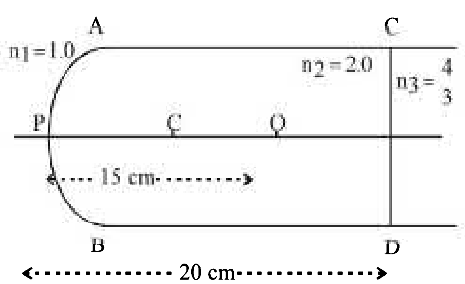
CHAPTER - 16
RAY & WAVE OPTICS

Section-A JEE Advanced/ IIT-JEE

A Fill in the Blanks

1. A light wave of frequency 5×10^{14} Hz enters a medium of refractive index 1.5. In the medium the velocity of the light wave is .... and its wavelength is ....*(1983 - 2 Marks)*
2. A convex lens *A* of focal length 20 cm and a concave lens *B* of focal length 5 cm are kept along the same axis with a distance *d* between them. If a parallel beam of light falling on *A* leaves *B* as a parallel beam, then *d* is equal to ...... cm. *(1985 - 2 Marks)*
3. A monochromatic beam of light of wavelength 6000 Å in vacuum enters a medium of refractive index 1.5. In the medium its wavelength is ....., its frequency is ...... *(1985 - 2 Marks)*
4. In Young's double-slit experiment, the two slits act as coherent sources of equal amplitude '*A*' and of wavelength 'λ'. In another experiment with the same set-up the two slits are sources of equal amplitude '*A*' and wavelength 'λ', but are incoherent. The ratio of the intensity of light at the midpoint of the screen in the first case to that in the second case is .... *(1986 - 2 Marks)*
5. A thin lens of refractive index 1.5 has a focal length of 15 cm in air. When the lens is placed in a medium of refractive index $\frac{4}{3}$, its focal length will become ....cm. *(1987 - 2 Marks)*
6. A point source emits sound equally in all directions in a non-absorbing medium. Two points *P* and *Q* are at a distance of 9 meters and 25 meters respectively from the source. The ratio of amplitudes of the waves at *P* and *Q* is .... *(1989 - 2 Marks)*
7. A slab of a material of refractive index 2 shown in fig. has a curved surface *APB* of radius of curvature 10 cm and a plane surface *CD*. On the left of *APB* is air and on the right of *CD* is water with refractive indices as given in the figure. An object *O* is placed at a distance of 15 cm from the pole *P* as shown. The distance of the final image of *O* from *P*, as viewed from the left is .... *(1991 - 2 Marks)*



8. A thin rod of length $\frac{f}{3}$ is placed along the optic axis of a concave mirror of focal length f such that its image which is real and elongated, just touches the rod. The magnification is .... *(1991 - 1 Mark)*
9. A ray of light undergoes deviation of 30° when incident on an equilateral prism of refractive index $\sqrt{2}$. The angle made by the ray inside the prism with the base of the prism is .... *(1992 - 1 Mark)*
10. The resolving power of electron microscope is higher that that of an optical microscope because the wavelength of electrons is .... than the wavelength of visible light. *(1992 - 1 Mark)*
11. If ε_0 and μ_0 are, respectively, the electric permittivity and magnetic permeability of free space, ε and μ the corresponding quantities in a medium, the index of refraction of the medium in terms of the above parameters is .... *(1992 - 1 Mark)*
12. A light of wavelength 6000Å in air, enters a medium with refractive index 1.5 Inside the medium its frequency is .... Hz and its wavelength is .... Å. *(1997 - 2 Marks)*
13. Two thin lenses, when in contact, produce a combination of power +10 diopters. When they are 0.25 m apart, the power reduces to +6 diopters. The focal length of the lenses are .... *m* and ... *m*. *(1997 - 2 Marks)*
14. A ray of light is incident normally on one of the faces of a prism of apex angle 30° and refractive index $\sqrt{2}$. The angle of deviation of the ray is... degrees. *(1997 - 2 Marks)*

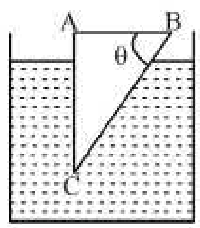
B True/False

1. The setting sun appears higher in the sky than it really is. *(1980)*
2. The intensity of light at a distance '*r*' from the axis of a long cylindrical source is inversely proportional to '*r*'. *(1981- 2 Marks)*
3. A convex lens of focal length 1 meter and a concave lens of focal length 0.25 meter are kept 0.75 meter apart. A parallel beam of light first passes through the convex lens, then through the concave lens and comes to a focus 0.5 m away from the concave lens. *(1983 - 2 Marks)*
4. A beam of white light passing through a hollow prism give no spectrum. *(1983 - 2 Marks)*
5. The two slits in a Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. No interference pattern will be observed on the screen. *(1984- 2 Marks)*

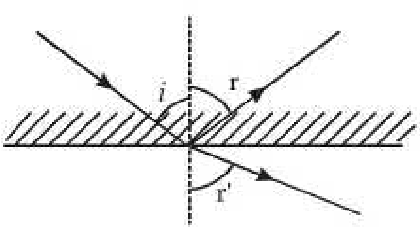
6. In a Young's double slit experiment performed with a source of white light, only black and white fringes are observed. *(1987 - 2 Marks)*
7. A parallel beam of white light fall on a combination of a concave and a convex lens, both of the same meterial. Their focal lengths are 15 cm and 30 cm respectively for the mean wavelength in white light. On the other side of the lens system, one sees coloured patterns with violet colour at the outer edge. *(1988 - 2 Marks)*

C MCQs with One Correct Answer

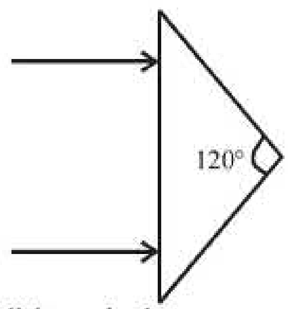
1. When a ray of light enters a glass slab from air, *(1980)*
   (a) its wavelength decreases.
   (b) its wavelength increases.
   (c) Its frequency decreases.
   (d) neither its wavelength nor its frequency changes.
2. A glass prism of refractive index 1.5 is immersed in water (refractive index 4/3). A light beam incident normally on the face AB is totally reflected to reach on the face BC if *(1981- 2 Marks)*
   (a) $\sin\theta \geq \frac{8}{9}$
   (b) $\frac{2}{3} < \sin\theta < \frac{8}{9}$
   (c) $\sin\theta \leq \frac{2}{3}$
   (d) None of these



3. In Young's double-slit experiment, the separation between the slits is halved and the distance between the slits and the screen is doubled. The fringe width is *(1981- 2 Marks)*
   (a) unchanged. (b) halved.
   (c) doubled (d) quadrupled
4. A ray of light from a denser medium strike a rarer medium at an angle of incidence i (see Fig). The reflected and refracted rays make an angle of 90° with each other. The angles of reflection and refraction are r and r' The critical angle is *(1983 - 1 Mark)*

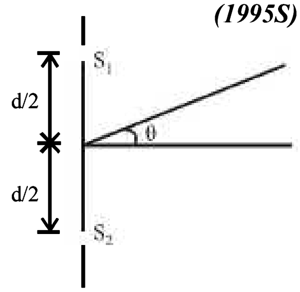


   (a) $\sin^{-1}(\tan r)$ (b) $\sin^{-1}(\tan i)$
   (c) $\sin^{-1}(\tan r')$ (d) $\tan^{-1}(\sin i)$
5. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are *(1988 - 1 Mark)*
   (a) $5I$ and I (b) $5I$ and $3I$
   (c) $9I$ and I (d) $9I$ and $3I$
6. Spherical aberration in a thin lens can be reduced by
   (a) using a monochromatic light *(1994 - 1 Mark)*
   (b) using a doublet combination
   (c) using a circular annular mark over the lens
   (d) increasing the size of the lens.
7. A beam of light of wave length 600 nm from a distance source falls on a single slit 1 mm wide and a resulting diffraction pattern is observed on a screen 2m away. The distance between the first dark fringes on either side of central bright fringe is *(1994 - 1 Mark)*
   (a) 1.2 cm (b) 1.2 mm
   (c) 2.4 cm (d) 2.4 mm
8. An isosceles prism of angle 120° has a refractive index 1.44. Two parallel monochromatic rays enter the prism parallel to each other in air as shown. The rays emerge from the opposite faces *(1995S)*



   (a) are parallel to each other
   (b) are diverging
   (c) make an angle $2[\sin^{-1}(0.72) - 30°]$ with each other
   (d) make an angle $2\sin^{-1}(0.72)$ with each other
9. A diminished image of an object is to be obtained on a screen 1.0 m from it. This can be achieved by appropriately placing *(1995S)*
   (a) a concave mirror of suitable focal length
   (b) a convex mirror of suitable focal length
   (c) a convex lens of focal length less than 0.25 m
   (d) a concave lens of suitable focal length
10. The focal lengths of the objective and the eye piece of a compound microscope are 2.0 cm and 3.0 cm, respectively. The distance between the objective and the eye piece is 15.0 cm. The final image formed by the eye piece is at infinity. The two lenses are thin. The distance in cm of the object and the image produced by the objective, measured from the objective lens, are respectively *(1995S)*
    (a) 2.4 and 12.0 (b) 2.4 and 15.0
    (c) 2.0 and 12.0 (d) 2.0 and 3.0
11. Consider Fraunhoffer diffraction pattern obtained with a single slit illuminated at normal incidence. At the angular position of the first diffraction minimum the phase difference (in radians) between the wavelets from the opposite edges of the slit is *(1995S)*
    (a) $\pi/4$ (b) $\pi/2$ (c) 2π (d) π
12. In an interference arrangement similar to Young's double-slit experiment, the slits S_1 and S_2 are illuminated with coherent microwave sources, each of frequency 10^6 Hz. The sources are synchronized to have zero phase difference. The slits are separated by a distance d = 150.0 m. The intensity $I(\theta)$ is measured as a function of θ, where θ is defined as shown. If I_0 is the maximum intensity, then $I(\theta)$

for $0 \le \theta \le 90°$ is given by (1995S)



(a) $I(\theta) = I_0/2$ *for* $\theta = 30°$

(b) $I(\theta) = I_0/4$ *for* $\theta = 90°$

(c) $I(\theta) = I_0$ *for* $\theta = 0°$

(d) $I(\theta)$ is constant for all values of θ.

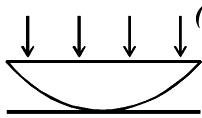
13. A concave lens of glass, refractive index 1.5 has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a *(1999S - 2 Marks)*

(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

14. Yellow light is used in a single slit diffraction experiment with slit width of 0.6 mm. If yellow light is replaced by X– rays, then the observed pattern will reveal,

(a) that the central maximum is narrower *(1999S - 2 Marks)*
(b) more number of fringes
(c) less number of fringes
(d) no diffraction pattern

15. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate as shown in Figure.
The observed interference fringes from this combination shall be *(1999S - 2 Marks)*

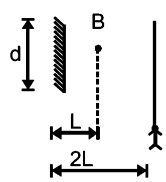


(a) straight
(b) circular
(c) equally spaced
(d) having fringe spacing which increases as we go outwards

16. 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 *(2000S)*

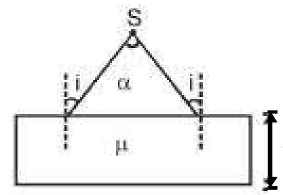
(a) air and placed in air (b) air and immersed in L_1
(c) L_1 and immersed in L_2 (d) L_2 and immersed in L_1

17. A point source of light B is placed at a distance L in front of the centre of a mirror of width 'd' hung vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror at a distance $2L$ from it as shown in fig. The greatest distance over which he can see the image of the light source in the mirror is *(2000S)*



(a) $d/2$ (b) d (c) $2d$ (d) $3d$

18. A diverging beam of light from a point source S having divergence angle α, falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is t and the refractive index n, then the divergence angle of the emergent beam is

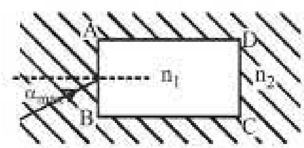


(2000S)

(a) zero (b) α

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

19. 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



(2000S)

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

20. In a double slit experiment instead of taking slits of equal widths, one slit is made twice as wide as the other. Then, in the interference pattern *(2000S)*

(a) the intensities of both the maxima and the minima increase
(b) the intensity of the maxima increases and the minima has zero intensity
(c) the intensity of the maxima decreases and that of the minima increases
(d) the intensity of the maxima decreases and the minima has zero intensity

21. In a compound microscope, the intermediate image is

(a) virtual, erect and magnified *(2000S)*
(b) real, erect and magnified
(c) real, inverted and magnified
(d) virtual, erect and reduced

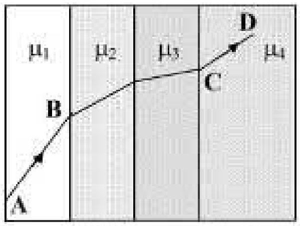
22. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between the resultant intensities at A and B is

(a) $2I$ (b) $4I$ *(2001S)*
(c) $5I$ (d) $7I$

23. In a Young's double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is given by *(2001S)*

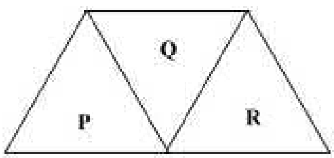
(a) 12 (b) 18 (c) 24 (d) 30

24. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray *CD* is parallel to the incident ray *AB*, we must have **(2001S)**



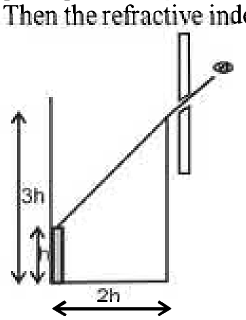
(a) $\mu_1 = \mu_2$ (b) $\mu_2 = \mu_3$
(c) $\mu_3 = \mu_4$ (d) $\mu_4 = \mu_1$

25. A given ray of light suffers minimum deviation in an equilateral prism *P*. Additional prism *Q* and *R* of identical shape and of the same material as *P* are now added as shown in the figure. The ray will now suffer **(2001S)**



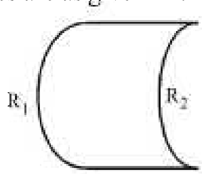
(a) greater deviation (b) no deviation
(c) same deviation as before (d) total internal reflection

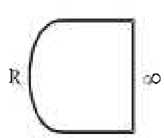
26. An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is 3h and its radius h. When the beaker is filled with a liquid up to a height 2h, he can see the lower end of the rod. Then the refractive index of the liquid is **(2002S)**

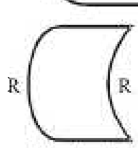


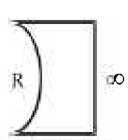
(a) $\frac{5}{2}$ (b) $\sqrt{\frac{5}{2}}$ (c) $\sqrt{\frac{3}{2}}$ (d) $\frac{3}{2}$

27. Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams. **(2002S)**

(a) 

(b) 

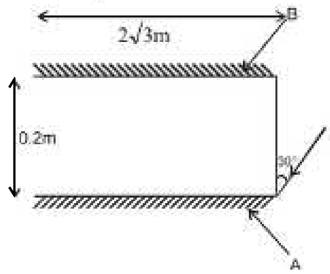
(c) 

(d) 

28. In the ideal double-slit experiment, when a glass-plate (refractive index 1.5) of thickness t is introduced in the path of one of the interfering beams (wave-lenght λ), the intensity at the position where the central maximum occurred previously remains unchanged. The minimum thickness of the glass-plate is **(2002S)**

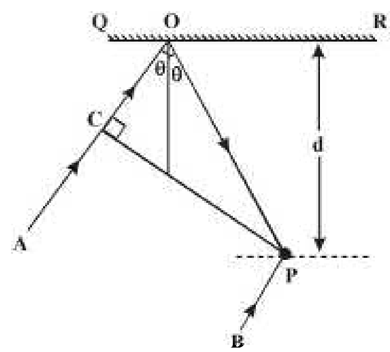
(a) 2λ (b) $2\lambda/3$ (c) $\lambda/3$ (d) λ

29. 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 30° at a point just inside one end of *A*. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is **(2002S)**



(a) 28 (b) 30 (c) 32 (d) 34

30. In the adjacent diagram, *CP* represents a wavefront and *AO* & *BP*, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray *BP* and reflected ray *OP*. **(2003S)**

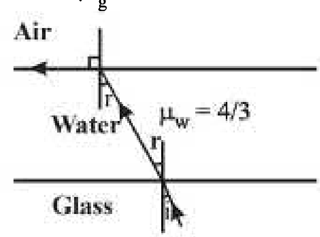


(a) $\cos\theta = 3\lambda/2d$ (b) $\cos\theta = \lambda/4d$
(c) $\sec\theta - \cos\theta = \lambda/d$ (d) $\sec\theta - \cos\theta = 4\lambda/d$

31. The size of the image of an object, which is at infinity, as formed by a convex lens of focal length 30 cm is 2 cm. If a concave lens of focal length 20 cm is placed between the convex lens and the image at a distance of 26 cm from the convex lens, calculate the new size of the image. **(2003S)**

(a) *d*/2 (b) *d* (c) 2*d* (d) 3*d*

32. A ray of light is incident at the glass-water interface at an angle i, it emerges finally parallel to the surface of water, then the value of μ_g would be **(2003S)**

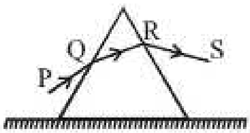


(a) (4/3)sin*i* (b) 1/sin*i*
(c) 4/3 (d) 1

33. A beam of white light is incident on glass air interface from glass to air such that green light just suffers total internal reflection. The colors of the light which will come out to air are *(2004S)*

(a) Violet, Indigo, Blue (b) All colors except green
(c) Yellow, Orange, Red (d) White light

34. An equilateral prism is placed on a horizontal surface. A ray *PQ* is incident onto it. For minimum deviation *(2004S)*



(a) *PQ* is horizontal (b) *QR* is horizontal
(c) *RS* is horizontal
(d) Any one will be horizontal

35. Monochromatic light of wavelength 400 nm and 560 nm are incident simultaneously and normally on double slits apparatus whose slits separation is 0.1 mm and screen distance is 1m. Distance between areas of total darkness will be *(2004S)*

(a) 4mm (b) 5.6mm (c) 14mm (d) 28mm

36. A source emits sound of frequency 600 Hz inside water. The frequency heard in air will be equal to (velocity of sound in water = 1500 m/s, velocity of sound in air = 300 m/s) *(2004S)*

(a) 3000 Hz (b) 120 Hz
(c) 600 Hz (d) 6000 Hz

37. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of virtual image from the surface is *(2004S)*

(a) 6 cm (b) 4 cm (c) 12 cm (d) 9 cm

38. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is *(2005S)*

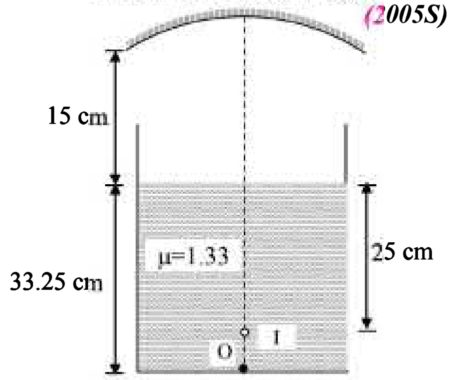
(a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$
(c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

39. 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? *(2005S)*

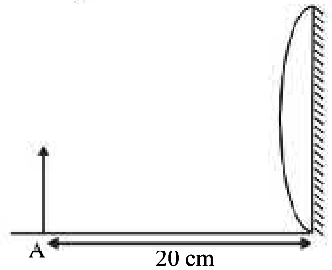
(a) –15, 10 (b) –10, 15
(c) 75, 50 (d) –75, 50

40. A container is filled with water ($\mu = 1.33$) upto a height of 33.25 cm. A concave mirror is placed 15 cm above the water level and the image of an object placed at the bottom is formed 25 cm below the water level. Focal length of the mirror is *(2005S)*

(a) 15 cm
(b) 20 cm
(c) –18.31 cm
(d) 10 cm

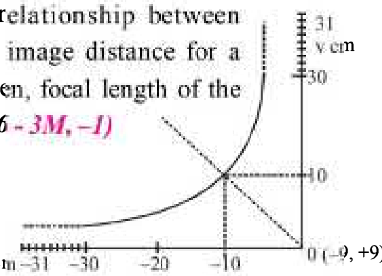


41. Focal length of the plano-convex lens is 15 cm. A small object is placed at A as shown in the figure. The plane surface is silvered. The image will form at *(2006 - 3M, –1)*



(a) 60 cm to the left of lens (b) 12 cm to the left of lens
(c) 60 cm to the right of lens (d) 30 cm to the left of lens

42. The graph shows relationship between object distance and image distance for a equiconvex lens. Then, focal length of the lens is *(2006 - 3M, –1)*



(a) 0.50 ± 0.05 cm
(b) 0.50 ± 0.10 cm
(c) 5.00 ± 0.05 cm
(d) 5.00 ± 0.10 cm

43. 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 *(2007)*

(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

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, *(2007)*

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

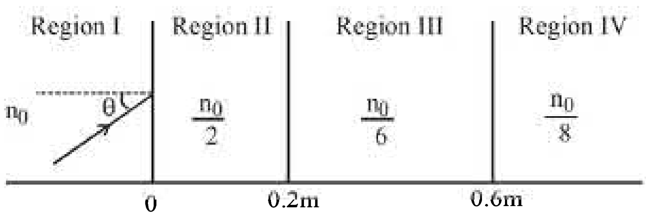
45. A ray of light traveling in water is incident on its surface open to air. The angle of incidence is θ, which is less than the critical angle. Then there will be *(2007)*

(a) only a reflected ray and no refracted ray
(b) only a refracted ray and no reflected ray
(c) a reflected ray and a refracted ray and the angle between them would be less than $180° – 2\theta$
(d) a reflected ray and a refracted ray and the angle between them would be greater than $180° – 2\theta$

46. Two beams of red and violet colours are made to pass separately through a prism (angle of the prism is 60°). In the position of minimum deviation, the angle of refraction will be *(2008)*

(a) 30° for both the colours
(b) greater for the violet colour
(c) greater for the red colour
(d) equal but not 30° for both the colours

47. A light beam is travelling from Region I to IV (figure). The refractive index in regionals I, II, III and IV are $n_0, \frac{n_0}{2}, \frac{n_0}{6}$ and $\frac{n_0}{8}$ respectively. The angle of incidence θ for which the beam just misses entering region IV is – *(2008)*



(a) $\sin^{-1}(3/4)$ (b) $\sin^{-1}(1/8)$
(c) $\sin^{-1}(1/4)$ (d) $\sin^{-1}(1/3)$

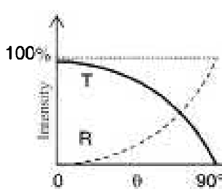
48. A ball is dropped from a height of 20 m above the surface of water in a lake. The refractive index of water is 4.3. A fish inside the lake, in the line of fall of the ball, is looking at the ball. At an instant, when the ball is 12.8 m above the water surface, the fish sees the speed of ball as [Take $g = 10$ m/s^2.]

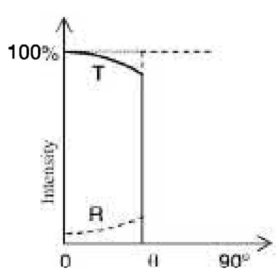
(a) 9 m/s (b) 12 m/s *(2009)*
(c) 16 m/s (d) 21.33 m/s

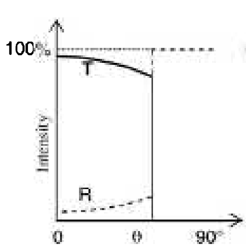
49. A biconvex lens of focal length 15 cm is in front of a plane mirror. The distance between the lens and the mirror is 10 cm. A small object is kept at a distance of 30 cm from the lens. The final image is *(2010)*

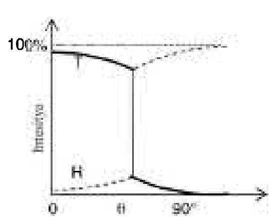
(a) virtual and at a distance of 16 cm from the mirror
(b) real and at a distance of 16 cm from the mirror
(c) virtual and at a distance of 20 cm from the mirror
(d) real and at a distance of 20 cm from the mirror

50. A light ray travelling in glass medium is incident on glass-air interface at an angle of incidence θ. The reflected (R) and transmitted (T) intensities, both as function of θ, are plotted. The correct sketch is *(2011)*

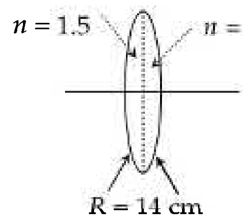
(a)


(b)


(c)


(d)


51. A bi-convex lens is formed with two thin plano-convex lenses as shown in the figure. Refractive index n of the first lens is 1.5 and that of the second lens is 1.2. Both the curved surface are of the same radius of curvature $R = 14$ cm. For this bi-convex lens, for an object distance of 40 cm, the image distance will be *(2012)*



(a) -280.0 cm (b) 40.0 cm
(c) 21.5 cm (d) 13.3 cm

52. Young's double slit experiment is carried out by using green, red and blue light, one color at a time. The fringe widths recorded are b_G, b_R and b_B, respectively. Then,

(a) $b_G > b_B > b_R$ (b) $b_B > b_G > b_R$ *(2012)*
(c) $b_R > b_B > b_G$ (d) $b_R > b_G > b_B$

53. A ray of light travelling in the direction $\frac{1}{2}(\hat{i} + \sqrt{3}\hat{j})$ is incident on a plane mirror. After reflection, it travels along the direction $\frac{1}{2}(\hat{i} - \sqrt{3}\hat{j})$. The angle of incidence is *(JEE Adv. 2013)*

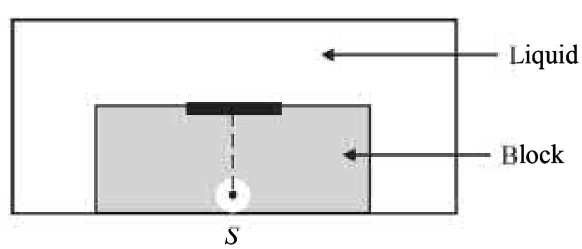
(a) 30° (c) 60°
(b) 45° (d) 75°

54. In the Young's double slit experiment using a monochromatic light of wavelength λ, the path difference (in terms of an integer n) corresponding to any point having half the peak intensity is *(JEE Adv. 2013)*

(a) $(2n+1)\frac{\lambda}{2}$ (b) $(2n+1)\frac{\lambda}{4}$

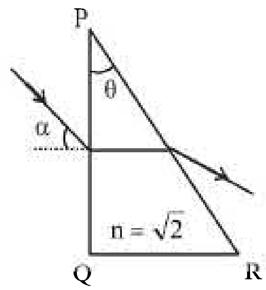
(c) $(2n+1)\frac{\lambda}{8}$ (d) $(2n+1)\frac{\lambda}{16}$

55. A point source S is placed at the bottom of a transparent block of height 10 mm and refractive index 2.72. It is immersed in a lower refractive index liquid as shown in the figure. It is found that the light emerging from the block to the liquid forms a circular bright spot of diameter 11.54 mm on the top of the block. The refractive index of the liquid is *(JEE Adv. 2014)*



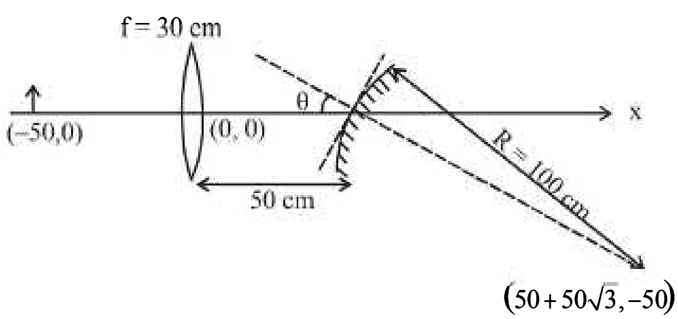
(a) 1.21 (b) 1.30
(c) 1.36 (d) 1.42

56. A parallel beam of light is incident from air at an angle α on the side PQ of a right angled triangular prism of refractive index $n = \sqrt{2}$. Light undergoes total internal reflection in the prism at the face PR when α has a minimum value of 45°. The angle θ of the prism is *(JEE Adv. 2016)*



(a) 15° (b) 22.5°
(c) 30° (d) 45°

57. A small object is placed 50 cm to the left of a thin convex lens of focal length 30 cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 50 cm. The mirror is tilted such that the axis of the mirror is at an angle θ = 30° to the axis of the lens, as shown in the figure.



If the origin of the coordinate system is taken to be at the centre of the lens, the coordinates (in cm) of the point (x, y) at which the image is formed are *(JEE Adv. 2016)*

(a) (0, 0) (b) $(50-25\sqrt{3}, 25)$
(c) $(25, 25\sqrt{3})$ (d) $(125/3, 25\sqrt{3})$

D MCQs with One or More than One Correct

1. In the Young's double slit experiment, the interference pattern is found to have an intensity ratio between the bright and dark fringes as 9. This implies that *(1982 - 3 Marks)*
(a) the intensities at the screen due to the two slits are 5 units and 4 units respectively
(b) the intensities at the screen due to the two slits are 4 units and 1 units respectively
(c) the amplitude ratio is 3
(d) the amplitude ratio is 2

2. A convex lens of focal length 40 cm is in contact with a concave lens of focal length 25 cm . The power of the combination is *(1982 - 3 Marks)*
(a) – 1.5 dioptres (b) – 6.5 dioptres
(c) + 6.5 dioptres (d) + 6.67 dioptres

3. White light is used to illuminate the two slits in a Young's double slit experiment. The separation between the slits is b and the screen is at a distance d (> b) from the slits. At a point on the screen directly in front of one of the slits, certain wavelengths are missing. Some of these missing wavelengths are *(1984- 2 Marks)*

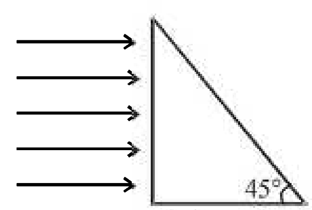
(a) $\lambda = \frac{b^2}{d}$ (b) $\lambda = \frac{2b^2}{d}$
(c) $\lambda = \frac{b^2}{3d}$ (d) $\lambda = \frac{2b^2}{3d}$

4. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen *(1986 - 2 Marks)*
(a) half the image will disappear.
(b) complete image will be formed.
(c) intensity of the image will increase.
(d) intensity of the image will decrease.

5. A short linear object of length b lies along the axis of a concave mirror of focal length f at a distanee u from the pole of the mirror. The size of the image is approximately equal to *(1988 - 2 Mark)*

(a) $b\left(\frac{u-f}{f}\right)^{1/2}$ (b) $b\left(\frac{f}{u-f}\right)^{1/2}$
(c) $b\left(\frac{u-f}{f}\right)$ (d) $b\left(\frac{f}{u-f}\right)^{2}$

6. A beam of light consisting of red, green and blue colours is incident on a right angled prism, fig. The refractive indices of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively. The prism will *(1989 - 2 Mark)*



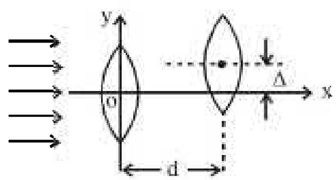
(a) separate part of the red colour from the green and blue colours
(b) separate part of the blue colour from the red and green colours
(c) separate all the three colours from one another
(d) not separate even partially any colour from the other two colours.

7. An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and the eyepiece is 36 cm and the final image is formed at infinity. The focal length f_0 of the objective and the focal length f_0 of the eyepiece are *(1989 - 2 Marks)*
(a) f_0 = 45 cm and f_e = –9 cm (b) f_0 = 50 cm and f_e = 10 cm
(c) f_0 = 7.2 cm and f_e = 5 cm (d) f_0 = 30 cm and f_e = 6 cm.

