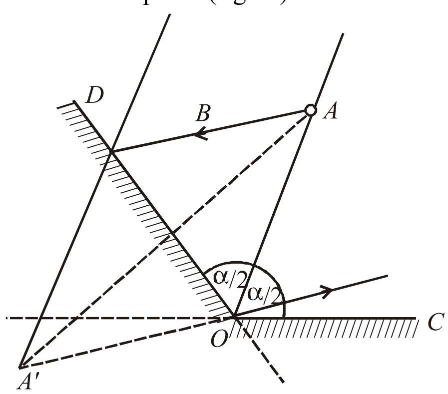
$$\frac{1}{f'} = (3-1)\left(\frac{1}{-10} - \frac{1}{10}\right), f' = -\frac{10}{4}$$

$$\frac{1}{f_{eq}} = \frac{1}{20} - \frac{4}{10} \quad \frac{1}{20} \quad \frac{2}{20} - \frac{4}{10} \Rightarrow f_{eq} = -\frac{10}{3}$$

35. **(d)** Dispersive power (ω)

$$= \frac{n_v - n_r}{n_y - 1} \quad \frac{1.521 - 1.510}{1.515 - 1} \quad 0.02$$

36. **(a)** Let us consider a certain luminous point A of the filament and an arbitrary ray AB emerging from it. We draw a plane through the ray and the filament. It follows from geometrical considerations that with all possible reflections, the given ray will remain in the constructed plane (figure).



After the first reflection at the conical surface, the ray AB will propagate as if it emerged from point A', viz. the virtual image of point A. The necessary condition so that none of the rays emerging from A ever gets on the mirror is that point A' must not be higher than the straight line OC, viz. the second generator of the cone, lying in the plane of the ray (point O is the vertex of the conical surface). This will be observed if

$$\angle A'OD + \angle AOD + \angle AOC = 3\frac{\alpha}{2} \geq 180$$

Consequently, $\alpha_{min} \geq 120$

37. **(a)** $\frac{1}{f} \quad \frac{2}{f_e} \quad \frac{2}{f_m}$

$f_m \quad \frac{R}{2}$

$f_m = 0$

$\frac{1}{f_e} \quad \frac{n-1}{R}$

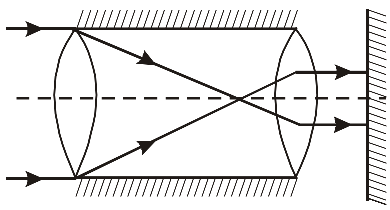
$f_e \quad \frac{n-1}{R}$

$f_2 \quad \frac{R}{2n}$

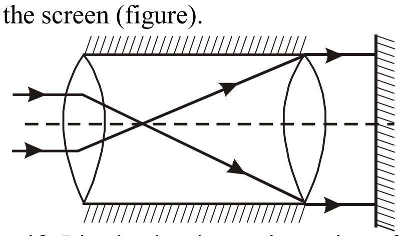
$f_1 \quad \frac{R}{2(n-1)}$

Ratio $\frac{f_1}{f_2} \quad \frac{n}{n-1}$

38. **(d)** By hypothesis, the foci of the two lenses are made to coincide, i.e., the separation between the lenses is $3f$, where f is the focal length of a lens with a lower focal power.



In the former case, all the rays entering the tube will emerge from it and form a circular spot of radius $r/2$, where r is the radius of the tube (figure). In the latter case, only the rays which enter the tube at a distance smaller than $r/2$ from the tube axis will emerge from the tube. Such rays will form a circular spot of radius r on the screen (figure).

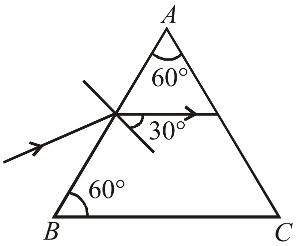


Thus, if J is the luminous intensity of the light entering the tube, the ratio of the illuminances of the spots before and after the reversal of the tube is

$$E_1 \quad \frac{J}{\pi (r/2)^2}, \quad E_2 \quad \frac{J/4}{\pi r^2},$$

$$\frac{E_2}{E_1} \quad \frac{1}{16}$$

39. **(c)** For minimum deviation, the ray must be symmetric to the prism. The angle of refraction is 30°. It is independent of refractive index.



40. **(a)** $\frac{|P_1|}{|P_2|} \quad \frac{2}{3} \Rightarrow \frac{f_2}{f_1} \quad \frac{2}{3}$ ...(i)

Focal length of their combination

$$\frac{1}{f} = \frac{1}{f_1} - \frac{1}{f_2} \Rightarrow \frac{1}{30} = \frac{1}{f_1} - \frac{1 \times 3}{2 f_1} \text{ from (i)}$$

$$\Rightarrow \frac{1}{30} = \frac{1}{f_1}\left[1 - \frac{3}{2}\right] = \frac{1}{f_1} \times \left(-\frac{1}{2}\right)$$

$\therefore \quad f_1 = -15$ cm

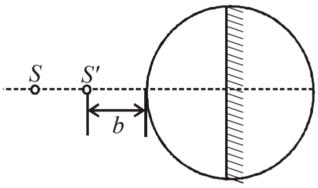
$\therefore \quad f_2 = \frac{2}{3} \times f_1 = \frac{2}{3} \times 15 \quad 10\,\text{cm}$

41. **(a)** For refracted ray, angle of refraction = 90° and hence $\delta_1 = 90 - \alpha$

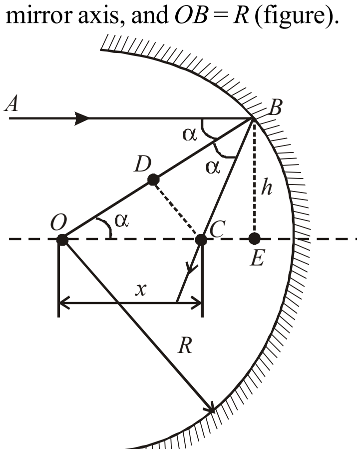
For reflected ray, deviation $\delta_2 = \pi - 2\alpha$

$$\delta_2 - \delta_1 = \frac{\pi}{2} - \alpha$$

42. **(a)** It follows from symmetry considerations that the image of the point source *S* will also be at a distance *b* from the sphere but on the opposite side (figure).



