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+2 PHYSICS STUDY MATERIAL

UNIT – 6 OPTICS

It includes

- **Book Back Answers**
- **Book Inside Questions**
- **One Marks Hints**
- **Creative One Marks**
- **Book Back Problem**

Unit – 6 Optics

Multiple choice questions

1.The speed of light in an isotropic medium depends on,

(a) its intensity (b)its wavelength

(c) the nature of propagation (d) the motion of the source w.r.to medium

Hint : $v = \frac{c}{\lambda}$

2. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. The length of the image is, (AIPMT Main 2012)

(a) 2.5 cm **(b) 5cm** (c) 10 cm (d) 15cm

Hint: $\frac{1}{v} + \frac{1}{u} = \frac{1}{F}$

$$\frac{1}{v_c} + \frac{1}{-30} = \frac{1}{-10}$$

On solving you will get $v = -20\ cm$

Length of image = $|v_A - v_c|$= 5cm

3. An object is placed in front of a convex mirror of focal length of f and the maximum and minimum distance of an object from the mirror such that the image formed is real and magnified. (IEE Main 2009)]

(a) 2f and c (b) c and ∞ (c) f and O **(d) None of these**

Hint : Convex mirror does not produce real images

4. For light incident from air onto a slab of refractive index 2. Maximum possible angle of refraction is,

(a) 30° (b) 45° (c) 60° (d) 90°

Hint : $n = \frac{\sin i}{\sin r}$

Angle of incidence = 30° n = 2

sin r = 0.5 r = $\sin^{-1}(0.5)$ = 30°

5. If the velocity and wavelength of light in air is V_a and λ_a and that in water is V_w and λ_w, then the refractive index of water is,

a) $\frac{V_w}{V_a}$ b) $\frac{V_a}{V_w}$ c) $\frac{\lambda_w}{\lambda_a}$ d) $\frac{\lambda_a V_a}{\lambda_w V_w}$

Hint : $n = \frac{c}{v}$

v = frequency × wavelength

6. Stars twinkle due to,

(a) reflection (b) total internal reflection **(c) refraction** (d) polarisation

7. When a biconvex lens of glass having refractive index 1.47 is dipped in a liquid, it acts as a plane sheet of glass. This implies that the liquid must have refractive index,

(a) less than one (b) less than that of glass
(c) greater than that of glass **(d) equal to that of glass**

Hint : $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

When Biconcave lens dipped in a liquid , acts as a plane sheet of glass , f = ∞ , 1/f = 0

$\frac{n_2}{n_1} - 1 = 0$ which means $n_2 = n_1$

8. The radius of curvature of curved surface at a thin planoconvex lens is 10 cm and the refractive index is 1.5. If the plane surface is silvered, then the focal length will be,

(a) 5 cm (b) 10 cm (c) 15 cm **(d) 20 cm**

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

$R_1 = \infty : R_2 = -R$ Where R = 10cm n= 1.5

f = 20cm

9. An air bubble in glass slab of refractive index 1.5 (near normal incidence) is 5 cm deep when viewed from one surface and 3 cm deep when viewed from the opposite face. The thickness of the slab is,

(a) 8 cm (b) 10 cm **(c) 12 cm** (d) 16 cm

Hint : Thickness of slab = $d_1n + d_2n$ = 5 × 1.5 + 3 × 1.5 = 12cm

10. A ray of light travelling in a transparent medium of refractive index n falls, on a surface separating the medium from air at an angle of incidents of 45°. The ray can undergo total internal reflection for the following *n*,

(a) *n* = 1.25 (b) *n* = 1.33 (c) *n* = 1.4 **(d) *n* = 1.5**

Hint : sin i > 1/n

n > 1/sin i

n > 1/ sin 45°

n > $\sqrt{2}$

n > 1.4141

11.A plane glass is placed over a various coloured letters (violet, green, yellow, red) The letter which appears to be raised more is,

(a) red (b) yellow (c) green **(d) violet**

Hint : μ = real depth / apparent depth

μ = c/λ

Violet has minimum wavelength so that μ of glass for violet is more than that of red light .Therefore apparent depth of letter V is least. Thus V is raised most

12. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm approximately. The maximum distance at which these dots can be resolved by the eye is, [take wavelength of light, λ = 500 nm]

(a) 1 m (b) 5 m (c) 3 m (d) 6m

Hint:sin θ $= \frac{Y}{d} = \frac{1.22\lambda}{d}$

$$D = \frac{Yd}{1.22\lambda} = \frac{10^{-3}\times3\times10^{-3}}{1.22\times500\times10^{-9}} = 5m$$

13. In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to,

(a) $2D$ (b) $\frac{D}{2}$ (c) $\sqrt{2}\,D$ (d) $\frac{D}{\sqrt{2}}$

Hint : $\beta = \frac{\lambda D}{d}$ $\beta' = \frac{\lambda D'}{d'}$ $d' = 2d$

$$\frac{\lambda D}{d} = \frac{\lambda D'}{2d}$$

$D' = 2D$

14. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are [IIT-JEE 1988]

(a) $5I$ and I (b) $5I$ and $3I$
(c) $9I$ and I (d) $9I$ and $3I$

Hint : $I_{Max} = \left(\sqrt{I}+\sqrt{4I}\right)^2 = (\sqrt{I}+2\sqrt{I})^2 = 9I$

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

15. When light is incident on a soap film of thickness 5×10^{-5} cm, the wavelength of light reflected maximum in the visible region is 5320 Å. Refractive index of the film will be,

(a) 1.22 **(b) 1.33** (c) 1.51 (d) 1.83.

Hint : $2\mu t\cos r = (2n+1)\frac{\lambda}{2}$

$$\mu = \frac{(2n+1)\lambda}{4t}$$

For visible region , n = 2

$$\mu = \frac{(2(2)+1)5320\times\mathbf{10^{-10}}}{4\times5000\times\mathbf{10^{-10}}} = 1.33$$

16. First diffraction minimum due to a single slit of width 1.0×10^{-5} cm is at 30°. Then wavelength of light used is,

(a) 400 Å (b) 500 Å (c) 600 Å (d) 700 Å

Hint:$d\ sin\theta = n\lambda$

$\theta = 30°$ d = 1.0×10^{-5} n = 1 (since it is first diffraction)

$\lambda = 500$Å

17. A ray of light strikes a glass plate at an angle 60°. If the reflected and refracted rays are perpendicular to each other, the refractive index of the glass is,

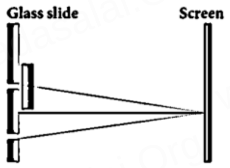
a)$\sqrt{3}$ b)$\frac{3}{2}$ c)$\sqrt{\frac{3}{2}}$ d)2

Hint : $n = \frac{\sin i}{\sin r}$

sin i = 30° sin r = 60°

Therefore n = $\sqrt{3}$

18. One of the of Young's double slits is covered with a glass plate as shown in figure. The position of central maximum will,



(a) get shifted downwards
(b) get shifted upwards
(c) will remain the same
(d) data insufficient to conclude

19. Light transmitted by Nicol prism is,
(a) partially polarised
(b) unpolarised
(c) plane polarised
(d) elliptically polarised

20. The transverse nature of light is shown in,
(a) interference
(b) diffraction
(c) scattering
(d) polarisation

Book inside

1. The velocity of light is maximum in a medium of
a)diamond b) water c) glass **d) vaccum**

2. A light of wavelength 320 nm enters in a medium of refractive index 1.6 from the air of refractive index 1.0 The new wavelength of light in the medium will be
a) 520nm **b) 400nm** c) 320nm d) 220nm

3. "Bhautik" runs towards a plane mirror with a speed of 20 ms^{-1} , what is the speed of his image ?
a) 45 ms^{-1} **b) 20 ms^{-1}** c) 15 ms^{-1} d) 7.5 ms^{-1}

4. A ray of light is incident at an angle 30^o on a mirror, The angle between normal and reflected ray is .
a)15^o b) 30^o c) 45^o **d) 60^o**

5.The no. of images formed between two parallel plane mirror are .
a) ∞ b) 0 c) 180 d) 360

6. If a glass rod is immersed in a liquid of the same refractive index, then it will .
a)appear bent b)) appear longer **c) disappear** d) appear shorter

7.A Plane mirror produces a magnification of .
a) 0 **b) +1** c) –1 d) ∞

8.A convex lens forms a real image of an object for it s two different positions on a screen if height of the image in both cases be 16 cm and 4 cm then height of the object is
a) –4 b) 4 c) –8 **d) 8**

9. A Sound wave travels from air to water. the angle of incidence α_1 and the angle of refraction is α_2 is If the snell's Law is valid then,
a) $\alpha_1 = \alpha_2$ **b) $\alpha_1 < \alpha_2$** c) $\alpha_1 > \alpha_2$ d) $\alpha_1 \geq \alpha_2$

10.Endoscopes work on the principle of
a)refraction b)diffraction **c)Total internal reflection** d)none of these

11. The critical angle for water is
a) 48.6° b)97.2° c)49.6° d)99.2°

12. Light travelling through transparent oil enters in to glass of refractive index 1.5. If the refractive index of glass with respect to the oil is 1.25, what is the refractive index of the oil?
a) 1.2 b)3.2 c)4.2 d)0.2

13. Speed of the Light travels from air in to glass slab of thickness 50 cm and refractive index 1.5.
a) 2×10^8 m/s b) 2×10^7 m/s **c) 2×10^9 m/s** d) 2×10^{10} m/s

14. Speed of light through the glass which has refractive index 1.5 is
a) 2×10^8 m/s b) 2×10^7 m/s **c) 2×10^9 m/s** d) 2×10^{10} m/s

15.Two plane mirror are at 45° to each other .If an object is placed between them , then number of images will be
a)1 b)5 **c)7** d)10

16.An object is at a distance of 0.5 in front of a plane mirror .Distance between the object and image
a) 0.5 m **b) 1m** c) 7m d) 10 m

17.To get three images of a single object , one should have two plane mirror at an angle of
a) 30° b) 60° **c) 90°** d) 180°

18. The radius of the illumination when seen above from inside a swimming pool from a depth of 10 m on a sunny day when the refractive index of water is 4/3
a)10.32 b)12.32 **c)11.32** d)13.32

19.It is difficult to see through fog because

a)light is scattered by droplets in fog b)fog absorbs light

c)refractive index of fog is infinity d)light suffers total internal reflection

20.In which of the following cases a man will not see image greater than himself

a) Convex mirror b) concave mirror c) plane mirror d) none of these

21.A mark at the bottom of the liquid appears to rise by 0.2 m .If the depth of the liquid is 2m , then the refractive index of the liquid is

a) 1.80 b)1.60 c) 1.33 **d) 1.11**

Hint : $n = h/h' \quad h' = 20 - 0.2 = 1.8$

22.One concave and convex lens placed is contact with each other .If the ratio of their power is 2/3 and focal length of the combination is 30cm , the individual focal length

a) 15cm and -10cm b) 30 cm and -20 cm

c) -15cm and 10cm d) – 30 cm and -30cm

Hint : $P_1/P_2 = 2/3$ $f_2 / f_1 = 3/2$ $f_2 = 2f_1/3$ using mirror formula

23.If a ray of light on a plane mirror at an angle of 30° then deviation produced by a plane mirror

a) 60° b) 90° **c) 120°** d) 150°

Hint : 180 – 60 = 120

23.The frequency of the material is 4×10^{14} Hz and the wavelength is 5000Å.The refractive index of the material

a)1.5 b)1.7 c)1.33 d)none of these

Hint : $v = c\lambda$ and $n = \frac{c}{v}$

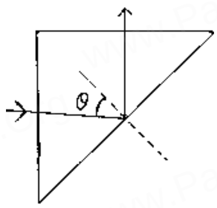
24.If the refractive index of a equilateral prism is $\sqrt{3}$ then the angle of minimum deviation

a) 50° **b) 60°** c) 39° d) 49°

25.A ray of light passes from the glass (n = 1.5) to medium (n = 1.60) .The value of the critical angle of glass is

a)$\sin^{-1}\left(\frac{16}{15}\right)$ b) $\sin^{-1}\left(\sqrt{\frac{16}{15}}\right)$ c) $\sin^{-1}\left(\frac{1}{2}\right)$ **d) $\sin^{-1}\left(\frac{15}{16}\right)$**

26.A prism is shown in figure , a ray is incident normally on one face is totally reflected .If θ is 45° , then the index of refraction of the glass is



a) < $\sqrt{2}$ b) >$\sqrt{2}$

c) = 2 d) none of these

Hint : $n = \frac{1}{sinc} = \sqrt{2}$

27.Two plano-convex lens of radius of curvature is R and refractive index n = 1.5 will have equivalent focal length equal to R when they are placed

a) at a distance of R b) at a distance R/4
c) at a distance R/2 **d) is contact with each other**

28.Which of the colour is scattered minimum?

a) Violet **b) red** c) blue d) yellow

Hint : wavelength maximum , scattering is minimum

29.An observer look at a tree of height 10 meters away with the telescope of magnifying power 10 . To him tree appears

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

Hint : Magnifying power is 10 so 10 times near

30.When the length of microscope tube increases , its magnifying power

a)decreases b) increases c) does not change d)none of these

31.A plano-convex lens of focal length is 20 cm is silvered at plane surface .New focal length will be

a) 20 cm b) 40 cm **c) 30cm** d) 60cm

Hint : $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ For a rarer medium to denser $-\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$ (u =∞ , v = f)

32.The radius of curvature of convex surface of a thin plano-convex lens is 5cm and refractive index of its material is 1.6 .The power of lens will be

a) 6 D b) 5 D **c) 4 D** d) 3D

Hint : $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $f = 0.25\ m$ P = 4D

33.An air bubble inside slab (n = 1.5) appear from one side at 6cm and from other side at 4cm . Then the thickness of glass slab is

a) 5cm **b) 10cm** c) 15 cm d) 20cm

34.Light of certain colour contains 2000 waves in the length of 1mm in air .What will be the wavelength of this light in medium of refractive index 1.25

a) 1000 Ǻ b) 2000 Ǻ c) 3000 Ǻ **d) 4000 Ǻ**

Hint : $\lambda' = \frac{\lambda}{n}$

35.A convex lens of glass (n = 1.5) has focal length 0.2 m .The lens is immersed in water of refractive index 1.33 .The change in the power of convex lens is

a) 3.72 D b) 4.62 D c) 6.44 D d) 1.86 D

Hint : $\frac{1}{f_a} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ **Hint :** $\frac{1}{f_w} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