8. A thin prism P_1 with angle 4° and made from glass of refractive index 1.54 is combined with another thin prism P_2 made from glass of refractive index 1.72 to produce dispersion without deviation. The angle of the prism P_2 is *(1990 - 2 Marks)*
(a) 5.33° (b) 4° (c) 3° (d) 2.6°

9. A planet is observed by an astronomical refracting telescope having an objective of focal length 16 m and an eyepiece of focal length 2 cm. *(1992 - 2 Marks)*
(a) The distance between the objective and the eyepiece is 16.02 m
(b) The angular magnification of the planet is – 800
(c) The image of the planet is inverted
(d) The objective is larger then the eyepiece

10. Two thin convex lenses of focal lengths f_1 and f_2 are separated by a horizontal distance d (where $d < f_1$, $d < f_2$) and their centres are displaced by a vertical separation Δ as shown in the fig. *(1993-2 Marks)*



Taking the origin of coordinates *O*, at the centre of the first lens the x and y coordinates of the focal point of this lens system, for a parallel beam of rays coming from the left, are given by:

(a) $x = \dfrac{f_1 f_2}{f_1 + f_2}, y = \Delta$

(b) $x = \dfrac{f_1(f_2 + d)}{f_1 + f_2 - d}, y = \dfrac{\Delta}{f_1 + f_2}$

(c) $x = \dfrac{f_1 f_2 + d(f_1 - d)}{f_1 + f_2 - d}, y = \dfrac{\Delta(f_1 - d)}{f_1 + f_2 - d}$

(d) $x = \dfrac{f_1 f_2 + d(f_1 - d)}{f_1 + f_2 - d}, y = 0$

11. Which of the following form(s) a virtual and erect image for all positions of the object ? *(1996 - 2 Marks)*
(a) Convex lens (b) Concave lens
(c) Convex mirror (d) Concave mirror.

12. A real image of a distant object is formed by a plano-convex lens on its principal axis. Spherical aberration *(1998 - 2 Marks)*
(a) is absent.
(b) is smaller if the curved surface of the lens faces the object.
(c) is smaller if the plane surface of the lens faces the object.
(d) is the same whichever side of the lens faces the object

13. A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence of 45°. The ray undergoes total internal reflection. If *n* is the refractive index of the medium with respect to air, select the possible value(s) of n from the following : *(1998 - 2 Marks)*
(a) 1.3 (b) 1.4 (c) 1.5 (d) 1.6

14. A parallel monochromatic beam of light is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of the incident beam. At the first minimum of the diffraction pattern, the phase difference between the rays coming from the two edges of the slit is *(1998 - 2 Marks)*
(a) 0 (b) $\pi/2$ (c) π (d) 2π

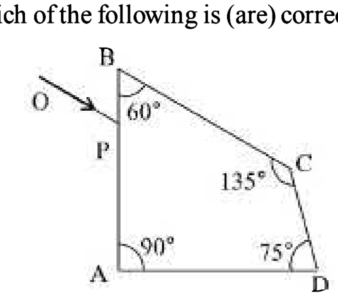
15. A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let *O* be the pole of the mirror and C its centre of curvature. A point object is placed at *C*. It has a real image, also located at *C*. If the mirror is now filled with water, the image will be. *(1998 - 2 Marks)*
(a) real, and will remain at *C*.
(b) real, and located at a point between *C* and ∞ .
(c) virtual, and located at a point between *C* and *O*.
(d) real, and located at a point between *C* and *O*

16. A spherical surface of radius of curvature R separates air (refractive index 1.0) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object P placed in air is found to have a real image *Q* in the glass. The line *PQ* cuts the surface at a point *O*, and *PO* = *OQ*. The distance *PO* is equal to *(1998 - 2 Marks)*
(a) 5*R* (b) 3*R* (c) 2*R* (d) 1.5*R*

17. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice(s). *(2008)*
(a) If $d = \lambda$, the screen will contain only one maximum
(b) If $\lambda < d < 2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen
(c) If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase
(d) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1, the intensities of the observed dark and bright fringes will increase

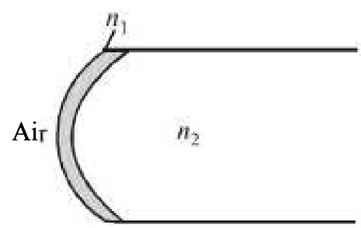
18. A student performed the experiment of determination of focal length of a concave mirror by *u*-*v* method using an optical bench of length 1.5 meter. The focal length of the mirror used is 24 cm. The maximum error in the location of the image can be 0.2 cm. The 5 sets of (*u, v*) values recorded by the student (in cm) are :
(42, 56), (48, 48), (60, 40), (66, 33), (78, 39). The data set(s) that cannot come from experiment and is (are) incorrectly recorded, is (are) *(2009)*
(a) (42,56) (b) (48,48) (c) (66,33) (d) (78,39)

19. A ray OP of monochromatic light is incident on the face AB of prism ABCD near vertex B at an incident angle of 60° (see figure). If the refractive index of the material of the prism is $\sqrt{3}$, which of the following is (are) correct? *(2010)*



(a) The ray gets totally internally reflected at face CD
(b) The ray comes out through face AD
(c) The angle between the incident ray and the emergent ray is 90°
(d) The angle between the incident ray and the emergent ray is 120°

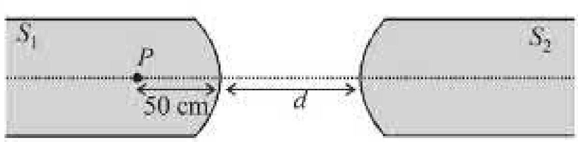
20. A transparent thin film of uniform thickness and refractive index $n_1 = 1.4$ is coated on the convex spherical surface of radius R at one end of a long solid glass cylinder of refractive index $n_2 = 1.5$, as shown in the figure. Rays of light parallel to the axis of the cylinder traversing through the film from air to glass get focused at distance f_1 from the film, while rays of light traversing from glass to air get focused at distance f_2 from the film, Then *(JEE Adv. 2014)*



(a) $|f_1| = 3R$ (b) $|f_1| = 2.8R$
(c) $|f_2| = 2R$ (d) $|f_2| = 1.4R$

21. A light source, which emits two wavelength $\lambda_1 = 400$ nm and $\lambda_2 = 600$ nm, is used in a Young's double slit experiment. If recorded fringe widths for λ_1 and λ_2 are β_1 and β_2 and the number of fringes for them within a distance y on one side of the central maximum are m_1 and m_2 respectively, then *(JEE Adv. 2014)*
(a) $\beta_2 > \beta_1$
(b) $m_1 > m_2$
(c) Form the central maximum, 3rd maximum of λ_2 overlaps with 5th minimum of λ_1
(d) The angular separation of fringes for λ_1 is greater than λ_2.

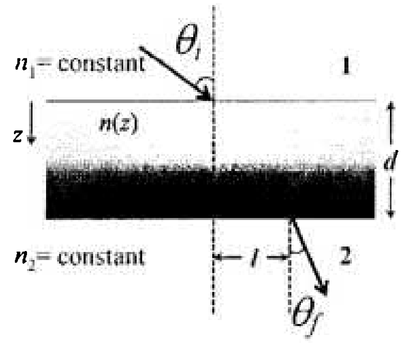
22. Two identical glass rods S_1 and S_2 (refractive index = 1.5) have one convex end of radius of curvature 10 cm. They are placed with the curved surfaces at a distance d as shown in the figure, with their axes (shown by the dashed line) aligned. When a point source of light P is placed inside rod S_1 on its axis at a distance of 50 cm from the curved face, the light rays emanating from it are found to be parallel to the axis inside S_2. The distance d is *(JEE Adv. 2015)*



(a) 60 cm (b) 70 cm (c) 80 cm (d) 90 cm

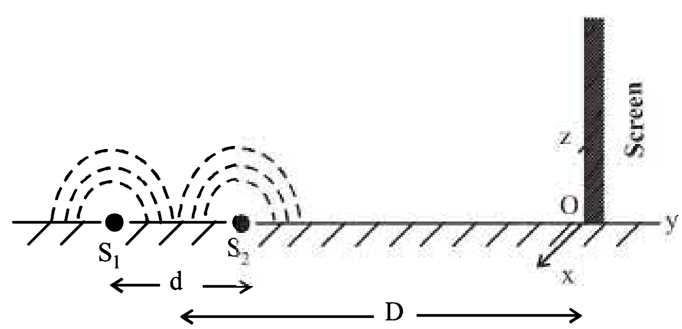
23. A plano–convex lens is made of a material of refractive index n. When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image is observed at a distance of 10 cm away from the lens. Which of the following statement(s) is(are) true? *(JEE Adv. 2016)*
(a) The refractive index of the lens is 2.5
(b) The radius of curvature of the convex surface is 45 cm
(c) The faint image is erect and real
(d) The focal length of the lens is 20 cm

24. A transparent slab of thickness d has a refractive index n(z) that increases with z. Here z is the vertical distance inside the slab, measured from the top. The slab is placed between two media with uniform refractive indices n_1 and n_2 ($> n_1$), as shown in the figure. A ray of light is incident with angle θ_i, from medium 1 and emerges in medium 2 with refraction angle θ_t with a lateral displacement l. *(JEE Adv. 2016)*



Which of the following statement(s) is(are) true?
(a) $n_1 \sin\theta_i = n_2 \sin\theta_f$
(b) $n_1 \sin\theta_i = (n_2 - n_1) \sin\theta_f$
(c) l is independent of n_2
(d) l is dependent on n(z)

25. While conducting the Young's double slit experiment, a student replaced the two slits with a large opaque plate in the x-y plane containing two small holes that act as two coherent point sources (S_1, S_2) emitting light of wavelength 600 nm. The student mistakenly placed the screen parallel to the x-z plane (for z > 0) at a distance D = 3 m from the mid-point of S_1S_2, as shown schematically in the figure. The distance between the sources d = 0.6003 mm. The origin O is at the intersection of the screen and the line joining S_1S_2. Which of the following is(are) true of the intensity pattern on the screen? *(JEE Adv. 2016)*



(a) Straight bright and dark bands parallel to the x-axis
(b) The region very close to the point O will be dark
(c) Hyperbolic bright and dark bands with foci symmetrically placed about O in the x-direction
(d) Semi circular bright and dark bands centered at point.

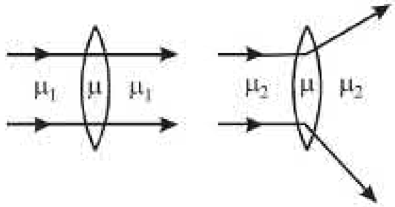
E Subjective Problems

1. A pin is placed 10 cm in front of a convex lens of focal length 20 cm, made a material of refractive index 1.5. The surface of the lens farther away from the pin is silvered and has a radius of curvature are of 22 cm. Determine the position of the final image. Is the image real as virtual? *(1978)*

2. 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. Show that the emergent ray is perpendicular to the face through which it emerges and calculate the refractive index of the material of the prism. *(1978)*

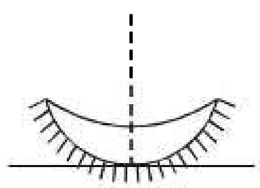
3. A rectangular block of glass is placed on a printed page lying on a horizontal surface. Find the minimum value of the refractive index of glass for which the letters on the page are not visible from any of the vertical faces of the block. *(1979)*

4. What is the relation between the refractive indices μ_1 and μ_2, if the behaviour of light rays is as shown in the figure? *(1979)*



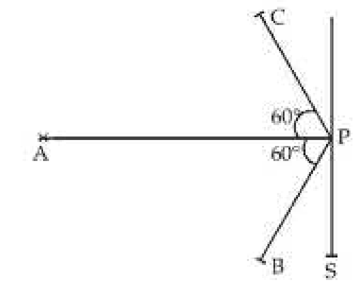
5. An object is placed 21 cm in front of a concave mirror of radius of curvature 10 cm. A glass slab of thickness 3 cm and refractive index 1.5 is then placed close to the mirror in the space between the object and the mirror.
Find the position of the final image formed. (You may take the distance of the near surface of the slab from the mirror to be 1 cm. *(1980)*

6. 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. *(1981- 6 Marks)*



(i) Where should a pin be placed on the optic axis such that its image is formed at the same place?
(ii) If the concave part is filled with water of refractive index 4/3, find the distance through which the pin should be moved so that the image of the pin again coincides with the pin.

7. Screen S is illuminated by two point sources *A* and *B*. Another source *C* sends a parallel beam of light towards point *P* on the screen (see figure). Line *AP* is normal to the screen and the lines *AP*, *BP* and *CP* are in one plane. The distance *AP*, *BP* and *CP* are 3 m, 1.5 m and 1.5 m respectively. The radiant powers of sources *A* and *B* are 90 watts and 180 watts respectively. The beam from C is of intensity 20 watts/m2. Calculate the intensity at *P* on the screen. *(1982 - 5 Marks)*

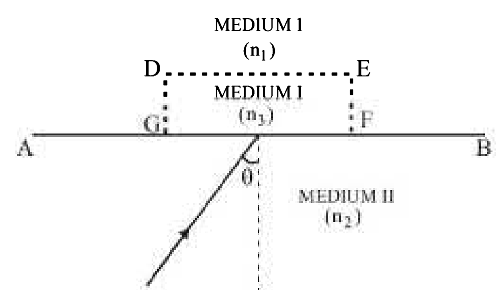


8. A plano convex lens has a thickness of 4 cm . When placed on a horizontal table, with the curved surface in contact with it, the apparent depth of the bottom most point of the lens is found to be 3 cm. If the lens is inverted such that the plane face is in contact with the table, the apparent depth of the centre of the plane face is found to be 25/8 cm. Find the focal length of the lens. *(1984- 6 Marks)*

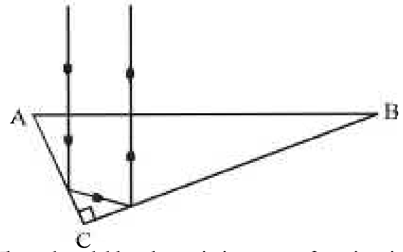
9. A beam of light consisting of two wavelengths, 6500Å and 5200Å, is used obtain interference fringes in a Young's double slit experiment : *(1985 - 6 Marks)*
(i) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 6500Å.
(ii) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?
The distance between the slits is 2 mm and the distance between the plane of the slits and the screen is 120 cm.

10. Monochromatic light is incident on a plane interface *AB* between two media of refractive indices n_1 and n_2 $(n_2 > n_1)$ at an angle of incidence θ as shown in fig. The angle θ is infinitesimally greater than the critical angle for the two media so that total internal reflection takes place. Now if a transparent slab *DEFG* of uniform thickness and of refractive index n_3 is introduced on the interface (as shown in the figure), show that for any value of n_3 all light will ultimately be reflected back again into medium II. Consider separately the cases *(1986 - 6 Marks)*

(i) $n_3 < n_1$ and (ii) $n_3 > n_1$.



11. A right prism is to be made by selecting a proper material and the angles *A* and *B* $(B \le A)$, as shown in Figure. It is desired that a ray of light incident on the face AB emerges parallel to the incident direction after two internal reflections.



(i) What should be the minimum refractive index n for this to be possible ?

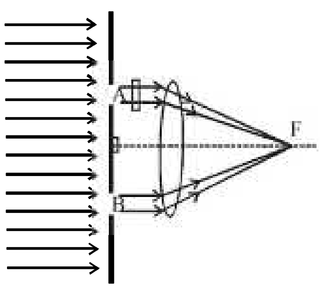
(ii) For $n = \frac{5}{3}$ is it possible to achieve this with the angle B equal to 30 degrees ? *(1987 - 7 Marks)*

12. A parallel beam of light travelling in water (refractive index = 4/3) is refracted by a spherical air bubble of radius 2 mm situated in water. Assuming the light rays to be paraxial *(1988 - 6 Marks)*

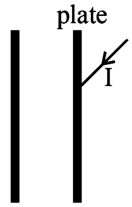
(i) Find the position of the image due to refraction at the first surface and the position of the final image.

(ii) Draw a ray diagram showing the positions of both the images.

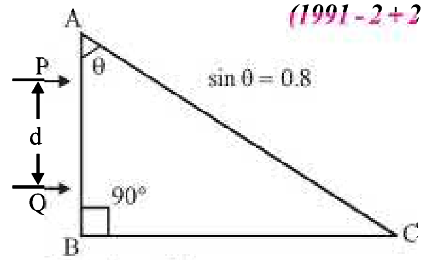
13. In a modified Young's double slit experiment, a monochromatic uniform and parallel beam of light of wavelength 6000 Å and intensity $(10/\pi)$ W m^{-2} is incident normally on two circular apertures A and B of radii 0.001 m and 0.002 m respectively. A perfectly transparent film of thickness 2000 Å and refractive index 1.5 for the wavelength of 6000 Å is placed in front of aperture A, see fig. Calculate the power (in watts) received at the focal spot F of the lens. The lens is symmetrically placed with respect to the apertures. Assume that 10% of the power received by each aperture goes in the original direction and is brought to the focal spot. *(1989 - 8 Mark)*



14. A narrow monochromatic beam of light of intensity I is incident on a glass plate as shown in figure. Another identical glass plate is kept close to the first one and parallel to it. Each glass plate reflects 25 per cent of the light incident on it and transmits the remaining. Find the ratio of the minimum and the maximum intensities in the interference pattern formed by the two beams obtained after one reflection at each plate. *(1990 - 7 Mark)*



15. Two parallel beams of light P and Q (separation d) containing radiations of wavelengths 4000 Å and 5000 Å (which are mutually coherent in each wavelength separately) are incident normally on a prism as shown in fig. The refractive index of the prism as a function of wavelength is given by the relation. $\mu(\lambda) = 1.20 + \frac{b}{\lambda^2}$ where λ is in Å and b is positive constant. The value of b is such that the condition for total reflection of the face AC is just satisfied for one wave length and is not satisfied for the other. *(1991 - 2 + 2 + 4 Marks)*

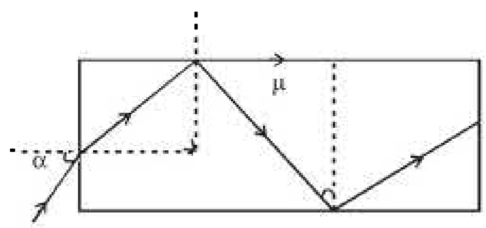


(a) Find the value of b.

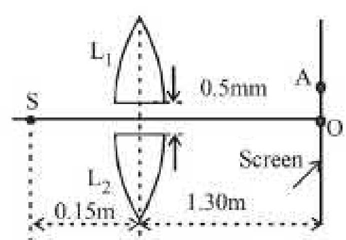
(b) Find the deviation of the beams transmitted through the face AC

(c) A convergent lens is used to bring these transmitted beams into focus. If the intensities of transmission form the face AC, are 4I and I respectively, find the resultant intensity at the focus.

16. 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 *(1992 - 8 Marks)*



17. In Fig., S is a monochromatic point source emitting light of wavelength $\lambda = 500$nm. A thin lens of circular shape and focal length 0.10 m is cut into two identical halves L_1 and L_2 by a plane passing through a diameter. The two halves are placed symmetrically about the central axis SO with a gap of 0.5 mm. The distance along the axis from S to L_1 and L_2 is 0.15 m while that from L_1 and L_2 to O is 1.30 m. The screen at O is normal to SO. *(1993 - 5+1 Marks)*

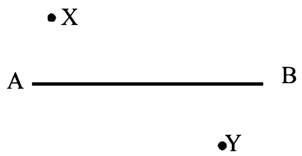


(i) If the third intensity maximum occurs at the point A on the screen, find the distance OA.

(ii) If the gap between L_1 and L_2 is reduced from its original value of 0.5mm, will the distance OA increase, decrease, or remain the same?

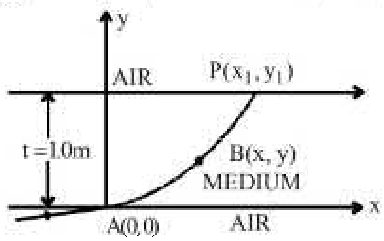
18. An image Y is formed of point object X by a lens whose optic axis is AB as shown in figure. Draw a ray diagram to locate the lens and its focus. If the image Y of the object X is formed by a concave mirror (Having the same axis as AB)

instead of lens, draw another ray diagram to locate the mirror and its focus. Write down the steps of construction of the ray diagrams. *(1994 - 6 Marks)*



19. A ray of light travelling in air is incident at grazing angle (incident angle $\cong 90°$) on a long rectangular slab of a transparent medium of thickness t = 1.0 m (see figure below). The point of incidence is the origin $A(0, 0)$. The medium has a variable index of refraction $n(y)$ given by

$$n(y) = [ky^{3/2} + 1]^{1/2}, \text{ where } k = 1.0 \text{ (metre)}^{-3/2}$$



The refractive index of air is 1.0. *(1995 - 10 Marks)*

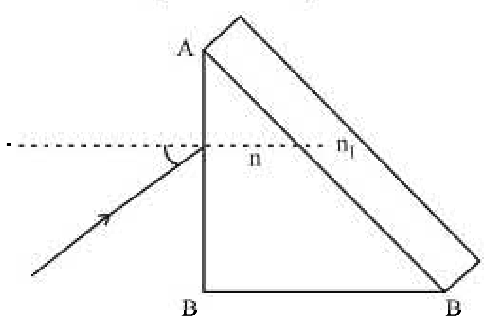
(a) Obtain a relation between the slope of the trajectory of the ray at a pint $B(x, y)$ in the medium and the incident angle at that point.

(b) Obtain an equation for the trajectory $y(x)$ of the ray in the medium.

(c) Determine the coordinates (x_1, y_1) of the point P, where the ray intersects the upper surface of the slab-air boundary.

(d) Indicate the path of the ray subsequently.

20. A right angled prism (45°–90°–45°) of refractive index n has a plate of refractive index $n_1 (n_1 < n)$ cemented to its diagonal face. The assembly is in air. A ray is incident on AB.



(i) Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.

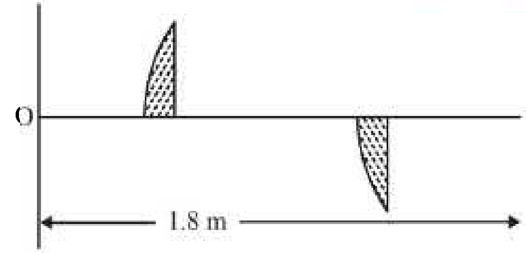
(ii) Assuming $n = 1.352$ calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated. *(1996 - 3 Marks)*

21. A double-slit apparatus is immersed in a liquid of refractive index 1.33. It has slit separation of 1mm, and distance between the plane of slits and screen is 1.33 m. The slits are illuminated by a parallel beam of light whose wavelength in air is 6300 Å. *(1996 - 3 Marks)*

(i) Calculate the fringe-width.

(ii) One of the slits of the apparatus is covered by a thin glass sheet of refractive index 1.53. Find the smallest thickness of the sheet to bring the adjacent minimum on the axis.

22. 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 and separation between the two halves. Draw the ray diagram for image formation. *(1996 - 5 Marks)*

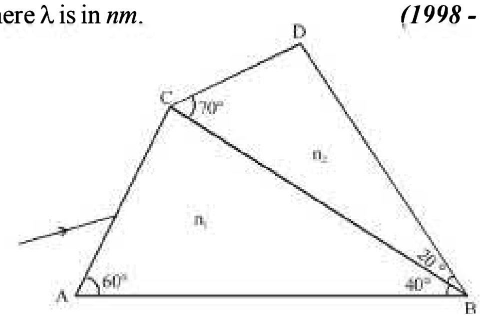


23. In Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4 while the lower slit is covered by another glass plate, having the same thickness as the first one but having refractive index 1.7. Interference pattern is observed using light of wavelength 5400 Å. It is found that the point P on the screen where the central maximum (n = 0) fells before the glass plates were inserted now has 3/4 the original intensity. It is further observed that what used to be the fifth maximum earlier, lies below the point P while the sixth minimum lies above P. Calculate the thickness of the glass plate. (Absorption of light by glass plate may be neglected.) *(1997 - 5 Marks)*

24. A prism of refractive index n_1 and another prism of refractive index n_2 are stuck together without a gap as shown in Figure. The angles of the prisms are as shown. n_1 and n_2 depend on λ, the wavelength of light, according to

$$n_1 = 1.20 + \frac{10.8 \times 10^4}{\lambda^2} \quad \text{and} \quad n_2 = 1.45 + \frac{1.80 \times 10^4}{\lambda^2}$$

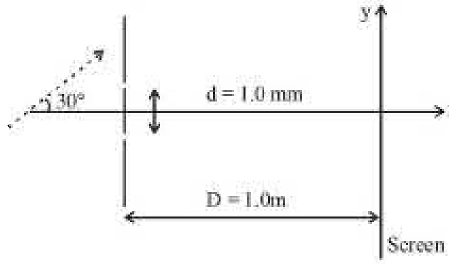
where λ is in *nm*. *(1998 - 8 Marks)*



(a) Calculate the wavelength λ_0 for which rays incident at any angle on the interface BC pass through without bending at that interface.

(b) For light of wavelength λ_0, find the angle of incidence i on the face AC such that the deviation produced by the combination of prisms is minimum.

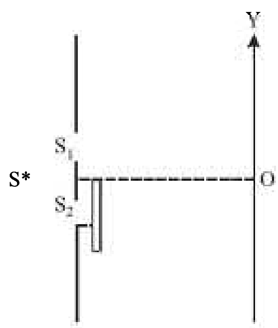
25. A coherent parallel beam of microwaves of wavelength λ = 0.5 mm falls on a Young's double slit apparatus. The separation between the slits is 1.0 mm. The intensity of microwaves is measured on a screen placed parallel to the plane of the slits at a distance of 1.0 m from it as shown in Fig.



(a) If the incident beam falls normally on the double slit apparatus, find the y-coordinates of all the interference minima on the screen.

(b) If the incident beam makes an angle of 30° with the x axis (as in the dotted arrow shown in Figure), find the y-coordinate of the first minima on either side of the central maximum. *(1998 - 8 Marks)*

26. The Young's double slit experiment is done in a medium of refractive index 4/3. A light of 600 nm wavelength is falling on the slits having 0.45 mm separation. The lower slit S_2 is covered by a thin glass sheet of thickness 10.4 μm and refractive index 1.5. The interference pattern is observed on a screen placed 1.5 m from the slits as shown in Figure. *(1999 - 10 Marks)*



(a) Find the location of the central maximum (bright fringe with zero path difference) on the y – axis.

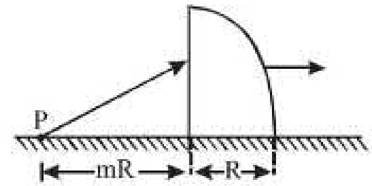
(b) Find the light intensity at point O relative to the maximum fringe intensity.

(c) Now, if 600 nm light is replaced by white light of range 400 to 700 nm, find the wavelengths of the light that form maxima exactly at point O.

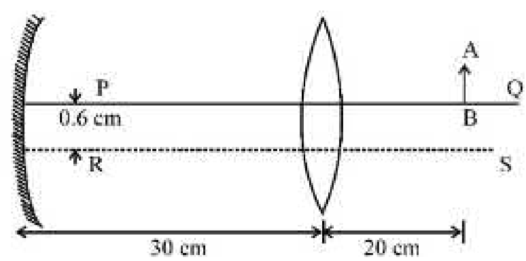
[All wavelengths in this problem are for the given medium of refractive index 4/3. Ignore dispersion]

27. The $x - y$ plane is the boundary between two transparent media. Medium –1 with $z \geq 0$ has a refractive index $\sqrt{2}$ and medium –2 with $z \leq 0$ has a refractive index $\sqrt{3}$. A ray of light in medium –1 given by the vector $A = 6\sqrt{3}i + 8\sqrt{3}\,j$ $-10\,\mathbf{k}$ is incident on the plane of separation. Find the unit vector in the direction of the refracted ray in medium –2. *(1999 - 10 Marks)*

28. A quarter cylinder of radius R and refractive index 1.5 is placed on a table. A point object P is kept at a distance of mR from it. Find the value of m for which a ray from P will emerge parallel to the table as shown in Figure. *(1999 - 5 Marks)*



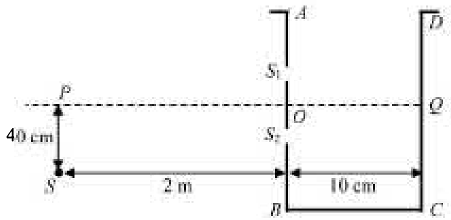
29. (a) A convex lens of focal length 15 cm and a cancave mirror of focal length 30 cm are kept with their optic axes PQ and RS parallel but separated in vertical direction by 0.6 cm as shown. The distance between the lens and mirror is 30 cm. An upright object AB of height 1.2 cm is placed on the optic axis PQ of the lens at a distance of 20 cm from the lens. If $A'B'$ is the image after refraction from the lens and reflection from the mirror, find the distance of $A'B'$ from the pole of the mirror and obtain its magnification. Also locate position of A' and B' with respect to the optic axis RS. *(2000 - 6 Marks)*



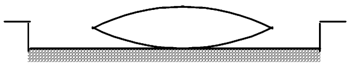
(b) A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength λ travelling in air is incident normally on the layer. It is partly reflected at the upper and the lower surface of the layer and the two reflected rays interfere. Write the condition for their constructive interference. If $\lambda = 648$ nm, obtain the least value of t for which the rays interfere constructively. *(2000 - 4 Marks)*

30. The refractive indices of the crown glass for blue and red lights are 1.51 and 1.49 respectively and those of flint glass are 1.77 and 1.73 respectively. An isosceles prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other flint glass isosceles prism is combined with the crown glass prism such that there is no deviation of the incident light. Determine the angle of the flint glass prism. Calculate the net dispersion of the combined system. *(2001 - 5 Marks)*

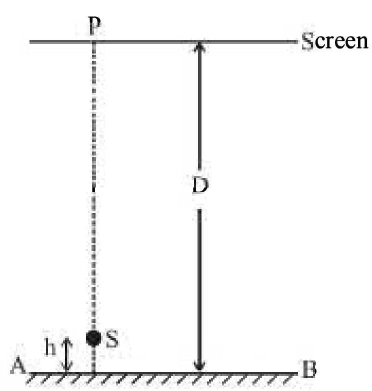
31. A vessel $ABCD$ of 10 cm width has two small slits S_1 and S_2 sealed with identical glass plates of equal thickness. The distance between the slits is 0.8 mm. POQ is the line perpendicular to the plane AB and passing through O, the middle point of S_1 and S_2. A monochromatic light source is kept at S, 40 cm below P and 2 m from the vessel, to illuminate the slits as shown in the figure below. Calculate the position of the central bright fringe on the other wall CD with respect to the line OQ. Now, a liquid is poured into the vessel and filled upto OQ. The central bright fringe is found to be at Q. Calculate the refractive index of the liquid. ***(2001-5 Marks)***



32. A thin biconvex lens of refractive index 3/2 is placed on a horizontal plane mirror as shown in the figure. The space between the lens and the mirror is then filled with water of refractive index 4/3. It is found that when a point object is placed 15 cm above the lens on its principal axis, the object coincides with its own image. On repeating with another liquid, the object and the image again coincide at a distance 25 cm from the lens. Calculate the refractive index of the liquid. ***(2001-5 Marks)***



33. A point source S emitting light of wavelength 600 nm is placed at a very small height h above a flat reflecting surface AB (see figure). The intensity of the reflected light is 36% of the incident intensity. Interference fringes are observed on a screen placed parallel to the reflecting surface at a very large distance D from it. **(2002 - 5 Marks)**

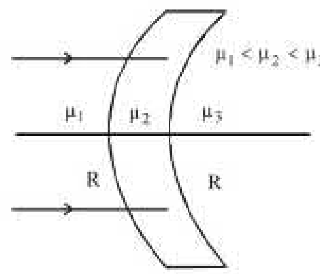


(a) What is the shape of the interference fringes on the screen?

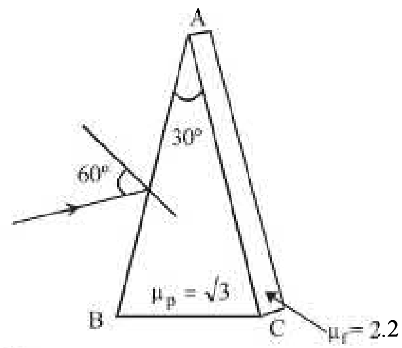
(b) Calculate the ratio of the minimum to the maximum intensities in the interference fringes formed near the point P (shown in the figure).

(c) If the intensity at point P corresponds to a maximum, calculate the minimum distance through which the reflecting surface AB should be shifted so that the intensity at P again becomes maximum.

34. Find the focal length of the lens shown in the figure. The radii of curvature of both the surfaces are equal to R. ***(2003 - 2 Marks)***



35. Shown in the figure is a prism of angle 30° and refractive index $\mu_p = \sqrt{3}$. Face AC of the prism is covered with a thin film of refractive index $\mu_f = 2.2$. A monochromatic light of wavelength $\lambda = 550$ nm fall on the face AB at an angle of incidence of 60°. ***(2003 - 4 Marks)***

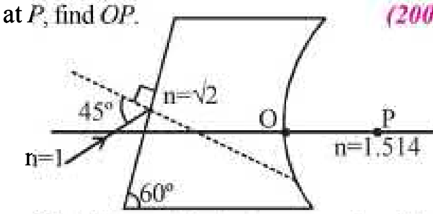


Calculate

(a) angle of emergence.