43. **(c)** Let *O* be the centre of the spherical surface of the mirror, *ABC* is the ray incident at a distance *BE* from the mirror axis, and *OB* = *R* (figure).



From the right triangle *OBE*, we find that $\sin \alpha = h/R$. The triangle *OBC* is isosceles since

$\angle ABO = \angle OBC$ according to the law of reflection, and

$\angle BOC = \angle ABO$ as the alternate-interior angles. Hence

$OD = DB = R/2$. From the triangle *ODC*, we obtain

$$x \quad \frac{R}{2\cos\alpha} \quad \frac{R^2}{2\sqrt{R^2 - h^2}}$$

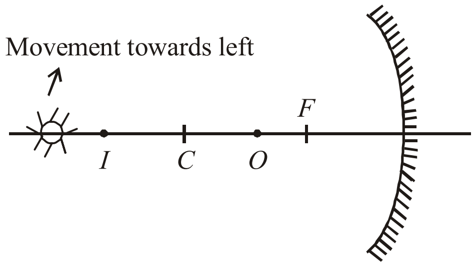
(*C* is the point of intersection of the ray reflected by the mirror and the optical axis).

For a ray propagating at a distance h_1, the distance $x_1 \approx R/2$, with an error of about 0.5% since $h_1^2 \quad R^2$.

For a ray propagation at a distance h_2, the distance $x_2 = 3.125$cm. Finally, we obtain $\Delta x = x_2 - x_1$

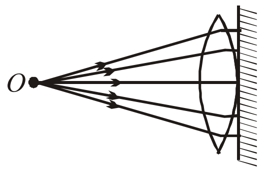
$\Delta x \approx 0.6$cm.

44. **(b)** As shown in the figure, when the object (*O*) is placed between *F* and *C*, the image (*I*) is formed beyond *C*. It is in this condition that when the student shifts his eyes towards left, the image appears to the right of the object pin.



45. **(c)** "*O*" act as focal point.

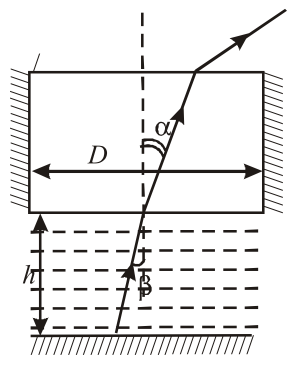
$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$



$$\frac{1}{40} = (\mu - 1)\left(\frac{1}{10} \quad \frac{1}{10}\right)$$

$$\frac{1}{40} = (\mu - 1)\left(\frac{2}{10}\right) \Rightarrow \mu \quad \frac{9}{8}$$

46. **(c)** An observer on the ship can see only the rays for which $\sin\alpha \quad 1/n_{g1}$ (if $\sin\alpha \quad 1/n_{g1}$, such a ray undergoes total internal reflection and cannot be seen by the observer, figure). For the angle β, we have the relation



$n_w \sin\beta = n_{g1} \sin\alpha,\ \sin\beta = \dfrac{n_{g1}}{n_w}\sin\alpha$

where n_{g1} is the refractive index of glass. Since $|\sin\alpha| \quad 1/n_{g1}$, $|\sin\beta| \quad 1/n_w$.

Therefore, the observer can see only the objects emitting light to the porthole at an angle of incidence $\beta \le \sin^{-1}(1/n_w)$. Figure shows that the radius of a circle at the sea bottom which is accessible to observation is $R \approx h\tan\beta$, and the sought area

$(h\tan\beta \quad D/2)$ is $S = \pi R^2 \approx \dfrac{\pi h^2}{n_w^2 - 1} \simeq 82\text{m}^2$

47. **(a)** $\vec{v}_{obj,\,mirror} \quad 4\hat{i} \quad 9\hat{j}$

$\dfrac{dx}{dt} \quad 4,\ \dfrac{dy}{dt} \quad 9\ ; \qquad u = -x$

$-\dfrac{1}{10} \quad \dfrac{1}{V} \quad \dfrac{1}{-x}\ ;\ V \quad \dfrac{-10x}{x-10}$

$v_{1x} \quad \dfrac{dV}{dt} \quad \left(\dfrac{10}{x-10}\right)^2 \left(\dfrac{dx}{dt}\right)\ ; v_{1x} = -16$

$m = -\dfrac{V}{-x} \quad \dfrac{-10}{x-10} \quad \dfrac{y_1^0}{y}$

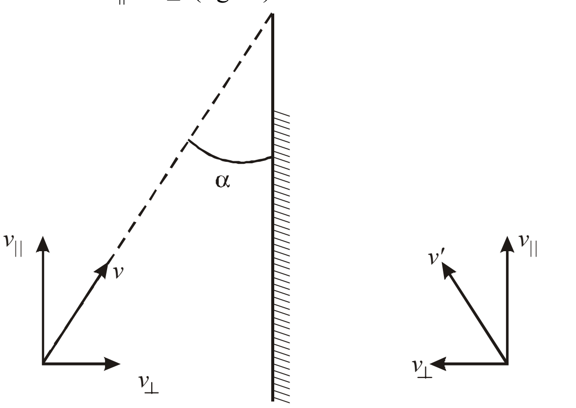
$v_{1y} = -\left(\dfrac{10}{x-10}\right)\dfrac{dy}{dt}\ ;\ v_{1y} = -18$

$\vec{v}_{image,\,mirror} = -16\hat{i} - 18\hat{j}\ ;\ \vec{v}_{image} = -12\hat{i} - 16\hat{j}$

$|v| = 20$ cm/s

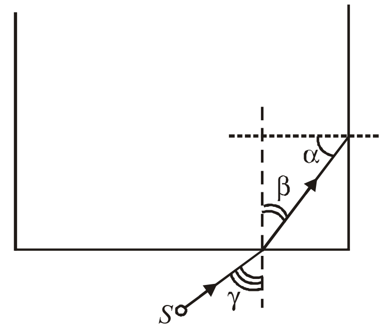
48. **(c)** Use the concepts related to image formation by spherical mirrors.