P_a = 5D P_w = 0.128 $P_a - P_w$ = 3.72 D

36.A ray of light is incident normally on one of the faces of a solid prism of angle 30° and refractive index $\sqrt{2}$. The angle of minimum deviation is

a) 39° b) 42° c) 52° **d) 15°**

37.A concave lens forms the image of an object such that the distance between the object and the image is 10cm and the magnification produced is ¼ , then the focal length will be

a) -6.2 cm b) -12.4 cm **c) -4.4 cm** d) – 8.8 cm

38.A prism of certain angle deviates the red and blue rays by 8° and 12° respectively.Another prism of deviates the red light at small angle and made of different materials .The dispersive power of the materials of the prism are in the ratio

a) 5:6 b) 9:11 **c) 6:5** d) 11:9

39.Interference in possible in

a) light waves only b) both light and sound waves

c) sound waves only d) none of these

40.The fringe width for red is β_r (λ_r = 8000 Ã) and fringe width for violet is β_v (λ_v = 4000 Ã) then $\frac{\beta_r}{\beta_v}$ is

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

41.When a wave travels from an optically rarer medium to an optically denser medium its velocity decreases because of change in

a) Frequency b) wavelength **c) amplitude** d) phase

42.In young's double slit experiment if the width of 3rd fringe is 10^{-2} cm , then the width of 5th fringe will be

a) 10^{-2} b) 0.05 c) 0.02 d) 100

43.nth bright fringe of red light (λ_1 = 7500Ã) coincides with (n+1)th bright fringe of green light (λ_2 = 6000Ã) .The value of n is

a) 8 **b) 4** c) 2 d) 1

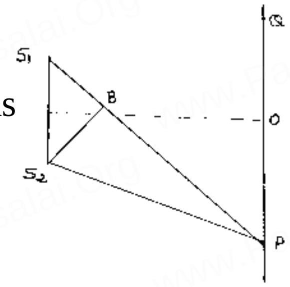
44.Which of the following will undergoes maximum diffraction?

a) α- particle b) γ – rays **c) radio waves** d) light waves

45.The distance between the first and sixth minima in the diffraction pattern of a single slit is 0.5mm .The screen is 0.5 m away from the slit. If the wavelength of light is 5000 Ã , then the width of the slit will be

a) 5mm **b) 2.5 mm** c) 1.25 mm d) 1 mm

46.In a given young's double slit experiment Q is the position of the first bright fringes on the right side of 0 , P is the 11th fringe on the other side as measured from Q .If $\lambda = 6000\tilde{A}$ then S_1B will be



a) 6.6×10^{-6} m b)3.3×10^{-6} m
c) 6×10^{-6} m d) 6×10^{6} m

47.The width of a single slit , if the first minimum is observed at an angle of 2^o with a wavelength of the light 6980 $\tilde{A}$ is
a) 0.2 mm b) 2×10^{-5} m c) 2×10^{-5} m **d) 0.02**

48. When a ray of light is incident on a glass surface at polarizing angle of 57.5^o, the angle between the incident ray and the reflected ray is
a) 57.5^o b) 32.5^o **c) 115^o** d) 90^o

49. Of the following, which one is a uniaxial crystal?
a) Mica b) Aragonite c) Topaz **d) Quartz**

50. A diffraction pattern is obtained using a beam of red light. What happens if the red light is replaced by blue light?
a) Bands disappear b) No change
c) Diffraction pattern becomes narrower and crowded together
d) Diffraction pattern becomes broader and further apart

51. In Young's double slit experiment, the separation between the slits is halved and the distance between the slits and the screen is doubled. Then the fringes width is
a) unchanged b) halved c) doubled **d) quadrupled**

52. The phenomenon of light used in the formation of Newton's rings is
a) diffraction **b) interference** c) refraction d) polarization

53. In case of fraunhofer diffraction, the wavefront under going diffraction is
a) Spherical wavefront b) Cylindrical wavefront
c) elliptical wavefront d) plane wavefront

54. Soap bubbles exhibit brilliant colours in sunlight due to
a) scattering of light b) diffraction of light
c) Polarization of light **d) interference of light**

55. In a pile of plates arrangement, the angle between the incident light and the reflected plane polarized light is
a) 57.5^o b) 32.5^o **c) 115^o** d) 90^o

56. In a Nicol prism, the ordinary ray is prevented from coming out of Canada balsam by the phenomenon of

a) reflection b) polarization c) diffraction **d) total internal reflection**

57. Consider a light beam incident from air to a glass slab at Brewster's angle as shown in Fig. A polaroid is placed in the path of the emergent ray at point P and rotated about an axis passing through the centre and perpendicular to the plane of the polaroid.

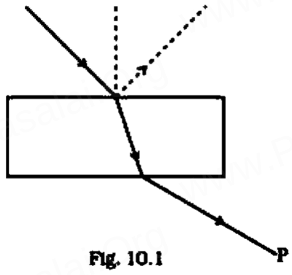


Fig. 10.1

(a) For a particular orientation there shall be darkness as observed through the polaroid.
(b) The intensity of light as seen through the Polaroid shall be independent of the rotation.
(c) The intensity of light as seen through the Polaroid shall go through a minimum but not zero for two orientations of the polaroid.
(d) The intensity of light as seen through the polaroid shall go through a minimum for four orientations of the polaroid.

Hint : When ray ABCD of light passes through prism in such a way that angle between reflected ray BE and refracted ray BC is 90° then only reflected ray is plane polarized. So Polaroid rotated in the way of CD the intensity will never be zero but varies in one complete rotation so, it verifies answer (c).

58. In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case
(a) there shall be alternate interference patterns of red and blue.
(b) there shall be an interference pattern for red distinct from that for blue.
(c) there shall be no interference fringes.
(d) there shall be an interference pattern for red mixing with one for blue.
Hint : For sustained interference, the source must be coherent and should emit the light of same frequency.
In this problem one hole is covered with red and other with blue, which has different frequency, so no interference takes place.

59. A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is
(a) blue. (b) green. (c) violet. **(d) red.**
Hint: The velocity of red colour is maximum in glass

60.An object approaches a convergent lens from the left of the lens with a uniform speed 5 m/s and stops at the focus. The image
(a) moves away from the lens with an uniform speed 5 m/s.
(b) moves away from the lens with an uniform acceleration.
(c) moves away from the lens with a non-uniform acceleration.
(d) moves towards the lens with a non-uniform acceleration.
Hint : When an object approaches towards a lens with uniform speed, its image moves away from the lens to infinity with non-uniform acceleration.

61. A passenger in an aeroplane shall

(a) never see a rainbow.

(b) may see a primary and a secondary rainbow as concentric circles.

(c) may see a primary and a secondary rainbow as concentric arcs.

(d) shall never see a secondary rainbow.

Hint : A passenger in an aeroplane may see primary and secondary rainbow as concentric circles.

62. You are given four sources of light each one providing a light of a single colour – red, blue, green and yellow. Suppose the angle of refraction for a beam of yellow light corresponding to a particular angle of incidence at the interface of two media is 90°. Which of the following statements is correct if the source of yellow light is replaced with that of other lights without changing the angle of incidence?

(a) The beam of red light would undergo total internal reflection.

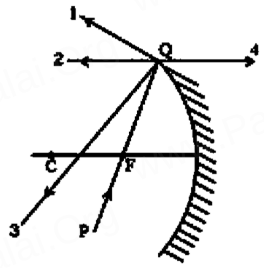
(b) The beam of red light would bend towards normal while it gets refracted through the second medium.

(c) The beam of blue light would undergo total internal reflection.

(d) The beam of green light would bend away from the normal as it gets refracted through the second medium.

Hint : We know that if angle of refraction is for the length then incidence angle is called critical angle. So light rays are passing from denser to rarer medium.

63. The direction of ray of light incident on a concave mirror is shown by PQ while directions in which the ray would travel after reflection is shown by four rays marked 1, 2, 3 and 4 . Which of the four rays correctly shows the direction of reflected ray?



(a) 1 **(b) 2** (c) 3 (d) 4

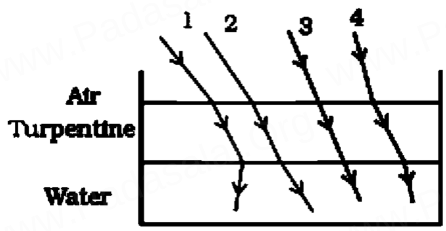
Hint : Incidence ray PQ is coming through principal focus F so it must be parallel to

principal axis, i.e. either 2 or 4.

As it is a concave mirror so, ray cannot go behind the mirror so ray (4) is discarded.

So ray 2 is the reflected ray. It is verifies answer (b)

64. The optical density of turpentine is higher than that of water while its mass density is lower. Fig shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in Fig , the path shown is correct?



(a) 1 **(b) 2** (c) 3 (d) 4

Hint : $\mu a < \mu T > \mu w$. Here, incidence ray passes from air to turpentine to water, i.e., from rare to denser then denser to rarer so first it bends towards normal then away from normal so the path shown is correct for ray (2).

Short Answer Questions (Book back)

1. State the laws of reflection.

(a) The incident ray, reflected ray and normal to the reflecting surface all are coplanar **(ie. lie in the same plane).**

(b) The angle of incidence *i* is equal to the angle of reflection *r*.($i = r$)

2. What is angle of deviation due to reflection?

The angle between the incident and deviated light ray is called *angle of deviation* of the light ray.

3. Give the characteristics of image formed by a plane mirror.

(i) The image formed by a plane mirror is virtual, erect, and laterally inverted.

(ii) The size of the image is equal to the size of the object.

(iii) The image distance far behind the mirror is equal to the object distance in front of it.

(iv). If an object is placed between two plane mirrors inclined at an angle θ, then the number of images *n* formed is as,

If $\left(\frac{360}{\theta}\right)$ is even then, $n = \left(\frac{360}{\theta} - 1\right)$ for objects placed symmetrically or unsymmetrically,

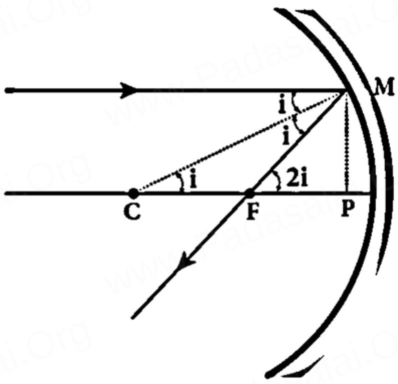
If $\left(\frac{360}{\theta}\right)$ is odd then, $n = \left(\frac{360}{\theta} - 1\right)$ for objects placed symmetrically,

If $\left(\frac{360}{\theta}\right)$ is odd then, $n = \left(\frac{360}{\theta}\right)$ for objects placed unsymmetrically.

4.

4.Derive the relation between *f* and *R* for a spherical mirror.

C - centre of curvature of the mirror.



(a) Concave mirror

- Consider a light ray parallel to the principal axis is incident on the mirror at *M* and passes through the principal focus *F* after reflection.
- line *CM* is the normal to the mirror at *M*.
- *i* - angle of incidence and the same will be the angle of reflection.
- If *MP* is the perpendicular from *M* on the principal axis, then from the geometry,
- The angles $\angle MCP = i$ and $\angle MFP = 2i$
- From right angle triangles ΔMCP and ΔMFP,

$$\tan i = \frac{PM}{PC} \qquad \tan 2i = \frac{PM}{PF}$$

Angles are small so $\tan i \approx i$

$$i = \frac{PM}{PC} \quad 2i = \frac{PM}{PF}$$

On simplification

2PF = PC

PF - focal length *f*

PC - radius of curvature *R*.

2f = R

5. What are the Cartesian sign conventions for a spherical mirror?

(i) The Incident light is taken from left to right (i.e. object on the left of mirror).

(ii) All the distances are measured from the pole of the mirror (pole is taken as origin).

(iii) The distances measured to the right of pole along the principal axis are taken as positive.
(iv) The distances measured to the left of pole along the principal axis are taken as negative.

(v) Heights measured in the upward perpendicular direction to the principal axis are taken as positive.

(vi) Heights measured in the downward perpendicular direction to the principal axis, are taken as negative.

6. What is optical path? Obtain the equation for optical path of a medium of thickness *d* and refractive index *n*.

Optical path of a medium is defined as the distance d' light travels in vacuum in the same time it travels a distance d in the medium.
consider a medium of **refractive index *n*** and **thickness *d***.

- Light travels with a speed v through the medium in a time t.

$t = \frac{d}{v}$

- In the same time, light can cover a greater distance d' in vacuum as it travels with greater speed c in vacuum

$t = \frac{d'}{c}$

- As the time taken in both the cases is the same, we can equate the time t

$$\frac{d}{v} = \frac{d'}{c}$$

$$d' = \frac{c}{v} d$$

Where $n = \frac{c}{v}$

$$\boldsymbol{d' = nd}$$

7. State the laws of refraction (Or) Snell's

a) The incident ray, refracted ray and normal to the refracting surface are all coplanar (ie. lie in the same plane).

b) The ratio of angle of incident i in the first medium to the angle of reflection r in the second medium is equal to the ratio of refractive index of the second medium n_2 to that of the refractive index of the first medium n_1.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

8. What is angle of deviation due to refraction?

Angle between the incident and deviated light is called angle of deviation.

- When light travels from rarer to denser medium
- Angle of deviation $\boldsymbol{d = i - r}$
- When light travels from denser to rarer medium
- Angle of deviation $\boldsymbol{d = r - i}$

9. What is principle of reversibility?

- It states that light will follow exactly the same path if its direction of travel is reversed.
- This is true for both reflection and refraction

10. What is relative refractive index?

From Snell's law $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$

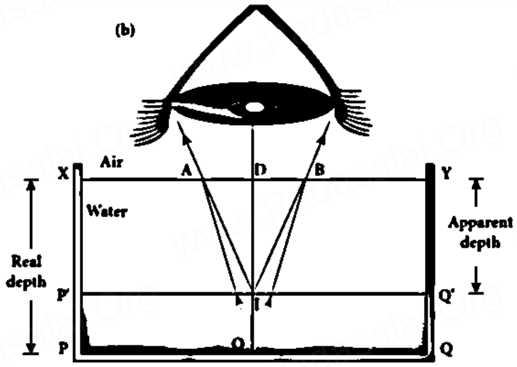
Term $\left(\frac{n_2}{n_1}\right)$ is called *relative refractive index* of second medium with respect to the first medium which is denoted as (n_{21})

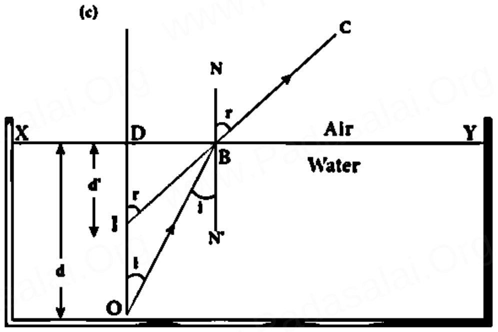
$$\boldsymbol{n_{21} = \frac{n_2}{n_1}}$$

11. Obtain the equation for apparent depth.

The bottom of a tank filled with water appears raised

Light from the object O at the bottom of the tank passes from denser medium (water) to rarer medium (air) to reach our eyes.