(b) minimum value of thickness t so that intensity of emergent ray is maximum.

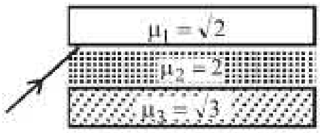
36. A ray is incident on a medium consisting of two boundaries, one plane and other curved as shown in the figure. The plane surface makes an angle 60° with horizontal and curved surface has radius of curvature 0.4 m. The refractive indices of the medium and its environment are shown in the figure. If after refraction at both the surfaces the ray meets principle axis at P, find OP. ***(2004 - 2 Marks)***



37. In $YDSE$ a light containing two wavelengths 500 nm and 700 nm are used. Find the minimum distance where maxima of two wavelengths coincide. Given $D/d = 10^3$, where D is the distance between the slits and the screen and d is the distance between the slits. ***(2004 - 4 Marks)***

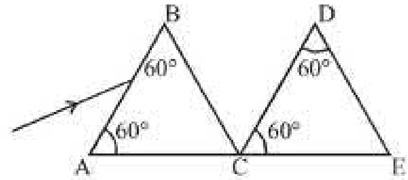
38. An object is moving with velocity 0.01 m/s towards a convex lens of focal length 0.3 m. Find the magnitude of rate of separation of image from the lens when the object is at a distance of 0.4 m from the lens. Also calculate the magnitude of the rate of change of the lateral magnification. ***(2004 - 4 Marks)***

39. What will be the minimum angle of incidence such that the total internal reflection occurs on both the surfaces?



(2005 - 2 Marks)

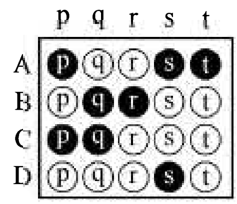
40. Two identical prisms of refractive index $\sqrt{3}$ are kept as shown in the figure. A light ray strikes the first prism at face *AB*. Find, ***(2005 - 4 Marks)***



(a) the angle of incidence, so that the emergent ray from the first prism has minimum deviation.
(b) through what angle the prism *DCE* should be rotated about *C* so that the final emergent ray also has minimum deviation.

F Match the Following

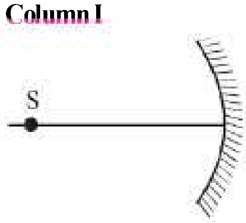
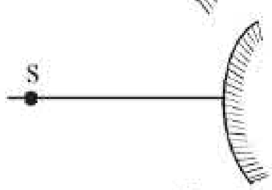
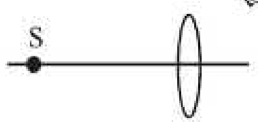
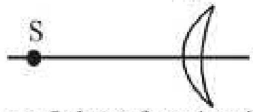
DIRECTIONS (Q. No. 1-4) : *Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r and s. Any given statement in Column-I can have correct matching with ONE OR MORE 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 then the correct darkening of bubbles will look like the given.



1. A simple telescope used to view distant objects has eyepiece and objective lens of focal lengths f_e and f_o, respectively. Then ***(2006 - 6M)***

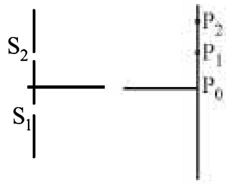
Column I	Column II
(A) Intensity of light received by lens	(p) Radius of aperture
(B) Angular magnification	(q) Dispersion of lens
(C) Length of telescope	(r) Focal length of objective lens and eyepiece lens
(D) Sharpness of image	(s) Spherical aberration

2. An optical component and an object S placed along its optic axis are given in Column I. The distance between the object and the component can be varied. The properties of images are given in Column II. Match all the properties of images from Column II with the appropriate components given in Column I. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS. ***(2008)***

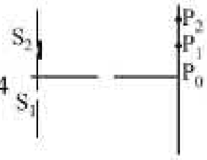
Column I	Column II
(A) 	(p) real image
(B) 	(q) virtual image
(C) 	(r) magnified image
(D) 	(s) image at infinity

3. **Column-I** shows four situations of standard Young's double slit arrangement with the screen placed far away from the slits S_1 and S_2. In each of these cases $S_1P_0 = S_2P_0$, $S_1P_1 - S_2P_1 = \lambda/4$ and $S_1P_2 - S_2P_2 = \lambda/3$, where λ is the wavelength of the light used. In the cases B, C and D, a transparent sheet of refractive index μ and thickness t is pasted on slit S_2. The thicknesses of the sheets are different in different cases. The phase difference between the light waves reaching a point P on the screen from the two slits is denoted by δ (P) and the intensity by I(P). Match each situation given in **Column-I** with the statetment(s) in **Column-II** valid for that situation. ***(2009)***

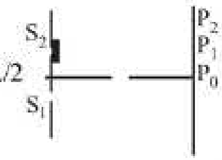
Column-I | **Column-II**

(A) 

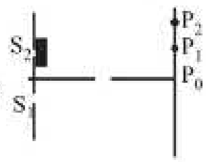
(p) $\delta(P_0) = 0$

(B) $(\mu - 1)\, t = \lambda/4$ 

(q) $\delta(P_1) = 0$

(C) $(\mu - 1)\, t = \lambda/2$ 

(r) $I(P_1) = 0$

(D) $(\mu - 1)\, t = 3\lambda/4$ 

(s) $I(P_0) > I(P_1)$

(t) $I(P_2) > I(P_1)$

4. Two transparent media of refractive indices μ_1 and μ_3 have a solid lens shaped transparent material of refractive index μ_2 between them as shown in figures in Column II. A ray traversing these media is also shown in the figures. In Column I different relationships between μ_1, μ_2, and μ_3 are given. Match them to the ray diagrams shown in **Column II.** ***(2010)***

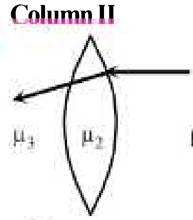
Column I | **Column II**

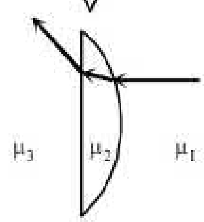
(A) $\mu_1 < \mu_2$

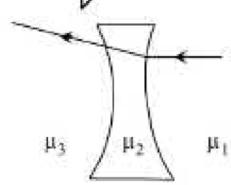
(B) $\mu_1 > \mu_2$

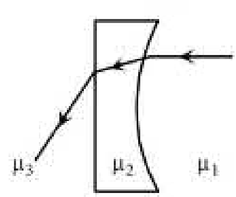
(C) $\mu_2 = \mu_3$

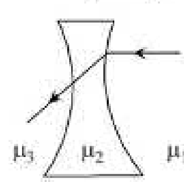
(D) $\mu_2 > \mu_3$

(p) 

(q) 

(r) 

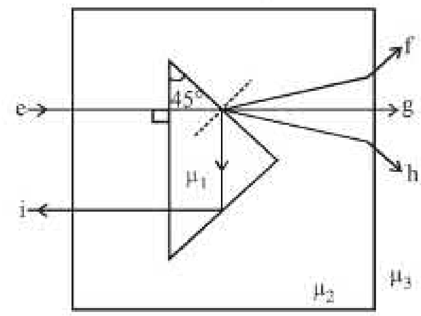
(s) 

(t) 

DIRECTION (Q. No. 5 & 6) *Following question has matching lists. The codes for the lists have choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

5. A right angled prism of refractive index μ_1 is placed in a rectangular block of refractive index μ_2, which is surrounded by a medium of refractive index μ_3, as shown in the figure. A ray of light 'e' enters the rectangular block at normal incidence. Depending upon the relationships between μ_1, μ_2 and μ_3, it takes one of the four possible paths 'ef', 'eg', 'eh' or 'ei'.
Match the paths in List I with conditions of refractive indices in List II and select the correct answer using the codes given below the lists: *(JEE Adv. 2013)*

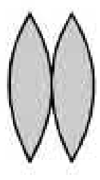
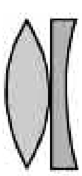
	List I		List II
P.	$e \to f$	1.	$\mu_1 > \sqrt{2}\mu_2$
Q.	$e \to g$	2.	$\mu_2 > \mu_1$ and $\mu_2 > \mu_3$
R.	$e \to h$	3.	$\mu_1 = \mu_2$
S.	$e \to i$	4.	$\mu_2 < \mu_1 < \sqrt{2}\mu_2$ and $\mu_2 > \mu_3$



Codes:

	P	Q	R	S
(a)	2	3	1	4
(b)	1	2	4	3
(c)	4	1	2	3
(d)	2	3	4	1

6. Four combinations of two thin lenses are given in List-I. The radius of curvature of all curved surfaces is r and the refractive index of all the lenses is 1.5. Match lens combinations in List-I with their focal length in List-II and select the correct answer using the code given below the lists. *(JEE Adv. 2014)*

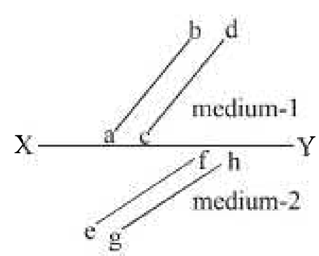
	List - I		List - II
P.		**1.**	$2r$
Q.		**2.**	$\frac{r}{2}$
R.		**3.**	$-r$
S.		**4.**	r

Codes:
(a) P-1, Q-2, R-3, S-4 (b) P-2, Q-4, R-3, S-1 (c) P-4, Q-1, R-2, S-3 (d) P-2, Q-1, R-3, S-4

G Comprehension Based Questions

PASSAGE - 1

The figure shows a surface XY separating two transparent media, medium-1 and medium-2. The line ab and cd represent waveforms of a light wave travelling in medium-1 and incident on XY. The lines ef and gh represent wavefronts of the light wave in medium-2 after refraction. *(2007)*



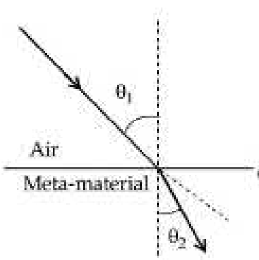
1. Light travels as a
   (a) parallel beam in each medium
   (b) convergent beam in each medium
   (c) divergent beam in each medium
   (d) divergent beam in one medium and convergent beam in the other medium.
2. The phases of the light wave at c, d, e and f are ϕ_c, ϕ_d, ϕ_e and ϕ_f respectively. It is given that $\phi_c \neq \phi_f$.
   (a) ϕ_c cannot be equal to ϕ_d
   (b) ϕ_d can be equal to ϕ_e
   (c) $(\phi_d - \phi_f)$ is equal to $(\phi_c - \phi_e)$
   (d) $(\phi_d - \phi_c)$ is not equal to $(\phi_f - \phi_e)$
3. Speed of light is
   (a) the same in medium-1 and medium-2
   (b) larger in medium-1 than in medium-2
   (c) larger in medium-2 than in medium-1
   (d) different at b and d.

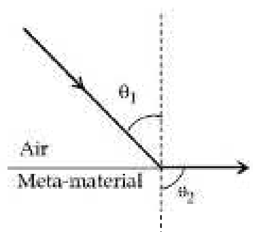
PASSAGE-2

Most materials have the refractive index, $n > 1$. So, when a light ray from air enters a naturally occurring material, then by Snell's law, $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$, it is understood that the refracted ray bends towards the normal. But it never emerges on the same side of the normal as the incident ray. According to electromagnetism, the refractive index of the medium is given by the relation, $n = c/v = \pm\sqrt{\varepsilon_r\mu_r}$, where c is the speed of electromagnetic waves in vacuum, v its speed in the medium, ε_r and μ_r are the relative permittivity and permeability of the medium respectively.

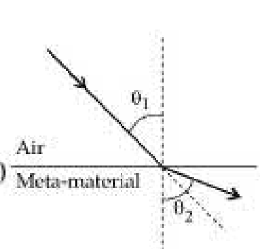
In normal materials, both ε_r and μ_r, are positive, implying positive n for the medium. When both ε_r and μ_r are negative, one must choose the negative root of n. Such negative refractive index materials can now be artificially prepared and are called meta-materials. They exhibit significantly different optical behavior, without violating any physical laws. Since n is negative, it results in a change in the direction of propagation of the refracted light. However, similar to normal materials, the frequency of light remains unchanged upon refraction even in meta-materials. ***(2012)***

4. For light incident from air on a meta-material, the appropriate ray diagram is

(a)


(b)


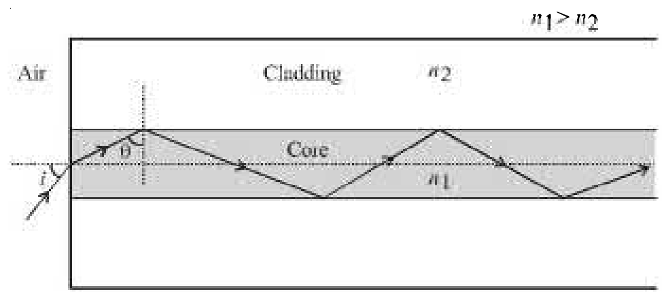
(c)


(d)


5. Choose the correct statement.
   (a) The speed of light in the meta-material is $v = c|n|$
   (b) The speed of light in the meta-material is $v = \frac{c}{|n|}$
   (c) The speed of light in the meta-material is $v = c$.
   (d) The wavelength of the light in the meta-material (λ_m) is given by $\lambda_m = \lambda_{air}|n|$, where λ_{air} is wavelength of the light in air.

PASSAGE-3

Light guidance in an optical fibre can be understood by considering a structure comprising of thin solid glass cylinder of refractive index n_1 surrounded by a medium of lower refractive index n_2. The light guidance in the structure takes place due to successive total internal reflections at the interface of the media n_1 and n_2 as shown in the figure. All rays with the angle of incidence i less than a particular value i_m are confined in the medium of refractive index n_1. The numerical aperture (NA) of the structure is defined as $\sin i_m$.



6. For two structure namely S_1 with $n_1 = \sqrt{45}/4$ and $n_2 = 3/2$, and S_2 with $n_1 = 8/5$ and $n_2 = 7/5$ and taking the refractive index of water to be 4/3 and that of air to be 1, the correct option(s) is(are) ***(JEE Adv. 2015)***
   (a) NA of S_1 immersed in water is the same as that of S_2 immersed in a liquid of refractive index $\frac{16}{3\sqrt{15}}$
   (b) NA of S_1 immersed in liquid of refractive index $\frac{6}{\sqrt{15}}$ is the same as that of S_2 immersed in water
   (c) NA of S_1 placed in air is the same as that of S_2 immersed in liquid of refractive index $\frac{4}{\sqrt{15}}$
   (d) NA of S_1 placed in air is the same as that of S_2 placed in water
7. If two structure of same cross-sectional area, but different numerical apertures NA_1 and NA_2 $(NA_2 < NA_1)$ are joined longitudinally, the numerical aperture of the combined structure is ***(JEE Adv. 2015)***
   (a) $\frac{NA_1\, NA_2}{NA_1 + NA_2}$ (b) $NA_1 + NA_2$
   (c) NA_1 (d) NA_2

H Assertion & Reason Type Questions

1. **STATEMENT-1** *(2007)*
The formula connecting u, v and f for a spherical mirror is valid for mirrors whose sizes are very small compared to their radii of curvature.
because
STATEMENT-2
Laws of reflection are strictly valid for plane surfaces, but not for large spherical surfaces.
(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(b) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(c) Statement-1 is True, Statement-2 is False
(d) Statement-1 is False, Statement-2 is True

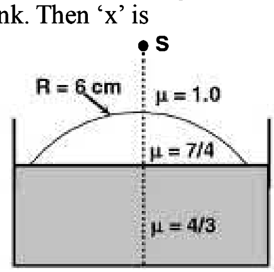
I Integer Value Correct Type

1. The focal length of a thin biconvex lens is 20 cm. When an object is moved from a distance of 25 cm in front of it to 50 cm, the magnification of its image changes from m_{25} to m_{50}.
The ratio $\frac{m_{25}}{m_{50}}$ is *(2010)*

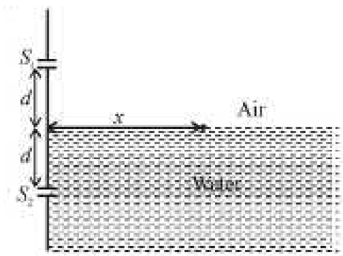
2. A large glass slab ($\mu = 5/3$) of thickness 8 cm is placed over a point source of light on a plane surface. It is seen that light emerges out of the top surface of the slab from a circular area of radius R cm. What is the value of R? *(2010)*

3. Image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from $\frac{25}{3}$ m to $\frac{50}{7}$ m in 30 seconds. What is the speed of the object in km per hour? *(2010)*

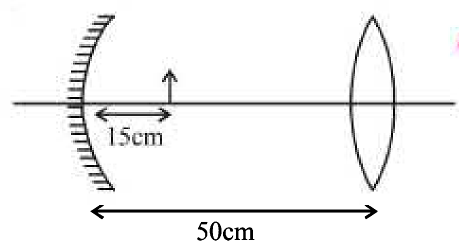
4. Water (with refractive index = $\frac{4}{3}$) in a tank is 18 cm deep. Oil of refractive index $\frac{7}{4}$ lies on water making a convex surface of radius of curvature 'R = 6 cm' as shown. Consider oil to act as a thin lens. An object 'S' is placed 24 cm above water surface. The location of its image is at 'x' cm above the bottom of the tank. Then 'x' is *(2011)*



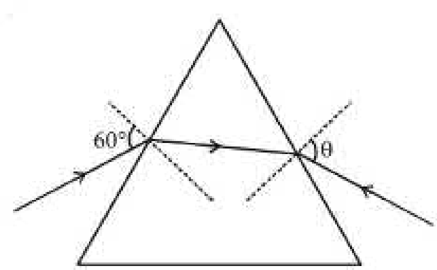
5. A Young's double slit interference arrangement with slits S_1 and S_2 is immersed in water (refractive index = $\frac{4}{3}$) as shown in the figure. The positions of maximum on the surface of water are given by $x^2 = p^2m^2\lambda^2 - d^2$, where λ is the wavelength of light in air (refractive index = 1), $2d$ is the separation between the slits and m is an integer. The value of p is *(JEE Adv. 2015)*



6. Consider a concave mirror and a convex lens (refractive index = 1.5) of focal length 10 cm each, separated by a distance of 50 cm in air (refractive index = 1) as shown in the figure. An object is placed at a distance of 15 cm from the mirror. Its erect image formed by this combination has magnification M_1. When the set-up is kept in a medium of refractive index $\frac{7}{6}$, the magnification becomes M_2. The magnitude $\left|\frac{M_2}{M_1}\right|$ is *(JEE Adv. 2015)*



7. The monochromatic beam of light is incident at 60° on one face of an equilateral prism of refractive index n and emerges from the opposite face making an angle $\theta(n)$ with the normal (see the figure). For $n = \sqrt{3}$ the value of θ is 60° and $\frac{d\theta}{dn} = m$.
The value of m is *(JEE Adv. 2015)*



Section-B JEE Main / AIEEE

1. An astronomical telescope has a large aperture to [2002]
(a) reduce spherical aberration
(b) have high resolution
(c) increase span of observation
(d) have low dispersion.

2. If two mirrors are kept at 60° to each other, then the number of images formed by them is [2002]
(a) 5 (b) 6 (c) 7 (d) 8

3. Electromagnetic waves are transverse in nature is evident by [2002]
(a) polarization (b) interference
(c) reflection (d) diffraction

4. Wavelength of light used in an optical instrument are $\lambda_1 = 4000\,\text{Å}$ and $\lambda_2 = 5000\,\text{Å}$, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is [2002]
(a) $16:25$ (b) $9:1$ (c) $4:5$ (d) $5:4$.

5. Which of the following is used in optical fibres? [2002]
(a) total internal reflection
(b) scattering
(c) diffraction
(d) refraction.

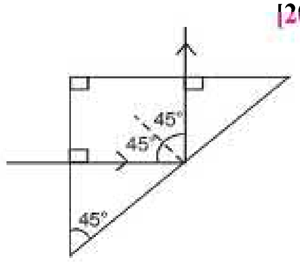
6. Consider telecommunication through optical fibres. Which of the following statements is **not** true? [2003]
(a) Optical fibres can be of graded refractive index
(b) Optical fibres are subject to electromagnetic interference from outside
(c) Optical fibres have extremely low transmission loss
(d) Optical fibres may have homogeneous core with a suitable cladding.

7. To demonstrate the phenomenon of interference, we require two sources which emit radiation [2003]
(a) of nearly the same frequency
(b) of the same frequency
(c) of different wavelengths
(d) of the same frequency and having a definite phase relationship

8. The image formed by an objective of a compound microscope is [2003]
(a) virtual and diminished
(b) real and diminished
(c) real and enlarged
(d) virtual and enlarged

9. To get three images of a single object, one should have two plane mirrors at an angle of [2003]
(a) 60° (b) 90° (c) 120° (d) 30°

10. A light ray is incident perpendicularly to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index n [2004]
(a) $n > \frac{1}{\sqrt{2}}$
(b) $n > \sqrt{2}$
(c) $n < \frac{1}{\sqrt{2}}$
(d) $n < \sqrt{2}$



11. A plano convex lens of refractive index 1.5 and radius of curvature 30 cm. Is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens an object be placed in order to have a real image of size of the object [2004]
(a) 60 cm (b) 30 cm
(c) 20 cm (d) 80 cm

12. The angle of incidence at which reflected light is totally polarized for reflection from air to glass (refractive index n), is [2004]
(a) $\tan^{-1}(1/n)$ (b) $\sin^{-1}(1/n)$
(c) $\sin^{-1}(n)$ (d) $\tan^{-1}(n)$

13. The maximum number of possible interference maxima for slit-separation equal to twice the wavelength in Young's double-slit experiment is [2004]
(a) three (b) five
(c) infinite (d) zero

14. An electromagnetic wave of frequency $\nu = 3.0$ MHz passes from vacuum into a dielectric medium with permittivity $\in = 4.0$. Then [2004]
(a) wave length is halved and frequency remains unchanged
(b) wave length is doubled and frequency becomes half
(c) wave length is doubled and the frequency remains unchanged
(d) wave length and frequency both remain unchanged.

15. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is $\frac{4}{3}$ and the fish is 12 cm below the surface, the radius of this circle in cm is [2005]
(a) $\frac{36}{\sqrt{7}}$ (b) $36\sqrt{7}$ (c) $4\sqrt{5}$ (d) $36\sqrt{5}$

16. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye? [Take wavelength of light = 500 nm] [2005]
(a) 1m (b) 5m
(c) 3m (d) 6m

17. A thin glass (refractive index 1.5) lens has optical power of $-5\,D$ in air. Its optical power in a liquid medium with refractive index 1.6 will be [2005]
(a) $-1D$ (b) $1D$ (c) $-25D$ (d) $25D$

18. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is [2005]
(a) circle (b) hyperbola
(c) parabola (d) straight line

19. If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled? [2005]
(a) $4I_0$ (b) $2I_0$ (c) $\frac{I_0}{2}$ (d) I_0

20. When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is **[2005]**

(a) $\frac{1}{4}I_0$ (b) $\frac{1}{2}I_0$ (c) I_0 (d) zero

21. The refractive index of a glass is 1.520 for red light and 1.525 for blue light. Let D_1 and D_2 be angles of minimum deviation for red and blue light respectively in a prism of this glass. Then, **[2006]**

(a) $D_1 < D_2$
(b) $D_1 = D_2$
(c) D_1 can be less than or greater than D_2 depending upon the angle of prism
(d) $D_1 > D_2$

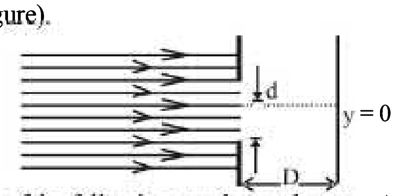
22. In a Young's double slit experiment the intensity at a point where the path difference is $\frac{\lambda}{6}$ (λ being the wavelength of light used) is I. If I_0 denotes the maximum intensity, $\frac{I}{I_0}$ is equal to **[2007]**

(a) $\frac{3}{4}$ (b) $\frac{1}{\sqrt{2}}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\frac{1}{2}$

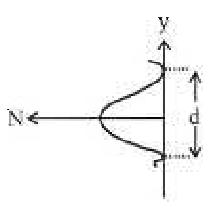
23. Two lenses of power –15 *D* and +5 *D* are in contact with each other. The focal length of the combination is **[2007]**

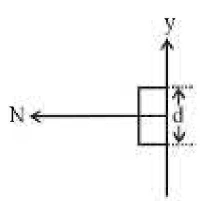
(a) + 10 cm (b) – 20 cm
(c) – 10 cm (d) + 20 cm

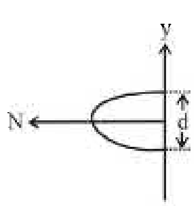
24. In an experiment, electrons are made to pass through a narrow slit of width '*d*' comparable to their de Broglie wavelength. They are detected on a screen at a distance '*D*' from the slit (see figure).

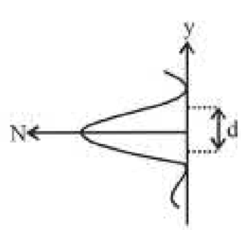


Which of the following graphs can be expected to represent the number of electrons '*N*' detected as a function of the detector position '*y*'(*y* = 0 corresponds to the middle of the slit) **[2008]**

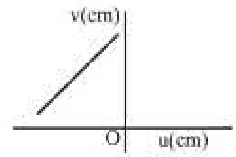
(a)


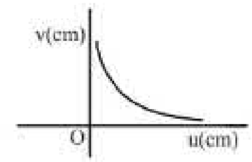
(b)


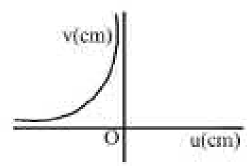
(c)


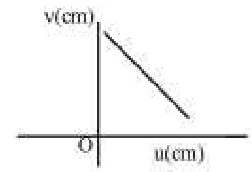
(d)


25. A student measures the focal length of a convex lens by putting an object pin at a distance '*u*' from the lens and measuring the distance '*v*' of the image pin. The graph between '*u*' and '*v*' plotted by the student should look like **[2008]**

(a)


(b)


(c)


(d)


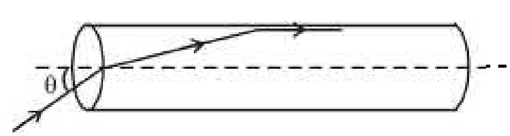
26. An experment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are measured by **[2008]**

(a) a vernier scale provided on the microscope
(b) a standard laboratory scale
(c) a meter scale provided on the microscope
(d) a screw gauge provided on the microscope

27. A mixture of light, consisting of wavelength 590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4th bright fringe of the unknown light. From this data, the wavelength of the unknown light is: **[2009]**

(a) 885.0 nm (b) 442.5 nm
(c) 776.8 nm (d) 393.4 nm

28. A transparent solid cylindrical rod has a refractive index of $\frac{2}{\sqrt{3}}$. It is surrounded by air. A light ray is incident at the mid-point of one end of the rod as shown in the figure.



The incident angle θ for which the light ray grazes along the wall of the rod is : **[2009]**

(a) $\sin^{-1}\left(\sqrt{3}/2\right)$ (b) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$

(c) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (d) $\sin^{-1}\left(1/2\right)$

29. In an optics experiment, with the position of the object fixed, a student varies the position of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at P. The coordinates of P will be : **[2009]**

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

DIRECTIONS : *Questions number 30-32 are based on the following paragraph.*

An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.

30. As the beam enters the medium , it will **[2010]**
(a) diverge
(b) converge
(c) diverge near the axis and converge near the periphery
(d) travel as a cylindrical beam

31. The initial shape of the wavefront of the beam is **[2010]**
(a) convex
(b) concave
(c) convex near the axis and concave near the periphery
(d) planar

32. The speed of light in the medium is **[2010]**
(a) minimum on the axis of the beam
(b) the same everywhere in the beam
(c) directly proportional to the intensity I
(d) maximum on the axis of the beam

33. Let the x-z plane be the boundary between two transparent media. Medium 1 in $z \geq 0$ has a refractive index of $\sqrt{2}$ and medium 2 with $z < 0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}$ is incident on the plane of separation. The angle of refraction in medium 2 is: **[2011]**
(a) 45° (b) 60° (c) 75° (d) 30°

34. This question has a paragraph followed by two statements, Statement – 1 and Statement – 2. Of the given four alternatives after the statements, choose the one that describes the statements.

A thin air film is formed by putting the convex surface of a plane-convex lens over a plane glass plate. With monochromatic light, this film gives an interference pattern due to light reflected from the top (convex) surface and the bottom (glass plate) surface of the film. **[2011]**

Statement – 1 : When light reflects from the air-glass plate interface, the reflected wave suffers a phase change of π.

Statement – 2 : The centre of the interference pattern is dark.

(a) Statement – 1 is true, Statement – 2 is true, Statement – 2 is the correct explanation of Statement – 1.
(b) Statement – 1 is true, Statement – 2 is true, Statement – 2 is not the correct explanation of Statement – 1.
(c) Statement – 1 is false, Statement – 2 is true.
(d) Statement – 1 is true, Statement – 2 is false.

35. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15 m/s. The speed of the image of the second car as seen in the mirror of the first one is : **[2011]**

(a) $\frac{1}{15}$ m/s (b) 10 m/s (c) 15 m/s (d) $\frac{1}{10}$ m/s

36. An electromagnetic wave in vacuum has the electric and magnetic field $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by $\vec{X}$ and that of wave propagation by $\vec{k}$. Then **[2012[**

(a) $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{B}\times\vec{E}$

(b) $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{E}\times\vec{B}$

(c) $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{E}\times\vec{B}$

(d) $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{B}\times\vec{E}$

37. In Young's double slit experiment, one of the slit is wider than other, so that amplitude of the light from one slit is double of that from other slit. If I_m be the maximum intensity, the resultant intensity I when they interfere at phase difference ϕ is given by : **[2012]**

(a) $\frac{I_m}{9}(4+5\cos\phi)$ (b) $\frac{I_m}{3}\left(1+2\cos^2\frac{\phi}{2}\right)$

(c) $\frac{I_m}{5}\left(1+4\cos^2\frac{\phi}{2}\right)$ (d) $\frac{I_m}{9}\left(1+8\cos^2\frac{\phi}{2}\right)$

38. An object 2.4 m in front of a lens forms a sharp image on a film 12 cm behind the lens. A glass plate 1 cm thick, of refractive index 1.50 is interposed between lens and film with its plane faces parallel to film. At what distance (from lens) should object shifted to be in sharp focus of film? **[2012[**

(a) 7.2 m (b) 2.4 m
(c) 3.2 m (d) 5.6 m

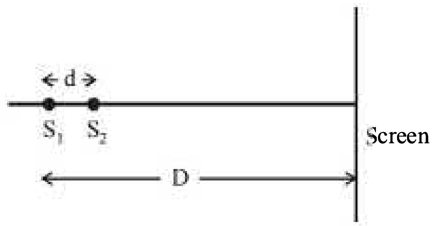
39. Diameter of a plano-convex lens is 6 cm and thickness at the centre is 3 mm. If speed of light in material of lens is 2×10^8 m/s, the focal length of the lens is **[JEE Main 2013]**

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

40. A beam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A. The intensity of the emergent light is **|JEE Main 2013|**

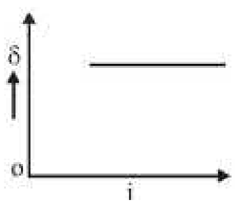
(a) I_0 (b) $I_0/2$
(c) $I_0/4$ (d) $I_0/8$

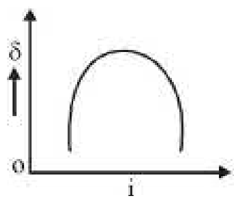
41. Two coherent point sources S_1 and S_2 are separated by a small distance 'd' as shown. The fringes obtained on the screen will be **|JEE Main 2013|**

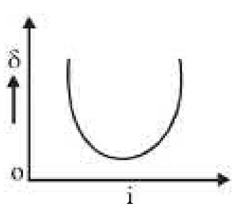


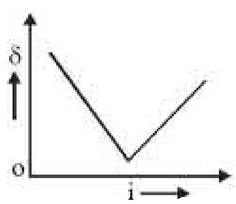
(a) points (b) straight lines
(c) semi-circles (d) concentric circles

42. The graph between angle of deviation (δ) and angle of incidence (i) for a triangular prism is represented by **|JEE Main 2013[**

(a) 

(b) 

(c) 

(d) 

43. A thin convex lens made from crown glass $\left(\mu = \frac{3}{2}\right)$ has focal length f. When it is measured in two different liquids having refractive indices $\frac{4}{3}$ and $\frac{5}{3}$, it has the focal lengths f_1 and f_2 respectively. The correct relation between the focal lengths is: **|JEE Main 2014|**

(a) $f_1 = f_2 < f$
(b) $f_1 > f$ and f_2 becomes negative
(c) $f_2 > f$ and f_1 becomes negative
(d) f_1 and f_2 both become negative

44. A green light is incident from the water to the air - water interface at the critical angle (θ). Select the correct statement. **|JEE Main 2014|**

(a) The entire spectrum of visible light will come out of the water at an angle of 90° to the normal.
(b) The spectrum of visible light whose frequency is less than that of green light will come out to the air medium.
(c) The spectrum of visible light whose frequency is more than that of green light will come out to the air medium.
(d) The entire spectrum of visible light will come out of the water at various angles to the normal.