49. **(a)** We resolve the velocity vector $\vec{v}$ of the person into two components, one parallel to the mirror, $\vec{v}_{||}$ and the other perpendicular to the mirror, $\vec{v}_{\perp}$, i.e. $\vec{v} \quad \vec{v}_{||} \quad \vec{v}_{\perp}$ (figure).



The velocity of the image will obviously be $\vec{v}' = \vec{v}_{||} - \vec{v}_{\perp}$. Therefore, the velocity at which the person approaches his image is defined as his velocity relative to the image. From the formula $v_{rel} \quad 2v_{\perp} \quad 2v\sin\alpha$.

50. **(b)** None of the rays will emerge from the lateral surface of the cylinder if for a ray with an angle of incidence $\gamma \approx \dfrac{\pi}{2}$ (figure), the angle of incidence α on the inner surface will satisfy the relation sin α > 1/*n*. In this case, the ray will undergo total internal reflection on the lateral surface.



It follows from geometrical considerations that

$\sin\alpha = \sqrt{1 - \sin^2\beta},\ \sin\beta \quad \dfrac{1}{n}$

Thus, $n_{\min} \quad \sqrt{2}$

51. **(a)** Let refractive index of glass be μ.

Let after first refraction, image distance be *v* then

$\dfrac{\mu}{v} - \dfrac{1}{\infty} = \dfrac{\mu - 1}{R} \Rightarrow v \quad \dfrac{\mu R}{\mu - 1}$

Now second refraction will take place.

So distance of first image from *O* is

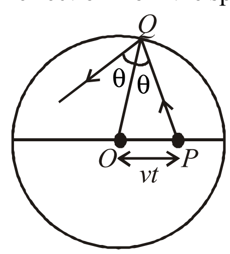
$u_1 = \dfrac{\mu R}{\mu - 1} - R \quad \dfrac{R}{\mu - 1}$

and image is formed at *R*

$\therefore\ \dfrac{1}{R} - \dfrac{\mu(\mu - 1)}{R} \quad \dfrac{2(1-\mu)}{R}$

$\Rightarrow \mu^2 - 3\mu \quad 1 \quad 0$ So, $\mu \quad \dfrac{3 \quad \sqrt{5}}{2}$

52. **(a)** This dark ring will be visible if ray from source gets total internal reflection from the spherical shell.



Let the source at any instant be at point *P* then at point *Q* ray will be totally reflected if θ is equal to or greater than critical angle. If *QP* is equal to *x*, then

$z = \cos\theta \quad \dfrac{R^2 + x^2 - v^2t^2}{2Rx}$

For θ to be minimum

$$\frac{dz}{dx} \quad \frac{2x\,(2Rx) - 2R\,(R^2 + x^2 - v^2t^2)}{4R^2x^2} \quad 0$$

$$\Rightarrow x = \sqrt{R^2 - v^2t^2}$$

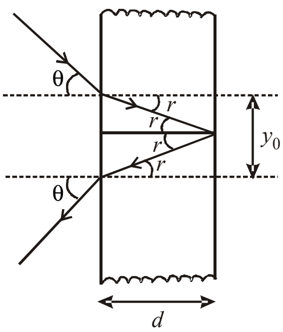
$$\text{So, } \cos\theta \quad \frac{2\,(R^2 - v^2t^2)}{2R\sqrt{R^2 - v^2t^2}} \quad \frac{\sqrt{R^2 - v^2t^2}}{R}$$

For no light come out, $\sin\theta \geq \frac{1}{\sqrt{2}}$ or $\theta \geq 45$

$$\frac{\sqrt{R^2 - v^2t^2}}{R} \quad \frac{1}{\sqrt{2}} \;;\; t \quad \frac{R}{\sqrt{2}V}$$

53. **(a)** $\frac{y_0}{2} \quad d\tan r \;;\; \left(\frac{\sin\theta}{\sin r}\right) \quad n$

$$y_0 \quad 2d\left(\frac{\sin\theta}{\sqrt{n^2 - \sin^2\theta}}\right)$$

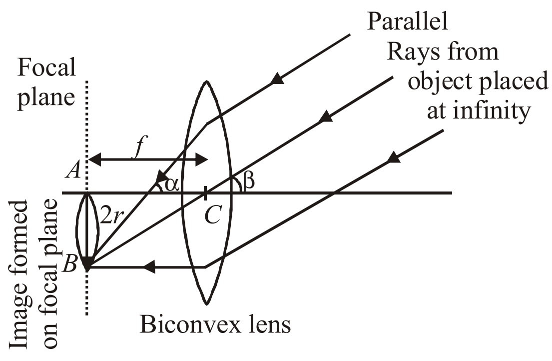


54. **(b)** From the figure in ΔABC, $\tan\beta \quad \frac{AB}{AC}$

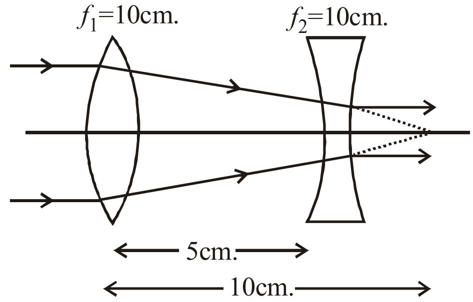
$\Rightarrow \; AB = AC\tan\beta$

$2r = f\tan\beta$

$\Rightarrow$ Area of image $= \pi r^2 \quad f^2$



55. **(a)** The diameter of emergent rays is half of the incident one. Hence the intensity will be 4-times.



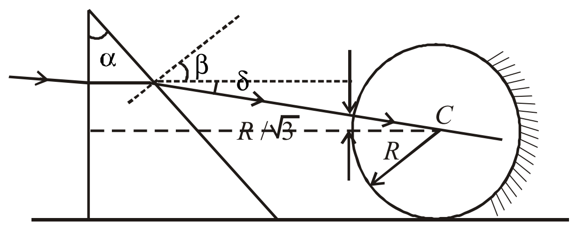
56. **(b)** Here, three optical phenomena take place-first refraction, then reflection, and finally refraction.