- It deviates away from the normal in the rarer medium at the point of incidence *B*.
- The refractive index of the denser medium is n_1 and rarer medium is n_2. Here, $n_1 > n_2$.
- **i** - angle of incidence in the denser medium **r** -the angle of refraction in the rarer medium
- The lines NN' and OD are parallel. Thus angle $\angle DIB$ is also r.
- The angles i and r are very small as the diverging light from O entering the eye is very narrow.
- The Snell's law in product form for this refraction is,

$$\boldsymbol{n_1 \sin i = n_2 \sin r}$$

As the angles i and r are small, we can approximate, $\sin i \approx \tan i$;

$$\boldsymbol{n_1 \tan i = n_2 \tan r}$$

In triangles ΔDOB and ΔDIB,

$$\tan i = \frac{DB}{DO} \qquad \tan r = \frac{DB}{DI}$$

$$n_1 \frac{DB}{DO} = n_2 \frac{DB}{DI}$$

DO is the actual depth d a
DI is the apparent depth d'.

$$n_1 = \frac{1}{d} = n_2 \frac{1}{d'}$$

$$\frac{d'}{d} = \frac{n_2}{n_1}$$

Apparent depth becomes $d' = \frac{n_2}{n_1} d$

As the rarer medium is air and its refractive index n_2 can be taken as 1, (n_2 =1). And the refractive index $n1$ of denser medium could then be taken as n, (n_1=n).

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

The bottom appears to be elevated by d-d',

$$\boldsymbol{d - d' = d = \frac{d}{n}}$$

12. Why do stars twinkle?

- Due to refraction of light through different layers of atmosphere which vary in refractive index, the path of light deviates continuously when it passes through atmosphere
- Movement of the atmospheric layers with varying refractive indices which is clearly seen in the night sky.

13. What is critical angle and total internal reflection?

Critical angle

The angle of incidence in the denser medium for which the refracted ray graces the boundary is called *critical angle* i_c

Total internal reflection

Phenomenon by which the entire light is reflected back into the denser medium itself. called *total internal reflection*.

14. Obtain the equation for critical angle.

Snell's law in the product form, equation for critical angle incidence becomes

$$n_1 \sin i_c = n_2 \sin r$$

r = 90° sin 90° = 1

$$\sin i_c = \frac{n_2}{n_1}$$

Here n_2 = 1(rarer medium is air, then its refractive index is 1)

n_1 = 1

$$i_c = \sin^{-1}\left(\frac{1}{n}\right)$$

15. Explain the reason for glittering of diamond.

- Diamond appears dazzling because the total internal reflection of light happens inside the diamond.
- The refractive index of only diamond is about 2.417 and critical angle 24.4°
- A skilled diamond cutter makes use of this larger range of angle of incidence (24.4° to 90° inside the diamond), to ensure that light entering the diamond is total internally reflected from the many cut faces before getting out

16. What are mirage and looming?

Due to the shaky nature of the layers of air, the observer feels as if the object is getting reflected by a pool of water or wet surface beneath the object This phenomenon is called ***mirage***.

In the cold regions like glaciers and frozen lakes and seas, the reverse effect of mirage will happen. Hence, an inverted image is formed little above the surface This phenomenon is called ***looming***.

17. Write a short notes on the prisms making use of total internal reflection.

Prisms can be designed to reflect light by 90° or by 180° by making use of total internal reflection .

In the first two cases, the critical angle i_c for the material of the prism must be less than 45°.

18. What is Snell's window?

When light entering the water from outside is seen from inside the water, the view is restricted to a particular angle equal to the critical angle i_c.

The restricted illuminated circular area is called *Snell's window*

19. Write a note on optical fibre.

- Transmitting signals through optical fibres is possible due to the phenomenon of total internal reflection. **Optical fibres consists of inner part called *core* and outer part called *cladding* (or) *sleeving*.**
- The refractive index of the material of the core must be higher than that of the cladding for total internal reflection to happen.
- Signal in the form of light is made to incident inside the core-cladding boundary at an angle greater than the critical angle.
- Hence, it undergoes repeated total internal reflections along the length of the fibre without undergoing any refraction.
- The light travels inside the core with no appreciable loss in the intensity of the light

20. Explain the working of an endoscope.

1. A bundle of optical fibres that are used to see inside a patient's body.
2. It works on the phenomenon of total internal reflection.
3. The optical fibres are inserted in to the body through mouth, nose or a special hole made in the body.

21. What are primary focus and secondary focus of convex lens?

The primary focus F_1 is defined as a point where an object should be placed to give parallel emergent rays to the principal axis

The secondary focus F_2 is defined as a point where all the parallel rays travelling close to the principal axis converge to form an image on the principal axis

22. What are the sign conventions followed for lenses?

(a) The sign of focal length is *not decided* on the direction of measurement of the focal length from the pole of the lens as they have two focal lengths, one to the left and another to the right (primary and secondary focal lengths on either side of the lens).
(b) The focal length of the thin lens is taken as positive for a converging lens and negative for a diverging lens.

23. Arrive at lens equation from lens maker's formula.
Refer : Long answer Q.no : 7

24. Obtain the equation for lateral magnification for thin lens.
Refer long answer Q.no : 8

25. What is power of a lens?

The power of a lens *P* is defined as the **reciprocal of its focal length**.

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

unit of power is **diopter**
Greater the power of lens, greater will be the deviation of ray and smaller will be the focal length.

26. Derive the equation for effective focal length for lenses in contact.

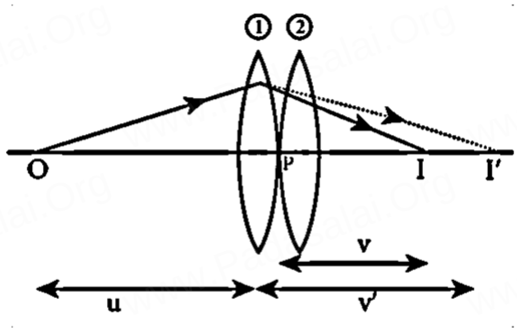


Figure. 6.37 Lenses in contact

1. Consider two lenses (1) and (2) of focal length f_1 and f_2 are placed coaxially in contact with each other so that they have a common principal axis. For an object placed at O beyond the focus of the first lens (1)on the principal axis, an image is formed by it at I'. This image I' acts as an object for the second lens (2) and the final image is formed at I .
2. As these two lenses are thin, the measurements are done with respect to the common optical centre *P* in the middle of the two lenses.
3. *PO* be object distance *u* and *PI'* be the image distance (v') for the first lens (1) and object distance for the second lens (2) and $PI = v$ be the image distance for the second lens (2)

lens equation for first lens (1)

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

Writing the lens equation for second lens (2)

$\frac{1}{v} - \frac{1}{u'} = \frac{1}{f_2}$.......(2)

(1) + (2)

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f_2} + \frac{1}{f_1}$ ....(3)

If the combination acts as a single lens of focal length *f* so that for an object at the position *O* it forms the image at *I* then,

$\frac{1}{v} + \frac{1}{u} = \frac{1}{F}$.......(4)

Comparing (3) and (4)

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

27. What is angle of minimum deviation?

The minimum value of angle of deviation is called angle of minimum deviation D. At minimum deviation,

(a) the angle of incidence is equal to the angle of emergence, $i_1 = i_2$.

(b) the angle of refraction at the face one and face two are equal, $r_1 = r_2$).

28. What is dispersion?

Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its *spectrum*.

29. How are rainbows formed?

1) Dispersion of sunlight through droplets of water during rainy days.
2) When sunlight falls on the water drop suspended in air, it splits (or dispersed) into its constituent seven colours.
3) Thus, water drop suspended in air behaves as a glass prism. Primary rain bow is formed when light entering the drop undergoes one total internal reflection inside the drop before coming out from the drop
4) A secondary rainbow appears outside of a primary rainbow and develops when light entering a raindrop undergoes two internal reflections.

30. What is Rayleigh's scattering?

If the scattering of light is by atoms and molecules which have size a very less than that of the wave length λ of light a<<λ, the scattering is called Rayleigh's scattering

31. Why does sky appear blue?

Amount of scattering α $\frac{1}{\lambda^4}$

When sunlight passes through the atmosphere , the blue colour (shorter wavelength) is scattered to a greater extent. So sky appears blue in color

32. What is the reason for reddish appearance of sky during sunset and sunrise?

Amount of scattering α $\frac{1}{\lambda^4}$

- During sunrise and sunset, the light from sun travels a greater distance through the atmosphere.
- The less-scattered red light of longer wavelength manages to reach our eye. This is the reason for the reddish appearance of sky during sunrise and sunset

33. Why do clouds appear white?

If light is scattered by large particles like dust and water droplets present in the atmosphere which have size *a* greater than the wavelength *λ* of light, *a* >> *λ*, the intensity of scattering is equal for all the wavelengths.

It is happening in clouds which contains large amount of dust and water droplets. Thus, in clouds all the colours get equally scattered irrespective of wavelength. This is the reason for the whitish appearance of cloud

34. What are the salient features of corpuscular theory of light?

- light is emitted as tiny, massless (negligibly small mass) and perfectly elastic particles called corpuscles
- As the corpuscles are very small, the source of light does not suffer appreciable loss of mass even if it emits light for a long time
- The energy of light is the kinetic energy of these corpuscles. When these corpuscles impinge on the retina of the eye, the vision is produced.
- Different size of the corpuscles is the reason for different colours of light. When the corpuscles approach a surface between two media, they are either attracted or repelled. The reflection of light is due to the repulsion of the corpuscles by the medium and refraction of light is due to the attraction of the corpuscles by the medium.

35. What is wave theory of light?

It explain the **propagation of light** through a medium light is a disturbance from a source that travels as longitudinal mechanical waves through the ether medium that was presumed to pervade all space as mechanical wave requires medium for its propagation

36. What is electromagnetic wave theory of light?

1) light is an electromagnetic wave which is transverse in nature carrying electromagnetic energy
2) No medium is necessary for the propagation of electromagnetic waves.

37. Write a short note on quantum theory of light.

1) light interacts with matter as photons to eject the electrons. A *photon* is a discrete packet of energy. Each photon has energy E of, $\boldsymbol{E = hv}$
2) light has both wave as well as particle nature it is said to have dual nature. Thus, it is concluded that light propagates as a wave and interact with matter as a particle

38. What is a wavefront?

A *wavefront* is the locus of points which are in the same state or phase of vibration.

39. What is Huygens' principle?

According to Huygens principle, each point of the wavefront is the source of secondary wavelets emanating from these points spreading out in all directions with the speed of the wave. These are called as secondary wavelets

40. What is interference of light?

The phenomenon of addition or superposition of two light waves which produces increase in intensity at some points and decrease in intensity at some other points is called interference of light.

41. What is phase of a wave?

Phase is the angular position of vibration

42. Obtain the relation between phase difference and path difference.

A **path difference** δ corresponds to a **phase difference** ϕ

$$\delta = \frac{\lambda}{2\pi} \times \emptyset$$

43. What are coherent sources?

Two light sources are said to be coherent if they produce waves which have same phase or constant phase difference, same frequency or wavelength (monochromatic), same waveform and preferably same amplitude.

44. What is intensity division?

When light allowed to pass through a partially silvered mirror (beam splitter), both reflection and refraction take place simultaneously. As the two light beams are obtained from the same light source, the two divided light beams will be coherent beams. They will be either in-phase or at constant phase difference

45. How does wavefront division provide coherent sources?

1) It is used for producing two coherent sources. We know a point source produces spherical wavefronts.
2) All the points on the wavefront are at the same phase. If two points are chosen on the wavefront by using a double slit, the two points will act as coherent sources

46. How do source and images behave as coherent sources?

source and its image will act as a set of coherent source, because the source and its image will have waves in-phase or constant phase difference

47. What is bandwidth of interference pattern?

The *bandwidth* (β) is defined as the distance between any two consecutive bright or dark fringes

48. What is diffraction?

Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

49. Differentiate between Fresnel and Fraunhofer diffraction.

Fresnel diffraction	Fraunhofer diffraction
Spherical or cylindrical wavefront undergoes diffraction	**Plane wavefront** undergoes diffraction
Light wave is from a source at finite distance	Light wave is from a source at infinity
Difficult to observe and analyse	**Easy to observe** and analyse
For laboratory conditions, **convex lenses need not be used**	**In laboratory conditions, convex lenses are to be used**

50. Discuss the special cases on first minimum in Fraunhofer diffraction.

Consider the condition for first minimum with ($n = 1$). $a \sin \theta = \lambda$

The first minimum has an angular spread of

$\sin \theta = \frac{\lambda}{a}$

i) When $a < \lambda$, the diffraction is not possible, because $\sin\theta$ can never be greater

(ii) When $a \geq \lambda$, the diffraction is possible. For $a = \lambda$, $\sin\theta = 1$ i.e, $\theta = 90^0$. That means the first minimum is at 90°
For $a >> \lambda$, $\sin\theta << 1$ i.e, the first minimum will fall within the width of the slit itself

(iii) When $a > \lambda$ and comparable say
$a = 2\lambda$ $\sin\theta = 30^o$

51. What is Fresnel's distance? Obtain the equation for Fresnel's distance.

Fresnel's distance is the distance upto which ray optics is obeyed and beyond which ray optics is not obeyed but, wave optics becomes significant.
From the diffraction equation for first minimum

$\sin\theta = \frac{\lambda}{a}$

From the definition of Fresnel distance

$\sin 2\theta = \frac{a}{z}$; $2\theta = \frac{a}{z}\ \frac{\lambda}{a} = \frac{a}{z}$

After rearranging, we get Fresnel's distance z^2 $z = \frac{a^2}{\lambda}$

52. Mention the differences between interference and diffraction.

Interference	Diffraction
Superposition of two waves	Bending of waves around edges
Superposition of waves from two coherent sources.	Superposition wavefronts emitted from various points of the same wavefront.
Equally spaced fringes.	Unequally spaced fringes
Intensity of all the bright fringes is almost same	Intensity falls rapidly for higher orders
Large number of fringes are obtained	Less number of fringes are obtained

53. What is a diffraction grating?

Grating is a plane sheet of transparent material on which opaque rulings are made with a fine diamond pointer.