45. Two beams, A and B, of plane polarized light with mutually perpendicular planes of polarization are seen through a polaroid. From the position when the beam A has maximum intensity (and beam B has zero intensity), a rotation of polaroid through 30° makes the two beams appear equally bright. If the initial intensities of the two beams are I_A and I_B respectively, then $\frac{I_A}{I_B}$ equals: **|JEE Main 2014|**

(a) 3 (b) $\frac{3}{2}$
(c) 1 (d) $\frac{1}{3}$

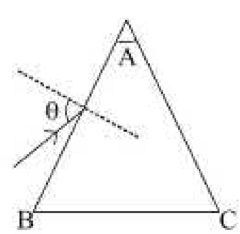
46. Assuming human pupil to have a radius of 0.25 cm and a comfortable viewing distance of 25 cm, the minimum separation between two objects that human eye can resolve at 500 nm wavelength is : **|JEE Main 2015|**

(a) 100 μm (b) 300 μm
(c) 1 μm (d) 30 μm

47. On a hot summer night, the refractive index of air is smallest near the ground and increases with height from the ground. When a light beam is directed horizontally, the Huygens' principle leads us to conclude that as it travels, the light beam : **|JEE Main 2015|**

(a) bends downwards
(b) bends upwards
(c) becomes narrower
(d) goes horizontally without any deflection

48. Monochromatic light is incident on a glass prism of angle A. If the refractive index of the material of the prism is μ, a ray, incident at an angle θ, on the face AB would get transmitted through the face AC of the prism provided : **|JEE Main 2015|**



(a) $\theta > \cos^{-1}\left[\mu \sin\left(A + \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(b) $\theta < \cos^{-1}\left[\mu \sin\left(A + \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(c) $\theta > \sin^{-1}\left[\mu \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

(d) $\theta < \sin^{-1}\left[\mu \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$

49. The box of a pin hole camera, of length L, has a hole of radius a. It is assumed that when the hole is illuminated by a parallel beam of light of wavelength λ the spread of the spot (obtained on the opposite wall of the camera) is the sum of its geometrical spread and the spread due to diffraction. The spot would then have its minimum size (say b_{min}) when : **[JEE Main 2016]**

(a) $a = \sqrt{\lambda L}$ and $b_{min} = \sqrt{4\lambda L}$

(b) $a = \frac{\lambda^2}{L}$ and $b_{min} = \sqrt{4\lambda L}$

(c) $a = \frac{\lambda^2}{L}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$

(d) $a = \sqrt{\lambda l}$ and $b_{min} = \left(\frac{2\lambda^2}{L}\right)$

50. An observer looks at a distant tree of height 10 m with a telescope of magnifying power of 20. To the observer the tree appears : **[JEE Main 2016]**

(a) 20 times taller (b) 20 times nearer
(c) 10 times taller (d) 10 times nearer

51. In an experiment for determination of refractive index of glass of a prism by $i - \delta$, plot it was found thata ray incident at angle 35°, suffers a deviation of 40° and that it emerges at angle 79°. In that case which of the following is closest to the maximum possible value of the refractive index? **[JEE Main 2016]**

(a) 1.7 (b) 1.8
(c) 1.5 (d) 1.6

SOLUTIONS

Section-A : JEE Advanced/ IIT-JEE

A

1. 2×10^8 m/s, 0.4×10^{-6} m **2.** $d=+15$ cm **3.** 4000Å, 5×10^{14} Hz **4.** 2

5. 60 cm **6.** $\frac{25}{9}$ **7.** 30 cm **8.** 1.5 **9.** zero **10.** smaller

11. $\frac{\sqrt{\mu\varepsilon}}{\sqrt{\mu_0\varepsilon_0}}$ **12.** 5×10^{14} Hz, 4000Å **13.** 0.125 m, 0.5 m **14.** 15°

B

1. T **2.** T **3.** F **4.** T **5.** T **6.** F **7.** T

C

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

D

1. (b, d) **2.** (a) **3.** (a, c) **4.** (b, d) **5.** (d) **6.** (a)
7. (d) **8.** (c) **9.** (a, b, c, d) **10.** (c) **11.** (b, c) **12.** (b)
13. (c, d) **14.** (d) **15.** (d) **16.** (a) **17.** (a, b) **18.** (c, d) **19.** (a, b, c)
20. (a,c) **21.** (a,b,c) **22.** (b) **23.** (a,d) **24.** (a,c,d) **25.** (b,d)

E

1. 11 cm, Real **2.** 1.732 **3.** 1.41 **4.** $\mu_1<\mu_2$ **5.** 7.67 cm **6.** **(i)** 15 cm **(ii)** 1.15 cm

7. 13.9 **8.** 75 cm **9.** **(i)** 1.17×10^{-3} m, **(ii)** 1.56×10^{-3} m **11.** **(i)** $\sqrt{2}$ **(ii)** No

12. **(i)** –6 mm, –5 mm **13.** 7×10^{-6} W **14.** $\frac{1}{49}$ **15.** **(a)** 0.8×10^{-14} m^2 **(b)** 27.2° **(c)** $9I$

16. $\sqrt{2}$ **17.** **(i)** 10^{-3} m **(ii)** increase **19.** **(a)** $\frac{dy}{dx}=\cot i$ **(b)** $y=k^2\left(\frac{x}{4}\right)^4$ **(c)** (4m, 1m)

20. **(i)** $\sin^{-1}\left[\frac{1}{\sqrt{2}}\left\{\sqrt{n^2-n_1^2}-n_1\right\}\right]$ **(ii)** 72.94°

21. **(i)** 6.3×10^{-4}m **(ii)** 1.575×10^{-6} m **22.** 0.4m, 0.6m **23.** 9.3×10^{-6}m **24.** **(a)** 600 nm **(b)** $\sin^{-1}\left(\frac{3}{4}\right)$

25. **(a)** ±0.26 m, ±1.13 m **(b)** 1.13 m, 0.26 m

26. **(a)** 4.33×10^{-3} m **(b)** 0.75 **(c)** 0.65×10^{-6} m, 0.433×10^{-6} m **27.** $\frac{1}{5\sqrt{2}}\left[3\hat{i}+4\hat{j}-5\hat{k}\right]$ **28.** $\frac{4}{3}$

29. **(a)** 15 cm, $\frac{1}{2}$ **(b)** 90 nm **30.** 4°, –0.04° **31.** 2 cm, 1.0016 **32.** 1.6 **33.** **(a)** circular **(b)** 1/16 **(c)** 300 nm

34. $\frac{\mu_3 R}{\mu_3-\mu_1}$ **35.** **(a)** zero **(b)** 125 nm **36.** 6.056 m **37.** 3.5 mm **38.** 0.09 m/sec, 0.35 s^{-1}

39. 60° **40.** **(a)** 60°, **(b)** 60°, anticlockwise

F

1. A-p; B-r; C-r; D-p, q, s **2.** A-p, q, r, s; B-q; C-p, q, r, s; D-p, q, r, s **3.** A-p, s; B-q; C-t; D-r, s, t
4. A-p, r; B-q, s, t; C-p, r, t; D-q, s **5.** (d) **6.** (b)

G

1. (a) **2.** (c) **3.** (b) **4.** (c) **5.** (b) **6.** (a,c) **7.** (d)

H

1. (c)

I

1. 6 **2.** 6 **3.** 3 **4.** 2 **5.** 3 **6.** 7 **7.** 2

Section-B : JEE Main/ AIEEE

1. (b)	2. (a)	3. (a)	4. (d)	5. (a)	6. (b)	7. (d)	8. (c)
9. (b)	10. (b)	11. (c)	12. (d)	13. (b)	14. (a)	15. (a)	16. (b)
17. (b)	18. (d)	19. (a)	20. (b)	21. (a)	22. (a)	23. (c)	24. (d)
25. (c)	26. (a)	27. (b)	28. (c)	29. (d)	30. (b)	31. (d)	32. (a)
33. (a)	34. (b)	35. (a)	36. (b)	37. (d)	38. (d)	39. (c)	40. (c)
41. (d)	42. (c)	43. (b)	44. (b)	45. (d)	46. (d)	47. (b)	48. (c)
49. (a)	50. (b)	51. (c)					

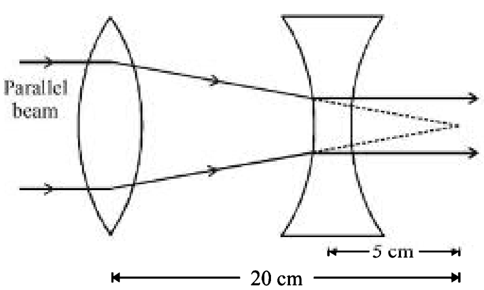
Section-A JEE Advanced/ IIT-JEE

A. Fill in the Blanks

1. $V_2 = \frac{3\times10^8}{1.5} = 2\times10^8\,\text{m/s};$

$$\lambda_2 = \frac{V_2}{v} = \frac{2\times10^8}{5\times10^{14}} = 0.4\times10^{-6}\,m$$

2.



From the diagram it is clear that the focus of both the lenses should coincide as shown in the diagram.
Therefore $d = 15$ cm.

3. **KEY CONCEPT :**

$${}^a_m\mu = \frac{\text{Speed of light in med 1}}{\text{Speed of light in med 2}} = \frac{\nu\lambda_a}{\nu\lambda_m} = \frac{\lambda_a}{\lambda_m}$$

[$\because$ v does not change with the medium]

$$\therefore \quad \lambda_m = \frac{\lambda_a}{{}^a_m\mu} = \frac{6000}{1.5} = 4000\text{Å}$$

$$\therefore \quad \nu_a = \frac{c_a}{\lambda_a} = \frac{3\times10^8}{6000\times10^{-10}} = 5\times10^{14}\,\text{Hz}$$

4. For coherent sources, for constructive interference
The amplitude at the mid point $= A + A = 2A$
$\Rightarrow\ I_1 \propto (2A)^2 \Rightarrow I_2 \propto 4I_0$ ... (i)
NOTE : For incoherent sources, the intensity add up normally (no interference).
Therefore, the total intensity $I_2 = 2I_0$ ... (ii)
From (i) and (ii)

$$\frac{I_1}{I_2} = \frac{4I_0}{2I_0} = 2$$

5. $${}^m_g\mu = \frac{{}_g\mu}{{}_m\mu} = \frac{1.5}{4/3} = 1.125$$

$$\frac{1}{15} = (1.5-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{[Lensmaker's formula]}$$

and $\frac{1}{f_2} = (1.125-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

On dividing we get

$$\frac{f_2}{15} = \frac{1.5-1}{1.125-1} = \frac{0.5}{0.125} = 4 \quad \therefore \quad f_2 = 60\,\text{cm}$$

6. $$\frac{I_1}{I_2} = \frac{A_1^2}{A_2^2} \quad \text{...(i)}$$

But $I \propto \frac{1}{r^2} \Rightarrow \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$ ...(ii)

From (i) and (ii),

$$\frac{A_1}{A_2} = \frac{r_2}{r_1} = \frac{25}{9}.$$

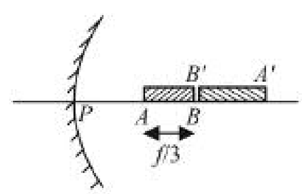
7. For refraction at APB

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

$$\Rightarrow \frac{-2}{-15} + \frac{1}{v} = \frac{1-2}{-10} \Rightarrow v = -30\,\text{cm}$$

$\Rightarrow$ Image of O will be formed at 30 cm to the right at P.

8. Since the image formed is real and elongated, the situation is as shown in the figure. Since the image of B is formed at B' itself



$\therefore$ B is situated at the centre of curvature that is at a distance at $2f$ from the pole.

$$\therefore \quad PA = 2f - \frac{f}{3} = \frac{5f}{3}$$

Let us find the image of A. For point A, $u = -\frac{5f}{3}, v = ?$

Applying, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{\frac{-5f}{3}} + \frac{1}{v} = \frac{1}{-f}$

$$\Rightarrow \frac{1}{v} = -\frac{1}{f} + \frac{3}{5f} \Rightarrow v = -2.5f$$

Image length = $2.5f - 2f = 0.5f$

$\therefore$ Magnification $= \dfrac{0.5f}{f/3} = 1.5$

9. $\mu = \dfrac{\sin\left(\dfrac{A+\delta m}{2}\right)}{\sin A/2}$, $\sqrt{2} = \dfrac{\sin\left(\dfrac{60+\delta m}{2}\right)}{\sin 60/2}$

$\therefore \dfrac{60+\delta m}{2} = 45° \Rightarrow \delta m = 30°$

$\Rightarrow$ The condition is for minium deviation. In this case the ray inside the prism becomes parallel to base. Therefore the angle made by the ray inside the prism with the base of the prism is **zero.**

10. **KEY CONCEPT :**The resolving power of a microscope device is inversely proportional to the wavelength used.
$\Rightarrow$ The resolving power of an electron microscope is higher than that of an optical microscope because the wavelength of electrons is smaller than the wavelength of visible light.

11. Velocity of light in vacuum $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

and the velocity of light in a medium $v = \dfrac{1}{\sqrt{\mu\varepsilon}}$

$$n = \frac{\text{Velocity light in vacuum}}{\text{Velocity light in medium}} = \frac{c}{v} = \frac{1/\sqrt{\mu_0\varepsilon_0}}{1/\sqrt{\mu\varepsilon}} = \frac{\sqrt{\mu\varepsilon}}{\sqrt{\mu_0\varepsilon_0}}$$

12. Frequency remains the same

$$f = \frac{c}{\lambda} = \frac{3\times10^8}{6000\times10^{-10}} = 5\times10^{14}\,\text{Hz}$$

and $\lambda_2 = \dfrac{\lambda_1}{\mu} = \dfrac{6000Å}{1.5} = 4000Å$

13. $P_1 + P_2 = 10\,\text{m}^{-1}$
$P_1 + P_2 - (0.25)P_1P_2 = 6\text{m}^{-1}$
From these two expressions, we get
$P_1P_2 = 16\text{m}^{-2}$

$$P_1 - P_2 = \sqrt{(P_1+P_2)^2 - 4P_1P_2}$$
$$= \sqrt{(10^{-1})^2 - 4(16^{-1})} = 6\text{m}^{-1}$$

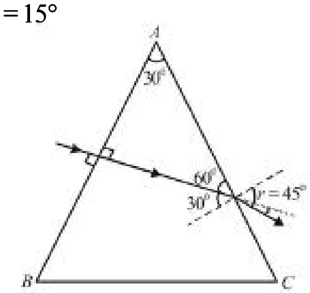
$\therefore$ $P_1 = 8\text{m}^{-1}$ and $P_2 = 2\,\text{m}^{-1}$, Hence

$$f_1 = \frac{1}{P_1} = \frac{1}{8}\text{m} = 0.125\,\text{m and } f_2 = \frac{2}{P_2} = \frac{1}{2}\text{m} = 0.5\text{m}$$

14. Using Snell's law for the refraction at AC, we get
$\mu \sin i = (1)\sin r$

$\sqrt{2}\sin 30° = \sin r \Rightarrow r = 45°$

Angle of deviation at face AC
$= 45° - 30° = 15°$



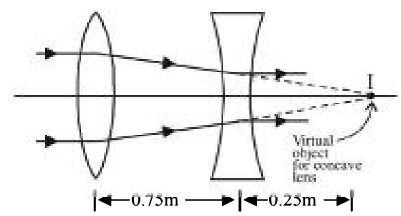
B. True/ False

1. This is due to atmospheric refraction. The light coming from sun bends towards the normal. Therefore, sun appears higher.

2. **KEY CONCEPT :** Formula for intensity of a line source of power (P) at a distance r from the source is

$$I = \frac{P}{2\pi rl}$$

3. The image formed by the convex lens at the focus of the concave lens. Therefore I will act as a virtual object for concave lens and angle will be formed at infinity.



4. **NOTE :** For the light to split, the material through which the light passes should have refractive index greater than 1. Since the prism is hollow, we get no spectrum. The thickness of glass slabs through which the prism is made can be neglected.

5. When the two slits of Young's double slit experiment are illuminated by two different sodium lamps, then the sources are not coherent and hence sustained interference pattern will not be achieved. It will change so quickly that there will be general illumination and hence interference pattern will not be observed .

6. In Young's double slit experiment if source is of white light than the central fringe is white with coloured fringes on either side.

7. $\dfrac{1}{F} = \dfrac{1}{f_1} + \dfrac{1}{f_2}$

$\Rightarrow \dfrac{1}{F} = \dfrac{1}{-15} + \dfrac{1}{30} = \dfrac{-2+1}{30} \Rightarrow F = -30$ cm.

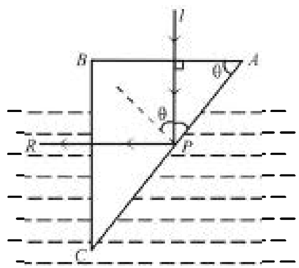
This combination behaves as a concave lens of focal length 30 cm.
Since $F_v < F_r$.
$\therefore$ One sees coloured pattern with violet colour at the outer edge.

C. MCQs with ONE Correct Answer

1. **(a)** **NOTE :**
When the ray enters a glass slab from air, its frequency remains unchanged.
Since glass slab in an optically denser medium, the velocity of light decreases and therefore we can conclude that the wavelength decreases.
$(\because\ v = \nu\lambda)$

2. **(a)** The phenomenon of total internal reflection takes place during reflection at P.

$$\sin\theta = \frac{1}{{}_g^w\mu} \qquad ...(i)$$



Now, ${}_g^w\mu = \frac{{}_g^a\mu}{{}_w^a\mu} = \frac{1.5}{4/3} = 1.125 \quad \therefore \sin\theta = \frac{1}{1.125} = \frac{8}{9}$

$\therefore$ sin θ should be greater than $\frac{8}{9}$.

3. (d) $\beta = \frac{\lambda D}{d},\ \beta' = \frac{\lambda(2D)}{d/2} = 4\frac{\lambda D}{d} = 4\beta$

4. (a) $C = \text{Sin}^{-1}\left(\frac{1}{{}_2^1\mu}\right)$ ..... (i)

Applying Snell's law at *P*, we get

$${}_2^1\mu = \frac{\sin r'}{\sin i} = \frac{\sin(90-r)}{\sin r} \qquad [\because i = r; r' + r = 90°]$$

$$\therefore \quad {}_2^1\mu = \frac{\cos r}{\sin r} \qquad ...(ii)$$

From (i) and (ii)

$C = \sin^{-1}(\tan r)$

5. (c) Let $I_1 = I$ and $I_2 = 4I$

$$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = \left(\sqrt{I} + \sqrt{4I}\right)^2 = \left(3\sqrt{I}\right)^2 = 9I$$

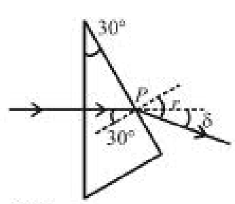
$$I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2 = \left(\sqrt{I} - \sqrt{4I}\right)^2 = I$$

6. (c) Spherical aberration occurs due to the inability of a lens to converge marginal rays of the same wavelength to the focus as it converges the paraxial rays. This can be done by using a circular annular mask over the lens.

7. (d) The distance between the first dark fringe on either side of the central maximum = width of central maximum

$$= \frac{2D\lambda}{a} = \frac{2\times 2\times 600\times 10^{-9}}{10^{-3}} = 2.4\times 10^{-3}\,\text{m} = 2.4\,\text{mm}$$

8. (c) Applying Snell's law at *P*,



$$\mu = \frac{\sin r}{\sin 30°}$$

$$\sin r = \frac{1.44}{2} = 0.72$$

$\therefore \quad \delta = r - 30° = \sin^{-1}(0.72) - 30°$

$\therefore$ The rays make an angle of

$2\delta = 2[\sin^{-1}(0.72) - 30°]$ with each other.

9. (c) **NOTE :** A convex mirror and a concave lens always produce virtual image.

Therefore, option (b) and (d) are not correct. The image by a convex lens is diminished when the object is placed beyond 2*f*.

Let $u = 2f + x$

Using $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} - \frac{1}{-(2f+x)} = \frac{1}{f}$

$$\Rightarrow \frac{1}{v} = \frac{1}{f} + \frac{1}{2f+x} = \frac{2f+x-f}{f(2f+x)} = \frac{(f+x)}{f(2f+x)}$$

But $u + v = 1$ (given)

$$(2f+x) + \frac{f(2f+x)}{f+x} \le 1$$

$$2f + x\left[1 + \frac{f}{f+x}\right] \le 1 \Rightarrow \frac{(2f+x)^2}{f+x} \le 1$$

$\Rightarrow (2f+x)^2 \le f + x$. The above is true for $f < 0.25$ m.

10. (a) Here $f_o = 2$ cm and $f_e = 3$ cm.

Using lens formula for eye piece

$$\Rightarrow \frac{-1}{u_e} + \frac{1}{\infty} = \frac{1}{3} \Rightarrow u_e = -3\text{ cm}$$

But the distance between objective and eye piece is 15 cm (given)

$\therefore$ Distance of image formed by the objective $= v = 15 - 3 = 12$ cm.

Let u be the object distance from objective, then for objective lens

$$-\frac{1}{u_0} + \frac{1}{v_0} = \frac{1}{f_0} \text{ or } \frac{-1}{u} + \frac{1}{12} = \frac{1}{2}$$

$$\Rightarrow \frac{-1}{u} = \frac{1}{2} - \frac{1}{12} = \frac{5}{12},\ u = -\frac{12}{5} = -2.4\text{ cm}$$

11. (c) Path difference between the opposite edges is λ.

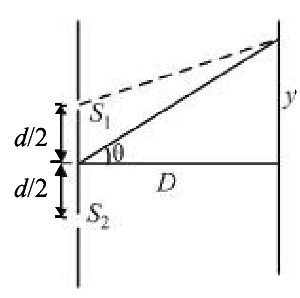
For a phase difference of 2π we get a path diff. of λ.

12. (c) We know that

$$I(\theta) = I_0\cos^2\frac{\delta}{2} \text{ where } \delta = \frac{2\pi d\tan\theta}{\lambda}$$

$$I(\theta) = I_0\cos^2\left(\frac{\pi d\tan\theta}{\lambda}\right) = I_0\cos^2\left(\frac{\pi\times 150\times\tan\theta}{3\times 10^8/10^6}\right)$$

$$= I_0\cos^2\left(\frac{\pi}{2}\tan\theta\right)$$



For $\theta = 30°; I(\theta) = I_o \cos^2\left(\frac{\pi}{2\sqrt{3}}\right)$

For $\theta = 90°; I(\theta) = I_o \cos^2(\infty)$

For $\theta = 0°$

$I(\theta) = I_0$

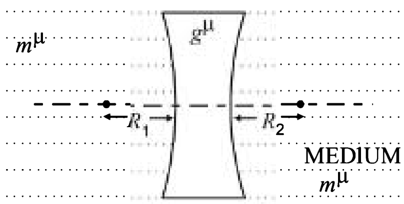
$I(\theta)$ is not constant.

Alternatively, when θ is zero the path difference between wave originating from S_1 and that from S_2 will be zero. This corresponds to a maxima.

13. (a) $\frac{1}{f} = \left({}_g^m\mu - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ Now, ${}_g^m\mu = \frac{{}_g\mu}{{}_m\mu} = \frac{1.5}{1.75}$

For concave lens as shown in figure in this case

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



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

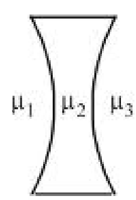
$\Rightarrow \quad f = +3.5R$

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

14. (d) For diffraction pattern to be observed, the dimension of slit should be comparable to the wave length of rays. The wavelength of X-rays (1 – 100 Å) is less than 0.6mm.

15. (a) Locus of equal path difference are lines running parallel to axis of the cylinder. Hence straight fringes will be observed.

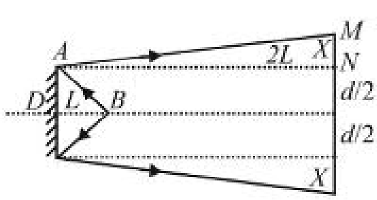
16. (d) $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$



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.

17. (d) From the ray diagram.



In ΔANM and ΔADB

$\angle ADB = \angle ANM = 90°$

$\angle MAN = \angle BAN$ (laws of reflection)

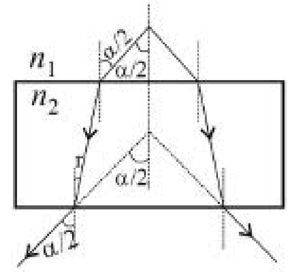
Also $\angle BAN = \angle ABD \quad \Rightarrow \quad \angle MAN = \angle ABD$

$\therefore \quad \Delta ANM$ is similar to ΔADB

$\therefore \quad \frac{x}{2L} = \frac{d/2}{L}$ or $x = d$

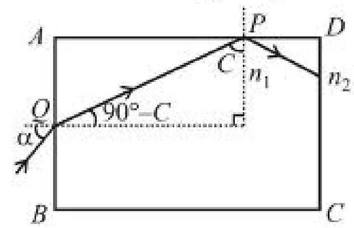
So, required distance $= d + d + d = 3d$.

18. (b)



The incident and emergent ray of a glass slab are parallel therefore, the angle remains the same.

19. (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*

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

Applying Snell's law at *Q*

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

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

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

20. (a) When slits are of equal width.

$I_{max} \propto (a + a)^2 \; (= 4a^2)$

$I_{min} \propto (a - a)^2 \; (= 0)$

When one slit's width is twice that of other

$\frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{a^2}{b^2} \Rightarrow \frac{W}{2W} = \frac{a^2}{b^2} \Rightarrow b = \sqrt{2}a$

$\therefore \quad I_{max} \propto (a + \sqrt{2}a)^2 = (5.8\,a^2)$

$I_{min} \propto (\sqrt{2}a - a)^2 = (= 0.17\,a^2)$

21. (c) **NOTE :** The intermediate image in compound microscope is real, inverted and magnified.

22. (b) $I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$ ...(1)

Applying eq. (1) when phase difference is $\pi/2$

$I_{\pi/2} = I + 4I \Rightarrow I_{\pi/2} = 5I$

Again applying eq. (1) when d phase difference is π

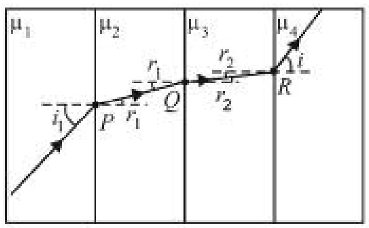
$I_\pi = I + 4I + 2\sqrt{I}\sqrt{4I}\cos\pi$

$\therefore \quad I_\pi = I \quad \therefore I_{\pi/2} - I_\pi = 4I$

23. **(b)** $\frac{12\lambda_1 D}{d} = \frac{k\lambda_2 D}{d}$, $k = \frac{12 \times 600}{400} = 18$

24. **(d)** Applying Snell's law at P,

$$^1\mu_2 = \frac{\sin i}{\sin r_1} = \frac{\mu_2}{\mu_1} \quad ...(1)$$



Applying Snell's law at Q,

$$^2\mu_3 = \frac{\sin r_1}{\sin r_2} = \frac{\mu_3}{\mu_2} \quad ...(2)$$

Again applying Snell's law at R

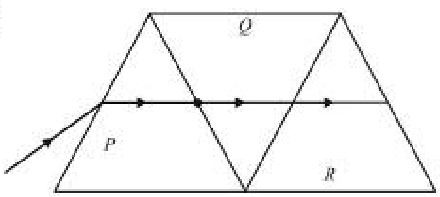
$$^3\mu_4 = \frac{\sin r_2}{\sin i} = \frac{\mu_4}{\mu_3} \quad ...(3)$$

Multiplying (i), (ii) and (iii), we get

$\mu_4 = \mu_1$

NOTE : If the emergent ray is parallel to incident ray after travelling a number of parallel interfaces then the refractive index of the first and the last medium is always same.

25. **(c)**



There will be no refraction from P to Q and then from Q to R (all being identical). Hence the ray will now have the same deviation.

26. **(b)** For the image of point P to be seen by the observer, it should be formed at point Q.

In ΔQNS,

$NS = QS = 2h$

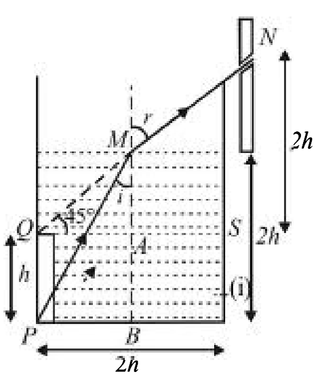
$\therefore \angle NQS = 45°$

$\therefore r = 45°$

Now in ΔQMA,

$\angle MQA = 45°$

$\therefore MA = QA = h$



$$^1_2\mu = \frac{\sin r}{\sin i} = \frac{\sin 45°}{\sin i}$$

In ΔPMB,

$PM^2 = 4h^2 + h^2 = 5h^2$

$$\therefore \quad \sin i = \frac{h}{\sqrt{5}h} = \frac{1}{\sqrt{5}} \quad ...(ii)$$

From (i) and (ii)

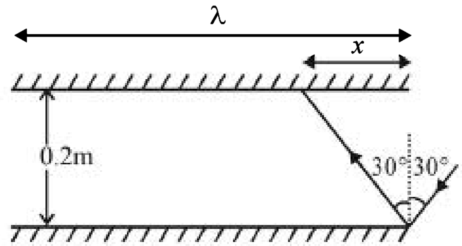
$$^1_2\mu = \sqrt{\frac{5}{2}}$$

27. **(c)** Since both surfaces have same radius of curvature on the same side, no dispersion will occur.

28. **(a)** Path difference $= (\mu - 1)\,t = n\lambda$;
For minimum $t, n = 1$; $\therefore t = 2\lambda$

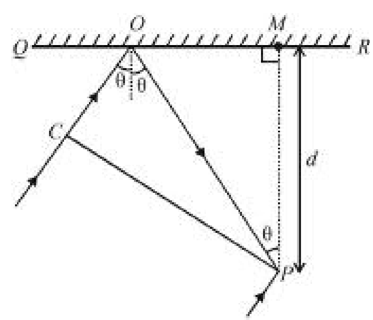
29. **(b)** Maximum number of reflection $= \frac{2\sqrt{3}}{x}$

where $x = 0.2 \tan 30° = 0.2/\sqrt{3}$.



30. **(b)** In $\Delta\, OPM$, $OP = \frac{d}{\cos\theta}$

In ΔCOP, $OC = \frac{d\cos 2\theta}{\cos\theta}$



Path difference between the two rays reaching P is

$$= CO + OP + \frac{\lambda}{2} = \frac{d\cos 2\theta}{\cos\theta} + \frac{d}{\cos\theta} + \frac{\lambda}{2}$$

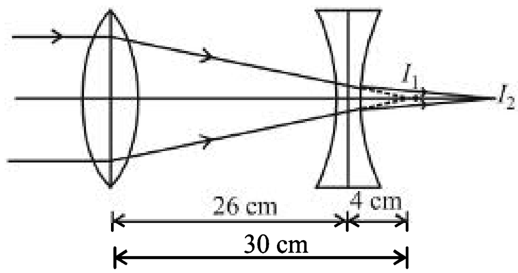
$$= \frac{d}{\cos\theta}(\cos 2\theta + 1) + \frac{\lambda}{2} = 2d\cos\theta + \frac{\lambda}{2}$$

For constructive interference, path difference should be $n\lambda$

$$\therefore \quad 2d\cos\theta + \frac{\lambda}{2} = n\lambda \Rightarrow \cos\theta = \frac{(2n-1)}{4}\frac{\lambda}{d}$$

For $n = 1$, $\cos\theta = \frac{\lambda}{4d}$

31. (b) Convex lens forms the image at I_1. I_1 is at the second focus of convex lens. Size of $I_1 = 2$ cm.
I_1 acts as virtual object for concave lens. Concave lens forms the image of I_1 and I_2.