For refraction at 1st.

$$\frac{1.5}{v} - \frac{1}{-2R} \quad \frac{1.5-1}{R}$$

$$\Rightarrow \frac{1.5}{v} = 0 \Rightarrow v = \infty$$

57. **(d)** $\mu\sin 30° = \sin\beta$



$$\sqrt{3}.\frac{1}{2} = \sin\beta \Rightarrow \beta \quad 60\;,\; \delta \quad 30$$

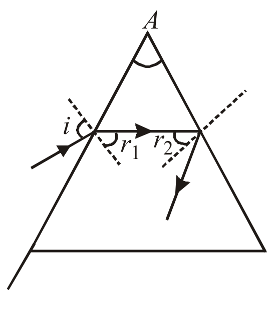
Point P where it strikes is $\frac{R}{\sqrt{3}}$

$$\tan 30° = \frac{R}{x\sqrt{3}} \Rightarrow x \quad R$$

$\Rightarrow$ Ray strikes normal to the spherical surface. It retraces the path.

$\therefore$ Angle of deviation = 180°

58. **(d)**



For ray to not emerge from second surface, $r_2 > C$

$\Rightarrow r_{2\,min} \geq C$

$\Rightarrow A - r_{1\,max} \geq C$

but $r_{1\,max} = C$ when $i = 90°$

$\Rightarrow A \geq 2C \Rightarrow A \geq 72°$

59. **(c)** The top portion of the rod is at a distance > $2f$. So v is less than $2f$ for this portion. So the image would lean towards the lens. The image would not be a straight line as the lateral magnification is not the same as the longitudinal magnification.

60. **(b)** For equiconvex lens

$$\frac{1}{f} = \frac{2(\mu - 1)}{R};\ \mu = 1.5 \Rightarrow R \quad f$$

A thin silvered lens is equivalent to a spherical mirror of equivalent focal length :

$$\frac{1}{F_{eq}} = \frac{1}{F_m} - \frac{2}{F_\ell}$$

where F_m = focal length of the silvered surface .

F_ℓ = focal length of the unsilvered lens.

Here, for the silvered half,

$$\frac{1}{F_{eq}} = \frac{1}{-40} - \frac{2}{40} \Rightarrow F_{eq} = -40/3$$

For the unsilvered part :

$F_{lens} = +40$cm.

So, distance between focii = $40 + \frac{40}{3} \quad \frac{160}{3}$ cm.

61. **(a)** The bubble behaves like a diverging lens, since the index of refraction of the air in the bubble is less than the index of refraction of the water. Thus the image will be smaller and inverted.

62. **(c)** Min. width of plane mirror to see full face

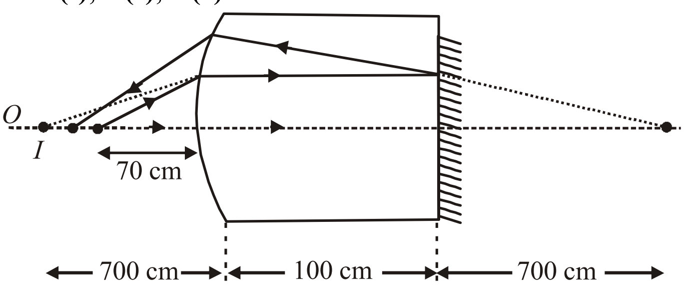
$$= \frac{D-d}{2} \quad \frac{10-4}{2} \quad 3\text{cm.}$$

63. **(a)** Use the first law of reflection. Only sphere 1 is in a position such that light leaving it can reflect from the mirror to the observer.

64. **(d)** Since the water has a greater index of refraction than the lens, the magnifier now acts like a diverging lens, resulting in an image that is smaller than the object.

B COMPREHENSION TYPE

1. **(c); 2. (a); 3. (d)**



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} \quad \frac{\mu_2 - \mu_1}{R}, \text{ when } x = 70 \text{ cm}$$

$$\frac{1.5}{v} - \frac{1.2}{-70} \quad \frac{1.5 - 1.2}{20}$$

$$\Rightarrow v \quad \frac{20 \times 70 \times 1.5}{-1.2 \times 20 + 0.3 \times 70}$$

$\Rightarrow v = -700$ cm

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} \quad \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1.2}{v} - \frac{1.5}{900} \quad \frac{1.2 - 1.5}{-20}$$

$$\Rightarrow v \quad \frac{900 \times 200 \times 1.2}{1.5 \times 200 - 900 \times 3}$$

$\Rightarrow v = -90$ cm

Similarly, for x = 80 cm

$v = 80$ cm

and for $x = 90$ cm

$v = 70$ cm

4. **(b)** For lens L_1, ray must move parallel to the axis after refraction

$$\frac{\mu_1}{\infty} \quad \frac{\mu_\omega}{x} \quad \frac{\mu_1 - \mu_\omega}{R_1} \Rightarrow x \quad 10cm$$

5. **(a)** For lens L_2, image must form at centre of curvature of the curved surface after refraction through plane part

$$\frac{\mu_2}{-R_2} \quad \frac{\mu_\omega}{x'} \quad 0$$

$\Rightarrow x' = 8$ cm

6. **(b)** Length of tube = $x + x'$ = 18 cm

7. **(d)** $\frac{-\mu_1}{-x} \quad \frac{\mu_2}{v} \quad \frac{\mu_2 - \mu_1}{R}$

$$\frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} - \frac{\mu_1}{x}$$

For real image $v > 0$

or $\frac{\mu_2 - \mu_1}{R} \quad \frac{\mu_1}{x}$

if $\mu_2 > \mu_1$ then $x > \frac{\mu_1 R}{\mu_2 - \mu_1}$ to form real image.

8. **(a)** $\frac{\mu_2}{v} = -\left[\frac{(\mu_1 - \mu_2)}{R} \quad \frac{\mu_1}{x}\right]$

if $\mu_2 < \mu_1$ then, v is –ve for any value of x.

9. **(b)** $\frac{-\mu_1}{-x} \quad \frac{\mu_2}{v} \quad \frac{\mu_2-\mu_1}{R}$

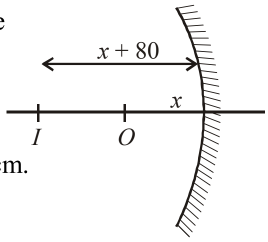
$\frac{\mu_2}{v} = -\left[\frac{\mu_2-\mu_1}{R} \quad \frac{\mu_1}{x}\right]$

Thus

(a) for $\mu_2 > \mu_1$ virtual image is always formed

(b) for $\mu_2 < \mu_1$ virtual image is formed if $x < \frac{\mu_1 R}{\mu_1 - \mu_2}$.