54. What are resolution and resolving power?

Resolution

It is the quality of the image which is decided by diffraction effect and Rayleigh criterion .

Resolving power

The ability of an optical instrument to separate or distinguish small or closely adjacent objects through the image formation is said to be *resolving power* of the instrument

55. What is Rayleigh's criterion?

- According to *Rayleigh's criterion*, for two point objects to be just resolved, the minimum distance between their diffraction images must be in such a way that the central maximum of one coincides with the first minimum of the other and vice versa

- The Rayleigh's criterion is said to be limit of resolution.

56. What is polarisation?

The phenomenon of restricting the vibrations of light (electric or magnetic field vector) to a particular direction perpendicular to the direction of wave propagation motion is called *polarization* of light.

57. Differentiate between polarised and unpolarised light

Polarised light	Unpolarised light
Consists of waves having their electric field vibrations in a single plane normal to the direction of ray	Consists of waves having their electric field vibrations equally distributed in all directions normal to the direction of ray.
Asymmetrical about the ray direction	Symmetrical about the ray direction
It is obtained from unpolarised light with the help of polarisers	Produced by conventional light sources.

58. Discuss polarisation by selective absorption.

- *Selective absorption* is the property of a material which transmits waves whose electric fields vibrate in a plane parallel to a certain direction of orientation and absorbs all other waves.
- The *polaroids* or *polarisers* are thin commercial sheets which make use of the property of selective absorption to produce an intense beam of plane polarised light. Selective absorption is also called as *dichroism*.

59. What are polariser and analyser?

The Polaroid which plane polarises the unpolarised light passing through it is called a *polariser*.

The polaroid which is used to examine whether a beam of light is polarised or not is called an *analyser*

60. What are plane polarised, unpolarised and partially polarised light?

In *plane polarised* light the intensity varies from maximum to zero for every rotation of 90^o of the analyser

If the intensity of light varies between maximum and minimum for every rotation of 90^o of the analyser, the light is said to be ***partially polarised* light**

Unpolarised light

Consists of waves having their electric field vibrations equally distributed in all directions normal to the direction of ray.

61. State and obtain Malus' law.

It states that when a beam of plane polarised light of intensity I_0 is incident on an analyser, the light transmitted of intensity I from the analyser varies directly as the square of the cosine of the angle θ between the transmission axis of polariser and analyser

$$I = I_0 cos^2\theta$$

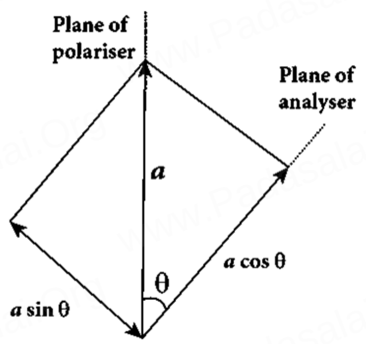
1) consider the plane of polariser and analyser are inclined to each other at an angle θ .
   I_0 - intensity
   a - the amplitude of the electric vector transmitted by the polariser.
2) The amplitude a of the incident light has two rectangular components, ($a\cos\theta$) and ($a\sin\theta$) which are the parallel and perpendicular components to the axis of transmission of the analyser.
3) Only the component ($a\cos\theta$) will be transmitted by the analyser. The intensity of light transmitted from the analyser is proportional to the square of the component of the amplitude transmitted by the analyser.

$I \alpha \ (a\cos\theta)^2$

$I = k\ (a\cos\theta)^2$

$I = k\ a^2 cos^2\theta$

$\boldsymbol{I = I_0 cos^2\theta}$ **where** $\boldsymbol{I_0 = ka^2}$



62. List the uses of polaroids.

1. Polaroids are used in goggles and cameras to avoid glare of light.
2. Polaroids are useful in three dimensional motion pictures i.e., in holography.
3. Polaroids are used to improve contrast in old oil paintings.
4. Polaroids are used in optical stress analysis.
5. Polaroids are used as window glasses to control the intensity of incoming light.
6. Polarised laser beam acts as needle to read/write in compact discs (CDs).
7. Polaroids produce polarised lights to be used in liquid crystal display (LCD).

63. State Brewster's law.

The law states that the tangent of the polarising angle for a transparent medium is equal to its refractive index. The value of Brewster's angle depends on the nature of the transparent refracting medium and the wavelength of light used.

$$\tan i_p = n$$

64. What is angle of polarisation and obtain the equation for angle of polarisation.

The angle of incidence at which the reflected beam is plane polarised is called *polarising angle* i_p

65. Discuss about pile of plates.

1) The phenomenon of polarisation by reflection is used in the construction of pile of plates.
2) It consists of a number of glass plates placed one over the other in a tube .
3) The plates are inclined at an angle of 33.7° to the axis of the tube.
4) A beam of unpolarised light is allowed to fall on the pile of plates along the axis of the tube.
5) So, the angle of incidence of light will be at 56.3° which is the polarising angle for glass.
6) The vibrations perpendicular to the plane of incidence are reflected at

each surface and those parallel to it are transmitted.

7) The larger the number of surfaces, the greater is the intensity of the reflected plane polarised light.
8) The pile of plates is used as a polarizer and also as an analyser.

66. What is double refraction or birefringence ?

When a ray of unpolarised light is incident on a calcite crystal, two refracted rays are produced. Hence, two images of a single object are formed. This phenomenon is called *double refraction*

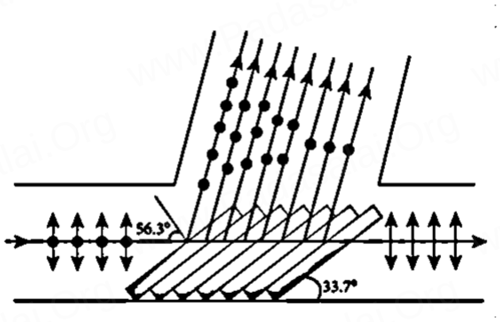
67. Mention the types of optically active crystals with example.

Crystals like calcite, quartz, tourmaline and ice having only one optic axis are called **uniaxial crystals**.

Crystals like mica, topaz, selenite and aragonite having two optic axes are called **biaxial crystals.**

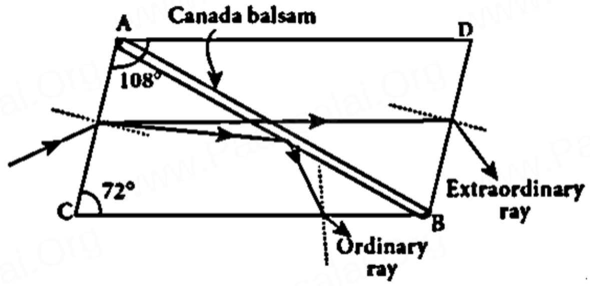
68. Discuss about Nicol prism.

- Nicol prism is an optical device incorporated in optical instruments both for producing and analysing plane polarised light.
- The construction of a Nicol prism is based on the **phenomenon of Double refraction**
- It consists of calcite crystal which is a double refracting crystal with its length three times its breadth.
- It is cut into two halves along the diagonal so that their face angles are 72° and 108° . The two halves are joined together by a layer of *canada balsam*, a transparent cement.
- consider a ray of unpolarised light from monochromatic source such as a sodium vapour lamp is incident on the face *AC* of the Nicol prism. Double refraction takes place and the ray is split into ordinary and extraordinary rays.
- They travel with different velocities. The refractive index of the crystal for the ordinary ray (monochromatic sodium light) is 1.658 and for



extraordinary ray is 1.486.

- The refractive index of canada balsam is 1.523. Canada balsam does not polarise light.
- The ordinary ray is total internally reflected at the layer of canada balsam and is prevented from emerging from the other face. The extraordinary ray alone is transmitted through the crystal which is plane polarised.'



Uses of Nicol prism

(i) It produces plane polarised light and functions as a polariser

(ii) It can also be used to analyse the plane polarised light i.e used at an analyser.

Drawbacks of Nicol prism

(i) Its cost is very high due to scarity of large and flawless calcite crystals
(ii) Due to extraordinary ray passing obliquely through it, the emergent ray is always displaced a little to one side.
(iii) The effective field of view is quite limited
(iv) Light emerging out of it is not uniformly plane polarised.

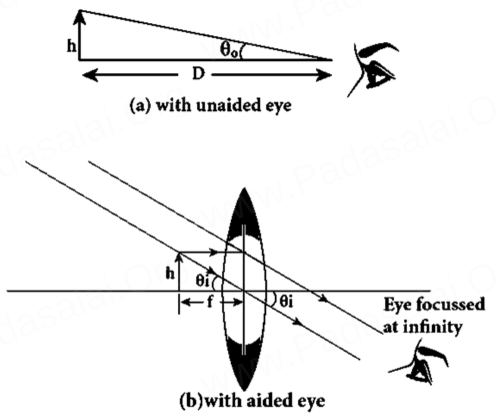


Figure 6.83 Normal focusing

69. How is polarisation of light obtained by scattering of light?

1) The light from a clear blue portion of the sky shows a rise and fall of intensity when viewed through a polaroid which is rotated.
2) This is because of sunlight, which has changed its direction (having been scattered) on encountering the molecules of the earth's atmosphere.
3) The incident sunlight is unpolarised. The electric field of light interact with the electrons present in the air molecules. Under the influence of the electric field of the incident wave the electrons in the molecules acquire components of motion in both these directions.
4) We have shown an observer looking at 90° to the direction of the sun. Clearly, charges accelerating parallel do not radiate energy towards this observer since their acceleration has no transverse component.
5) The radiation scattered by the molecule is therefore polarized perpendicular to the plane
6) This explains the reason for polarisation of sunlight by scattering.

70. Discuss about simple microscope and obtain the equations for magnification for near point focusing and normal focusing.

Simple microscope is a single magnifying (converging) lens of small focal length. The idea is to get an erect, magnified and virtual image of the object. For this the object is placed between F and P on one side of the lens and viewed from other side of the lens

<u>Magnification in near point focusing</u>

Object distance *u* is less than *f*.
The image distance is the near point *D*.
The magnification m is given by the relation,

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

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

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

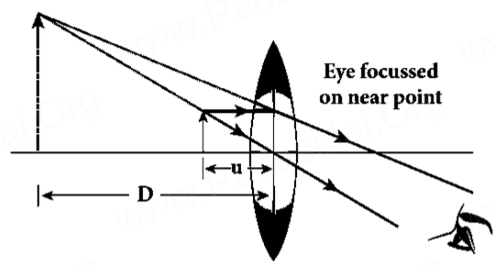


Figure 6.82 Near point focusing

$v = -D$

$$\boldsymbol{m = 1 + \frac{D}{f}}$$

<u>Magnification in normal focusing (angular magnification)</u>

The ratio of height of image to height of object $\left(m = \frac{h'}{h}\right)$ was taken .

The angular magnification is defined as the ratio of angle θ_i subtended by the image with aided eye to the angle θ_o subtended by the object with unaided eye

$$m = \frac{\theta_i}{\theta_o}$$

For unaided eye

$$\boldsymbol{tan\ \theta_o \approx \theta_o = \frac{h}{D}}$$

For aided eye

$$\boldsymbol{tan\ \theta_i \approx \theta_i = \frac{h}{f}}$$

The angular magnification is

$$m = \frac{\theta_i}{\theta_o} = \frac{h/f}{h/D}$$

$$\boldsymbol{m = \frac{D}{f}}$$

This is the magnification for normal focusing.

71. What are near point and normal focusing?

Near point focusing – The image is formed at near point, i.e. 25 cm for normal eye. This distance is also called as *least distance D* of distinct vision. In this position, the eye feels comfortable but there is little strain on the eye

Normal focusing – The image is formed at infinity. In this position the eye is most relaxed to view the image.

72. Why is oil immersed objective preferred in a microscope?

- The ability of microscope depends not only in magnifying the object but also in resolving two points on the object separated by a small distance d_{min}.
- Smaller the value of d_{min} better will be the resolving power of the microscope.
- To further reduce the value of d_{min} the optical path of the light is increased by immersing the objective of the microscope in to a bath containing oil of refractive index n.

73. What are the advantages and disadvantages of using a reflecting telescope?

Advantages

1) Only one surface it to be polished and maintained.
2) Support can be given from the entire back of the mirror rather than only at the rim for lens. Mirrors weigh much less compared to lens.

Disadvantages

1) objective mirror would focus the light inside the telescope tube.
2) An eye piece should present inside obstructing some light.

74. What is the use of an erecting lens in a terrestrial telescope?

A terrestrial telescope has an additional erecting lens to make the final image erect

75. What is the use of collimator?

- The collimator is an arrangement to produce a parallel beam of light.
- It consists of a long cylindrical tube with a convex lens at the inner end

and a vertical slit at the outer end of the tube.

- The distance between the slit and the lens can be adjusted such that the slit is at the focus of the lens.
- The slit is kept facing the source of light. The width of the slit can be adjusted.
- The collimator is rigidly fixed to the base of the instrument.

76. What are the uses of spectrometer?

1) To study the spectra of different sources of light
2) To measure the refractive indices of materials.

77. What is myopia? What is its remedy?

person suffering from nearsightedness or *myopia* cannot see distant objects clearly. This may result because the lens has too short focal length due to thickening of the lens or larger diameter of the eyeball than usual.

Remedy

concave lens slightly diverges the parallel rays from infinity and makes them focus now at the retina

78. What is hypermetropia? What is its remedy?

A person suffering from farsightedness or *hypermetropia* or *hyperopia* cannot clearly see objects close to the eye. It occurs when the eye lens has too long focal length due to thining of eye lens or shortening of the eyeball than normal.

Remedy

convex lens slightly converges the rays coming from beyond *retina* and makes them focus now at the retina

79. What is presbyopia?

- Due to aging people may develop combination of more than one defect. If it is the combination of nearsightedness and farsightedness then, such persons may need a converging glass for reading purpose and a diverging glass for seeing at a distance.
- Bifocal lenses and progressive lenses provide solution for these problems.

80. What is astigmatism?

- Astigmatism is the defect arising due to different curvatures along different planes in the *eye* lens. Astigmatic person cannot see all the directions equally well
- The remedy to astigmatism is using of lenses with different curvatures in different planes

Book inside

1.What do you meant by reflection of light?