For concave lens,

$$\frac{1}{v}-\frac{1}{4}=-\frac{1}{20} \text{ or } \frac{1}{v}=-\frac{1}{20}+\frac{1}{4}=\frac{4}{20}=\frac{1}{5}$$

or $v = 5$ cm = Distance of I_2 from concave lens.

$$\therefore \quad \text{Magnification} = \frac{v}{u}=\frac{\text{size of image}}{\text{size of object}}=\frac{5}{4}$$

$$\text{or} \quad \frac{\text{size of image}}{2}=1.25$$

or size of image due to concave lens = 2.5 cm

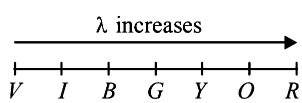
32. (b) $\mu_g \sin i = \mu_{air} \sin 90°$

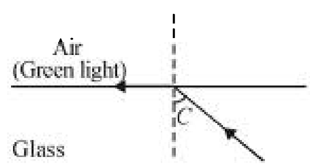
$$\mu_g = \frac{1}{\sin i}$$

34. (c) **KEY CONCEPT :** $\sin C = \frac{1}{\mu}$ and $\mu \propto \frac{1}{\lambda}$

$\therefore \quad \sin C \propto \lambda$

For higher value of λ, the angle C also increases





34. (b) **NOTE :** For minimum deviation, incident angle is equal to emerging angle and QR is parallel to base.

35. (d) At the area of total darkness minima will occur for both the wavelengths.

$$\therefore \quad \frac{(2n+1)}{2}\lambda_1=\frac{(2m+1)}{2}\lambda_2 \Rightarrow (2n+1)\lambda_1=(2m+1)\lambda_2$$

$$\text{or} \quad \frac{(2n+1)}{(2m+1)}=\frac{560}{400}=\frac{7}{5} \text{ or } 10n=14m+2$$

by inspection for $m = 2$, $n = 3$ and for $m = 7$, $n = 10$, the distance between them will be the distance between such points.

$$\text{i.e.,} \quad \Delta s=\frac{D\lambda_1}{d}\left\{\frac{(2n_2+1)-(2n_1+1)}{2}\right\}$$

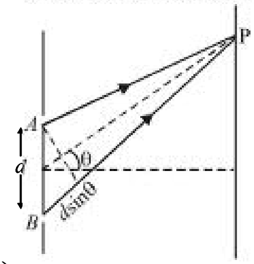
put $n_2 = 10, n_1 = 3$

On solving we get, $\Delta s = 28$mm.

36. (c) **NOTE :** Frequency does not change with change of medium.

37. (a) The rays coming from the point object fall on the glass-air interface normally and hence pass undeviated. Therefore if we retrace the path of the refracted rays backwards, the image will be formed at the centre only.

38. (c) $I = I_{max}\cos^2\frac{\pi d\sin\theta}{\lambda}$



$$\Rightarrow \quad \frac{I_{max}}{4}=I_{max}\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$$

$$\therefore \quad \cos\frac{\pi d\sin\theta}{\lambda}=\frac{1}{2} \quad \therefore \quad \frac{\pi d\sin\theta}{\lambda}=\frac{\pi}{3}$$

$$\therefore \quad \theta=\sin^{-1}\left(\frac{\lambda}{3d}\right)$$

39. (a) $\frac{|f_1|}{|f_2|}=\frac{2}{3}$

f_1 : focal length of convex lens.

$$\frac{1}{f}=\frac{1}{f_1}-\frac{1}{f_2} \Rightarrow \frac{1}{30}=\frac{1}{f_1}-\frac{2}{3f_1}$$

$f_1 = 10$ cm, $f_2 = -15$ cm

40. (c) The image I' for first refraction (i.e., when the ray comes out of liquid) is at a depth of

$$=\frac{33.25}{1.33}=25\text{cm} \left[\because \text{ Apparent depth} = \frac{\text{Real depth}}{\mu}\right]$$

Now, reflection will occur at concave mirror. For this I' behaves as an object.

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

$$\text{and } v=-\left[15+\frac{25}{1.33}\right]$$

Where $\frac{25}{1.33}$ is the real depth of the image.

Using mirror formula we get

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}, \quad f = -18.31 \text{ cm}$$

41. (b) The focal length f of the equivalent mirror is

$$\frac{1}{f}=\frac{2}{f_1}+\frac{1}{f_m}=\frac{2}{15}+\frac{1}{\infty} \Rightarrow f=\frac{15}{2}\text{cm}$$

Since f has a positive value, the combination behaves as a converging mirror.

Here $u = -20$cm, $f=-\frac{15}{2}$cm, $v = ?$

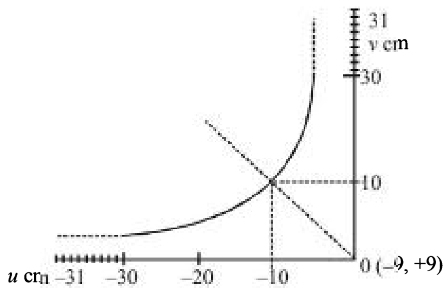
According to mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\Rightarrow \frac{1}{v}-\frac{1}{-20}=\frac{1}{-15/2} \Rightarrow v=-12$ cm

Negative sign indicates that the image is 12 cm in front of mirror.

42. (c) We know that in case of a convex lens when object is placed at C', the image is obtained at C. This situation is represented in the graph by the point corresponding to $u=-10$ cm, $v=10$ cm.

Therefore $R=10$ cm $\Rightarrow \frac{R}{2}=5\text{ cm}=f$



Lens formula is

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \Rightarrow \frac{\Delta f}{f^2}=\frac{\Delta v}{v^2}+\frac{\Delta u}{u^2}$$

(for maximum error in f)

$\Rightarrow \frac{\Delta f}{25}=\frac{0.1}{(10)^2}+\frac{0.1}{(10)^2}$ [$\Delta u=\Delta v=0.1$ from graph)

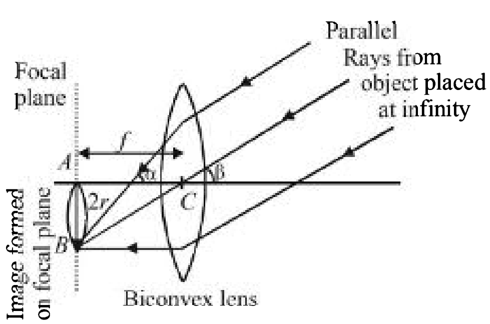
$\Rightarrow \Delta f=25\times 0.1\times 2\times 0.01=0.05$

Therefore, the focal length $=(5.00\pm 0.05)$ cm.

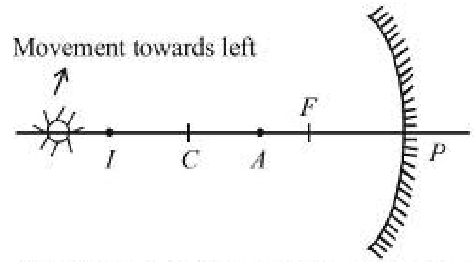
43. (b) From the figure in ΔABC, $\tan\beta=\frac{AB}{AC}$

$\Rightarrow AB=AC\tan\beta, 2r=f\tan\beta$

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

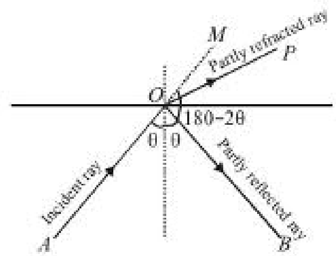


44. (b) As shown in the figure, when the object (A) is placed between F and C, the image (I) is formed beyond C. It is in this condition that when the student shifts his eyes towards left, the image appears to the right of the object pin. (Image distance > object distance)



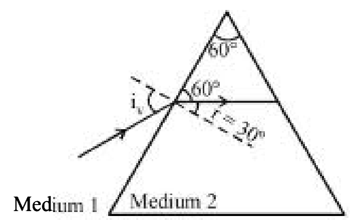
45. (c) The ray is partly reflected and partly refracted

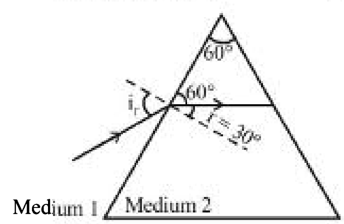
$\angle MOB=180-2\theta$



But the angle between refracted and reflected rays is $\angle POB$. Clearly is $\angle POB$ is less than $\angle MOB$.

46. (a)



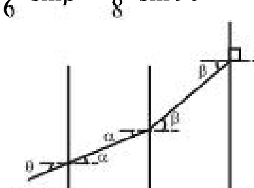


For minimum deviation the ray in the prism is parallel to the base of the prism. This condition does not depend on the colour (or wave length) of incident radiation. So in both the cases, by geometry, r = 30°. So (a) is correct option.

47. (b) For refraction at parallel interfaces

$$n_0 \sin\theta=\frac{n_0}{2}\sin\alpha=\frac{n_0}{6}\sin\beta=\frac{n_0}{8}\sin 90°$$

$\therefore \sin\theta=\frac{1}{8}$



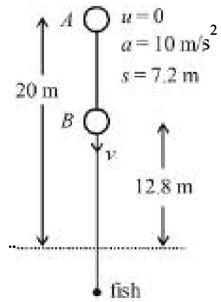
48. (c) Consider the activitiy A to B

Applying $v^2-u^2=2as$

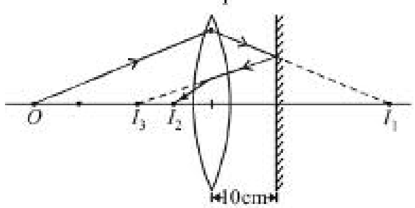
$v^2-0^2=2\times 10\times 7.2 \Rightarrow v=12$ m/s

The velocity of ball as perceived by fish is

$$v'={}_w\mu\times v=\frac{4}{3}\times 12=16\text{ m/s}$$



49. **(b)** Focal length of the biconvex lens is 15 cm. A small object is placed at a distance of 30cm from the lens i.e. at a distance of 2f. Therefore the image should form at 30cm from the lens at I_1.



But since the ray strike the plane mirror before reaching I_1, the image I_1 acts as the virtual object for reflection on plane mirror kept at a distance of 20 cm from it.

It should produce an image I_2 but as the ray encounters the lens, it gets refracted and the final image is formed at I_3. For the last refraction from the biconvex lens, $u = 10$ cm.

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

$$\Rightarrow \frac{1}{v}-\frac{1}{10}=\frac{1}{15} \Rightarrow \frac{1}{v}=\frac{1}{15}+\frac{1}{10}=\frac{25}{150}$$

$\Rightarrow v = 6$ cm.

Therefore a real image is formed at a distance of 16 cm from the plane mirror.

50. **(c)** When the light is incident on glass - an interface at an angle less than critical angle a small part of light will be reflected and most part will be transmitted.

When the light is incident greater than the critical angle, it gets completed reflected (total internal reflection) These characteristics are depicted in option (c).

51. **(b)** The focal length (f_1) of the lens with $n = 1.5$ is given by

$$\frac{1}{f_1}=(n_1-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$=(1.5-1)\left[\frac{1}{14}-\frac{1}{\infty}\right]=\frac{1}{28}$$

The focal length (f_2) of the lens with $n = 1.2$ is given by

$$\frac{1}{f_2}=(n_2-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$=(1.2-1)\left[\frac{1}{\infty}-\frac{1}{-14}\right]=\frac{1}{70}$$

The focal length F of the combination is

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{20}$$

Applying lens formula for the combination of lens

$$\frac{1}{V}-\frac{1}{U}=\frac{1}{F} \Rightarrow \frac{1}{V}-\frac{1}{-40}=\frac{1}{20}$$

$\Rightarrow$ V = 40 cm

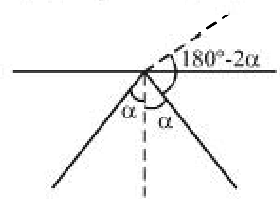
52. **(d)** We know that $\beta=\frac{\lambda D}{d}$

Now, $\lambda_R > \lambda_G > \lambda_B$

$\therefore$ $\beta_R > \beta_G > \beta_B$

53. **(a)** $$\cos(180°-2\alpha)=\frac{\left(\frac{\hat{i}}{2}+\frac{\sqrt{3}}{2}\hat{j}\right)\cdot\left(\frac{\hat{i}}{2}-\frac{\sqrt{3}}{2}\hat{j}\right)}{\sqrt{\left(\frac{1}{2}\right)^2+\left(\frac{\sqrt{3}}{2}\right)^2}\sqrt{\left(\frac{1}{2}\right)^2+\left(-\frac{\sqrt{3}}{2}\right)^2}}$$

$\therefore \cos(180°-2\alpha)=-\frac{1}{2}$



$\therefore$ 180° − 2α = 120°

$\therefore$ α = 30°

option (a) is correct

54. **(b)** The intensity I is given as

$I = I_o \cos^2\frac{\phi}{2}$ where I_o is the peak intensity

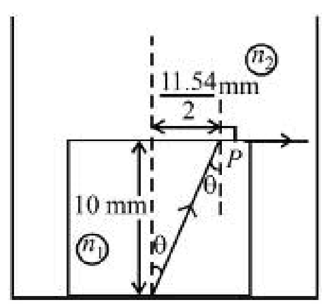
Here $I=\frac{I_o}{2}$, $\therefore \frac{I_o}{2}=I_o\cos^2\frac{\phi}{2}$ $\therefore \phi=\frac{\pi}{2}(2n+1)$

For a phase difference of 2π the path difference is λ

$\therefore$ For a phase difference of $(2n+1)\frac{\pi}{2}$ the path difference

is $(2n+1)\frac{\lambda}{4}$. option (b) is correct.

55. (c)



Applying Snell's law at point P

$n_1 \sin\theta = n_2 \sin 90°$

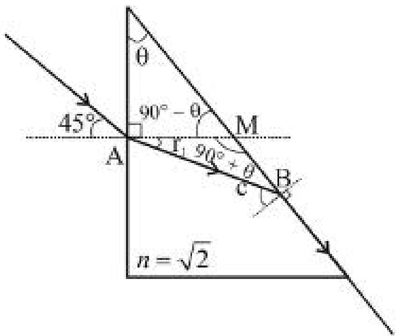
$$\therefore \quad n_2 = 2.72\times\frac{11.54/2}{\sqrt{(10)^2+\left(\frac{11.54}{2}\right)^2}}$$

$\therefore$ $n_2 = 1.36$

56. **(a)** Applying Snell's law at A

$1 \times \sin 45° = \sqrt{2} \times \sin r_1$

$\therefore r_1 = 30°$ ...(i)



Applying Snell's law at B

$\sqrt{2}\ \sin C = 1 \times \sin 90°$

$\therefore\ C = 45°$ ...(ii)

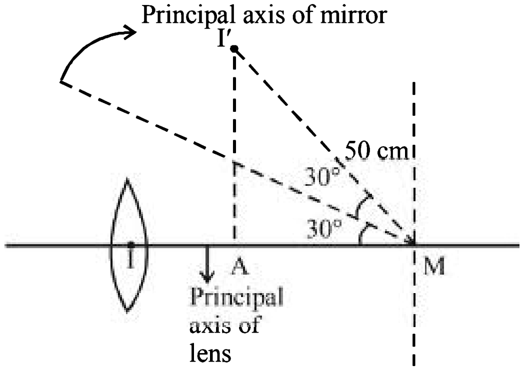
In $\Delta AMB,\ 90° + \theta + r_1 + (90° - C) = 180°$ (From fig.)

$\therefore\ \theta = 15°$

57. **(c)** *For lens* $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\frac{1}{v} - \frac{1}{-50} = \frac{1}{30}$

$\therefore\quad v = 75$ cm



Therefore object distance for mirror is 25 cm and object is virtual

For minor $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \therefore \frac{1}{v} + \frac{1}{25} = \frac{1}{50}$ $\therefore v = -50$ cm

The image I would have formed as shown had the mirror been straight. But here the mirror is tilted by 30°. Therefore the image will be tilted by 60° and will be formed at A.

Here $MA = 50 \cos 60° = 25$ cm

and $I'A = 50 \sin 60° = 25\sqrt{3}$ cm

D. MCQs with ONE or MORE THAN ONE Correct

1. **(b, d)** $\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1} + \sqrt{I_2})^2}{(\sqrt{I_1} - \sqrt{I_2})^2} = \frac{9}{1}$

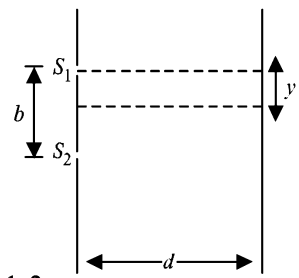
$\therefore\ \frac{I_1}{I_2} = 4 = \frac{a^2}{b^2} \Rightarrow \frac{a}{b} = 2$

2. **(a)** $P = \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{0.4} + \frac{1}{-0.25} = -1.5$ dioptre.

3. **(a, c)** Here $y = (2n-1)\frac{\lambda}{2}\frac{D}{d} = (2n-1)\frac{\lambda}{2}\frac{d}{b}$

$(\because d = b \text{ and } D = d)$

But $y = \frac{b}{2}$



$\therefore\ \frac{b}{2} = (2n-1)\frac{\lambda}{2}\frac{d}{b}$

$\Rightarrow\ \lambda = \frac{b^2}{(2n-1)d}$ when n = 1, 2

$\lambda = \frac{b^2}{d}, \frac{b^2}{3d}, ...$

4. **(b, d)** The image formed will be complete because light rays from all parts of the object will strike on the lower half. But since the upper half light rays are cut off, the intensity will reduce.

5. **(d)** $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}\quad \therefore -\frac{dv}{v^2} - \frac{du}{u^2} = 0$

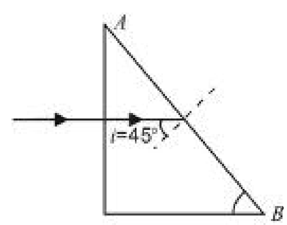
$\therefore\ \frac{dv}{du} = \frac{-v^2}{u^2} = -\left(\frac{f}{u-f}\right)^2$

$\therefore$ image length $= \left(\frac{f}{f-u}\right)^2 \times b$

6. **(a)** For total internal reflection

$\mu = \frac{1}{\sin C} = \frac{1}{\sin 45°} = 1.414$

i.e. for an angle of incidence of 45°, that colour will suffer total internal reflection for which the refractive index is less than 1.414.



Therefore, red light will be refracted at interface AB whereas blue and green light will suffer total internal reflection.

7. **(d)** In an astronomical telescope when the object and final image are at infinity, M and L are given as shown:
Angular magnification $M = f_o/f_e$
Seperation between lenses, $L = f_o + f_e$

$$\therefore \quad \frac{f_o}{f_e} = 5 \text{ or } f_o = 5f_e. \quad \text{...(i)}$$

$$f_o + f_e = 36 \text{ or } 5f_e + f_e = 36$$

or $f_e = 6$ cm ...(ii)

$\therefore \quad f_o = 5f_e$ or $f_o = 30$ cm

Hence $f_o = 30$ cm, $f_e = 6$ cm

8. **(c)** The angle of deviation for the first prism P_1

$\delta_1 = (\mu_1 - 1)A_1$

The angle of deviation for the second prism P_2

$\delta_2 = (\mu_2 - 1)A_2$

Since total deviation is to be zero

$\therefore \quad \delta_1 + \delta_2 = 0$

$\Rightarrow \quad (\mu_1 - 1)A_1 + (\mu_2 - 1)A_2 = 0$

$$\Rightarrow \quad A_2 = \frac{-(1.54-1)}{(1.72-1)}4° = -3°$$

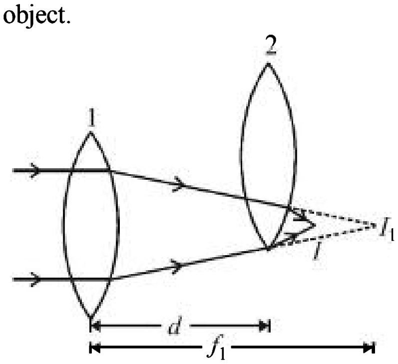
9. **(a, b, c, d)** In case of an astronomical telescope the distance between the objective lens and eyepiece lens

$= f_0 + f_e = 16 + 0.02 = 16.02$ m

$$\text{The angular magnification} = -\frac{f_{objective}}{f_{eye piece}} = \frac{-16}{0.02} = -800$$

NOTE : The image seen by the astronomical telescope is inverted. Also the objective lens is larger than eye piece lens.

10. **(c)** The image I_1 of parallel rays formed by lens 1 will act as virtual object.



Applying lens formula for lens 2

$$\Rightarrow \quad \frac{1}{v_2} - \frac{1}{f_1 - d} = \frac{1}{f_2} \Rightarrow v_2 = \frac{f_2(f_1-d)}{f_2+f_1-d}$$

$\therefore$ The horizontal distance of the image I from O is

$$x = d + \frac{f_2(f_1-d)}{f_2+f_1-d} = \frac{f_1f_2 + d(f_1-d)}{f_1+f_2-d}$$

To find the y-coordinate, we use magnification formula for lens 2

$$m = \frac{v_2}{u_2} = \frac{\frac{f_2(f_1-d)}{f_1+f_2-d}}{f_1-d} = \frac{f_2}{f_1+f_2-d}$$

$$\text{Also } m = \frac{h_2}{\Delta} \Rightarrow h_2 = \frac{\Delta \times f_2}{f_1+f_2-d}$$

$\therefore$ The y-coordinate $y = \Delta - h_2$

$$= \Delta - \frac{\Delta f_2}{f_1+f_2-d} = \frac{\Delta(f_1-d)}{f_1+f_2-d}$$

11. **(b, c) NOTE :** Concave lens and convex mirror are diverging in nature. Therefore the refracted/reflected rays do not meet. These rays are produced backwards to make them meet. Therefore the image formed is virtual and erect.

12. **(b)** Spherical aberation is smaller when the curved surface is facing the object because the total deviation is shared between the two surfaces.

13. **(c, d) KEY CONCEPT :** For total internal reflection to take place :

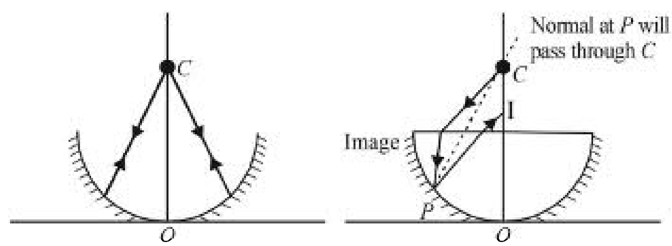
Angle of incidence $i >$ critical angle, θ_c

$$\text{or} \sin 45° > \frac{1}{n} \text{ or } \frac{1}{\sqrt{2}} > \frac{1}{n} \text{ or } n > \sqrt{2} \text{ or } n > 1.414.$$

Therefore, possible values of n can be 1.5 or 1.6 in the given options.

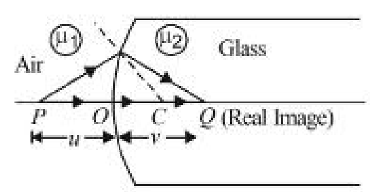
14. **(d)** For first minima the path difference between the rays coming from the two edges should be λ which corresponds to a phase difference of 2π.

15. **(d)** The ray diagram is shown in figure. Therefore, the image will be real and between C and O.



16. **(a)** The formula for spherical refracting surface is

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

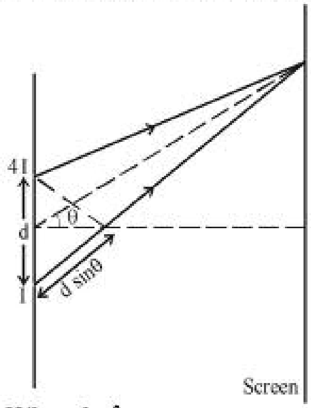


Here $u = -x$, $v = +x$, $R = +R$, $\mu_1 = 1$, $\mu_2 = 1.5$

$$\frac{-1}{-x} + \frac{1.5}{x} = \frac{1.5-1}{R} \Rightarrow x = 5R$$

17. (a,b) The condition to obtain maxima in the phenomenon observed in young's double slit experiment is

$d\sin\theta = n\lambda$ where n is an integer



When d = λ

$$\lambda \sin\theta = n\lambda$$

$$\Rightarrow \quad \sin\theta = n$$

When n = 0, $\theta = 0$

When n = 1, $\theta = 90°$ (This will be a point on the screen which will be at infinity and therefore not practical)

Other values of n are invalid as $-1 \le \sin\theta \le 1$.

⇒The screen will have only one maxima.

When $\lambda < d < 2\lambda$

$$\Rightarrow \lambda < \frac{n\lambda}{\sin\theta} < 2\lambda \qquad \left[\because d = \frac{n\lambda}{\sin\theta}\right]$$

$$\Rightarrow 1 < \frac{n}{\sin\theta} < 2$$

The possible values of n are 0, +1, –1.

⇒There is at least one more maxima (besides the central maxima, option [B] is correct.

We know that

$$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2, \; I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$$

Initially $I_1 = 4I$ and $I_2 = I$

$\therefore \quad I_{max} = 9I$ and $I_{min} = I$

When $I_1 = I_2 = I$ then $I_{max} = 4I$ and $I_{min} = 0$

i.e., when the intensities become equal, I_{min} reduces to zero. Options [C] and [D] are incorrect.

18. (c, d) Given $f = -24$ cm

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

For (66, 33)

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-24} + \frac{1}{66} = \frac{-66+24}{24\times 66} = \frac{-42}{24\times 66}$$

$$\Rightarrow \quad v = -\frac{24\times 66}{42} = -37.7$$

But the value of $v = 33$. The absolute error is 37.7 – 33 = 4.7 cm which is greater than 0.2 cm. Therefore a wrong reading.

For (78, 39) when $u = 78$ then

$$\frac{1}{v} + \frac{1}{-78} = \frac{1}{-24}$$

$$\Rightarrow \quad v = -34.67$$

The absolute error is 39 – 34.67 = 4.33 which is greater than 0.2 cm.

19. (a,b,c)

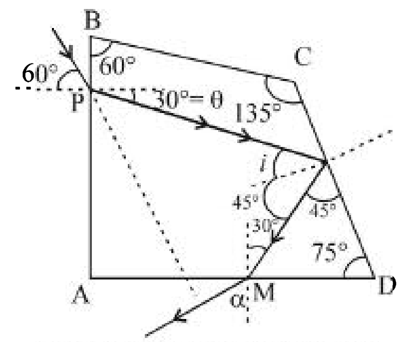
Applying Snell's law at P

$n_1 \sin 60° = n_2 \sin\theta$

$\Rightarrow \sin 60° = \sqrt{3}\sin\theta$

$\Rightarrow \theta = 30°$

In quadrilateral BCQP,



$60° + (90° + 30°) + 135° + \angle PQC = 360°$

$\Rightarrow \angle PQC = 45° \quad \Rightarrow i = 45°$

The critical angle for prism - air pair of media is

$C = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$ which is less than 45°.

Therefore total internal reflection takes place at face CD.

option (a) is correct.

In ΔQDM, $\angle QMD = 180° - (45° + 75°) = 60°$

Therefore the angle of incidence of ray QM on AD is 30°.

This angle is less than the critical angle. Therefore the ray emerges out of face AD.

Option (b) is correct.

Applying Snell's law at M, we get

$$\sqrt{3}\sin 30° = 1\times\sin\alpha \Rightarrow \alpha = \sin^{-1}\frac{\sqrt{3}}{2} = 60°$$

In quadrilateral PQMN, $\angle PNM = 360° - [60° + 90° + 120°] = 90°$

∴ The angle between the incident ray and the emergent ray is 90°

Option (c) is correct.

20. (a, c) There will be no effect of the transparent thin film of uniform thickness and refractive index $n_1 = 1.4$

Therefore, $-\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$ [For case (i)]

$$\Rightarrow \quad -\frac{1}{\infty} + \frac{1.5}{f_1} = \frac{1.5-1}{R} \Rightarrow f_1 = 3R$$

∴ (a) is a correct option

Again applying $-\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$ [For case (ii)]

$$-\frac{1.5}{\infty}+\frac{1}{f_2}=\frac{1-1.5}{-R}\Rightarrow f_2=2R$$

$\therefore$ (c) is a correct option.

21. (a, b, c)

We know that $\beta=\dfrac{\lambda D}{d}$

As $\lambda_2>\lambda_1 \therefore \beta_2>\beta_1$ $\quad\therefore$ (a) is correct option.
Therefore $m_1>m_2$ $\quad\therefore$ (b) is correct option.

As $3\times\dfrac{\lambda_2 D}{d}=\dfrac{(2\times5-1)\lambda_1}{2}\dfrac{D}{d}$

$3\times600=4.5\times400$ $\quad\therefore$ (c) is correct option.

The angular width = $\dfrac{\lambda}{d}$ $\quad\therefore$ (d) is incorrect option.

22. (b) For refraction in S_1

$$-\frac{n_1}{u}+\frac{n_2}{v}=\frac{n_2-n_1}{R}\Rightarrow-\frac{1.5}{-50}+\frac{1}{V}=\frac{1-1.5}{-10}$$

$\Rightarrow v=50$ cm.

For refraction in S_2

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

$$-\frac{1}{-(d-50)}+\frac{1.5}{\infty}=\frac{1.5-1}{10}$$

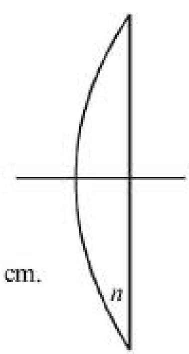
$$\therefore\quad \frac{1}{d-50}=\frac{1}{20}$$

$\therefore\quad d=70$ cm.

B is the correct option.

23. (a, d)

For lens



$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{v}-\frac{1}{-30}=\frac{1}{f}$$

Also $m=\dfrac{v}{u}\Rightarrow-2=\dfrac{v}{u}$

On solving we get $f=+20$ cm and $v=60$ cm.

For reflection

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{R}\Rightarrow\frac{1}{10}+\frac{1}{-30}=\frac{2}{R}\Rightarrow R=30\,\text{cm}$$

The image formed by convex side is faint erect and virtual.

By lens maker formula

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

$$\therefore\ \frac{1}{20}=\left(\frac{n_l}{1}-1\right)\left(\frac{1}{30}\right)\ \therefore n_l=2.5$$

24. (a, c, d)

$n_1\sin\theta_i=n_2\sin\theta_f$ [$\because$ 1 and 2 interfaces are parallel]

l depends on the refractive index of transparent slab but not on n_2. In fact θ_f depends on n_2.

25. (b,d)

Path difference at O = d = 0.6003mm

Now, = mm = 300×10^{-6} mm

For n = d we get n = 2001

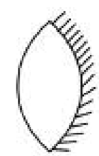
As n is a whole number, the condition for minima is satisfied.

Therefore 'O' will be dark.

Also, as the screen is perpendicular to the plane containing the slits, therefore fringes obtained will be semi-circular (Top half of the screen is available)

E. Subjective Problems

1. The focal length of the equivalent mirror is



$$\frac{1}{F}=\frac{2}{f}+\frac{1}{f_m}$$

$$=\frac{2}{20}+\frac{2}{22}=\frac{1}{10}+\frac{1}{11}=\frac{21}{110}$$

$$\Rightarrow\quad F=\frac{110}{21}$$

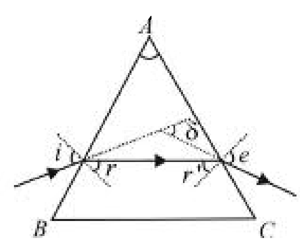
NOTE : Since the focal length is positive it is a converging mirror

Now, $\dfrac{1}{u}+\dfrac{1}{v}=\dfrac{1}{f}\quad\Rightarrow\quad\dfrac{1}{-10}+\dfrac{1}{v}=\dfrac{1}{-110/21}$

$\Rightarrow\quad\dfrac{1}{v}=\dfrac{1}{10}-\dfrac{21}{110}\quad\Rightarrow\quad v=-11$cm

NOTE : The negative sign indicates the image is real.

2. The situation can be shown as in the figure.



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

We know that, $A+\delta=i+e$ ....(1)

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

From (1),

$e=A+\delta-i=30°+30°-60°=0$

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

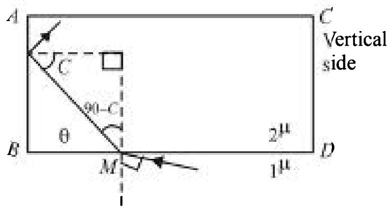
When $e=0$, $r'=0$

$\therefore\quad$ From (2), $A=r=30°$.

From Snell's law, refractive index of prism,

$$\mu=\frac{\sin i}{\sin r}=\frac{\sin 60°}{\sin 30°}=\frac{\sqrt{3}/2}{1/2}=\sqrt{3}=1.732.$$

3.