10. **(a)** As the magnification is three



$-\frac{-(x \quad 80)}{-x} = -3 \Rightarrow x \quad 40\text{cm}.$

From mirror formula

$\frac{1}{v} \quad \frac{1}{u} \quad \frac{1}{f} \Rightarrow \frac{1}{-120} \quad \frac{1}{-40} \quad \frac{1}{-f} \Rightarrow f = -30 \text{ cm}.$

11. **(d)** $m = -\frac{v}{u} \Rightarrow -3 = -\frac{80 \quad x}{x} \Rightarrow x \quad 40\text{cm}.$

12. **(d)** The pin are interchanged and so will be object.

Image distances

$m = -\left(\frac{-40}{-120}\right) = -\frac{1}{3}$

$\Rightarrow$ magnification $= \frac{1}{3}$

13. **(a)** $\frac{h_i}{h_0} \quad \frac{-v}{u} \quad \frac{r_i}{r_0} \quad \frac{-v}{u} \quad \frac{-\frac{uf}{u-f}}{u} \quad \frac{-f}{u-f}$

So only dimension of image changes and not the shape. (v is same for every part)

14. **(b)** $\frac{r_i}{r_0} = \frac{-v}{u} \Rightarrow r_i = -r_0 \frac{v}{u} = -\frac{r_0 f}{u-f} \quad 1.2\text{cm}.$

$\therefore$ Area of image $= \pi r_i^2 = \pi(1.2)^2 = 1.44\pi \text{ cm}^2$

15. **(a)** $\frac{dr_i}{dt} \quad 0.2$

C REASONING TYPE

1. **(a)** $\mu = A \quad \frac{B}{\lambda^2}$

and $\theta_c \quad \sin^{-1}\left(\frac{1}{\mu}\right).$

2. **(d)** If the mirror is shifted parallel to itself such that the velocity of the mirror is parallel to its surface, the image shall not shift. Hence statement-1 is false.

3. **(d)** Using a plane mirror we see our virtual image, hence statement-1 is false.

4. **(d)** For lens two focus can be considered. Statement-1 is false, Statement-2 is true.

5. **(c)** $P \propto \left(\frac{\mu_L}{\mu_M} - 1\right)$;

$P \uparrow \mu_M \downarrow \mu_y < \mu_x$

If $\mu_M > \mu_L$ lens nature changes.

$\therefore \mu_z > \mu_x > \mu_y$.

6. **(d)** As x increases angle of incidence increases.

D MULTIPLE CORRECT CHOICE TYPE

1. **(a, b, c, d)** Motion of mirror perpendicular to its area normal will not made any difference to the velocity of its image.

2. **(a, b, c, d)**

$v + u = D$ and $v - u = x$

$\Rightarrow v = \frac{D+x}{2}, u \quad \frac{D-x}{2}$

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

$m_1 = \frac{D+x}{D-x}, \quad m_2 \quad \frac{D-x}{D \quad x}$

3. **(c, d)** From first lens,

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

$\frac{1}{v} - \frac{1}{-30} \quad \frac{1}{15}$

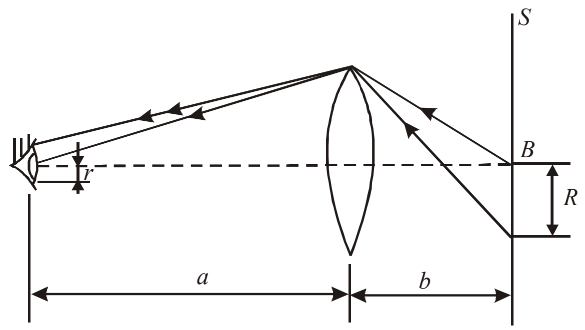
$\Rightarrow \frac{1}{v} \quad \frac{\frac{1}{15} - \frac{1}{30}}{30} \quad \frac{1}{30}$

$\Rightarrow v = +30$ cm

Thus the first lens will form image at optical centre of lens L_2 and lens L_2 will form image at its optical itself because object distance is close to zero.

4. **(a, b, c, d)** μ depends on wavelength hence focal length, power, image distance and chromatic aberration depends on the colour/wavelength of the incident light.

5. **(a, c)** Let us first neglect the size of the pupil, assuming that it is point-like. Obviously, only those of the beams passing through the lens will get into the eye which have passed through point *B* before they fall on the lens (figure). This point is conjugate to the point at which the pupil is located.



The distance b from the lens to point *B* can be calculated by using the formula for a thin lens :

$$\frac{1}{F} \quad \frac{1}{a} \quad \frac{1}{b}, \quad b \quad \frac{aF}{a-F} \quad 12\text{cm.}$$

It is clear now that the screen must coincide with the real image of the pupil in the plane *S*, figure shows that the minimum radius of the screen is

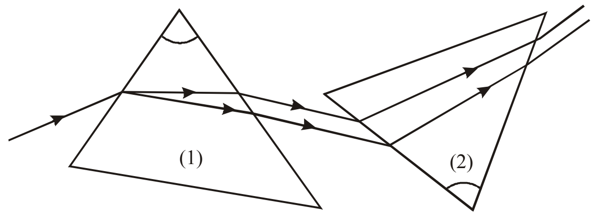
$R \quad \frac{b}{a} r \simeq 0.5$ mm , and the screen must be placed in the plane *S* with its centre at point *B*.

6. **(a, b, c, d)** Short-sighted persons use concave (diverging) glasses which reduce the focal power of their eyes, while long-sighted persons use convex (converging) glasses. It is clear that behind a diverging lens, the eye will look smaller, and behind a converging lens the eye will look larger. If, however you have never seen your companion without glasses, it is very difficult to say whether his eyes are magnified or reduced, especially if the glasses are not very strong. The easiest way is to determine the displacement of the visible contour of the face behind the glasses relative to other parts of the face : if it is displaced inwards, the lenses are diverging, and your companion is short-sighted, if its is displaced outwards, the lenses are converging, and the person is long-sighted.