The bouncing back of light into the same medium when it encounters a reflecting surface is called *reflection* of light.

2.What is Paraxial Rays and Marginal Rays?

The rays travelling very close to the principal axis and make small angles with it are called ***paraxial rays.***

Rays travelling far away from the principal axis and fall on the mirror far away from the pole are called as ***marginal rays.***

3. What is lateral or transverse magnification?

The lateral or transverse magnification is defined as the ratio of the height of the image to the height of the object

Magnification(m)= $\frac{height\ of\ image\ (h')}{height\ of\ object\ (h)}$

4.What is Refractive index ?

Refractive index of a transparent medium is defined as the ratio of speed of light in vacuum (or air) to the speed of light in that medium.

$$n = \frac{c}{v}$$

5.What are Characteristics of refraction

a) When light passes from rarer medium to denser medium it deviates towards normal in the denser medium.

b) When light passes from denser medium to rarer medium it deviates away from normal in the rarer medium

c) In any refracting surface there will also be some reflection taking place. Thus, the intensity of refracted light will be lesser than the incident light. **The phenomenon in which a part of light from a source undergoing reflection and the other part of light from the same source undergoing refraction at the same surface is called *simultaneous reflection* or *simultaneous refraction*.**

6.What are the two conditions for total internal reflection

(a) light must travel from denser to rarer medium,

(b) angle of incidence in the denser medium must be greater than critical angle

7.Why Dazzling colours are exhibited by thin films of oil spread on the surface of water and also by soap bubbles?

Colours are due to interference of white light undergoing multiple reflections from the top and the bottom surfaces of thin films.

8.What is two way mirror and how to identify it?

- A glass can be made partially see through and partially reflecting by varying the amount of coating on its surface.
- Place the finger nail against the mirror surface. If there is a gap between nail and its image, then it is a regular mirror. If the fingernail directly touches its image, then it is a two way mirror.

Long Answer Questions

1. Derive the mirror equation and the equation for lateral magnification.

- The mirror equation establishes a relation among object distance *u*, image distance *v* and focal length *f* for a spherical mirror.
- An object *AB* is considered on the principal axis of a concave mirror beyond the center of curvature *C*.

- consider three paraxial rays from point *B* on the object.
- The first paraxial ray *BD* travelling parallel to principal axis is incident on the concave mirror at *D*, close to the pole *P*.
- After reflection the ray passes through the focus *F*.
- The second paraxial ray *BP* incident at the pole *P* is reflected along *PB´*.
- The third paraxial ray *BC* passing through centre of curvature *C*, falls normally on the mirror at *E* is reflected back along the same path.
- The three reflected rays intersect at the point B′ .
- A perpendicular drawn$A'B'$ as to the principal axis is the real, inverted image of the object *AB*.
- By law of reflection, the angle of incidence $\angle BPA$ is equal to the angle of reflection $\angle B'P'A'$
- The triangles ΔBPA and $\Delta B'P'A'$are similar. Thus, from the rule of similar triangles,

$$\frac{A'B'}{AB} = \frac{PA'}{PA} \ldots\ldots\ldots(1)$$

The other set of similar triangles are, ΔDPF and $\Delta D'P'F'$. (*PD* is almost a straight vertical line)

$$\frac{A'B'}{PD} = \frac{A'F}{PF}$$

PD = AB

$$\frac{A'B'}{AB} = \frac{A'F}{PF} \ldots\ldots\ldots(2)$$

From (1) & (2)

$$\frac{PA'}{PA} = \frac{A'F}{PF}$$

$$A'F = PA' - PF$$

$$\frac{PA'}{PA} = \frac{PA' - PF}{PF}$$

By applying the sign conventions for the various distances

PA =-u $PA' = -v$ $PF = -f$

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

On further simplification

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

Dividing either side with v and rearranging

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

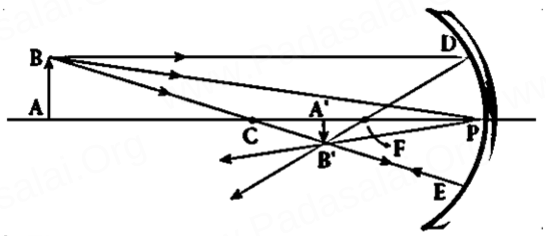


Figure 6.12 Mirror equation

<u>lateral or transverse magnification</u>

The **lateral or transverse magnification** is defined as the ratio of the height of the image to the height of the object

Magnification(m)= $\dfrac{\textbf{height of image } (h')}{\textbf{height of object } (h)}$

$$m = \frac{h'}{h}$$

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

$A'B' = -h, AB = h, PA' = -v$,

$PA = -u$

$$\frac{-h}{h} = \frac{-v}{-u}$$

On simplifying we get

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

Using mirror equation,

$$\boldsymbol{m = \frac{h'}{h} = \frac{f-v}{f} = \frac{f}{f-u}}$$

2. Describe the Fizeau's method to determine speed of light.

Construction

- The light from the source *S* was first allowed to fall on a partially silvered glass plate *G* kept at an angle of 45° to the incident light from the source.
- The light then was allowed to pass through a rotating toothed-wheel with *N* teeth and *N* cuts of equal widths whose speed of rotation could be varied through an external mechanism .
- The light passing through one cut in the wheel will get reflected by a mirror *M* kept at a long distance *d*, about 8 *km* from the toothed wheel. If the toothed wheel was not rotating, the reflected light from the mirror would again pass through the same cut and reach the eyes of the observer through the partially silvered glass plate.

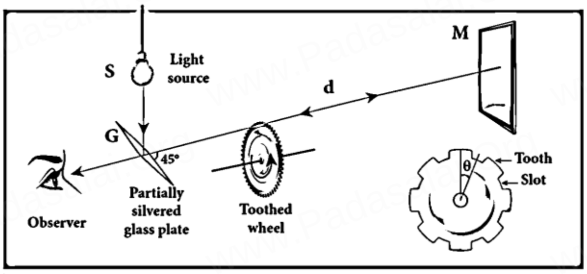


Figure 6.13 Speed of light by Fizeau's method

Working:

The angular speed of rotation of the toothed wheel was increased from zero to a value ω until light passing through one cut would completely be blocked by the adjacent tooth.

This is ensured by the disappearance of light while looking through the partially silvered glass plate.

Expression for speed of light:

The speed of light in air *v* is equal to the ratio of the distance the light travelled from the toothed wheel to the mirror and back 2*d* to the time taken *t*.

$$v = \frac{2d}{t} \;\ldots\ldots (1)$$

The distance *d* is a known value from the arrangement. The time taken *t* for the light to travel the distance to and fro is calculated from the angular speed ω of the toothed wheel.

The angular speed ω of the toothed wheel when the light disappeared for the first time is,

$$\omega = \frac{\theta}{t} \ldots\ldots(2)$$

$$\theta = \frac{total\ angle\ of\ circle\ in\ radian}{number\ of\ teeth + number\ of\ cuts}$$

$$\theta = \frac{2\pi}{2N} = \frac{\pi}{N} \ldots\ldots(3)$$

Sub (3) in (2)

$$\omega = \frac{\frac{\pi}{N}}{t}$$

Rearranging for t

$$t = \frac{\pi}{\omega N} \ldots\ldots(4)$$

Sub (4) in (1) and we get

$$v = \frac{2dN\omega}{\pi}$$

3. Obtain the equation for radius of illumination (or) Snell's window.

- When a light source like electric bulb is kept inside a water tank, the light from the source travels in all direction inside the water.
- The light that is incident on the water surface at an angle less than the critical angle will undergo refraction and emerge out from the water.
- The light incident at an angle greater than critical angle will undergo total internal reflection.

- The light falling particularly at critical angle graces the surface.
- Thus, the entire surface of water appears illuminated when seen from outside .
- On the other hand, when light entering the water from outside is seen from inside the water, the view is restricted to a particular angle equal to the critical angle i_c.
- The restricted illuminated circular area is called *Snell's window*

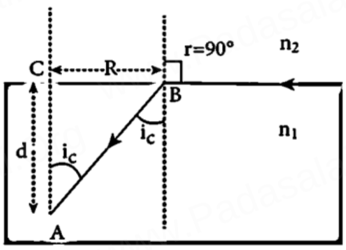


Figure 6.27 Radius of Snell's window

Light is seen from a point *A* at a depth *d*.

$$n_1 \sin i_c = n_2 \sin 90°$$

$$\sin i_c = \frac{n_2}{n_1} \ldots\ldots\ldots\ldots(1)$$

From the right angle triangle ΔABC,

$$\sin i_c = \frac{CB}{AB} = \frac{R}{\sqrt{d^2+R^2}} \ldots\ldots\ldots(2)$$

Equating (1) & (2)

$$\frac{n_2}{n_1} = \frac{R}{\sqrt{d^2+R^2}}$$

Squaring on both sides

$$\frac{R^2}{R^2+d^2} = \frac{{n_2}^2}{{n_1}^2}$$

Taking reciprocal

$$\frac{R^2+d^2}{R^2} = \frac{{n_1}^2}{{n_2}^2}$$

On further simplification

$$\frac{\boldsymbol{d^2}}{\boldsymbol{R^2}} = \frac{\boldsymbol{{n_1}^2}}{\boldsymbol{{n_2}^2}} - \mathbf{1} = \frac{\boldsymbol{{n_1}^2 - {n_2}^2}}{\boldsymbol{{n_2}^2}}$$

Again taking reciprocal and rearranging

$$R^2 = d^2\left(\frac{{n_2}^2}{{n_1}^2 - {n_2}^2}\right)$$

The radius of illumination is,

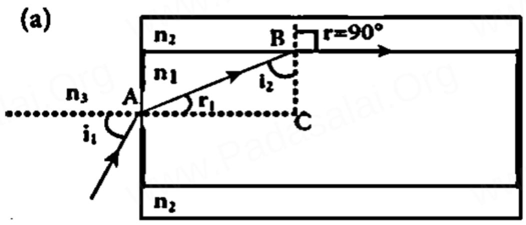
$$\boldsymbol{R = d\sqrt{\left(\frac{{n_2}^2}{{n_1}^2 - {n_2}^2}\right)}}$$

If the rarer medium outside is air, then, $\boldsymbol{n_2 = 1}$, and we can take $\boldsymbol{n_1 = n}$

$$\boldsymbol{R = \frac{d}{\sqrt{n^2-1}}}$$

4. Derive the equation for acceptance angle and numerical aperture, of optical fiber.

- To ensure the critical angle incidence in the core-cladding boundary inside the optical fibre, the light should be incident at a certain angle at the end of the optical fiber while entering in to it. This angle is called ***acceptance angle***.
- It depends on the refractive indices of the core n_1, cladding n_2 and the outer medium n_3. Assume the light is



incident at an angle called acceptance angle i_a at the outer medium and core boundary at *A*.

The Snell's law for this refraction at the point *A*

$$n_3 \sin i_a = n_1 \sin r_a \ldots\ldots(1)$$

The Snell's law for this refraction at the point *B*

$$n_1 \sin i_c = n_2 \sin 90°$$

$$n_1 \sin i_c = n_2$$

$$\sin i_c = \frac{n_2}{n_1} \ldots\ldots(2)$$

From the right angle triangle Δ*ABC*

$$i_c = 90° - r_a \ldots\ldots(3)$$

Sub (3) in (2)

$$\sin(90° - r_a) = \frac{n_2}{n_1}$$

$\cos r_a = \frac{n_2}{n_1}$

$sin^2\theta + cos^2\theta = 1$

$\sin r_a = \sqrt{\left(1 - \left(\frac{n_2}{n_1}\right)^2\right)} = \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}}$......(4)

Sub (4) in (1)

$$n_3 \sin i_a = n_1 \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}} = n_1^2 - n_2^2$$

On further simplification

$$\sin i_a = \frac{n_1^2 - n_2^2}{n_3}$$

$$i_a = \sin^{-1}\left(\sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}\right)$$

If outer medium is air, then $n_3 = 1$

$$\boldsymbol{i_a = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right)}$$

Light can have any angle of incidence from 0 to i_a with the normal at the end of the optical fibre forming a conical shape called ***acceptance cone***

Numerical aperture

$$NA = n_3 \sin i_a = \sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}$$

If outer medium is air, then $\boldsymbol{n_3 = 1}$

$$NA = n_3 \sin i_a = \sqrt{n_1^2 - n_2^2}$$

5. Obtain the equation for lateral displacement of light passing through a glass slab.

1) Consider a glass slab of thickness *t* and refractive index *n* is kept in air medium.
2) The path of the light is *ABCD* and the refractions occur at two points *B* and *C* in the glass slab.
3) The angles of incidence *i* and refraction *r* are measured with respect to the normal N_1 and N_2 at the two points *B* and *C* respectively.
4) The lateral displacement *L* is the perpendicular distance *CE* drawn between the path of light and the undeviated path of light at point *C*.

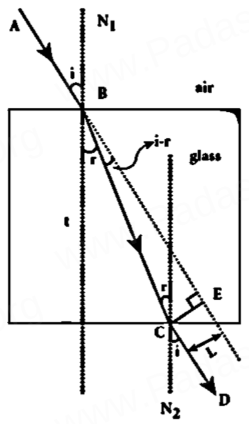


Figure 6.30 Refraction in glass slab

In the right angle triangle ΔBCE,

$\sin(i - r) = \frac{L}{BC}$; $BC = \frac{L}{\sin(i-r)}$.......(1)

In the right angle triangle ΔBCF

$cosr = \frac{t}{BC}$; $BC = \frac{t}{cos\, r}$.......(2)

Equating (1) and (2)

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

$\boldsymbol{L = t\left(\frac{\sin(i-r)}{cos\, r}\right)}$.......(3)

Lateral displacement depends upon the thickness of the slab. Thicker the slab, greater will be the lateral displacement. Greater the angle of incident, larger will be the lateral displacement.

6. Derive the equation for refraction at single spherical surface.

1) Consider two transparent media having refractive indices n_1 and n_2 are separated by a spherical surface.
2) Let *C* be the centre of curvature of the spherical surface.
3) Let a point object *O* be in the medium *n*1. The line *OC* cuts the

spherical surface at the pole P of the surface.

4) As the rays considered are paraxial rays, the perpendicular dropped for the point of incidence to the principal axis is very close to the pole or passes through the pole itself.