For a grazing incident ray at *BD* for which i ≈ 90° the angle of refraction (90 – *C*) is maximum. For this *C* is least. Let *C* is greater than the critical angle.
Applying Snell's law at *M*

$$ {}_2^1\mu = \frac{\sin 90^\circ}{\sin(90-C)} \Rightarrow {}_2^1\mu = \frac{1}{\cos C} \qquad ...(i)$$

Also $ {}_2^1\mu = \dfrac{1}{\sin C}$ ...(ii)

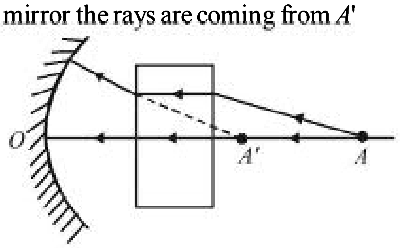
When *C* is the critical angle.

From (i) and (ii), $\dfrac{1}{\cos C} = \dfrac{1}{\sin C} \Rightarrow C = 45^\circ$

$\therefore \quad {}_2^1\mu = \dfrac{1}{\sin 45^\circ} = \sqrt{2} = 1.41$

4. For case (i), there is no refraction. Therefore $\mu_1 = \mu$
NOTE : Here the convex lens behaves as a diverging lens. Therefore, $\mu < \mu_2$.

5. 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 $AA' = \text{shift} = t\left(1 - \dfrac{1}{\mu}\right)$

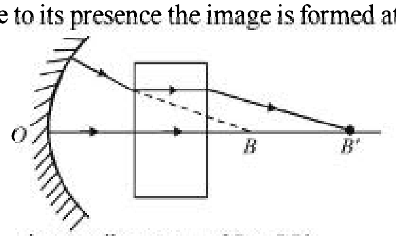
Therefore the object distance

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

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

$$\therefore \quad v = \frac{uf}{u-f} = \frac{20 \times 5}{20-5} = \frac{20}{3}\text{cm} = 6.67\text{cm}$$

The reflected rays again pass 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*'.

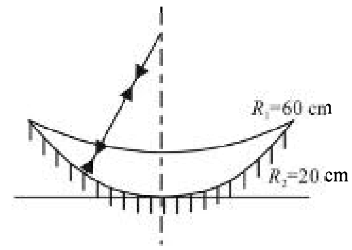


Therefore image distance = *OB* + *BB*'

$$\frac{20}{3} + t\left(1 - \frac{1}{\mu}\right), \ \frac{20}{3} + 1 = \frac{23}{3} = 7.67\,\text{cm}$$

6. (i) **KEY CONCEPT :** The given silvered concavo-convex lens behaves like a mirror whose focal length can be calculated by the formula $\dfrac{1}{f} = \dfrac{2}{f_1} + \dfrac{1}{f_2}$

f_1 = focal length of concave surface.
f_2 = focal length of concave mirror



$\therefore \quad \dfrac{1}{f} = \dfrac{2}{-30} + \dfrac{1}{-10} = -\dfrac{4}{30}$

$\therefore \quad f = -7.5\,\text{cm}$

Using mirror formula

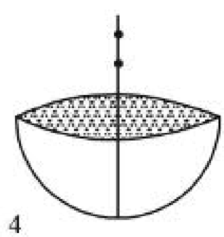
$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{-7.5} = \frac{1}{-x} + \frac{1}{-x}$$

$x = 15\,\text{cm}$

(ii) Let the object distance be *u*. When water is poured over the concave surface the apparent object distance will be *v* then

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

For flat surface $R = \infty$



$$\therefore \quad -\frac{\mu_1}{u} + \frac{\mu_2}{v} = 0$$

$$\Rightarrow \quad v = u\frac{\mu_2}{\mu_1} = u \times {}_2^1\mu = u \times \frac{4}{3}$$

Since the ray enters the lens from water into glass

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

$$\Rightarrow \quad \frac{-4/3}{\frac{4}{3}u} + \frac{1.5}{-20} = \frac{1.5 - 4/3}{-60} \quad \Rightarrow \quad u = -13.85\,\text{cm}$$

$\therefore$ Downward shift = 15 – 13.85 = 1.15 cm.

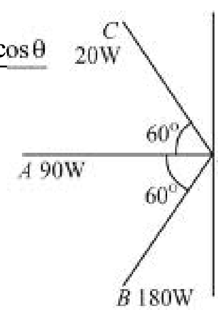
7. The total intensity at point P will be

$= I_A + I_B + I_C$

$$I_A = \frac{(\text{Illumination power}) \times \cos\theta}{4\pi r^2}$$

$$= \frac{90 \times \cos 0}{4\pi \times 3^2}$$

$$= \frac{10}{4\pi}\text{watt/m}^2$$

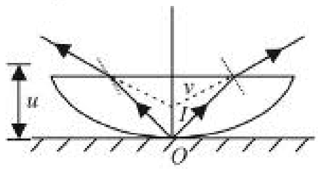


$$I_B = \frac{180 \times \cos 60°}{4\pi \times (1.5)^2} = \frac{10}{\pi} \text{watt}/\text{m}^2$$

$I_C = 20 \cos 60° = 10$

$$\therefore \quad I_P = \frac{10}{4\pi} + \frac{10}{\pi} + 10 = 13.9 \text{W}/\text{m}^2$$

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



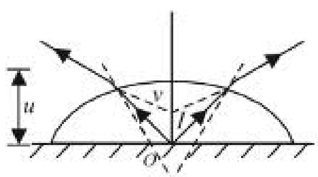
$$-\frac{\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} \Rightarrow -\frac{\mu_1}{-4} + \frac{\mu_2}{-3} = 0$$

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

Again applying

$$-\frac{\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} \Rightarrow -\frac{1}{u} + \frac{\mu_2/\mu_1}{v} = \frac{(\mu_2/\mu_1) - 1}{R}$$

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



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

Applying Len's maker formula,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{4}{3} - 1\right)\left(\frac{1}{25} - \frac{1}{\infty}\right) \therefore f = 75\text{cm}$$

9. (i) The distance of the nth bright fringe from the central maxima is given by the expression

$$y_n = \frac{n\lambda D}{d}, \text{ For 3rd bright fringe } n = 3$$

$$\therefore \quad y = \frac{3 \times 6500 \times 10^{-10} \times 120 \times 10^{-2}}{2 \times 10^{-3}} = 1.17 \times 10^{-3} \text{ m}$$

(ii) Let nth bright fringe of wavelength 6500 Å coincide with mth bright fringe of wavelength 5200Å. Their distance will be same from the central bright. Therefore,

$$\frac{n\lambda_1 D}{d} = \frac{m\lambda_2 D}{d} \quad \therefore \quad \frac{n}{m} = \frac{5200}{6500} = \frac{4}{5}$$

i.e., at the least distance 4th bright fringe of 6500 Å will coincide with 5th bright fringe of 5200 Å. Its distance from the central maxima will be

$$y_n = \frac{4 \times 6500 \times 10^{-10} \times 120 \times 10^{-2}}{2 \times 10^3} = 1.56 \times 10^{-3} \text{m}$$

10. **KEY CONCEPT :** For total internal reflection, the conditions are

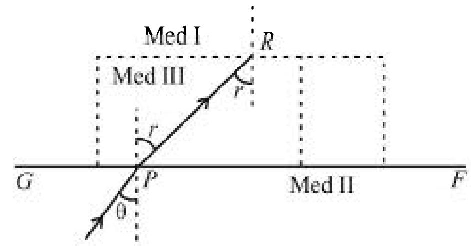
- The object should be in the denser medium.
- The angle of incidence should be greater than the critical angle

Case (i) : When $n_3 < n_1$

Obviously $n_3 < n_2$ and the angle θ is greater than the critical angle required for the ray passing from medium II to medium III. Therefore total internal reflection will also take place when a ray strikes with the same angle at the interface of medium II and medium III.

Case (ii) : $n_3 > n_1$ but $n_3 < n_2$

The ray will get refracted in medium III as the angle θ will now be less than the critical angle required for medium II and medium III pair.



$$\therefore \quad \frac{\sin\theta}{\sin r} = \frac{n_3}{n_2} \quad \text{(Applying Snell's law at } P)$$

$$\therefore \quad \sin r = \frac{n_2}{n_3} \sin\theta$$

As $n_2 > n_3$ So, $r > \theta$

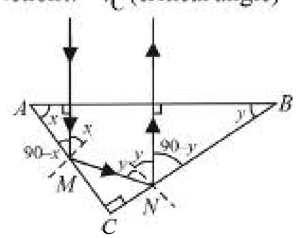
When the refracted ray PR meets the boundary DE, it is travelling from a denser medium to a rarer medium. Therefore the ray will be totally internally reflected at DE if its angle of incidence r is more than the critical angle for med III and I.

$$\sin i'' = \frac{n_1}{n_3}$$

Since, $\sin r > \frac{n_1}{n_3} \Rightarrow \sin r > \sin i'' \Rightarrow r > i''$

Therefore ray PR will be totally internal reflected along RQ. On reaching Q, the ray will be refracted in med II. Thus, the ray will ultimately be reflected back in medium II.

11. (i) Let x is the incident angle for reflection at AC. For total internal reflection $x > i_C$ (critical angle)



Let y be the incident angle of the ray on face CB. For total internal reflection

$y > i_C$

$\therefore \quad x + y > 2i_C$

But $x = \angle A$ and $y = \angle B$ (from geometry)

$\therefore \quad x + y = 90°$

$\Rightarrow \quad 90 > 2i_C \Rightarrow i_C < 45°$

The refractive index of the medium for this to happen.

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

(ii) $\mu = \frac{5}{3}$

$\Rightarrow \quad \sin i_C' = \frac{1}{\mu} = \frac{1}{5/3} = \frac{3}{5} \quad \Rightarrow \quad i_C' = 37°$

$y = 30°$ (Given) $\therefore \; x = 60°$

$x > i_C'$ but $y < i_C'$

$\Rightarrow$ Total internal reflection will take place on face AC but not on CB.

12. (i) Initially the object is in denser medium and $u = \infty$ using the formula of refraction at a spherical surface for AB

$$-\frac{\mu_2}{u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R} \quad \Rightarrow \quad \frac{-4/3}{-\infty} + \frac{1}{v} = \frac{1 - 4/3}{2}$$

$\Rightarrow \quad v = -6$ mm

NOTE : This is the position of the image due to refraction at the first surface. This image will behave as a virtual object for the refraction at the second surface.

$u = -6 - 4 = -10$ mm

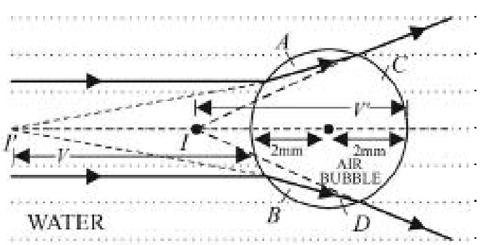
Again using the formula of refraction at a spherical surface for CD

$$-\frac{\mu_1}{u'} + \frac{\mu_2}{v'} = \frac{+\mu_2 - \mu_1}{R}, \quad -\frac{1}{10} + \frac{4/3}{v'} = \frac{\frac{4}{3} - 1}{-2}$$

$\Rightarrow \quad v' = -5$ mm.

The is the position of final image.

(ii) Ray Diagram.



13. The power transmitted through A

$$= \left[10\% \text{ of} \left(\frac{10}{\pi}\right)\right] \times \pi (0.001)^2 = 10^{-6} \text{ W}$$

The power transmitted through B

$$= \left[10\% \text{ of} \left(\frac{10}{\pi}\right)\right] \times \pi \times (0.002)^2 = 4 \times 10^{-6} \text{ W}$$

Let $\Delta\phi$ be the phase difference introduced by film

$$\therefore \quad \Delta\phi = \frac{2\pi}{\lambda} \text{ (path difference introduced by the film)}$$

$$= \frac{2\pi}{\lambda} \times (\mu - 1)t = \frac{2\pi}{6000 \times 10^{-10}} [1.5 - 1] \times 2000 \times 10^{-10}$$

$$= \frac{\pi}{3} \text{ radian}$$

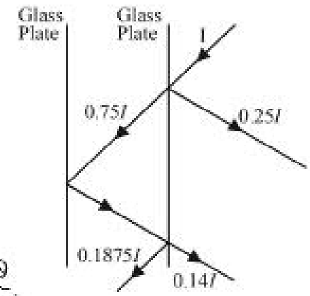
The power received at F

$$P = P_1 + P_2 + 2\sqrt{P_1 P_2} \cos \Delta\phi$$

$$= 10^{-6} + 4 \times 10^{-6} + 2\sqrt{10^{-6} \times 4 \times 10^{-6}} \cos\frac{\pi}{3}$$

$$= 7 \times 10^{-6} \text{ W.}$$

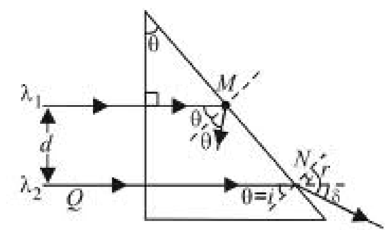
14. As shown in the figure, the interference will be between $0.25I = I_1$ and $0.14I = I_2$



$$\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1} + \sqrt{I_2})^2}{(\sqrt{I_1} - \sqrt{I_2})^2}$$

$$= \frac{[\sqrt{0.25I} + \sqrt{0.14I}]^2}{[\sqrt{0.25I} - \sqrt{0.14I}]^2} = \frac{49}{1}.$$

15. (a) $\lambda_1 = 4000$ Å and $\lambda_2 = 5000$ Å



For total internal reflection to take place, θ should be greater than C. For smaller values of C, the values of μ should be high or in other words the value of λ should be small.

Therefore, total internal reflection will be given by

$\lambda_1 = 4000$ Å

Here, $\sin\theta = 0.8$ (given) $\Rightarrow \theta = 53.1°$

$$\therefore \quad \mu = \frac{1}{\sin\theta} = \frac{1}{0.8} = 1.25$$

$$\therefore \quad \mu = 1.2 + \frac{b}{(4000 \times 10^{-10})^2} = 1.25$$

$\Rightarrow \quad b = 0.8 \times 10^{-14}$ m^2

(b) Applying Snell's law at N for wavelength λ_2

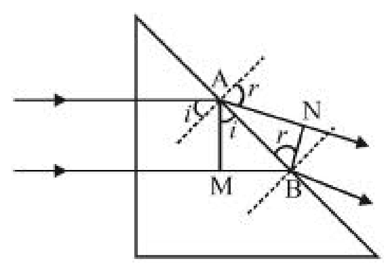
$$\mu = \frac{\sin r}{\sin i} \text{ where } \mu = 1.5 + \frac{0.8 \times 10^{-14}}{(5000 \times 10^{-10})^2} = 1.232$$

$$\Rightarrow \quad 1.232 = \frac{\sin r}{0.8} \Rightarrow r = 80.3°$$

From the figure it is clear that the deviation,

$\delta = r - i = 80.3° - 53.1° = 27.2°$

(c) The intensities of transmitted beams are $4I$ and I respectively.



Path diff = $\mu(MB) - AN$

$= \frac{\sin r}{\sin i}(AB\sin i) - AB\sin\theta$

$= 0$

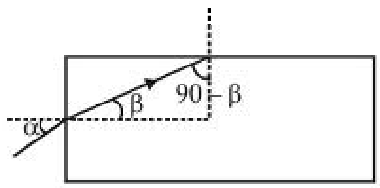
Since both the radiations are mutually coherent and while coming to focus these travel equal paths, therefore, these two beams will arrive in phase at focus.

∴ Resultant Intensity

$$I_{max} = \left(\sqrt{I_1}+\sqrt{I_2}\right)^2 = \left(\sqrt{4I}+\sqrt{I}\right)^2$$

$$= (3\sqrt{I})^2 = 9I.$$

16. The light entering the rod does not emerge from the curved surface of the rod when the angle (90° – β) is greater than the critical angle.



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

Here, $C = 90 - \beta$

$\Rightarrow \mu \le \frac{1}{\sin(90° - \beta)} \Rightarrow \mu \le \frac{1}{\cos\beta}$

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

Applying Snell's law at A

$\mu = \frac{\sin\alpha}{\sin\beta} \Rightarrow \sin\beta = \frac{\sin\alpha}{\mu}$ ...(ii)

NOTE : The smallest angle of incidence 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)

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

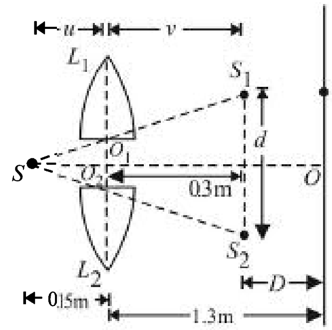
From (i) and (ii), $\sin\beta = \cos\beta$

$\Rightarrow \beta = 45°$

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

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

17. (i) In this case, the two identical halves of convex lens will create two seperate images S_1 and S_2 of the source S. These Images (S_1 and S_2) will behave as two coherent sources and the further dealing will be in accordance to Young's double slit experiment.



For lens L_1

The object is S

$u = -0.15$ m, $v = ?$, $f = +0.1$ m

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{0.1} + \frac{1}{-0.15}$

$\Rightarrow v = 0.3$ m

ΔSO_1O_2 and ΔSS_1S_2 are similar. Also the placement of O_1 and O_2 are symmetrical to S

∴ $\frac{S_1S_2}{O_1O_2} = \frac{u+v}{u}$

$\Rightarrow S_1S_2 = \frac{(u+v)(O_1O_2)}{u} = \frac{(0.15+0.3)}{(0.15)} \times 0.5 \times 10^{-3}$

$\Rightarrow S_1S_2 = d = 1.5 \times 10^{-3}$ m ∴ $D = 1.3 - 0.3 = 1$m

The fringe width

$$\beta = \frac{\lambda D}{d} = \frac{500\times10^{-9}\times1}{1.5\times10^{-3}} = \frac{1}{3}\times10^{-3}\text{m}$$

∴ Therefore,

$$OA = 3\beta = 3\times\frac{1}{3}\times10^{-3}\text{m} = 10^{-3}$$

(ii) If the gap between L_1 and L_2 i.e., O_1O_2 is reduced. Then d will be reduced. Then the fringe width will increase and hence OA will increase.

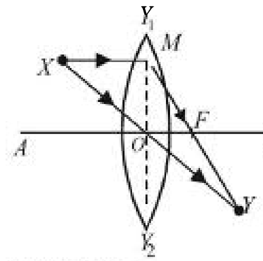
18. (i) Since Y is below of optic axis, therefore the image is real and inverted.

(i) STEPS OF CONSTRUCTION OF DIAGRAM.

For convex lens

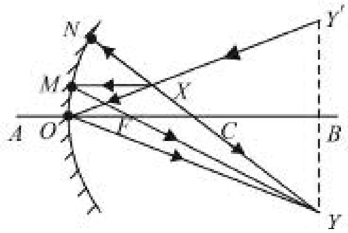
(1) Join XY. This represents the ray originating from the source and meeting the image Y. Since the ray is undeviated after passing through the lens, therefore O is the optical centre of the lens. Draw Y_1OY_2 perpendicular to AB.

(2) Draw a ray from X, parallel to AB. It strikes Y_1OY_2 at M. Join MY. It cuts AB at F. This is the focus of the convex lens.



(ii) For concave mirror

As the image is real and inverted, the concave mirror has to be placed towards the left of X. **To find the exact position of the concave mirror**, we draw a line YY' perpendicular to AB such that BY = BY'



Join $Y'X$ and extend the line to meet AB at O. If the concave mirror is placed at O then after reflection at O, this line will meet Y.

To find the radius of curvature of the mirror

Join X and Y. Let it cut AB at C. This C should be the centre of curvature of the concave mirror. With OC as radius, draw a part of sphere. This is the concave mirror.

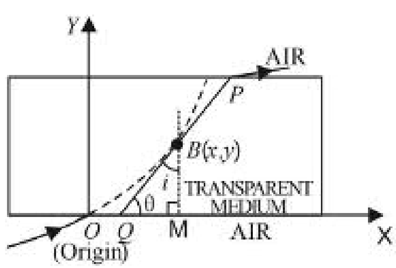
To find the focus of the concave mirror

Draw XM parallel to the principal axis. Join M to Y. Let it cut AD at F. Therefore, F is the focus of concave mirror.

19. (a) SLOPE AT P

To find the slope at B, we draw a tangent to the trajectory at B. The trajectory is such that as the ray passes through the rectangular transparent medium, the ray continuously deviates towards the normal. The tangent at B makes an angle θ with the x-axis. Therefore, the

slope at point B is $\tan\theta = \frac{dy}{dx}$ ... (i)



i is the angle of incidence at B then according to ΔBQM

$$i + \theta + \frac{\pi}{2} = \pi \quad \text{... (ii)}$$

Substituting the value of θ from (ii) in (i)

$$\tan\left(\frac{\pi}{2} - i\right) = \frac{dy}{dx} \Rightarrow \frac{dy}{dx} = \cot i \quad \text{... (iii)}$$

(b) EQUATION OF TRAJECTORY

According to Snell's law, when light propagates through a series of parallel layers of different media, then

$$n \sin i = \text{constant}$$

Let us consider the rectangular state to be made up of parallel layers such that as we move in the + Y direction, the refractive index increases as given by the relationship

$$n(y) = [ky^{3/2} + 1]^{1/2} \quad \text{...(iv)}$$

Applying Snell's law at O, we get $1 \times \sin 90° = \text{constant} = 1$.

Again applying Snell's law at B, we get

$n \sin i = \text{const.} = 1$ (from above equation)

$$\therefore \quad n = \frac{1}{\sin i} = \operatorname{cosec} i = \sqrt{1 + \cot^2 i} = \sqrt{1 + \left(\frac{dy}{dx}\right)^2},$$

$$\sqrt{ky^{3/2} + 1} = \sqrt{1 + \left(\frac{dy}{dx}\right)^2} \quad \text{from (iv)}$$

$$\Rightarrow \frac{dy}{dx} = [ky^{3/2}]^{1/2} \Rightarrow \frac{dy}{y^{3/4}} = k^{1/2} dx = dx \quad (\because k = 1)$$

$$\Rightarrow \int \frac{dy}{y^{3/4}} = \int dx$$

$\Rightarrow$ $4y^{1/4} = x + C$ where C is an integration constant.

But at $x = 0, y = 0$

$$\therefore \quad C = 0 \quad \therefore 4y^{1/4} = x \Rightarrow y = \left(\frac{x}{4}\right)^4$$

(c) CO-ORDINATES (x_1, y_1) OF THE POINT P

At $P, y = 1\text{m} \quad \therefore x = 4y^{1/4} = 4$

The coordinates of P are (4m, 1m)

(d) The refractive index at P

$$n_p = [ky^{3/2} + 1]^{1/2} = [1\,(1)^{3/2} + 1]^{1/2} = \sqrt{2}$$

If i_p is angle of incidence at P then according to Snell's law,

$$n_p \sin i_p = 1 \Rightarrow \sin i_p = \frac{1}{\sqrt{2}}$$

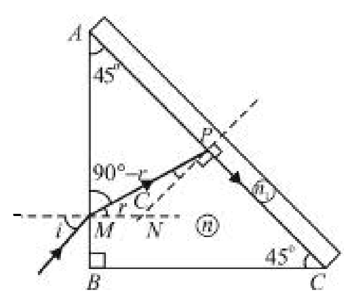
Also by Snell's law, $n_{air} \sin r_p = n_p \sin i_p$

$$1 \sin r_p = \sqrt{2} \times \frac{1}{\sqrt{2}} \Rightarrow \sin r_p = 1 \Rightarrow r_p = \frac{\pi}{2}$$

$\Rightarrow$ After emerging from the rectangular glass slab, the light ray becomes parallel to slab length.

20. (i) The ray incident on AB at M makes an angle of incidence i. It gets refracted at M. The angle of refraction is r. Applying Snell's law at M

$$n = \frac{\sin i}{\sin r} \quad \text{...(i)}$$



From fig

$\angle APM = 180° - (45° + 90° - r) = 45° + r$
and $C = 90° - (45° + r) = 45° - r$
The ray after refraction at M enter the prism and strikes its diagonal face AC making an angle C with the normal at P. Here C is the critical angle, therefore, the ray after refraction at P makes angle of refraction 90°
Applying Snell's law at P

$$\frac{n}{n_1} = \frac{\sin 90°}{\sin C} \Rightarrow \sin C = \frac{n_1}{n} \quad \text{...(ii)}$$

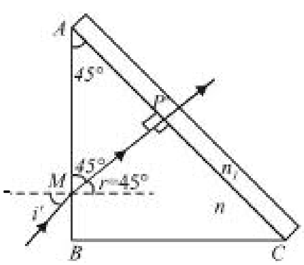
From (i), $\sin i = n \sin r = n \sin(45° - C)$
$= n[\sin 45° \cos C - \cos 45° \sin C]$

$$= \frac{n}{\sqrt{2}}[\sqrt{1-\sin^2 C} - \sin C]$$

$$\sin i = \frac{n}{\sqrt{2}}\left[\sqrt{1-\frac{n_1^2}{n^2}} - \frac{n_1}{n_2}\right] \quad \text{[From (ii)]}$$

$$\Rightarrow \quad i = \sin^{-1}\left[\frac{1}{\sqrt{2}}\{\sqrt{n^2 - n_1^2} - n_1\}\right]$$

(ii) Angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated. For this to happen, the angle of incidence of ray MP on diagonal face should be zero. It means that the ray should strike normal to AC.



Applying Snell's law at M, we get $n = \frac{\sin i'}{\sin r}$

Since $\angle AP'M = 90°$ $\angle AMP = 45 \Rightarrow r = 45°$

$$\therefore \quad \sin i' = n \sin r = n \sin 45° = \frac{1.352}{\sqrt{2}} = 0.956$$

$$\Rightarrow \quad i' = 72.94°$$

21. (i) $\quad {}^a_m\mu = \frac{\lambda_a}{\lambda_m} \Rightarrow \lambda_m = \frac{\lambda_a}{{}^a_m\mu}$

$$\therefore \quad \text{Fringe width} = \frac{\lambda_a D}{{}^a_m\mu d} = \frac{6300 \times 10^{-10} \times 1.33}{1.33 \times 10^{-3}}$$

$= 6.3 \times 10^{-4}$ m

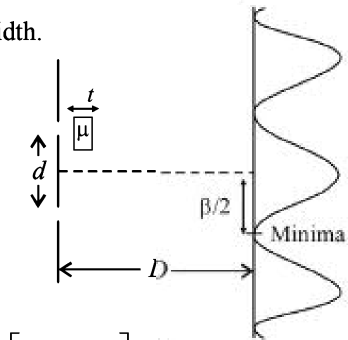
(ii) **KEY CONCEPT :** The shift of fringes when one slit is covered with thin glass sheet is

$$= \frac{Dt}{d}\left[\frac{{}_g\mu}{{}_m\mu} - 1\right]$$

where, t = thickness of glass sheet.

The shift has to be such that the minima shifts to the axis.

For this the shifting of the fringes should be $\frac{\beta}{2}$ where β is fringe width.

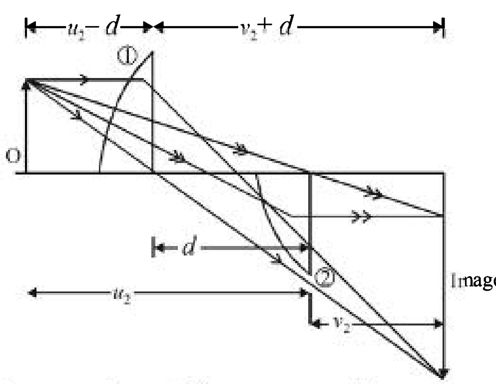


$$\therefore \quad \frac{Dt}{d}\left[\frac{{}_g\mu - {}_m\mu}{{}_m\mu}\right] = \frac{\beta}{2}$$

$$\Rightarrow \quad t = \frac{\beta d_m \mu}{2({}_g\mu - {}_m\mu) \times D} = \frac{6.3 \times 10^{-4} \times 10^{-3} \times 1.33}{2(1.53 - 1.33) \times 1.33}$$

$= 15.75 \times 10^{-7}$ m $= 1.575 \times 10^{-6}$ m

22.



Given $\quad u_2 + v_2 = 1.8$ m $\quad$ ... (i)
The magnification of lens (1) is 2

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

From (i) and (ii)

$$u_2 = 0.6 + d, \; v_2 = 1.2 - d$$

Applying lens formula

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

$$\frac{1}{v_2} + \frac{1}{u_2} = \frac{1}{f} \quad \text{... (iv) for lens (2)}$$

From (iii) and (iv)

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

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

On solving, we get

$\Rightarrow d = 0.6\,\text{m}$

Substituting this value in (iv)

$$\frac{1}{1.2-0.6}+\frac{1}{0.6+0.6}=\frac{1}{f}$$

$\therefore\quad f = 0.4\,\text{m}$

23. The phase difference $\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}(5\lambda + \Delta)$

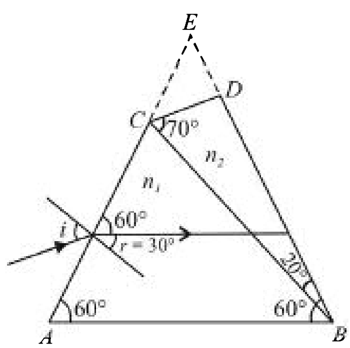
We know that $I(\phi) = I_{max}\cos^2\left(\frac{\phi}{2}\right)$

$\Rightarrow \frac{3}{4}I_{max} = I_{max}\cos^2\frac{\phi}{2} \Rightarrow \frac{\phi}{2} = 30° = \frac{\pi}{6}$

$\Rightarrow \frac{2\pi}{6} = \frac{2\pi}{\lambda}(5\lambda+\Delta) \Rightarrow \Delta x = \frac{\lambda}{6} = 0.3\,t$

$\Rightarrow t = 9.3\times10^{-6}\,\text{m}$

24.



For Minimum Deviation

(a) The rays of wavelength λ_0 incident at any angle on the interface BC will pass through without bending, provided the refractive indices n_1 and n_2 have the same value for the wavelength λ_0. Equating the expressions of n_1 and n_2, we get

$$1.20+\frac{10.8\times10^{-4}}{\lambda_0^2}=1.45+\frac{1.80\times10^{-4}}{\lambda_0^2}$$

(where λ_0 is in nm)

or $\lambda_0 = \left(\frac{9.0\times10^4}{0.25}\right)^{1/2} = 600\,\text{nm}$

(b) For the wavelength 600 nm, the combination of prism acts as a single prism shaped like an isosceles triangle (ABE). At the minimum deviation, the ray inside the prism will be parallel to the base. Hence, the angle of refraction on the face AC will be r = 30°.

Now $\sin i = n\sin r = n\sin 30° = \frac{n}{2}$ ... (1)

The value of n at 600 nm is

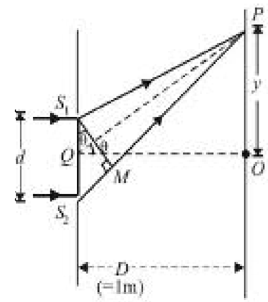
$n = 1.20 + \frac{10.8\times10^4}{(600)^2} = 1.50$ ... (2)

From (1) and (2),

the angle of incidence is $i = \sin^{-1}\left(\frac{3}{4}\right)$

25. (a) The path difference (Δx) from the ray starting from S_1 and S_2 and reaching a point P will be

$\Delta x = d\sin\theta$



We know that the path difference for minimum intensity is $(2m-1)\frac{\lambda}{2}$ where $m = 1, 2, 3...$

$\therefore\quad d\sin\theta = (2m-1)\frac{\lambda}{2}$

$\Rightarrow\quad \sin\theta = \frac{(2m-1)\lambda}{2d} = \frac{(2m-1)0.5}{2\times1.0} = \frac{2m-1}{4}$

Also $-1 \le \sin\theta \le 1$. Therefore, possible values of m are $\pm 1, \pm 2, 0$

From ΔPOQ

$y = D\tan\theta = \frac{D\sin\theta}{\sqrt{1-\sin^2\theta}}$ ...(i)

Positions of minima

For $m = +1,\ \sin\theta = \frac{1}{4}$ and $y = 0.26$

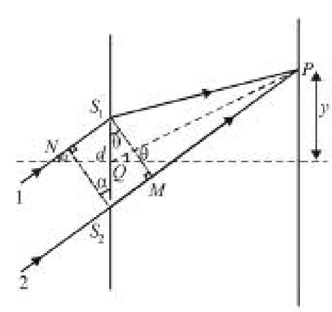
$m = -1,\ \sin\theta = -\frac{3}{4}$ and $y = -1.13$ m

$m = +2,\ \sin\theta = \frac{3}{4}\quad \therefore\quad y = +1.13$ m

$m = 0,\ \sin\theta = -\frac{1}{4}\quad \therefore\quad y = -0.26$ m

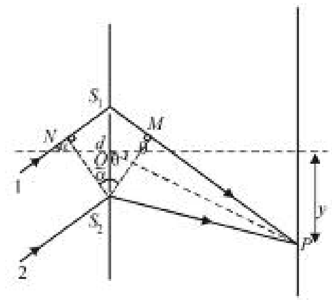
(b) WHEN THE INCIDENT BEAM MAKES AN ANGLE OF 30° WITH X-AXIS

Two cases arise as shown by the following two figures.