7. **(a, b, c)** *n* for liquid = *n* for Glass/yellow light but *n* for liquid < *n* for glass (red light) deviated toward base

8. **(b, d)** The intensity of light in the region *AB* (when the lens is absent) now gets distributed over the region *CD*. In the regions *AC* and *BD* light intensity is due to both the direct beam and the diverged light from the lens.

9. **(a, c)**



Deviation, $\delta = i + e - A$

dispersion, $\theta = (\delta_V - \delta_R) = (n_V - n_R) A$

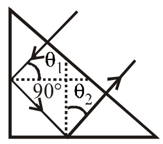
$\delta_1 = -\delta_2$

$\delta_1 + \delta_2 = 0$

$\therefore$ Final ray will be parallel to initial ray.

But $\theta_1 \neq \theta_2 \Rightarrow \theta_1 + \theta_2 \neq 0$

10. **(a, b, c)**



$\sin\theta_1 \geq 1/\mu$

$\sin\theta_2 \geq 1/\mu, \theta_1 + \theta_2 \quad 90 \Rightarrow \cos\theta_1 \geq 1/\mu$

Remember it is not given that $\theta_1 = \theta_2 \quad 45$

If $\theta_1 \quad 30 \,, \frac{\sqrt{3}}{2} \geq \frac{1}{\mu} \Rightarrow \mu \geq \frac{2}{\sqrt{3}} \geq 1.15$

E MATRIX-MATCH TYPE

1. A-s; B-q; C-r; D-p

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

2. A-q; B-p; C-s; D-r

3. A-q; B-r; C-q; D-p

4. A-s; B-p; C-q; D-r

5. A-p, q, s; B-p, s; C-p; D-r

6. A-q, r; B-s; C-s; D-q, r

Concave mirror can form virtual, magnified and real, diminished image like convex (converging) lens. Convex mirror form virtual diminshed image like concave (diverging) lens.

7. A-r, B-s; C-p; D-q

(A) Velocity of the image of fish in air = $4\times\frac{3}{4}=3\,\text{cm/s}\uparrow$,

Velocity of image of fish w.r.t bird = 3 + 6 = 9 cm/s $\uparrow$

(B) Velocity of image of fish after reflection from mirror in air = $4\times\frac{3}{4}=3\,\text{m/s}\downarrow$

w.r.t bird = – 3 + 6 = 3 m/s $\uparrow$

(C) Velocity of the image of bird in water = $6\times\frac{4}{3}=8\,\text{cm/s}\downarrow$

w.r.t fish = 8 + 4 = 12 cm/s $\downarrow$

(D) Velocity of the image of bird in water after reflection from mirror = 8 $\uparrow$

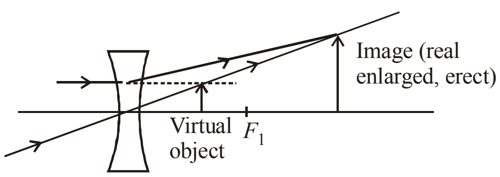
w.r.t fish = 8 – 4 = 4 cm/s $\uparrow$

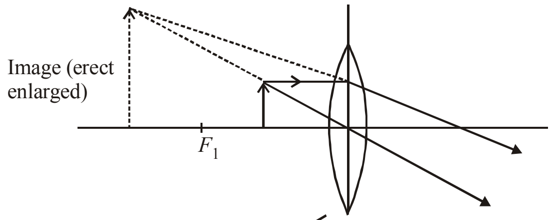
8. A-p, q; B-p, r, s; C-p, r; D-p, r

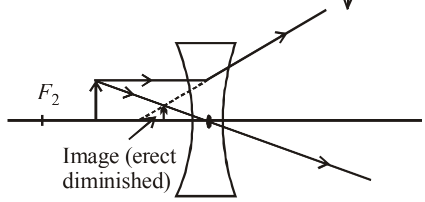
In refraction phase remains same.

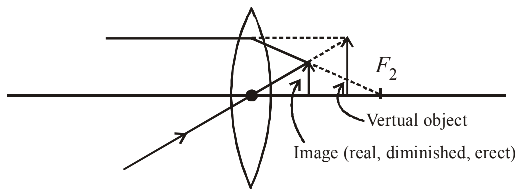
In denser medium speed decreases.

9. A-q, r, t; B-q, r; C-q, s; D-q, s, t

(A)


(B)


(C)


(D)


10. A-s; B-q; C-p; D-r

(A) $\delta\quad 180\ -2i$

(B) $\delta=i-r$; $\frac{\sin i}{\sin r}=\mu$; Increasing i increases δ.

(C) $\delta=i-r$; $\frac{\sin i}{\sin r}\quad\frac{1}{\mu}$; Increasing i increases δ upto $i<i_c$; $i>i_c$ TIR occur and $\delta=180°-2i$

(D) For Prism $\delta\quad(i_1\quad i_2)-A$, on increasing i, δ first decreases attain minimum value and then increases.

11. A-p, q, s, t; B-r, t; C-p, q, s, t; D-p, q, t

(A) When a ray of white light is incident on one face of an equilateral glass prism it will disperse, a divergent beam is obtained after refraction and if angle of incidence is greater then critical angle then TIR occurs.

(B) When a ray of white light is incident at an angle on a thick glass sheet, a lateral shift occurs after refraction.

(C) When a ray of white light passes from an optically denser medium to an optically rarer medium, it will disperse, a divergent beam is obtained after refraction and if angle of incidence is greater than critical angle then TIR occurs.

(D) When a parallel beam of monochromatic light passes symmetrically through a glass lens, a divergent beam is obtained after refraction and if angle of incidence is greater than critical angle then TIR occurs.

12. A-p, q, r, s, t; B-q, s; C-q, s; D-p, q, r, s, t

For real object, concave mirror & convex lens can form real , virtual , magnified , diminished or of same size image. For real object, convex mirror & concave lens can form virtual and diminished image.

13. A-q, r; B-p, s; C-q, r; D-p, q, r

Convex lens (power positive) can form enlarged (or of same size) real, inverted image.

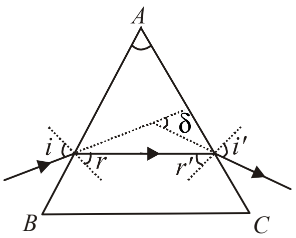
Concave lens (power negative) can form virtual, erect, diminished image.