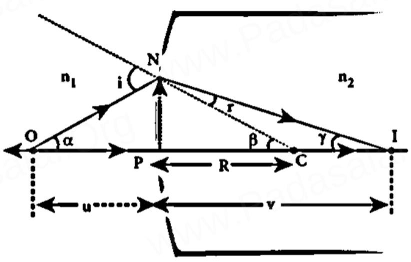


Figure 6.31 Refraction at single spherical surface

5) Light from O falls on the refracting surface at N.
6) The normal drawn at the point of incidence passes through the centre of curvature C.
7) As $n_2 > n_1$, light in the denser medium deviates towards the normal and meets the principal axis at I where the image is formed.

Snell's law in product form for the refraction at the point N

$n_1 \sin i_c = n_2 \sin r$…….(1)

Angles are small

$\sin i = i; \sin r = r$

$n_1 i = n_2 r$ ……..(2)

Let the angles,

$\angle NOP = \alpha$, $\angle NCP = \beta$, $\angle NIP = \gamma$

$$\tan\alpha = \frac{PN}{PO};\ \tan\beta = \frac{PN}{PC};\ \tan\gamma = \frac{PN}{PI}$$

As these angles are small, tan of the angle could be approximated to the angle itself.

$$\alpha = \frac{PN}{PO};\ \beta = \frac{PN}{PC};\ \gamma = \frac{PN}{PI}$$

For the triangle, ΔONC,

$i = \alpha + \beta$

For the triangle, ΔINC,

$r = \beta - \gamma$

Sub i and r values in (2)

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

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

Substituting for α, β and γ

$$n_1\frac{PN}{PO} + n_2\frac{PN}{PI} = (n_2 - n_1)\frac{PN}{PC}$$

Further simplifying by cancelling PN,

$$\frac{n_1}{PO} + \frac{n_2}{PI} = \frac{n_2 - n_1}{PC}$$

Following sign conventions,

$PO = -u$, $PI = +v$ and $PC = +R$

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

After rearranging, finally we get,

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

If the first medium is air then, $n_1 = 1$ and the second medium is taken just as $n_2 = n$, then the equation is reduced to,

$$\boldsymbol{\frac{n}{v} - \frac{1}{u} = \frac{n-1}{R}}$$

7. Obtain lens maker's formula and mention its significance.

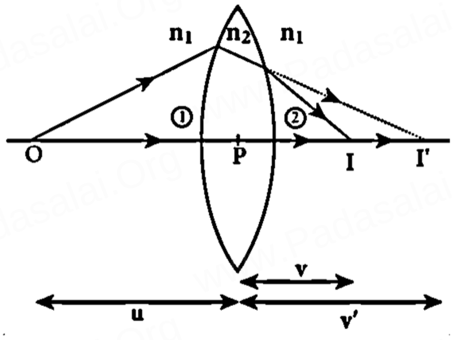


Figure 6.34 Refraction through thin lens

- Consider a thin lens made up of a medium of refractive index n_2 is placed in a medium of refractive index n_1. Let R_1 and R_2 be the radii of curvature of two spherical surfaces (1) and (2)
- P be the pole
- Consider a point object O on the principal axis. The ray which falls very close to P, after refraction at the surface (1) forms image at I'. Before it does so, it is again refracted by the surface (2). Therefore the final image is formed at I.
- General equation for the refraction at a spherical surface

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

For the refracting surface (1) , the light goes from n_1 to n_2

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad \text{.........(1)}$$

For the refracting surface (2) , the light goes from n_2 to n_1

$$\frac{n_2}{v} - \frac{n_1}{v'} = \frac{n_2 - n_1}{R_2} \quad \text{.........(2)}$$

Adding (1) & (2)

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

Further simplifying and rearranging,

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

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

If the object is at infinity, the image is formed at the focus of the lens. Thus, for u = ∞, v = f. Then the equation becomes.

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{........(2)}$$

If the refractive index of the lens is n2 and it is placed in air, then $n_2 = n$ and $n_1 = 1$

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

The above equation is called the **lens maker's formula**,

By comparing (1) and (2)

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

This equation is known as **lens equation**

8. Derive the equation for thin lens and obtain its magnification.

lens equation

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

The above equation is called the ***lens maker's formula***, because it tells the lens manufactures what curvature is needed to make a lens of desired focal length with a material of particular refractive index. This formula holds good also for a concave lens.

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

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{........(2)}$$

By comparing (1) and (2)

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

This equation is known as ***lens equation***

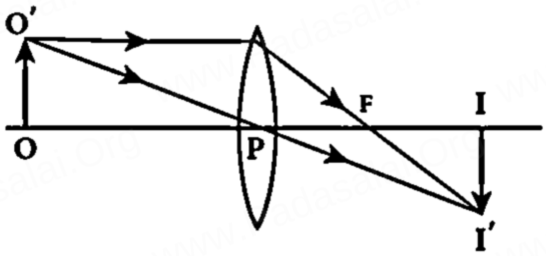


Figure 6.35 Lateral magnification in thin lens

- Let us consider an object OO' of height h_1 placed on the principal axis with its height perpendicular to the principal axis .
- The ray OP passing through the pole of the lens goes undeviated. The inverted real image II' formed has a height h_2.
- The lateral or transverse magnification m is defined as the ratio of the height of the image to that of the object.

$m = \frac{II'}{OO'}$............(1)

From the two similar triangles $\Delta\ POO'$ and $\Delta\ PII'$

$$\frac{II'}{OO'} = \frac{PI}{PO}$$

Applying sign convention

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

By (1)

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

The magnification is negative for real image and positive for virtual image. In the case of a concave lens, the magnification is always positive and less than one.

$$\boldsymbol{m = \frac{h_2}{h_1} = \frac{f}{f+u}} \text{ (or) } \boldsymbol{m = \frac{h_2}{h_1} = \frac{f-v}{f}}$$

9. Derive the equation for effective focal length for lenses in out of contact.

- Let O be a point object on the principal axis of a lens.
- OA is the incident ray on the lens at a point A at a height h above the optical centre.
- The ray is deviated through an angle δ and forms the image at I on the principal axis.
- The incident and refracted rays subtend the angles, $\angle AOP = \alpha$ and $\angle AIP = \beta$ with the principal axis respectively.

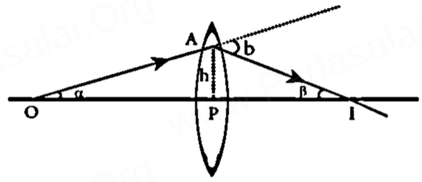


Figure 6.38 Angle of deviation in lens

In the triangle ΔOAI, the angle of deviation δ can be written as,

$\delta = \alpha + \beta$

If the height h is small as compared to PO and PI, the angles α, β and δ are also small. Then,

$\alpha \approx tan\alpha = \frac{PA}{PO}$ and $\beta \approx tan\beta = \frac{PA}{PI}$

$$\delta = \frac{PA}{PO} + \frac{PA}{PI}$$

$PA = h$, $PO = -u$ and $PI = v$

$$\delta = \frac{h}{-u} + \frac{h}{v}$$

After rearranging

$$\boldsymbol{\delta = h\left(\frac{1}{v} - \frac{1}{u}\right) = \frac{h}{f}}$$

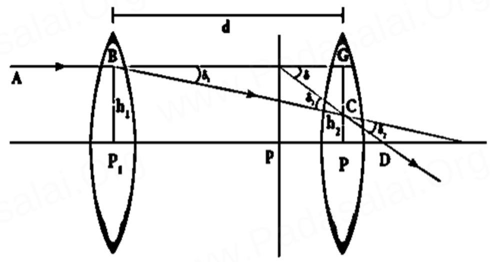


Figure 6.39 Lens in out of contact

Two lenses of focal length f_1 and f_2 arranged coaxially but separated by a distance d

For a parallel ray that falls on the arrangement, the two lenses produce deviations δ_1 and δ_2 respectively

The net deviation δ is

$\delta = \delta_1 + \delta_2 \ldots\ldots.(1)$

$\delta_1 = \frac{h_1}{f_1}$; $\delta_2 = \frac{h_2}{f_2}$; $\delta = \frac{h_1}{f}$

$\frac{h_1}{f} = \frac{h_1}{f_1} + \frac{h_2}{f_2} \ldots\ldots\ldots(1)$

From the geometry,

$h_2 - h_1 = P_2G - P_2C = CG$

$h_2 - h_1 = BG \tan\delta_1 = BG\delta_1$

$h_2 - h_1 = d\frac{h_1}{f_1}$

$h_2 = h_1 + d\frac{h_1}{f_1} \ldots\ldots\ldots(2)$

Sub (2) in (1)

$$\frac{h_1}{f} = \frac{h_1}{f_1} + \frac{1}{f_2}\left(h_1 + d\frac{h_1}{f_1}\right)$$

On further simplification,

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

10. Derive the equation for angle of deviation produced by a prism and thus obtain the equation for refractive index of material of the prism.

- Let light ray *PQ* is incident on one of the refracting faces of the prism
- The angles of incidence and refraction at the first face *AB* are i_1 and r_1. The path of the light inside the prism is *QR*.
- The angle of incidence and refraction at the second face *AC* is r_2 and i_2 respectively. RS is the ray emerging from the second face. Angle i_2 is also called angle of emergence.
- **The angle between the direction of the incident ray *PQ* and the emergent ray *RS* is called the *angle of deviation d*.**
- The two normals drawn at the point of incidence *Q* and emergence *R* are *QN* and *RN*. They meet at point *N*. The incident ray and the emergent ray meet at a point *M*.

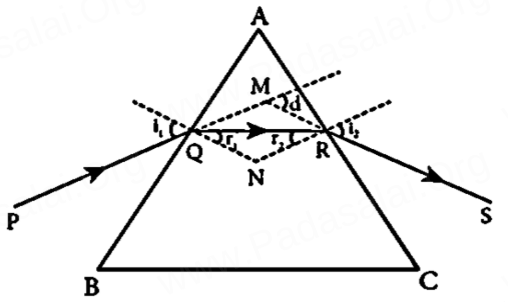


Figure 6.41 Refraction through prism

The deviation d_1 at the surface *AB* is

$\angle RQM = d_1 = i_1 - r_1 \ldots\ldots\ldots(1)$

The deviation d_2 at the surface *AC* is,

$\angle QRM = d_2 = i_2 - r_2 \ldots\ldots\ldots(2)$

Total angle of deviation *d* produced

$d = d_1 + d_2$

$d = (i_1 + i_2) - (r_1 + r_2) \ldots\ldots.(3)$

In the quadrilateral *AQNR*, two of the angles (at the vertices *Q* and *R*) are right angles. Therefore, the sum of the other angles of the quadrilateral is 180°.

$\angle A + \angle QNR = 180°$

From the triangle ΔQNR,

$r_1 + r_2 + \angle QNR = 180°$

Comparing above two equations

$r_1 + r_2 = A \ldots\ldots(4)$

Sub (4) in (1)

$\boldsymbol{d = i_1 + i_2 - A}$

<u>Refractive index of the material of the prism</u>

At minimum deviation

Sub , $i_1 = i_2 = i$ in (4)

$\boldsymbol{d = 2i - A}$

$$\boldsymbol{i = \frac{A + D}{2}}$$

$r_1 + r_2 = A$

$r_1 = r_2 = r$

$2r = A$

$$r = \frac{A}{2}$$

Substituting *i* and *r* in Snell's law,

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

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

11. What is dispersion? Obtain the equation for dispersive power of a medium.

Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its *spectrum*

Dispersive power (ω)

Dispersive power (ω) is the ability of the material of the prism to cause dispersion. It is defined as the ratio of the angular dispersion for the extreme colours to the deviation for any mean colour

$$\omega = \frac{angular\ dispersion}{mean\ deviation} = \frac{\delta_V - \delta_R}{\delta}$$

For violet light $\delta_V = (n_V - 1)A$

For Red light $\delta_V = (n_R - 1)A$

$$\delta = (n - 1)A$$

$$\omega = \frac{n_V - n_R}{n - 1}$$

- Dispersive power is a dimensionless quality. It has no unit. Dispersive power is always positive.
- The dispersive power of a prism depends only on the nature of material of the prism and it is independent of the angle of the prism.

12. Prove laws of reflection using Huygens' principle.

- Consider a parallel beam of light, incident on a reflecting plane surface such as a plane mirror *XY*.
- The incident wavefront is *AB* and the reflected wavefront'*AB* ' is in the same medium.
- These wavefronts are perpendicular to the incident rays *L*, *M* and reflected rays'*L*,'*M*
- respectively. By the time point *A* of the incident wavefront touches the reflecting surface, the point *B* is yet to travel a distance to touch the reflecting surface *B*′ .
- When the point *B* falls on the reflecting surface at B′ the point *A* would have reached A′ .
- Thus, the reflected wavefront A′B′ emanates as a plane wavefront.
- The two normals *N* and N′ are considered at the points where the rays *L* and *M* fall on the reflecting surface.
- As reflection happens in the same medium, the speed of light is same before and after the reflection.
- Hence, the time taken for the ray to travel from *B* to B′ is the same as the time taken for the ray to travel from *A* to A′ .
- Thus, the distance BB′ is equal to the distance AA′.

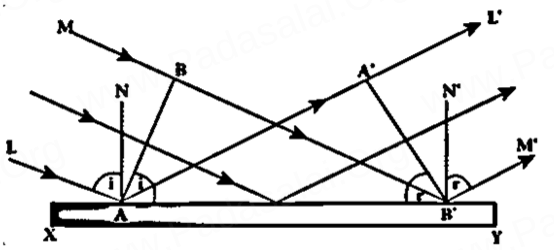


Figure 6.50 Laws of reflection

(i) The incident rays, the reflected rays and the normal are in the same plane.

(ii) Angle of incidence,

$$\boldsymbol{i} = \angle NAL = 90° - \angle NAB = \angle BAB'$$

$$\boldsymbol{r} = \angle N'B'M' = 90° - \angle N'B'A' = \angle A'B'A'$$

For the two right angle triangles, $\Delta ABB'$ and $\Delta BAB'$, the right angles, $\angle B$ and $\angle A'$ are equal, ($\angle B$ and $\angle A'$ = 90°); the two sides AA′ **and** BB′ are equal, ;the side AB' is the common. Thus, the two triangles are congruent.