Path difference between ray 1 and 2 reaching $P = S_2M - NS_1$

$\therefore \quad \Delta x_1 = d\sin\theta - d\sin\alpha$ (Case 1)



Path difference between ray 1 and 2 reaching $P = NS_1 + S_1M$

$\Delta x_2 = d\sin\alpha + d\sin\theta$ (Case 2)

Position of Central maxima : Path difference should be zero. Therefore $\Delta x_1 = 0$ or $\Delta x_2 = 0$

$\Rightarrow \quad d\sin\alpha = d\sin\theta$

$\Rightarrow \quad \sin\theta = \frac{1}{2} \qquad [\because \alpha = 30°]$

From equation (i), $y = 0.58\,\text{m}$

For first minima; $d\sin\theta + d\sin\alpha = \frac{\lambda}{2}$

$\Rightarrow \quad d\sin\theta = \frac{\lambda}{2} + d\sin\alpha$

$\therefore \quad \sin\theta = \frac{\lambda}{2d} + \sin\alpha = \frac{0.5}{2\times 1} + \sin 30° = \frac{1}{4} + \frac{1}{2} = \frac{3}{4}$

From equation (i), $y = 1.15\,\text{m}$

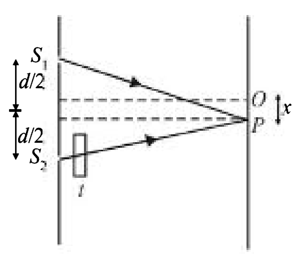
For first minima on the other side

$d\sin\alpha + d\sin\theta = \frac{\lambda}{2} \Rightarrow \sin\theta = \frac{-1}{4}$

$\therefore$ From (i), $y = -0.26\,\text{m}$

26. (a) Let the central maxima is obtained at a distance x below O. [This is because a glass sheet is present in front of S_2 which increases its path length to the screen. Therefore the path length of ray from S_1 to the screen should also increase].

Here,



$\Rightarrow \quad \frac{xd}{D} = \left(\frac{\mu_g}{\mu_m} - 1\right)t$

$\Rightarrow x = \left(\frac{\mu_g}{\mu_m} - 1\right)t \times \frac{D}{d} = \left(\frac{1.5}{4/3} - 1\right) \times \frac{(10.4\times 10^{-6})(1.5)}{0.45\times 10^{-3}}$

$= 4.33 \times 10^{-3}\,\text{m}$

(b) **For O,** path difference $= \left(\frac{\mu_g}{\mu_m} - 1\right)t$

$\therefore$ Phase difference

$\phi = \frac{2\pi}{\lambda}\left(\frac{\mu_g}{\mu_m} - 1\right)t = \frac{2\times 3.14}{6\times 10^{-7}}\left(\frac{1.5}{4/3} - 1\right)(10.4\times 10^{-6})$

$= 6.8\,\text{rad}$

We know that $I = I_0\cos^2\frac{\phi}{2} \quad \therefore \quad \frac{I}{I_0} = \cos^2(6.8) = 0.75$

(c) **For maximum at O**

Again path difference $= \left(\frac{\mu_g}{\mu_m} - 1\right)t$

We know that for maxima, path difference $= n\lambda$

$\therefore \quad n\lambda = \left(\frac{\mu_g}{\mu_m} - 1\right)t$

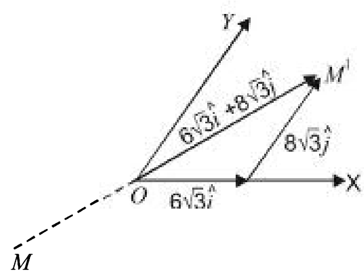
$\Rightarrow \quad \lambda = \left(\frac{\mu_g}{\mu_m} - 1\right)\frac{t}{n} = \left(\frac{1.5}{4/3} - 1\right)\frac{10.4\times 10^{-6}}{n}$

$= \frac{1.3\times 10^{-6}\,\text{m}}{n}$

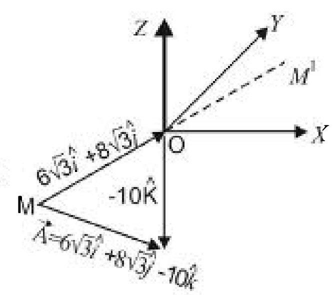
Putting different values of n for find the wave length in the range of 0.4×10^{-6} m to 0.7×10^{-6} m we get

$\lambda = 0.65 \times 10^{-6}$ m and 0.433×10^{-6} m

27.



(Fig. 1)



(Fig. 2)

Figure 1 shows vector $OM' = 6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j}$

Figure 2 shows vector $\vec{A} = 6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}$

The perpendicular to line MOM' is Z-axis which has a unit vector of $\hat{k}$.

Angle between vector $\overrightarrow{MP}$ and $\overrightarrow{OP}$ can be found by dot product.

$\overrightarrow{MP}\,.\,\overrightarrow{OP} = (MP)\,(OP)\cos i$

$$\frac{\left(6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}\right).(-\hat{k})}{\sqrt{(6\sqrt{3})^2 + (8\sqrt{3})^2 + (-10)^2} + \sqrt{(-1)^2}} = \cos i$$

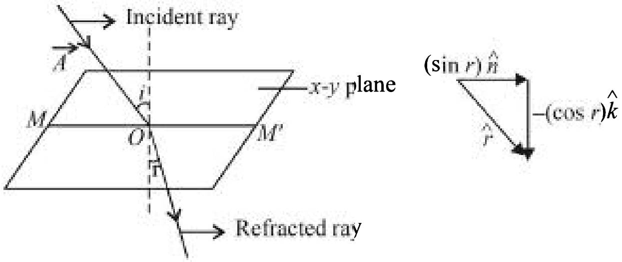
$\Rightarrow \quad i = 60°$

Unit vector in the direction of MOM' from fig. (1) is

$$\hat{n} = \frac{6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j}}{[(6\sqrt{3})^2 + (8\sqrt{3})^2]^{1/2}}, \quad \hat{n} = \frac{3}{5}\hat{i} + \frac{4}{5}\hat{j}$$

To find the angle of refraction, we use Snell's law

$$\frac{\sqrt{3}}{\sqrt{2}} = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin r} \Rightarrow r = 45°$$

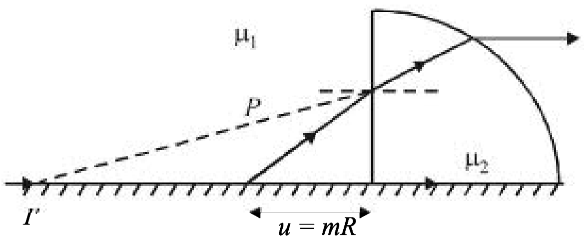


Now, $\hat{r} = (\sin r)\hat{n} - (\cos r)\hat{k}$

$$= (\sin 45°)\left[\frac{3}{5}\hat{i} + \frac{4}{5}\hat{j}\right] - (\cos 45°)\hat{k}$$

$$= \frac{1}{5\sqrt{2}}[3\hat{i} + 4\hat{j} - 5\hat{k}]$$

28. First of all, we consider the refraction at plane surface. Here the image of P will form at I' after refraction from I surface.



For plane surface :

Object distance $u = -mR$

Radius of curvature of the plane surface $= \infty$

The ray is coming from air and incident on the glas.

Here $\mu_1 = 1, \mu_2 = 1.5$.

Apply $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}; \frac{\mu_2}{v} = \frac{\mu_1}{u}$ (as $R = \infty$)

$\therefore$ Image distance $v = \frac{\mu_1}{\mu_2}u = \frac{1.5}{1.0}(-\text{mR}) = -1.5\text{ mR}$

Now we consider refraction at the curved surface.

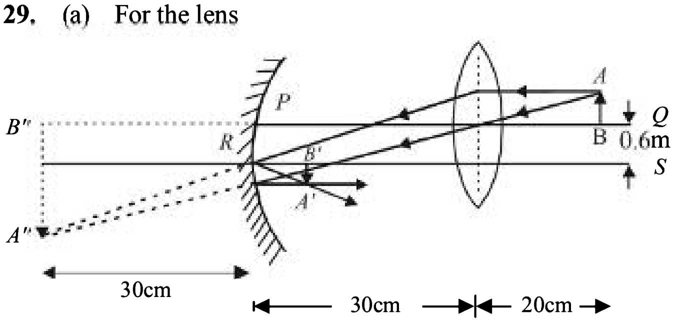
Object distance, $u = -(1.5\text{ mR} + \text{R})$

Here, $\mu_2 = 1, \mu_1 = 1.5$, Image distance, $v = \infty$,

Radius of curvature $= -R$

Here, $\frac{1}{\infty} + \frac{1.5}{(1.5m+1)R} = \frac{1-1.5}{-R}$ $\quad\therefore m = \frac{4}{3}$

29. (a) For the lens



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_\ell} \Rightarrow \frac{1}{v} - \frac{1}{-20} = \frac{1}{15}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{15} - \frac{1}{20} = \frac{1}{60} \Rightarrow v = 60\text{ cm}, \; m = \frac{v}{u} = \frac{60}{-20} = -3$$

The image is formed to the left of the lens, real, inverted and three times the actual size (3.6 cm in height below PQ).

For the mirror,

$$\frac{1}{v'} + \frac{1}{u'} = \frac{1}{f_m} \Rightarrow \frac{1}{v'} = \frac{1}{-30} - \frac{1}{30} = -\frac{2}{30}$$

$$\Rightarrow v' = -15\text{ cm}$$

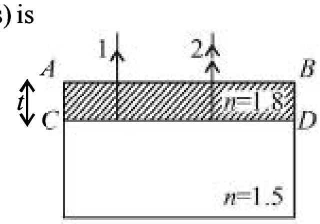
$$m = -\frac{v'}{u'} = -\frac{-15}{30} = \frac{1}{2}$$

size of image $= \frac{1}{2} \times 3.6 = 1.8$ cm.

This image will be inverted w.r.t. the original image and its position will be 0.3 cm above RS and 1.5 cm below RS. The position of the image is 15 cm to the right of the mirror.

(b) The path difference between the two rays reflected from the upper surface AB (shown by ray 1, single arrow upwards) and lower surface CD (shown by ray 2 double arrow pointing upwards) is

$$\Delta x = {}_m n \times 2t + \frac{\lambda}{2}$$



Here $\frac{\lambda}{2}$ is the path difference as the ray 1 suffer reflection from a denser medium on surface AB

We known that for constructive interference

Path difference $= m\lambda$ where m is 1, 2,....

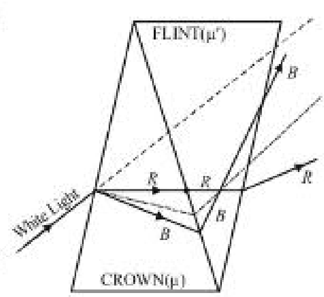
$$\therefore \; {}_m n \times 2t + \frac{\lambda}{2} = m\lambda \Rightarrow 2\,{}_m nt = \left(m - \frac{1}{2}\right)\lambda$$

when $m = 1$, $t = \frac{\lambda}{4\,{}_m n} = \frac{648}{4 \times 1.8} = 90$ nm.

30. For no deviation condition

$$A' = \left[\frac{\mu - 1}{\mu' - 1}\right]A$$

$$\Rightarrow A' = \frac{1.5 - 1}{1.75 - 1} \times 6° = 4°$$



Now, the angular dispersion produced by crown glass prism

$$\delta_b - \delta_r = A(\mu_b - \mu_r)$$

Also the angular dispersion produced by flint glass prism

$\delta_b' - \delta_r' = A'(\mu_b' - \mu_r')$

$\therefore$ Net deviation in blue light

$$\delta_b = (\mu_{b_1} - 1)A_1 - (\mu_{b_2} - 1)A_2$$

$$= (1.51 - 1)\,6° - (1.77 - 1)\,4° = -0.02°$$

Similarly Net deviation of red light

$$\delta_r = (\mu_{r_1} - 1)A_1 - (\mu_{r_2} - 1)A_2$$

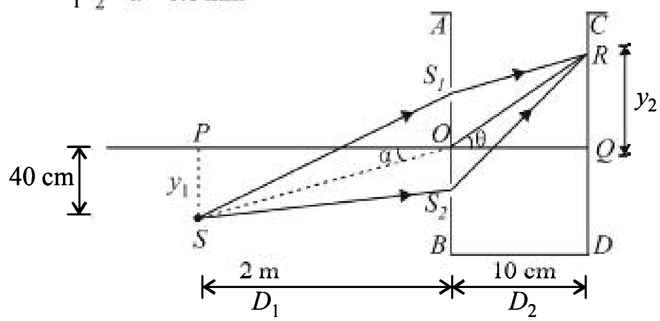
$$= (1.49 - 1)\,6° - (1.73 - 1)\,4° = 0.02$$

$\therefore$ Net dispersion $= \delta_b - \delta_r = -0.04°$

$\therefore$ The magnitude of the net angular dispersion = 0.04

31. (i) O is the middle point of two slits S_1 and S_2.

$S_1S_2 = d = 0.8$ mm



$$\tan\alpha = \frac{y_1}{D_1} = \frac{40}{200} = \frac{1}{5}$$

$$\therefore \quad \sin\alpha = \frac{1}{\sqrt{26}} = \frac{1}{5.1} \approx \frac{1}{1.5} \approx \tan\alpha$$

Path difference $\Delta X_1 = SS_1 - SS_2$

or $\Delta X_1 = d\sin\alpha = (0.8 \text{ mm})\left(\frac{1}{5}\right) = 0.16 \text{ mm}$ ...(i)

Let R denotes the position of central bright fringe. Net path difference will be zero.

Now $\Delta X_2 = S_2R - S_1R$ or $\Delta X_2 = d\sin\theta$ ...(ii)

For central bright fringe

$\Delta X_2 - \Delta X_1 = 0$ or $d\sin\theta - \Delta X_1 = 0$

or $d\sin\theta = \Delta X_1 = 0.16$ mm

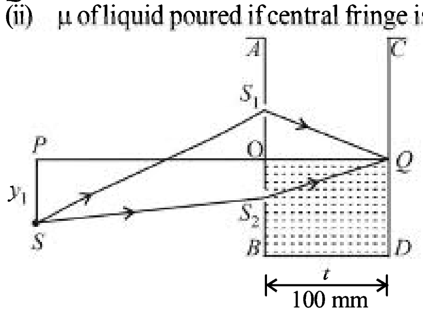
or $(0.8)\sin\theta = 0.16$ or $\sin\theta = \frac{0.16}{0.8} = \frac{1}{5}$

$\therefore \tan\theta = \frac{1}{\sqrt{24}} = \frac{1}{4.9} \approx \frac{1}{5} = \sin\theta \quad \therefore \tan\theta = \frac{y_2}{D_2}$

or $\frac{1}{5} = \frac{y_2}{D_2}$ or $y_2 = \frac{D_2}{5} = \frac{10}{5} = 2$ cm

Hence position of central bright fringe is 2 cm above point Q on side CD.

(ii) μ of liquid poured if central fringe is at Q:



The liquid is poured into vessel upto OQ.

The central bright fringe is formed at Q.

For central bright fringe net path difference = 0.

$(\mu - 1)t = \Delta X_1$ or $(\mu - 1)(100) = 0.16$

or $\mu - 1 = 0.0016$ or $\mu = 1.0016$

32. The lens maker formula is

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

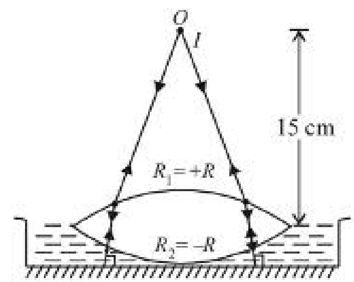
When the space between the lens and the mirror is filled with water, a system of two lenses is formed.

(i) a glass lens

(ii) a plano concave water lens

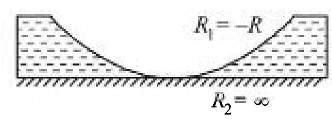
For glass lens Here $R_1 = +R$ and $R_2 = -R$

$$\frac{1}{f_\ell} = (1.5 - 1)\left(\frac{1}{R} - \frac{1}{-R}\right) = \frac{1}{R}$$



For water lens

$$\frac{1}{f_w} = (1.33 - 1)\left(\frac{1}{-R} - \frac{1}{-\infty}\right) = \frac{-0.33}{R}$$



The focal length of the combination of two lenses will be

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{R} - \frac{0.33}{R} = \frac{0.67}{R} \quad ...(i)$$

A convex lens placed on a plane mirror behaves like a concave mirror. The image is formed at the object itself if the object is placed at centre of curvature of concave mirror. After refraction through lens, the rays fall on the plane mirror normally and retrace their path to form image at the object itself.

$\therefore$ Focal length of system (f) = 15 cm ...(ii)

From (i) and (ii)

$$\frac{1}{15} = \frac{0.67}{R} \Rightarrow R = 10.05 \text{ cm}$$

The same situation is repeated with two differences

(a) The object and image distance are now 25 cm and

(b) In place of water there is a new liquid of refraction index μ

Again $\frac{1}{f_\ell} = \frac{1}{R}$ and $\frac{1}{f'} = \frac{-(\mu - 1)}{R}$ where f' is the focal length of new liquid lens.

$\therefore$ New combined lens,

$$\frac{1}{F} = \frac{1}{f_\ell} + \frac{1}{f'} = \frac{1}{R} - \frac{+(\mu - 1)}{R} = \frac{1 - \mu + 1}{R} = \frac{2 - \mu}{R} \quad .... (i)$$

For new combined lens,

$\therefore \quad \frac{1}{F} = \frac{1}{25}$ ... (ii)

From (i) and (ii)

$\frac{2-\mu}{10.02} = \frac{1}{25} \quad \therefore \mu = 1.6$

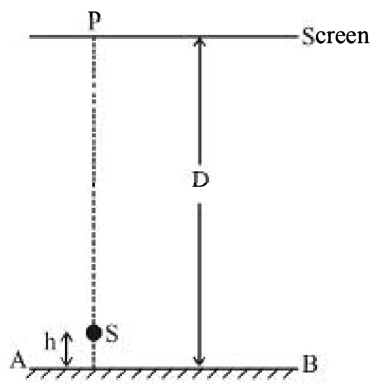
33. **(a)** Because S is a point source, fringes will be circular.

(b) $\frac{I_{min}}{I_{max}} = \left(\frac{\sqrt{I} - \sqrt{0.36I}}{\sqrt{I} + \sqrt{0.36I}}\right)^2 = \left(\frac{0.4}{1.6}\right)^2 = \frac{1}{16}$

[$\because$ If intensity of light falling on P directly from S is I, then the intensity of light falling at P after reflection from AB is $0.36I$]

(c) For maximum at P, path difference $= n\lambda$

If AB is shifted by a distance x, it will cause an additional path difference of $2x$.



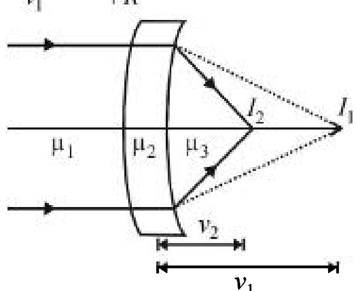
$2x = \lambda$ (for minimum value of x) $\Rightarrow x = \frac{\lambda}{2} = 300\,\text{nm}$

34. For an object placed at infinity the image after first refraction will be formed at a distance v_1

$\frac{\mu_2}{v_1} - \frac{\mu_1}{-\infty} = \frac{\mu_2 - \mu_1}{+R}$ ... (i)

Image afte second refraction will be formed at a distance v_2

$\frac{\mu_3}{v_2} - \frac{\mu_2}{v_1} = \frac{\mu_3 - \mu_2}{+R}$ ... (ii)



Adding (i) and (ii),

$\frac{\mu_3}{v_2} - \frac{\mu_3 - \mu_1}{R} \Rightarrow v_2 = \frac{\mu_3 R}{\mu_3 - \mu_1}$

Final image is formed at the focus when incident rays are parallel.

Therefore, focal length will be $\frac{\mu_3 R}{\mu_3 - \mu_1}$

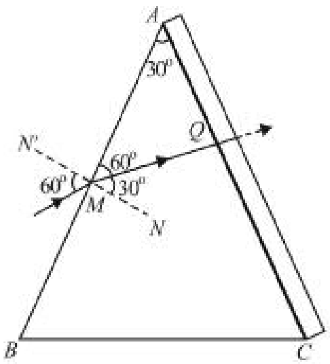
35. **(a)** Using Snell's law at surface AB

$\mu_{air} \sin 60° = \mu_p \sin r \Rightarrow \frac{\sqrt{3}}{2} = \sqrt{3} \sin r \Rightarrow r = 30°$

Now, NN' is the normal to surface AB.

$\therefore \quad \angle AMN = 90°$

But $\angle QMN = 30° \Rightarrow \angle AMQ = 60°$



In ΔAMQ

$\angle AQM = 180° - (60° + 30°) = 90°$

The refracted ray inside the prism hits the other face at 90°; hence deviation produced by this face is zero and hence angle of emergence is zero.

(b) Multiple reflections occur in the film for minimum thickness.

The intensity of emergent ray will be maximum if transmitted waves undergo constructive interference.

$\therefore$ For minimum thickness,

$\Delta x = \lambda$

$\Rightarrow \Delta x = 2\mu t = \lambda,$

where t = thickness $\Rightarrow t = \frac{\lambda}{2\mu} = 125\,\text{nm}$

36. Use Snell's law

$n_1 \sin i = n_2 \sin r$

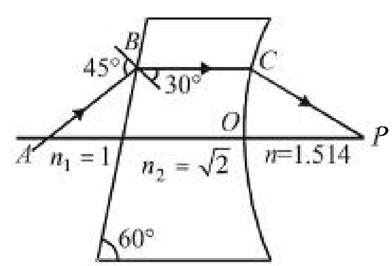
Here, $n_1 = 1, n_2 = \sqrt{2}, i = 45°, r = ?$

$\Rightarrow \sin r = \frac{1 \times \sin 45°}{\sqrt{2}} = \frac{1}{2} \Rightarrow r = 30°$

The angle made by refracted ray at B with normal is 30°.

$\therefore$ Angle made by the first surface with refracted ray BC is 60°.

Hence the refracted ray at B is parallel to horizontal arrow.



$\therefore$ For refraction at spherical surface, $u = \infty$

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

$\Rightarrow \frac{1.514}{v} = \frac{1.514 - 1.414}{0.4}$ or $v = 6.056\,\text{m}$

$\therefore \quad OP = 6.056\,\text{m}$

37. At the place where maxima for both the wavelengths coincide, y will be same for both the maxima, i.e.,

$$\frac{n_1\lambda_1 D}{d} = \frac{n_2\lambda_2 D}{d} \Rightarrow \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{700}{500} = \frac{7}{5}$$

Minimum integral value of n_2 is 5.

$\therefore$ Minimum distance of maxima of the two wavelengths from central fringe

$$= \frac{n_2\lambda_2 D}{d} = 5 \times 700 \times 10^{-9} \times 10^3 = 3.5\,\text{mm}.$$

38. $f = 0.3$ m, $u = -0.4$ m

Using lens formula

$$\frac{1}{v} - \frac{1}{-0.4} = \frac{1}{0.3} \Rightarrow v = 1.2\,\text{m}$$

Now we have $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, differentiating w.r.t. t

we have $-\frac{1}{v^2}\frac{dv}{dt} + \frac{1}{u^2}\frac{du}{dt} = 0$ given $\frac{du}{dt} = 0.01$ m/s

$$\Rightarrow \left(\frac{dv}{dt}\right) = \frac{(1.20)^2}{(0.4)^2} \times 0.01 = 0.09\,\text{m/s}$$

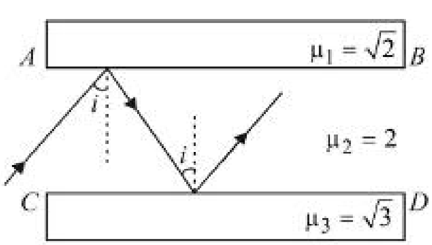
So, rate of separation of the image (w.r.t. the lens) $= 0.09$ m/s

$$\text{Now, } m = \frac{v}{u} \Rightarrow \frac{dm}{dt} = \frac{u\frac{dv}{dt} - v\frac{du}{dt}}{u^2}$$

$$= \frac{-(0.4)(0.09) - (1.2)(0.01)}{(0.4)^2} = -0.35\,\text{s}^{-1}$$

Magnitude of rate of change of lateral magnification = 0.35 s^{-1}.

39. For total internal reflection on interface AB



$$\sin i = \frac{1}{{}^{1}\mu_{2}} = \frac{{}_1\mu}{{}_2\mu} = \frac{\sqrt{2}}{2} = \frac{1}{\sqrt{2}} \Rightarrow i = 45°$$

For total internal reflection in interface CD.

$$\sin i = \frac{1}{{}^{3}\mu_{2}} = \frac{{}_3\mu}{{}_2\mu} = \frac{\sqrt{3}}{2} \Rightarrow i = 60°$$

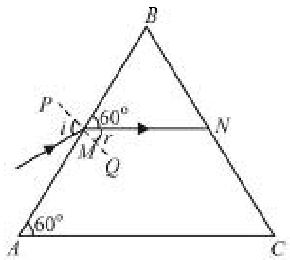
$\Rightarrow$ The minimum angle for total internal reflection for both the interface is 60°.

40. (a) For minimum deviation of emergent ray from the first prism. MN is parallel to AC

$\therefore \angle BMN = 60°$

$\Rightarrow \angle r = 30°$

Applying Snell's law at M



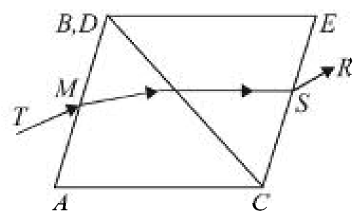
$$\mu = \frac{\sin i}{\sin r}$$

$$\sin i = \mu \sin r$$

$$\sin i = \sqrt{3} \times \sin 30° = \frac{\sqrt{3}}{2}$$

$$\Rightarrow i = 60°$$

(b) When the prism DCE is rotated about C in anticlockwise direction by 60°, as shown in the figure, then the final emergent ray SR becomes parallel to the incident ray TM. Thus, the angle of deviation becomes zero.



F. Match the Following

1. (A)$\rightarrow$(p).

More the radius of aperture more is the amount of light entering the telescope.

(B)$\rightarrow$(q).

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

(C)$\rightarrow$(r).

$L = f_0 + f_e$

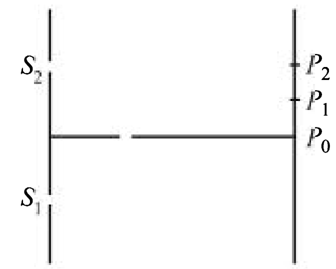
(D)$\rightarrow$(p), (q), (r).

Depends on dispersion of lens, spherical aberration and radius of aperture.

2. A-p, q, r, s

- When the object is at infinity, a real, inverted and diminished image is formed at the focus of the concave mirror.
- As the object is brought closer to the mirror, the image moves farther, remains real and inverted and increases in size (but still it is diminished as compared to the object)
- When the object is at C, a real, inverted and same size image is formed at C.
- When the object is brought still closer, a real, inverted and magnified image is formed beyond C.
- When the object is at focus (F), the image is highly magnified, real and inverted and formed at infinity.
- When the object is placed between pole and focus, a virtual, erect and magnified image is formed behind the mirror.

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



For path difference $\lambda/4$, phase difference is $\pi/2$.
For path difference $\lambda/3$, phase difference is $2\pi/3$.
Here, $S_1P_0 - S_2P_0 = 0$

$\therefore \quad \delta(P_0) = 0$

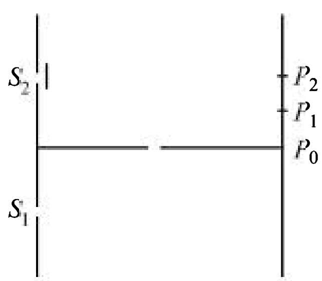
Therefore, (p) matches with (A).
The path difference for P_1 and P_2 will not be zero. The intensities at P_0 is maximum.

$$I(P_0) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos 0°$$
$$= (\sqrt{I_1} + \sqrt{I_2})^2 = (I_0 + I_0)^2 = 4I_0$$
$$I(P_1) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\frac{\pi}{2}$$
$$= I_1 + I_2 = I_0 + I_0 = 2I_0$$
$$I(P_2) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(2\pi/3)$$
$$= I_1 + I_2 - \sqrt{I_1}\sqrt{I_2} = I_0 + I_0 - I_0 = I_0$$

$\therefore \quad I(P_0) > I(P_1)$

Therefore, (s) matches with (A).

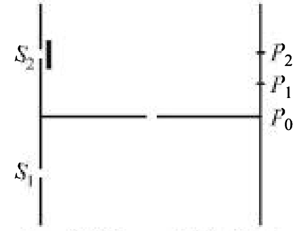
(B)



$$\delta P_0 = \frac{\lambda}{4},\ \delta P_1 = 0,\ \delta P_2 = \frac{\lambda}{12}$$
$$I(P_0) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\pi/2$$
$$= I_1 + I_2 = I_0 + I_0 = 2I_0$$
$$I(P_1) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2} = 4I_0$$
$$I(P_2) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\pi/6$$
$$= I_1 + I_2 + \sqrt{3}\sqrt{I_1}\sqrt{I_2}$$
$$= I_0 + I_0 + \sqrt{3}I_0 \ = (2+\sqrt{3})I_0$$

Therefore, q match with (B)

(C)



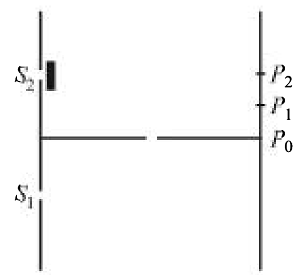
Here $\delta(P_0) = -\lambda/2;\ \delta(P_1) = -\lambda/4,\ \delta(P_2) = -\lambda/6$

$$I(P_0) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(-\pi)$$
$$= I_1 + I_2 - 2\sqrt{I_1}\sqrt{I_2} = I_0 + I_0 - 2I_0 = 0$$
$$I(P_1) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(-\pi/2)$$
$$= I_1 + I_2 = I_0 + I_0 = 2I_0$$
$$I(P_2) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\left(-\frac{\pi}{3}\right)$$
$$= I_1 + I_2 + \sqrt{I_1}\sqrt{I_2} = I_0 + I_0 + I_0 = 3I_0$$

$\therefore \quad I(P_2) > I(P_1)$

(t) matches (C).

(D)



Here $\delta P_0 = 3\lambda/4; \delta P_1 = -\lambda/2; \delta P_2 = -5\lambda/12$

$$I(P_0) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\left(\frac{-3\pi}{2}\right)$$
$$= I_1 + I_2 = I_0 + I_0 = 2I_0$$
$$I(P_1) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(-\pi)$$
$$= I_1 + I_2 - 2\sqrt{I_1}\sqrt{I_2} = I_0 + I_0 - 2\sqrt{I_0}\sqrt{I_0} = 0$$
$$I(P_2) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos[-5\pi/6]$$
$$= I_1 + I_2 - \sqrt{3}\sqrt{I_1}\sqrt{I_2} = \left(2-\sqrt{3}\right)I_0$$

(r), (s), (t) matches (D).

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

(a) When $\mu_1 < \mu_2$, the ray of light while entering the lens will bend towards the normal. Therefore p, r are the correct options

(B) When $\mu_1 > \mu_2$, the ray of light while entering the lens will bend away from the normal. Therefore q,s,t are the correct options.

(C) When $\mu_2 = \mu_3$, the ray of light while coming out from the lens does not deviate from its path. Therefore p,r,t are the correct option.

(D) $\mu_2 > \mu_3$, the ray of light coming out of the lens deviates away from the normal. Therefore q,s are the correct options.