Convex lens (power positive) can form enlarged, virtual, erect image.

F NUMERIC/INTEGER ANSWER TYPE

1. 1.73

The situation can be shown as in the figure.



Here, $i = 60°$, $A = 30°$, $\delta = 30°$, $i' = ?$

We know that, $A + \delta = i + i'$ ....(i)

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

From (1),

$i' = A + \delta - i = 30° + 30° - 60° = 0$

As the angle of emergence (i') is 0, hence the emergent ray is normal to the face from which it emerges.

When $i' = 0$, $r' = 0$

∴ From (2), $A = r = 30°$.

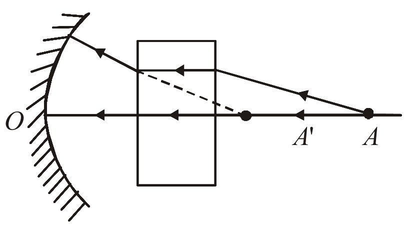
From Snell's law, R.I. of prism,

$$\mu \quad \frac{\sin i}{\sin r} \quad \frac{\sin 60}{\sin 30} \quad \frac{\sqrt{3}/2}{1/2} \quad \sqrt{3} \quad \mathbf{1.73.}$$

2. 7.67

The rays originating from A (the point object) suffer refraction before striking the concave mirror.

For the mirror the rays are coming from A' Such that



$$AA' \quad \text{shift} \quad t\left(1-\frac{1}{\mu}\right)$$

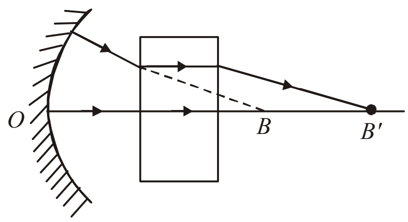
Therefore, the object distance

$$u \quad OA' \quad OA - AA' = 21 - t\left(1-\frac{1}{\mu}\right)$$

$$= 21 - 3\left(1-\frac{1}{1.5}\right) \quad 20\text{cm}$$

$$\therefore \quad V \quad \frac{uf}{u-f} \quad \frac{20\times 5}{20-5} \quad \frac{20}{3}\text{cm}$$

The reflected rays again through the glass slab the image should have formed at B is the absence of glass slab. But. due to its presence the image is formed at B'.



Therefore, image distance $= OB + BB'$

$$\frac{20}{3} + t\left(1-\frac{1}{\mu}\right)$$

$$\frac{20}{3} \quad 1 \quad \frac{23}{3} \quad \mathbf{7.67\,cm}$$

3. **70.8**

$f_0 = +50$ cm; $f_e = +5$ cm ; $D = 25$ cm ; $u_1 = -200$ cm

For objective lens

$$\frac{1}{v_0} \quad \frac{1}{f_0} \quad \frac{1}{u_0} \quad \frac{1}{50} - \frac{1}{200} \quad \frac{4-1}{200} \quad \frac{3}{200}$$

$$\Rightarrow v_0 \quad \frac{200}{3} e$$

For eyepiece lens

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

$$\Rightarrow u_e \quad \frac{25}{6}\text{cm}$$

[v_e is take negative because the image is virtual]

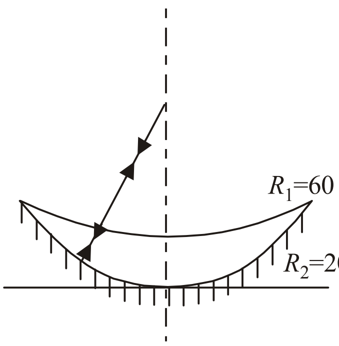
∴ Separation between objective and eyepiece

$= |v_0| + |u_e|$

$$\frac{200}{3} \quad \frac{25}{6} \quad \frac{400 \quad 25}{6} \quad \frac{425}{6} \quad \textbf{70.8cm}$$

4. **15**

This silvered concavo-convex lens behaves like a mirror whose focal length can be calculated by the formula



$$\frac{1}{f} \quad \frac{2}{f_1} \quad \frac{1}{f_2}$$

f_1 = focal length of concave surface.

f_2 = focal length of concave mirror

$$\therefore \quad \frac{1}{f} \quad \frac{2}{-30} \quad \frac{1}{-10} \quad -\frac{4}{30}$$

∴ $f = -7.5$ cm

Using mirror formula

$$\frac{1}{f} \quad \frac{1}{v} \quad \frac{1}{u} \Rightarrow \frac{1}{-7.5} \quad \frac{1}{-x} \quad \frac{1}{-x} \Rightarrow x = \textbf{15 cm}$$

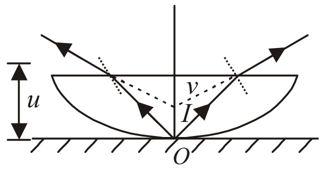
Alternatively :

$$-\frac{-\mu_1}{u} \quad \frac{\mu_2}{v} \quad \frac{\mu_2 - \mu_1}{R}$$

$$\Rightarrow -\frac{1}{-x} \quad \frac{1.5}{-20} \quad \frac{1.5-1}{-60} \Rightarrow x = \textbf{15 cm}$$

5. **75**

Here $R =$ i.e., plane surface is the refracting surface



$$-\frac{\mu_1}{u} + -\frac{\mu_2}{v} \quad \frac{\mu_2 - \mu_1}{R}$$

$$\therefore \quad -\frac{\mu_1}{-u} \quad \frac{\mu_2}{-3} \quad 0$$

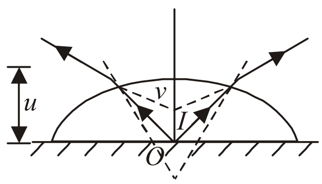
$$\therefore \quad \frac{\mu_2}{\mu_1} \quad \frac{3}{4} \qquad \text{...(i)}$$

Again applying

$$-\frac{\mu_1}{u} \quad \frac{\mu_2}{v} \quad \frac{\mu_2 - \mu_1}{R}$$

$$\Rightarrow -\frac{\mu_1}{u} \quad \frac{\mu_2/\mu_1}{v} \quad \frac{\mu_2/\mu_1 - 1}{R}$$

$$\Rightarrow -\frac{1}{-4} \quad \frac{3/4}{-25/8} \quad \frac{3/4-1}{R}$$



On solving we get $R = -25$cm.