As per the property of congruency, the two angles, $\angle A'B'A'$ and $\angle BAB$ must also be equal.

$$i = r$$

Angle of incidence is equal to angle of reflection

13. Prove laws of refraction using Huygens' principle.

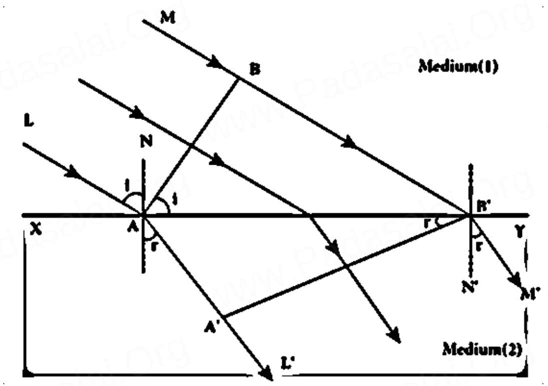


Figure 6.51 Law of refraction

- Consider a parallel beam of light is incident on a refracting plane surface XY such as a glass surface.
- The incident wavefront AB is in rarer medium (1) and the refracted wavefront $A'B'$ is in denser medium (2).
- These wavefronts are perpendicular to the incident rays L, M and refracted rays $L'M'$respectively.
- By the time the point A of the incident wavefront touches the refracting surface, the point B is yet to travel a distance BB' to touch the refracting surface at B' .
- When the point B falls on the refracting surface at B', the point A would have reached A' in the other medium.
- This is applicable to all the points on the wavefront.
- Thus, the refracted wavefront AB emanates as a plane wavefront.
- The two normals N and N' are considered at the points where the rays L and M fall on the refracting surface.
- As refraction happens from rarer medium (1) to denser medium (2), the speed of light is
- v_1 and v_2 before and after refraction and v_1 is greater than v_2 ($v_1 > v_2$).
- But, the time taken t for the ray to travel from B to B' is the same as the time taken for the ray to travel from A to A' .

$$t = \frac{BB\prime}{v_1} = \frac{AA\prime}{v_2} \text{ (OR) } \frac{BB\prime}{AA\prime} = \frac{v_1}{v_2}$$

(i) The incident rays, the refracted rays and the normal are in the same plane

(ii) **Angle of incidence,**

$$\boldsymbol{i} = \angle NAL = 90° - \angle NAB = \angle BAB'$$

Angle of refraction

$$\boldsymbol{r} = \angle N'B'^{M'} = 90° - \angle N'B'A'$$
$$= \angle A'B'A'$$

For the two right angle triangles, $\Delta ABB'$ and $\Delta BA'A$

$$\frac{\sin i}{\sin r} = \frac{\frac{BB'}{AB'}}{\frac{AA'}{AB'}} = \frac{v_1}{v_2} = \frac{\frac{c}{v_2}}{\frac{c}{v_1}}$$

c - speed of light in vacuum

$\frac{c}{v} = n$ **(Refractive index of the medium)**

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

Hence, the laws of refraction are proved

14. Obtain the equation for resultant intensity due to interference of light.

- The phenomenon of addition or superposition of two light waves which produces increase in intensity at some points and decrease in intensity at some other points is called *interference* of light.

- Consider two light waves from the two sources S_1 and S_2 meeting at a point P

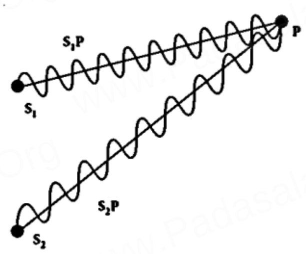


Figure 6.52 Superposition principle

The wave from S_1 at an instant t at P is

$y_1 = a_1 \sin \omega t$............(1)

The wave from S_2 at an instant t at P is

$y_2 = a_2 \sin(\omega t + \emptyset)$ ....(2)

Two waves have different amplitudes a_1 and a_2, same angular frequency ω, and a phase difference of ϕ between them.

Resultant displacement

$y = y_1 + y_2 = a_1 \sin \omega t + a_2 \sin(\omega t + \emptyset)$

After simplification using trigonometric identities

$$y = A \sin(\omega t + \emptyset)$$

$$A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \emptyset} \ldots\ldots(1)$$

$$\theta = \tan^{-1} \frac{a_2 \sin \emptyset}{a_1 + a_2 \cos \emptyset}$$

The resultant amplitude is maximum,

$A_{max} = \sqrt{(a_1 + a_2)^2}$ where $\emptyset = 0, \pm 2\pi, \pm 4\pi \ldots$

The resultant amplitude is maximum,

$A_{min} = \sqrt{(a_1 - a_2)^2}$ where $\emptyset = \pm\pi, \pm 3\pi \ldots$

The intensity of light is proportional to square of amplitude,

$I \,\alpha\, A^2$

(1) Becomes

$I \,\alpha\, I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \emptyset \ldots\ldots.(2)$

If the phase difference, $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots$, it corresponds to the condition for maximum intensity of light called as ***constructive interference***.

$I_{max} \,\alpha\, ((a_1 + a_2)^2) \,\alpha\, I_1 + I_2 + 2\sqrt{I_1 I_2}$

If the phase difference, $\phi = \pm\pi, \pm 3\pi, \pm 5\pi \ldots$,it corresponds to the condition for minimum intensity of light called ***destructive interference***.

The resultant minimum intensity is,

$I_{min} \,\alpha\, ((a_1 - a_2)^2) \,\alpha\, I_1 + I_2 - 2\sqrt{I_1 I_2}$

15. Explain the Young's double slit experimental setup and obtain the equation for path difference.

Young's double slit experimental setup

- An opaque screen with two small openings called double slit S_1 and S_2 kept equidistance from a source S
- The width of each slit is about 0.03 mm and they are separated by a distance of about 0.3 mm.
- As S_1 and S_2 are equidistant from S, the light waves from S reach S_1 and S_2 in-phase. So, S_1 and S_2 act as coherent sources which are the requirement of obtaining interference pattern.

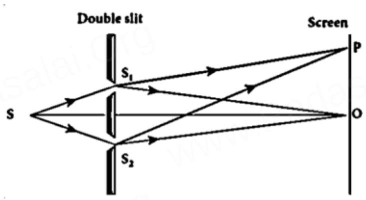


Figure 6.58 Young's double slit experiment

- Wavefronts from S_1 and S_2 spread out and overlapping takes place to the right side of double slit.
- When a screen is placed at a distance of about 1 meter from the slits, alternate bright and dark fringes which are equally spaced appear on the screen. These are called interference fringes or bands.
- Using an eyepiece the fringes can be seen directly.
- At the center point O on the screen, waves from S_1 and S_2 travel equal distances and arrive in-phase

- These two waves constructively interfere and bright fringe is observed at *O*.
- This is called central bright fringe.
- The fringes disappear and there is uniform illumination on the screen when one of the slits is covered.
- This shows clearly that the bands are due to interference

Equation for path difference

- The Let d be the distance between the double slits S_1 and S_2 which act as coherent sources of wavelength λ.
- A screen is placed parallel to the double slit at a distance *D* from it.
- The mid-point of S_1 and S_2 is *C* and the mid-point of the screen *O* is equidistant from S_1 and S_2.
- *P* is any point at a distance *y* from *O*.
- The waves from S_1 and S_2 meet at *P* either in-phase or out-of-phase depending upon the path difference between the two waves.

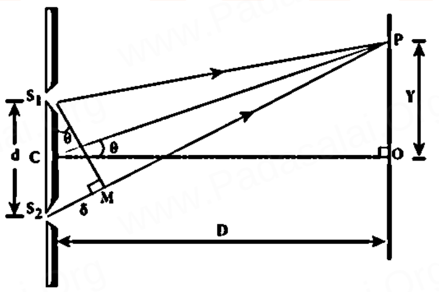


Figure 6.59 Young's double slit experimental setup

The path difference δ between the light waves from S_1 and S_2 to the point *P* is,

$\boldsymbol{\delta = S_2P - S_1P}$

$\boldsymbol{\delta = S_2M}$……..*(1)*

The angular position of the point *P* from *C* is θ. $\angle OCP = \theta$.

From the geometry, the angles $\angle OCP$ and $\angle S_2S_1M$ are equal.

$\angle OCP = \angle S_2S_1M = \theta$.

In right angle triangle ΔS_1S_2M, the path difference, $S_2M = d \sin\theta$……*(2)*

Sub (2) in (1)

$\boldsymbol{\delta} = d \sin\theta$

If the angle θ is small, $\sin\theta \approx \tan\theta \approx \theta$

From the right angle triangle ΔOCP,

$$\tan\theta = \frac{y}{D}$$

$$\boldsymbol{\delta = \frac{dy}{D}}$$

Based on the condition on the path difference, the point *P* may have a bright or dark fringe.

16. Obtain the equation for bandwidth in Young's double slit experiment.

Equation for path difference

- The Let d be the distance between the double slits S_1 and S_2 which act as coherent sources of wavelength λ.
- A screen is placed parallel to the double slit at a distance *D* from it.
- The mid-point of S_1 and S_2 is *C* and the mid-point of the screen *O* is equidistant from S_1 and S_2.
- *P* is any point at a distance *y* from *O*.
- The waves from S_1 and S_2 meet at *P* either in-phase or out-of-phase depending upon the path difference between the two waves.

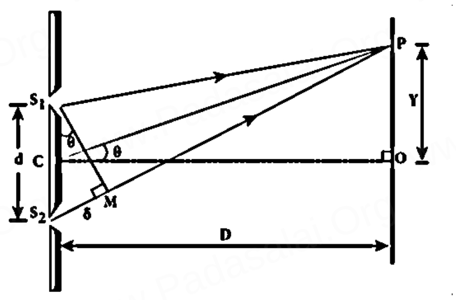


Figure 6.59 Young's double slit experimental setup

The path difference δ between the light waves from S_1 and S_2 to the point *P* is,

$\delta = S_2P - S_1P$

$\delta = S_2M$……*(1)*

The angular position of the point P from C is θ. $\angle OCP = \theta$.
From the geometry, the angles $\angle OCP$ and $\angle S_2S_1M$ are equal.
$\angle OCP = \angle S_2S_1M = \theta$.
In right angle triangle ΔS_1S_2M, the path difference, $S_2M = d \sin\theta$…….(2)
Sub (2) in (1)
$\delta = d \sin\theta$
If the angle θ is small, $\sin\theta \approx \tan\theta \approx \theta$
From the right angle triangle ΔOCP,

$$\tan\theta = \frac{y}{D}$$

$$\boldsymbol{\delta = \frac{dy}{D}}$$

Condition for bright fringe (or) maxima

The condition for the constructive interference or the point P to be have a bright fringe is,
Path difference, $\delta = n\lambda$
Where n = 0 , 1,2

$$\frac{dy}{D} = n\lambda$$

$$\boldsymbol{y_n = \frac{n\lambda D}{d}}$$

Condition for dark fringe (or) minima

The condition for the destructive interference or the point P to be have a dark fringe is,

$$\delta = (2n-1)\frac{\lambda}{2}$$

where, n = 1, 2, 3 . . .

$$\frac{dy}{D} = (2n-1)\frac{\lambda}{2}$$

$$\boldsymbol{y_n = \frac{(2n-1)}{2}\frac{\lambda D}{d}}$$

Equation for bandwidth

The *bandwidth* (β) is defined as the distance between any two consecutive bright or dark fringes.

The distance between $(n+1)^{th}$ and n^{th} consecutive bright fringes from O is given by,

$$\beta = y_{n+1} - y_n$$

$$= (n+1)\frac{\lambda D}{d} - \frac{n\lambda D}{d}$$

$$= \frac{\lambda D}{d}$$

The distance between $(n+1)^{th}$ and n^{th} consecutive dark fringes from O is given by,

$$\beta = y_{n+1} - y_n$$

$$= \frac{(2(n+1)-1)}{2}\frac{\lambda D}{d} - \frac{(2n-1)}{2}\frac{\lambda D}{d}$$

$$= \boldsymbol{\frac{\lambda D}{d}}$$

By bandwidth equation bright and dark fringes are of same width equally spaced on either side of central bright fringe.

17. Obtain the equations for constructive and destructive interference for transmitted and reflected waves in thin films.

- Consider a thin film of transparent material of refractive index μ and thickness d.
- A parallel beam of light is incident on the film at an angle.
- The wave is divided into two parts at the upper surface, one is reflected and the other is refracted.
- The refracted part, which enters into the film, again gets divided at the lower surface into two parts; one is transmitted out of the film and the other is reflected back in to the film. Reflected as well as refracted waves are sent by the film as multiple reflections take place inside the film.
- The interference is produced by both the reflected and transmitted light.

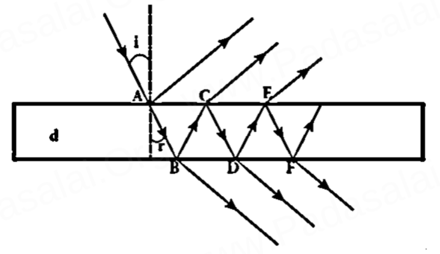


Figure 6.62 Interference in thin films

For transmitted light

- The light transmitted may interfere to produce a resultant intensity.
- Consider the path difference between the two light waves transmitted from *B* and *D*.
- The two waves moved together and remained in phase up to *B* where splitting occurred.
- The extra path travelled by the wave transmitted from D is the path inside the film , BC+ CD
- The extra distance travelled by the wave is approximately twice thickness of the film ,BC +CD = 2d.
- Extra path is traversed in a medium of refractive index μ, optical path difference

$\delta = 2\mu d$

The condition for constructive interference

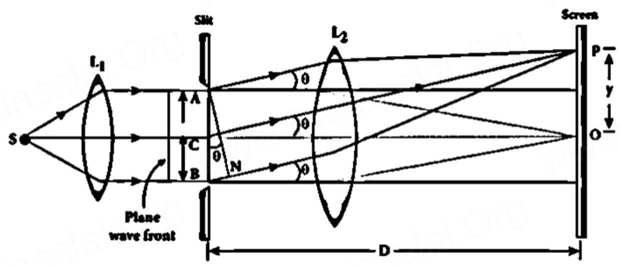
$2\mu d = n\lambda$

The condition for destructive interference

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

For reflected light

- while travelling in rarer medium and getting reflected by denser medium, undergoes a phase change of π



Hence, an additional path difference of λ/2 should be on considered.