5. **(d)** e → f. For the ray to bend towards the normal at the prism surface $\mu_2 > \mu_1$. The ray then moves away from the normal when it emerges out of the rectangular block. Therefore $\mu_2 > \mu_3$.

e → g. As there is no deviation of the ray as it emerges out of the prism, $\mu_2 = \mu_1$.

e → h. As the ray emerges out of prism, it moves away from the normal. Therefore $\mu_2 < \mu_1$. As the ray moves away from the normal as it emerges out of the rectangular block, therefore $\mu_2 > \mu_3$.

e → i. At the prism surface, total internal reflection has taken place. For this $\sin 45° > \frac{h_2}{h_1}$

$\therefore \quad \mu_1 > \sqrt{2}\,\mu_2$. (d) is the correct option.

6. **(b)** For (P) $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$$= (1.5 - 1)\left[\frac{2}{r}\right] = \frac{1}{r} \Rightarrow f = r$$

For the combination

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{r} + \frac{1}{r} = \frac{2}{r}$$

$$\therefore \quad F = \frac{r}{2}$$

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

$$= (1.5 - 1)\left[\frac{1}{\infty} - \frac{1}{-r}\right] = \frac{0.5}{r} = \frac{1}{2r}$$

$\therefore \quad f = 2r$

For the combination

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{2r} + \frac{1}{2r} = \frac{2}{2r} = \frac{1}{r}$$

$\therefore F = r$

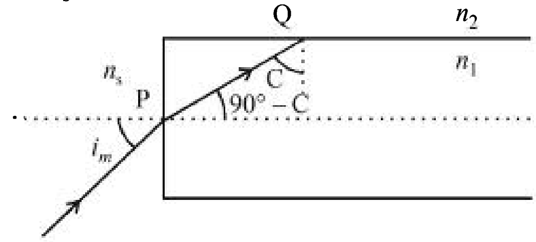
Similarly, we can either find or do not find the remaining options (b) is the correct option.

G. Comprehension Based Questions

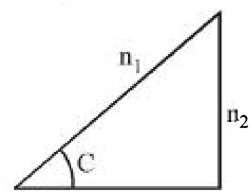
1. **(a)** For plane wave fronts the beam of light is parallel.
2. **(c)** Since points c and d are on the same wavefront, therefore $\phi_d = \phi_c$
   Similarly, $\phi_e = \phi_f \;\; \therefore \phi_d - \phi_f = \phi_c - \phi_f$
3. **(b)** The gap between consecutive wavefronts in medium 2 is less than that is medium 1. Therefore, wavelength of light in medium 2 is less than that in medium 1. Therefore, speed of light is more in medium 1 and less in medium 2.
4. **(c)** As n is negative, therefore direction charges
   $n_1 \sin\theta_1 = n_2 \sin\theta_2$
5. **(b)** The physical characteristics remain unchanged.
6. **(a, c)**

Applying Snell's law at P; $n_s \sin i_m = n_1 \sin(90° - C)$

n_s = Refractive index of surrounding



Also $\sin C = \frac{n_2}{n_1}$



Now

$$NA = \sin i_m = \frac{n_1}{n_s}\cos C = \frac{n_1}{n_s}\sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$\therefore \quad NA = \frac{\sqrt{n_1^2 - n_2^2}}{n_s}$$

For S_1 (in air)

$$NA = \sqrt{\frac{45}{16} - \frac{9}{4}} = \frac{3}{4}$$

For S_1 (in water)

$$NA = \frac{3}{4}\sqrt{\frac{45}{16} - \frac{9}{4}} = \frac{9}{16}$$

For s_1 $\left(\text{in } n_s = \frac{6}{\sqrt{15}}\right)$

$$NA = \frac{\sqrt{15}}{6}\sqrt{\frac{45}{16} - \frac{9}{4}} = \frac{3\sqrt{15}}{24}$$

For S_2 (in water)

$$NA = \frac{3}{4}\sqrt{\frac{64}{25} - \frac{49}{25}} = \frac{3}{4}\frac{\sqrt{15}}{5}$$

For S_2 (in air)

$$NA = \sqrt{\frac{64}{25} - \frac{49}{25}} = \frac{\sqrt{15}}{5}$$

For S_2 (in $n_s = \frac{4}{\sqrt{15}}$)

$$NA = \frac{\sqrt{15}}{4}\sqrt{\frac{64}{25} - \frac{49}{25}} = \frac{3}{4}$$

For S_2 $\left(\text{in } n_s = \frac{16}{3\sqrt{15}}\right)$

$$NA = \frac{3\sqrt{15}}{16}\sqrt{\frac{64}{25}-\frac{49}{25}} = \frac{9}{16}$$

(a), (c) are correct options

7. **(d)** $NA = \frac{1}{n_s}\sqrt{n_1^2 - n_2^2}$

Here

$NA_2 < NA_1$

$\therefore$ the NA of combined structure is equal to the smaller value of the two numerical apertures.

(d) is the correct option.

H. Assertion & Reason Type Questions

1. **(c)** **Statement 1 :**

NOTE : The mirror (spherical) formula $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ is valid only for mirrors of small apertures where the size of aperture is very small as compared to the radius of curvature of the mirror. This statement is true.

Statement 2 :

NOTE : Laws of mirror are valid for plane as well as large spherical surfaces.

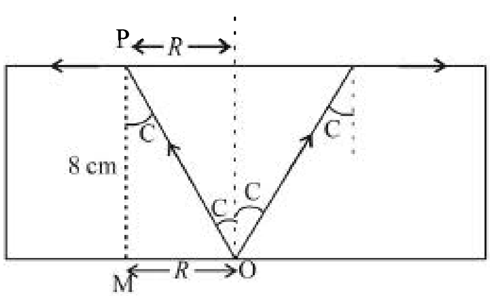
Therefore, statement 2 is wrong.

I. Integer Value Correct Type

1. **6** Given $f = +20$cm Also $m = \frac{f}{f+u}$

$$\therefore \frac{m_{25}}{m_{50}} = \frac{\frac{20}{20-25}}{\frac{20}{20-50}} = \frac{-30}{-5} = 6$$

2. **6** In the figure, C represents the critical angle

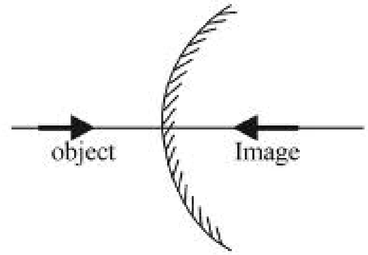


$$\therefore \sin C = \frac{1}{\mu} = \frac{3}{5} \quad \therefore \tan C = \frac{3}{4}$$

In Δ POM, $\tan C = \frac{OM}{PM} = \frac{R}{8}$

$$\therefore R = \frac{3}{4}\times 8 = 6\text{cm}$$

3. **3** **Using mirror formula for first position**



$u_1 = ?, v_1 = \frac{25}{3}\text{cm}, f = +10\text{cm}$

$\frac{1}{v_1}+\frac{1}{u_1}=\frac{1}{f}, \quad \frac{3}{25}+\frac{1}{u_1}=\frac{1}{10} \quad \therefore u_1 = -50\text{ m}$

Using mirror formula for the second position

$\frac{1}{v_2}+\frac{1}{u_2}=\frac{1}{f} \Rightarrow \frac{7}{50}+\frac{1}{u_2}=\frac{1}{10} \Rightarrow \frac{1}{u_2}=\frac{1}{10}-\frac{7}{50}$

$u_2 = -25$m

Change in position of object = 25 m

Speed of object $= \frac{25}{30}\times\frac{18}{5} = 3\text{ km h}^{-1}$

4. **2** For the convex spherical refracting surface of oil we apply

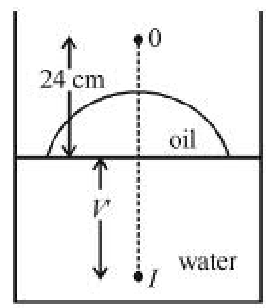
$$\frac{-\mu_1}{u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R}$$

$$\therefore \frac{-1}{(-24)}+\frac{7/4}{v}=\frac{\frac{7}{4}-1}{6}$$

$\therefore$ v = 21 cm

For water-oil interface

$$\frac{\frac{-7}{4}}{+21}+\frac{\frac{4}{3}}{V'}=0$$



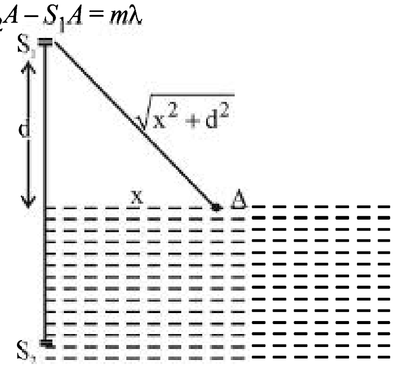
$\therefore$ V′ = 16 cm.

This is the image distance from water-oil interface. Therefore the distance of the image from the bottom of the tank is 2 cm.

5. **3** For maxima

Path defference = $m\lambda$

$\therefore$ $S_2A - S_1A = m\lambda$



$\therefore \quad \left[(n-1)\sqrt{d^2+x^2}+\sqrt{d^2+x^2}\right]-\sqrt{d^2-x^2}=m\lambda$

$\therefore \quad (n-1)\sqrt{(d^2+x^2)}=m\lambda$

$\therefore \quad \left(\frac{4}{3}-1\right)\sqrt{d^2+x^2}=m\lambda$

$\therefore \quad \sqrt{d^2+x^2}=3m\lambda$

$\therefore \quad d^2+x^2=9m^2\lambda^2$

$\therefore \quad x^2=9m^2\lambda^2-d^2$

$\therefore \quad p^2=9 \quad \Rightarrow \quad p=3$

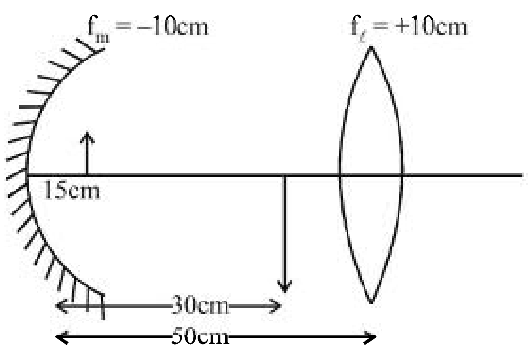
6. **7** Applying mirror formula

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

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-10}+\frac{1}{15}$$

$$\therefore \quad \frac{1}{v}=\frac{-15+10}{150}=\frac{-5}{150}=\frac{-1}{30}$$

$\therefore \quad v=-30\text{cm}$



For convex lens $u=|2f_\ell|$

Therefore image will have a magnification of *1*.

When the set – up is kept in a medium

The focal length of the lens will change

$$\frac{\frac{1}{f_\ell}}{\frac{1}{f'_\ell}}=\frac{\left(\frac{n_\ell}{n_s}-1\right)}{\left(\frac{n_\ell}{n'_s}-1\right)} \Rightarrow \frac{f'_\ell}{10}=\frac{\left[\frac{1.5}{1}-1\right]}{\left[\frac{1.5}{7/6}-1\right]}$$

$\Rightarrow \quad f'_\ell=17.5\text{ cm.}$

Applying lens formula $\quad \frac{1}{v}-\frac{1}{u}=\frac{1}{f'_\ell}$

$\therefore \quad \frac{1}{v}-\frac{1}{-20}=\frac{1}{17.5} \qquad \Rightarrow \quad v=140\text{ cm.}$

M'_ℓ = Magnification by lens $=\frac{v}{u}=\frac{140}{-20}=-7$

Now $\left|\frac{M_2}{M_1}\right|=\left|\frac{\text{Mmirror}\times M'_\ell}{\text{Mmirror}\times M_\ell}\right|=7$

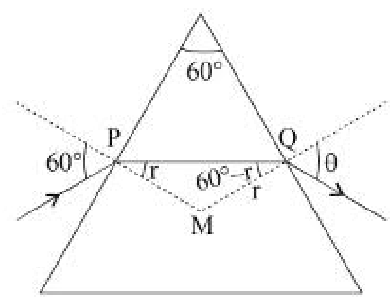
7. **2** Here $\angle MPQ+\angle MQP=60°$. If $\angle MPQ=r$ then $\angle MQP=60-r$

Applying Snell's law at P

$\sin 60°=n\sin r$ ...(i)

Differentiating w.r.t 'n' we get

$O=\sin r+n\cos r\times\frac{dr}{dn}$ ...(ii)



Applying Snell's law at Q

$\sin\theta=n\sin(60°-r)$ ...(iii)

Differentiating the above equation w.r.t 'n' we get

$$\cos\theta\frac{d\theta}{dn}=\sin(60°-r)+n\cos(60°-r)\left[-\frac{dr}{dn}\right]$$

$$\therefore \cos\theta\frac{d\theta}{dn}=\sin(60°-r)-n\cos(60°-r)\left[-\frac{\tan r}{n}\right]$$

[from (ii)]

$\therefore \quad \frac{d\theta}{dn}=\frac{1}{\cos\theta}[\sin(60°-r)+\cos(60°-r)\tan r]$ ...(iv)

From eq. (i), substituting $n=\sqrt{3}$ we get $r=30°$

From eq (iii), substituting $n=\sqrt{3}$, $r=30°$ we get $\theta=60°$

On substituting the values of r and θ in eq (iv) we get

$$\frac{d\theta}{dn}=\frac{1}{\cos 60°}[\sin 30°+\cos 30°\tan 30°]=2$$

Section-B JEE Main/ AIEEE

1. (b) **KEY CONCEPT :** The resolving power of a telescope

$R.P = \frac{D}{1.22\lambda}$ where D = diameter of the objective lens

λ = wavelength of light.

Clearly, larger the aperture, larger is the value of D, more is the resolving power or resolution.

2. (a) **KEY CONCEPT :** When two plane mirrors are inclined at each other at an angle θ then the number of the images of a point object placed between the plane mirrors is $\frac{360°}{\theta} - 1$, if $\frac{360°}{\theta}$ is even

$\therefore$ Number of images formed $= \frac{360°}{60°} - 1 = 5$

3. (a) The phenomenon of polarisation is shown only by transverse waves.

4. (d) $\frac{(R.P)_1}{(R.P)_2} = \frac{\lambda_2}{\lambda_1} = \frac{5}{4}$

5. (a) In an optical fibre, light is sent through the fibre without any loss by the phenomenon of total internal reflection as shown in the figure.

6. (b) Optical fibres form a dielectric wave guide and are free from electromagnetic interference or radio frequency interference.

7. (d) For the phenomenon of interference we require two sources of light of same frequency and having a definite phase relationship (a phase relationship that does not change with time)

8. (c) A real, inverted and enlarged image of the object is formed by the objective lens of a compound microscope.

9. (b) When $\theta = 90°$ then $\frac{360}{\theta} = \frac{360}{90} = 4$

is an even number. The number of images formed is given by

$n = \frac{360}{\theta} - 1 = \frac{360}{90} - 1 = 4 - 1 = 3$

10. (b) The incident angle is 45°.

Incident angle > critical angle, $i > i_c$

$\therefore \sin i > \sin i_c$ *or* $\sin 45 > \sin i_c$ $\quad \sin i_c = \frac{1}{n}$

$\therefore \sin 45° > \frac{1}{n}$ *or* $\frac{1}{\sqrt{2}} > \frac{1}{n} \Rightarrow n > \sqrt{2}$

11. (c) **KEY CONCEPT :** The focal length(F) of the final mirror is $\frac{1}{F} = \frac{2}{f_\ell} + \frac{1}{f_m}$

Here $\frac{1}{f_\ell} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= (1.5 - 1)\left[\frac{1}{\alpha} - \frac{1}{-30}\right] = \frac{1}{60}$

$\therefore \frac{1}{F} = 2 \times \frac{1}{60} + \frac{1}{30/2} = \frac{1}{10}$ $\quad \therefore F = 10$ cm

The combination acts as a converging mirror. For the object to be of the same size of mirror,

$u = 2F = 20$ cm

12. (d) The angle of incidence for total polarization is given by $\tan\theta = n \Rightarrow \theta = \tan^{-1} n$

Where n is the refractive index of the glass.

13. (b) For constructive interference $d\sin\theta = n\lambda$

given $d = 2\lambda \Rightarrow \sin\theta = \frac{n}{2}$

$n = 0, 1, -1, 2, -2$ hence five maxima are possible

14. (a) Frequency remains constant during refraction

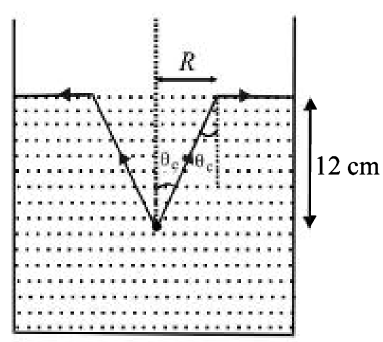
$v_{med} = \frac{1}{\sqrt{\mu_0 \in_0 \times 4}} = \frac{c}{2}$

$\frac{\lambda_{med}}{\lambda_{air}} = \frac{v_{med}}{v_{air}} = \frac{c/2}{c} = \frac{1}{2}$

$\therefore$ wavelength is halved and frequency remains unchanged

15. (a) $\sin\theta_c = \frac{1}{\mu} = \frac{3}{4}$

or $\tan\theta_c = \frac{3}{\sqrt{16-9}} = \frac{3}{\sqrt{7}} = \frac{R}{12}$



$\Rightarrow R = \frac{36}{\sqrt{7}}$ cm

16. **(b)** $\frac{y}{D} \geq 1.22\frac{\lambda}{d}$

$$\Rightarrow D \leq \frac{yd}{(1.22)\lambda} = \frac{10^{-3} \times 3 \times 10^{-3}}{(1.22) \times 5 \times 10^{-7}} = \frac{30}{6.1} \approx 5\text{m}$$

$\therefore D_{max} = 5\text{m}$

17. **(b)** $\frac{1}{f_a} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ .... (i)

$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$\frac{1}{f_m} = \left(\frac{1.5}{1.6} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ .... (ii)

Dividing (i) by (ii), $\frac{f_m}{f_a} = \left(\frac{1.5 - 1}{\frac{1.5}{1.6} - 1}\right) = -8$

$$P_a = -5 = \frac{1}{f_a} \Rightarrow f_a = -\frac{1}{5}$$

$$\Rightarrow f_m = -8 \times f_a = -8 \times -\frac{1}{5} = \frac{8}{5}$$

$$P_m = \frac{\mu}{f_m} = \frac{1.6}{8} \times 5 = 1\text{D}$$

18. **(d)** The shape of interference fringes formed on a screen in case of a monochromatic source is a straight line. Remember for double hole experiment a hyperbola is generated.

19. **(a)** $I = I_0\left(\frac{\sin\phi}{\phi}\right)^2$ and $\phi = \frac{\pi}{\lambda}(b\sin\theta)$

When the slit width is doubled, the amplitude of the wave at the centre of the screen is doubled, so the intensity at the centre is increased by a factor 4.

20. **(b)** $I = I_0 \cos^2\theta$

Intensity of polarized light $= \frac{I_0}{2}$

$\Rightarrow$ Intensity of untransmitted light $= I_0 - \frac{I_0}{2} = \frac{I_0}{2}$

21. **(a)** For a thin prism, $D = (\mu - 1)A$
Since $\lambda_b < \lambda_r \Rightarrow \mu_r < \mu_b \Rightarrow D_1 < D_2$

22. **(a)** The intensity of light at any point of the screen where the phase difference due to light coming from the two slits is ϕ is given by

$I = I_o \cos^2\left(\frac{\phi}{2}\right)$ where I_0 is the maximum intensity.

NOTE : This formula is applicable when $I_1 = I_2$. Here $\phi = \pi/3$

$$\therefore \frac{I}{I_0} = \cos^2\frac{\pi}{6} = \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4}$$

23. **(c)** Power of combination is given by
$P = P_1 + P_2 = (-15 + 5)D = -10D.$

Now, $P = \frac{1}{f} \Rightarrow f = \frac{1}{P} = \frac{1}{-10}$ metre

$$\therefore f = -\left(\frac{1}{10} \times 100\right)\text{cm} = -10\text{ cm.}$$

24. **(d)** The electron beam will be diffracted and the maxima is obtained at $y = 0$. Also the distance between the first minima on both side will be greater than d.

25. **(c)** This graph obeys the lens equation

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

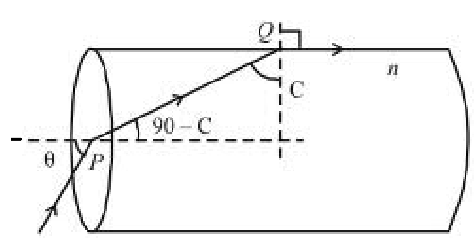
where f is a positive constant for a given convex lens.

26. **(a)** To find the refractive index of glass using a travelling microscope, a vernier scale is provided on the microscope

27. **(b)** Third bright fringe of known light coincides with the 4th bright fringe of the unknown light.

$$\therefore \frac{3(590)D}{d} = \frac{4\lambda D}{d} \Rightarrow \lambda = \frac{3}{4} \times 590 = 442.5\text{nm}$$

28. **(c)**

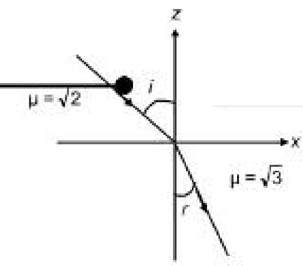


Applying Snell's law at Q

$$n = \frac{\sin 90°}{\sin C} = \frac{1}{\sin C}$$

$$\therefore \sin C = \frac{1}{n} = \frac{\sqrt{3}}{2}$$

$\therefore C = 60°$
Applying Snell's Law at P



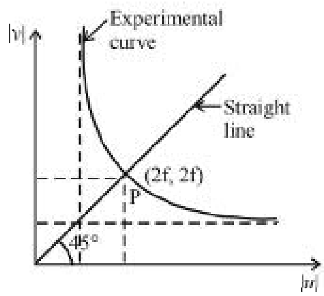
$n = \frac{\sin\theta}{\sin(90-C)} \Rightarrow \sin\theta = n \times \sin(90-C)$; from (1)

$\Rightarrow \sin\theta = n \cos$

$\therefore \theta = \sin^{-1}\left[\frac{2}{\sqrt{3}} \times \cos 60^0\right]$

or $\quad \theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

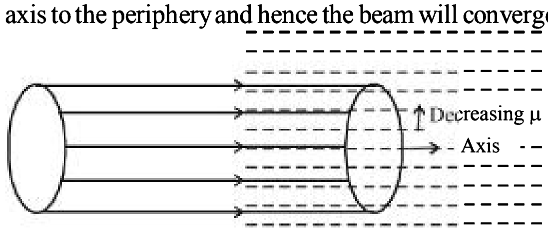
29. **(d)**



Here $u = -2f, v = 2f$

As $|u|$ increases, v decreases for $|u| > f$. The graph between $|v|$ and $|u|$ is shown in the figure. A straight line passing through the origin and making an angle of 45°with the x-axis meets the experimental curve at $P(2f, 2f)$.

30. **(b)** In the medium, the refractive index will decrease from the axis towards the periphery of the beam.
Therefore, the beam will move as one move from the axis to the periphery and hence the beam will converge.



31. **(d)** Initially the parallel beam is cylindrical . Therefore, the wavefront will be planar.

32. **(a)** The speed of light (c) in a medium of refractive index (μ) is given by

$\mu = \frac{c_0}{c}$, where c_0 is the speed of light in vacuum

$\therefore c = \frac{c_0}{\mu} = \frac{c_0}{\mu_0 + \mu_2(I)}$

As I is decreasing with increasing radius, it is maximum on the axis of the beam. Therefore, c is minimum on the axis of the beam.

33. **(a)** Angle of incidence is given by

$\cos(\pi - i) = \frac{(6\sqrt{3}\hat{i} + 8\sqrt{3}\hat{j} - 10\hat{k}).\hat{k}}{20}$

$-\cos i = -\frac{1}{2}$

$\angle i = 60°$

From Snell's law, $\sqrt{2}\sin i = \sqrt{3}\sin r$

$\angle r = 45°$

34. **(b)** A phase change of π rad appears when the ray reflects at the glass-air interface. Also, the centre of the interference pattern is dark.

35. **(a)** From mirror formula

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ so, $\frac{dv}{dt} = -\frac{v^2}{u^2}\left(\frac{du}{dt}\right)$

$\Rightarrow \quad \frac{dv}{dt} = -\left(\frac{f}{u-f}\right)^2 \frac{du}{dt} \Rightarrow \frac{dv}{dt} = \frac{1}{15}$ m/s

36. **(b)** $\because$ The E.M. wave are transverse in nature i.e.,

$= \frac{\vec{k} \times \vec{E}}{\mu\omega} = \vec{H}$ ...(i)

where $\vec{H} = \frac{\vec{B}}{\mu}$

and $\frac{\vec{k} \times \vec{H}}{\omega\varepsilon} = -\vec{E}$ ...(ii)

$\vec{k}$ is $\perp$ $\vec{H}$ and $\vec{k}$ is also $\perp$ to $\vec{E}$

or In other words $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$

37. **(d)** Let $a_1 = a, I_1 = a_1^2 = a^2$

$a_2 = 2a, I_2 = a_2^2 = 4a^2$. Therefore $I_2 = 4I_1$

$I_r = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

$I_r = I_1 + 4I_1 + 2\sqrt{4I_1^2}\cos\phi$

$\Rightarrow \quad I_r = 5I_1 + 4I_1\cos\phi$ ...(1)

Now, $I_{max} = (a_1 + a_2)^2 = (a + 2a)^2 = 9a^2$

$I_{max} = 9I_1 \Rightarrow I_1 = \frac{I_{max}}{9}$

Substituting in equation (1)

$I_r = \frac{5I_{max}}{9} + \frac{4I_{max}}{9}\cos\phi$

$I_r = \frac{I_{max}}{9}[5 + 4\cos\phi]$

$I_r = \frac{I_{max}}{9}\left[5 + 8\cos^2\frac{\phi}{2} - 4\right]$

$I_r = \frac{I_{max}}{9}\left[1 + 8\cos^2\frac{\phi}{2}\right]$

38. (d) The focal length of the lens

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}=\frac{1}{12}+\frac{1}{240}=\frac{20+1}{240}=\frac{21}{240}$$

$$f=\frac{240}{21}\text{cm}$$

$$\text{Shift}=t\left(1-\frac{1}{\mu}\right)\Rightarrow 1\left(1-\frac{1}{3/2}\right)=1\times\frac{1}{3}$$

$$\text{Now } v'=12-\frac{1}{3}=\frac{35}{3}\text{cm}$$

Now the object distance u.

$$\frac{1}{u}=\frac{3}{35}-\frac{21}{240}=\frac{1}{5}\left[\frac{3}{7}-\frac{21}{48}\right]$$

$$\frac{1}{u}=\frac{1}{5}\left[\frac{48-49}{7\times16}\right]$$

$$u=-7\times16\times5=-560\text{ cm}=-5.6\text{ m}$$

39. (c) $\therefore\ n=\dfrac{\text{Velocity of light in vacuum}}{\text{Velocity of light in medium}}$

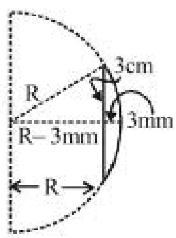
$\therefore\ n=\dfrac{3}{2}$

$3^2+(R-3mm)^2=R^2$

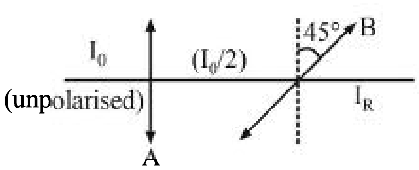
$\Rightarrow 3^2+R^2-2R(3mm)+(3mm)^2=R^2$

$\Rightarrow R\approx 15$ cm

$\dfrac{1}{f}=\left(\dfrac{3}{2}-1\right)\left(\dfrac{1}{15}\right)\Rightarrow f=30$ cm



40. (c) Relation between intensities



$$I_r=\left(\frac{I_0}{2}\right)\cos^2(45°)=\frac{I_0}{2}\times\frac{1}{2}=\frac{I_0}{4}$$

41. (d) It will be concentric circles.

42. (c) For the prism as the angle of incidence (i) increases, the angle of deviation (δ) first decreases goes to minimum value and then increases.

43. (b) By Lens maker's formula for convex lens

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

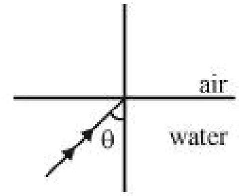
for, $\mu_{L_1}=\dfrac{4}{3}, f_1=4R$

for $\mu_{L_2}=\dfrac{5}{3}, f_2=-5R$

$\Rightarrow\ f_2=(-)$ ve

44. (b) For critical angle θ_c,

$\sin\theta_c=\dfrac{1}{\mu}$



For greater wavelength or lesser frequency μ is less.

So, critical angle would be more. So, they will not suffer reflection and come out at angles less then 90°.

45. (d) According to malus law, intensity of emerging beam is given by,

$I=I_0\cos^2\theta$

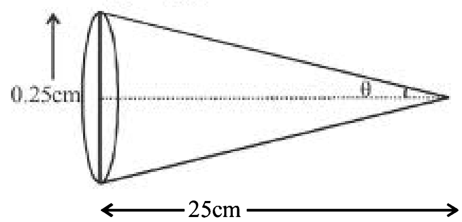
Now, $I_{A'}=I_A\cos^2 30°$

$I_{B'}=I_B\cos^2 60°$

As $I_{A'}=I_{B'}$

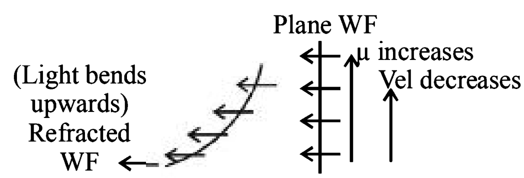
$\Rightarrow\ I_A\times\dfrac{3}{4}=I_B\times\dfrac{1}{4}\quad\therefore\quad\dfrac{I_A}{I_B}=\dfrac{1}{3}$

46. (d) $\sin\theta=\dfrac{0.25}{25}=\dfrac{1}{100}$



Resolving power $=\dfrac{1.22\lambda}{2\mu\sin\theta}=30\ \mu$m.

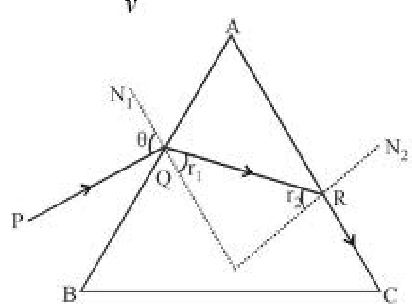
47. (b)



48. (c) When $r_2=C$, $\angle N_2Rc=90°$

Where C = critical angle

As $\sin C=\dfrac{1}{v}=\sin r_2$



Applying snell's law at 'R'

$\mu\sin r_2=1\sin 90°$ ...(i)

Applying snell's law at 'Q'

$1\times\sin\theta=\mu\ \sin r_1$ ...(ii)

But $r_1=A-r_2$

So, $\sin\theta = \mu \sin(A - r_2)$

$\sin\theta = \mu \sin A \cos r_2 - \cos A$ ...(iii) [using (i)]

From (1)

$$\cos r_2 = \sqrt{1-\sin^2 r_2} = \sqrt{1-\frac{1}{\mu^2}} \quad ...(iv)$$

By eq. (iii) and (iv)

$$\sin\theta = \mu \sin A \sqrt{1-\frac{1}{\mu^2}} - \cos A$$

on further solving we can show for ray not to transmitted through face AC

$$\theta = \sin^{-1}\left[u \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$$

So, for transmission through face AC

$$\theta > \sin^{-1}\left[u \sin\left(A - \sin^{-1}\left(\frac{1}{\mu}\right)\right)\right]$$

49. **(a)** Given geometrical spread = a

Diffraction spread $= \frac{\lambda}{a} \times L = \frac{\lambda L}{a}$

The sum $b = a + \frac{\lambda L}{a}$

For b to be minimum $\frac{db}{da} = 0 \qquad \frac{d}{da}\left(a + \frac{\lambda L}{a}\right) = 0$

$$a = \sqrt{\lambda L}$$

$$b\,\text{min} = \sqrt{\lambda L} + \sqrt{\lambda L} = 2\sqrt{\lambda L} = \sqrt{4\lambda L}$$

50. **(b)** A telescope magnifies by making the object appearing closer.

51. **(c)** We know that $i + e - A = \delta$

$35° + 79° - A = 40° \qquad \therefore \quad A = 74°$

$$\text{But } \mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2} = \frac{\sin\left(\frac{74+\delta_m}{2}\right)}{\sin\frac{74}{2}}$$

$$= \frac{5}{3}\sin\left(37° + \frac{\delta_m}{2}\right)$$

μ_{max} can be $\frac{5}{3}$. That is μ_{max} is less than $\frac{5}{3} = 1.67$

But δ_m will be less than 40° so

$$\mu < \frac{5}{3}\sin 57° < \frac{5}{3}\sin 60° \Rightarrow \mu = 1.45$$