Applying Len's maker formula,

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

$$\frac{1}{f} = \left(\frac{4}{3} - 1\right)\left(\frac{1}{25} - \frac{1}{\ }\right)$$

∴ $f = $ **75cm**

6. **1.41**

The light entering the rod does not emerge from the curved surface of the rod when the angle 90 – r is greater than the critical angle.

i.e., $\mu \le \frac{1}{\sin C}$ where C is the critical angle.

Here $C = 90 - r$

$$\Rightarrow \quad \mu \le \frac{1}{\sin(90 - r)} \quad \Rightarrow \mu \le \frac{1}{\cos r}$$

As a limiting case $\mu = \frac{1}{\cos r}$ ... (i)

Applying Snell's law at A

$$\mu = \frac{\sin\alpha}{\sin r} \Rightarrow \sin r = \frac{\sin\alpha}{\mu} \qquad \text{... (ii)}$$

The smallest angle of incident on the curved surface is when $\alpha = \frac{\pi}{2}$. This can be taken as a limiting case for angle of incidence on plane surface.

From (ii),

$$\sin r = \frac{\sin\pi/2}{\mu} \Rightarrow \mu = \frac{1}{\sin r} \qquad \text{... (iii)}$$

From (i) and (ii) $\sin r = \cos r$

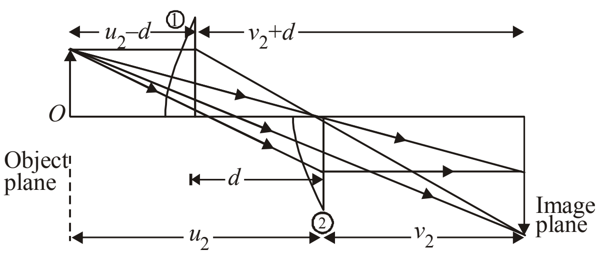
$\Rightarrow \quad r = 45°$

$$\Rightarrow \quad \mu = \frac{1}{\cos 45} \quad \frac{1}{1/\sqrt{2}}$$

$\Rightarrow \quad \mu = \sqrt{2} = 1.41$

This is the least value of the refractive index of rod for light entering the rod and not leaving it from the curved surface.

7. **0.4**



Given $\quad u_2 + v_2 = 1.8$ m ... (i)

The magnification of lens (i) is 2

$$\therefore \quad 2 = \frac{v_2 \quad d}{u_2 - d} \qquad \text{... (ii)}$$

$$\Rightarrow \quad 2 = \frac{1.8 - u_2 \quad d}{u_2 - d} \Rightarrow 2u_2 - 2d = 1.8 - u_2 + d$$

$\Rightarrow \quad 3u_2 = 1.8 + 3d$

$\Rightarrow \quad u_2 = 0.6 + d$

$\Rightarrow \quad v_2 = 1.8 - 0.6 - d$

$\quad v_2 = 1.2 - \text{d}$

Applying lens formula for lens (1)

$$\frac{1}{v_2 + d} \quad \frac{1}{u_2 - d} \quad \frac{1}{f} \qquad \text{.... (iii)} \qquad \text{for lens (2)}$$

$$\frac{1}{v_2} \quad \frac{1}{u_2} \quad \frac{1}{f} \qquad \text{... (iv)}$$

From (iii) and (iv)

$$\frac{1}{v_2 + d} \quad \frac{1}{u_2 - d} \quad \frac{1}{v_2} \quad \frac{1}{u_2}$$

$$\Rightarrow \quad \frac{1}{1.2 - d \quad d} \quad \frac{1}{0.6 \quad d - d} \quad \frac{1}{1.2 - d} \quad \frac{1}{0.6 \quad d}$$

$$\Rightarrow \quad \frac{1}{1.2} \quad \frac{1}{0.6} \quad \frac{0.6 \quad d \quad 1.2 - d}{(1.2 - d)(0.6 \quad d)}$$

$$\Rightarrow \quad \frac{3}{1.2} \quad \frac{1.8}{(1.2 - d)(0.6 \quad d)}$$

$\Rightarrow \quad (1.2 - d)(0.6 + d) = 0.6 \times 1.2$

$\Rightarrow \quad (1.2 \times 0.6 + 1.2\,d - 0.6\,d - d^2 = 0.6 \times 12)$

$\Rightarrow \quad d(d - 0.6) = 0 \Rightarrow d = 0.6$ m

Substituting this value in (iv)

$$\frac{1}{1.2 - 0.6} \quad \frac{1}{0.6 \quad 0.6} \quad \frac{1}{f}$$

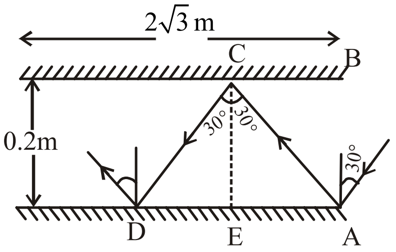
$$\Rightarrow \quad \frac{1}{0.6} \quad \frac{1}{1.2} \quad \frac{1}{f} \quad \frac{1.2 \quad 0.6}{0.6 \times 1.2} \quad \frac{1.8}{0.6 \times 1.2}$$

$$\Rightarrow \quad f = \frac{0.6 \times 1.2}{1.8} \quad 0.4\,\text{m}$$

8. **30**

Δ's ACE and DCE are congruent, therefore, $DE = AE$

$\therefore AD = 2DE$



In CDE, $\tan 30° = \dfrac{DE}{CE}$ or $\dfrac{0.2}{\sqrt{3}}$ $\quad DE$

$\therefore AD \quad \dfrac{2 \times 0.2}{\sqrt{3}}$

$\therefore$ No. of reflection on one face $\quad \dfrac{2\sqrt{3}}{AD} \quad \dfrac{2\sqrt{3} \times \sqrt{3}}{2 \times 0.2} \quad 15$

$\therefore$ Total number of reflections on two faces is

$= 15 + 15 =$ **30**