- Consider the path dif erence between the light waves reflected by the upper surface at A and the other wav coming out at C after passing through the film
- The extra path travelled by the wave coming out from from C is the path inside the film , AB+ BC =2d
- Extra path is traversed in a medium of refractive index μ, optical path difference

$\delta = 2\mu d$

The condition for constructive interference

$2\mu d + \frac{\lambda}{2} = n\lambda$

The condition for destructive interference

$2\mu d + \frac{\lambda}{\lambda} = (2n+1)\frac{\lambda}{2}$

18. Discuss diffraction at single slit and obtain the condition for nth minimum.

- A parallel beam of light fall normally on a single slit AB of width a.
- The diffracted beam falls on a screen kept at distance. The center of the slit is *C*.
- A straight line through *C* perpendicular to the plane of slit meets the center of the screen at *O*.
- intensity at any point *P* on the screen was find.
- The lines joining *P* to the different points on the slit can be treated as parallel lines, making an angle *θ* with the normal *CO*.
- All the waves start parallel to each other from different points of the slit and interfere at point *P* and other points to give the resultant intensities.
- The point *P* is in the geometrically shadowed region, up to which the

central maximum is spread due to diffraction .

Condition for P to be First minimum

The slit *AB was divided* into two half's *AC* and *CB*.

The width of *AC* is (a/2).

Different points on the slit which are separated by the same width (here a/2) called *corresponding points*

The path difference of light waves from different corresponding points meeting at point P and interfere destructively to make it first minimum.

The path difference δ between waves from these corresponding points is

$$\delta = \frac{a}{2} sin\theta$$

The condition for P to be first minimum,

$$\frac{a}{2} sin\theta = \frac{\lambda}{2}$$

a **sin** $\boldsymbol{\theta = \lambda}$ **(first minimum)**

Condition for P to be second minimum

The path difference δ between waves from these corresponding points is

$$\delta = \frac{a}{2} sin\theta$$

The condition for P to be first minimum,

$$\frac{a}{4} sin\theta = \frac{\lambda}{2}$$

a **sin** $\boldsymbol{\theta = 2\lambda}$ **(second minimum)**

Condition for P to be n^th^ order minimum

Dividing the slit into 2n number of (even number of) equal parts makes the light produced by one of the corresponding points to be cancelled by its counterpart.

Thus, the condition for n^{th} order minimum

$$\frac{a}{2n} sin\theta = \frac{\lambda}{2}$$

a **sin** $\boldsymbol{\theta = n\lambda}$ **(n^{th} minimum)**

19. Discuss the diffraction at a grating and obtain the condition for the mth maximum.

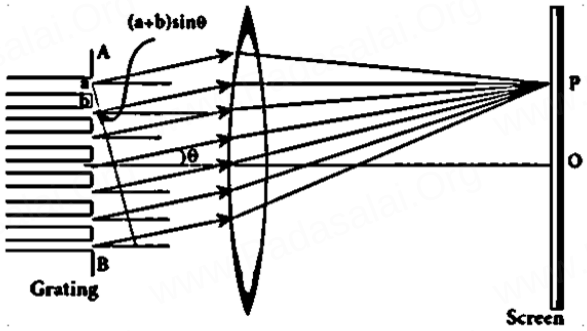


Figure 6.66 Diffraction grating experiment

- A plane transmission grating is represented by *AB*
- Plane wavefront of monochromatic light with wave length λ be incident normally on the grating.
- As the slits size is comparable to that of wavelength, the incident light diffracts at the grating.
- A diffraction pattern is obtained on the screen when the diffracted waves are focused on a screen using a convex lens.
- Let us consider a point *P* at an angle θ with the normal drawn from the center of the grating to the screen.
- The path difference δ between the diffracted waves from one pair of corresponding points is,
- $\boldsymbol{\delta = (a+b)\sin\theta}$**…….(1)**
- The point *P* will be bright, when

$\boldsymbol{\delta = m\lambda}$ **…….(2)**

where m = 0, 1, 2, 3

Equating (1) and (2)

$$\boldsymbol{(a+b)\sin\theta = m\lambda}$$

m is called order of diffraction

Condition for zero order maximum, m = 0

For $(a+b)\sin\theta = 0$, the position, $\theta = 0$.

$\boldsymbol{\sin\theta = 0}$ and $\boldsymbol{m = 0}$.

This is called zero order diffraction or central maximum.

Condition for first order maximum, m = 1

If $(a + b)\sin\theta_1 = \lambda$, the diffracted light meet at an angle θ_1 to the incident direction and the first order maximum is obtained.

Condition for higher order maximum

$$N = \frac{1}{a+b}$$

N gives the number of grating elements or rulings drawn per unit width of the grating.

$\sin\theta = Nm\lambda$

20. Discuss the experiment to determine the wavelength of monochromatic light using diffraction grating.

- The wavelength of a spectral line can be very accurately determined with the help of a diffraction grating and a spectrometer.
- Initially all the preliminary adjustments of the spectrometer are made.
- The slit of collimator is illuminated by a monochromatic light, whose wavelength is to be determined.
- The telescope is brought in line with collimator to view the image of the slit.
- The given plane transmission grating is then mounted on the prism table with its plane perpendicular to the incident beam of light coming from the collimator.
- The telescope is turned to one side until the first order diffraction image of the slit coincides with the vertical cross wire of the eye piece.
- The reading of the position of the telescope is noted.
- Similarly the first order diffraction image on the other side is made to coincide with the vertical cross wire and corresponding reading is noted. The difference between two positions gives 2θ. Half of its value gives θ, the diffraction angle for first order maximum .

The wavelength of light

$$\lambda = \frac{\sin\theta}{Nm}$$

N -number of rulings per metre in the grating

m - order of the diffraction image

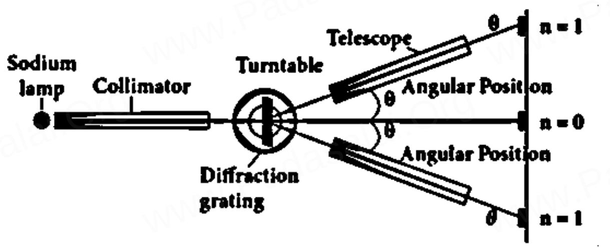


Figure 6.66 Determination of wavelength using grating and spectrometer

21. Discuss the experiment to determine the wavelength of different colours using diffraction grating.

- When white light is used, the diffraction pattern consists of a white central maximum and on both sides continuous coloured diffraction patters are formed.
- The central maximum is white as all the colours meet here constructively with no path difference.
- As θ increases, the path difference, $(a+b)\sin\theta$, passes through condition for maxima ofdiffraction of different orders for all colours from violet to red.
- It produces a spectrum of diffraction pattern from violet to red on either side of central maximum.

- By measuring the angle at which these colours appear for various orders of diffraction, the wavelength of different colours could be calculated using the formula,

$$\lambda = \frac{\sin\theta}{Nm}$$

N -number of rulings per metre in the grating
m - order of the diffraction image

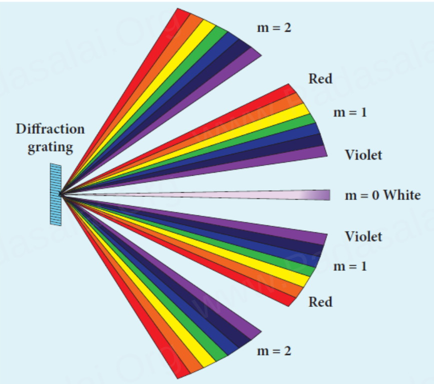


Figure 6.67 Diffraction with white light

22. Obtain the equation for resolving power of optical instrument.

- The ability of microscope depends not only in magnifying the object but also in resolving two points on the object separated by a small distance d_{min}.
- Smaller the value of d_{min} better will be the resolving power of the microscope.

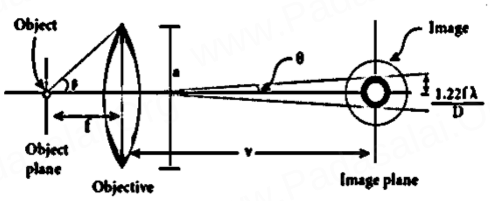


Figure 6.84 Resolving power of microscope

The radius of central maxima

$$r_o = \frac{1.22\lambda v}{a}$$

In the place of focal length f we have the image distance v. If the difference between the two points on the object to be resolved is d_{min}, then the magnification m is,

$$m = \frac{r_o}{d_{min}}$$

$$d_{min} = \frac{r_o}{m} = \frac{1.22\lambda v}{am} = \frac{1.22\lambda v}{a\left(\frac{v}{u}\right)} = \frac{1.22\lambda u}{a}$$

$$d_{min} = \frac{1.22\lambda f}{a} \qquad [\, u \approx f$$

On the object side,

$$2\tan\beta = 2\sin\beta = \frac{a}{f}\, [a = f2\sin\beta]$$

$$d_{min} = \frac{1.22\lambda}{2\sin\beta}$$

Value of d_{min} *was reduced so that* the optical path of the light is increased by immersing the objective of the microscope in to a bath containing oil of refractive index n.

$$\boldsymbol{d_{min} = \frac{1.22\lambda}{2\, n\sin\beta}}$$

Such an objective is called oil immersed objective. **The term *n sin β* is called *numerical aperture NA.***

$$\boldsymbol{d_{min} = \frac{1.22\lambda}{2(NA)}}$$

23. Discuss about simple microscope and obtain the equations for magnification for near point focusing and normal focusing.

Refer short answer **Q.No :70**

24. Explain about compound microscope and obtain the equation for magnification.

- The lens near the object, called the ***objective***, forms a real, inverted, magnified image of the object.
- This serves as the object for the second lens which is the ***eyepiece***.

- Eyepiece serves as a simple microscope that produces finally an enlarged and virtual image.
- The first inverted image formed by the objective is to be adjusted close to, but within the focal plane of the eyepiece so that the final image is formed nearly at infinity or at the near point.
- The final image is inverted with respect to the original object.

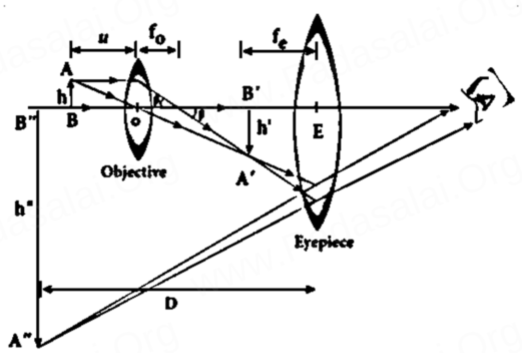


Figure 6.85 Compound microscope

Magnification of compound microscope

From the ray diagram, the linear magnification due to the objective

$$m_o = \frac{h'}{h}$$

$$\tan\beta = \frac{h}{f_o} = \frac{h'}{L}$$

$$\frac{h'}{h} = \frac{L}{f_o}$$

$$m_o = \frac{L}{f_o}$$

- The distance L is between the first focal point of the eyepiece to the second focal point of the objective.
- This is called the tube length L of the microscope as f_o and f_e are comparatively smaller than L.
- If the final image is formed at P (near point focussing), the magnification m_e of the eyepiece is,

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

The total magnification m in near point focusing is,

$$\boldsymbol{m = m_0 m_e = \left(\frac{L}{f_o}\right)\left(1 + \frac{D}{f_e}\right)}$$

25. Obtain the equation for resolving power of microscope.

Refer Q.no : 22

26. Discuss about astronomical telescope.

- An astronomical telescope is used to get the magnification of distant astronomical objects like stars, planets, moon etc. the image formed by astronomical telescope will be inverted.
- It has an objective of long focal length and a much larger aperture than the eyepiece as. Light from a distant object enters the objective and a real image is formed in the tube at its second focal point.
- The eyepiece magnifies this image producing a final inverted image

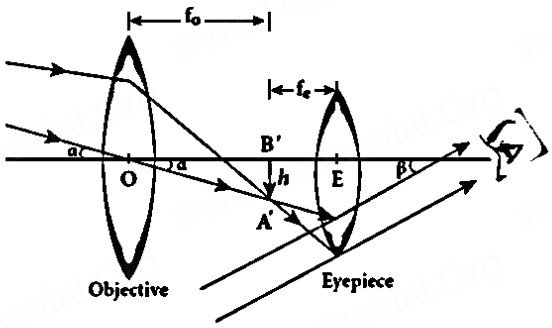


Figure 6.86 Astronomical telescope

Magnification of astronomical telescope

The magnification m is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye.

$$m = \frac{\beta}{\alpha}$$

From the diagram

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

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

The length of the telescope is approximately,

$L = f_o + f_e$

27. Mention different parts of spectrometer and explain the preliminary adjustments.

It consists of basically three parts. They are

(i) collimator,
(ii) prism table
(iii) Telescope.

(i) Collimator

The collimator is an arrangement to produce a parallel beam of light

(ii) Prism table

The prism table is used for mounting the prism, grating etc.

(iii) Telescope

The telescope is an astronomical type. It consists of an eyepiece provided with cross wires at one end and an objective lens at its other end.

Adjustments of the spectrometer

(a) *Adjustment of the eyepiece*

The telescope is turned towards an illuminated surface and the eyepiece is moved to and fro until the cross wires are clearly seen.

(b) Adjustment of the telescope

The telescope is adjusted to receive parallel rays by turning it towards a distant object and adjusting the distance between the objective lens and the eyepiece to get a clear image on the cross wire.

(c) *Adjustment of the collimator*

- The telescope is brought along the axial line with the collimator.
- The slit of the collimator is illuminated by a source of light.
- The distance between the slit and the lens of the collimator is adjusted until a clear image of the slit is seen at the cross wire of the telescope. Since the telescope is already adjusted for parallel rays, a well-defined image of the slit can be formed, only when the light rays emerging from the collimator are parallel.

(d) *Levelling the prism table* The prism table is adjusted or levelled to be in horizontal position by means of levelling screws and a spirit level.

28. Explain the experimental determination of refractive index of the material of the prism using spectrometer.

The preliminary adjustments of the telescope, collimator and the prism table of the spectrometer are made. The refractive index of the prism can be determined by knowing the angle of the prism and the angle of minimum deviation.

(i) Angle of the prism (A)

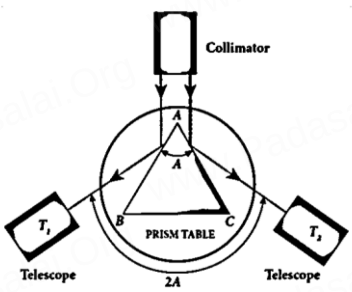


Figure 6.90 Angle of prism

- The prism is placed on the prism table with its refracting edge facing the collimator.
- The slit is illuminated by a sodium light (monochromatic light).
- The parallel rays coming from the collimator fall on the two faces *AB* and *AC*.
- The telescope is rotated to the position T_1 until the image of the slit formed by the reflection at the face *AB* is made to coincide with the vertical cross wire of the telescope
- The readings of the verniers are noted. The telescope is then rotated to the position T_2 where the image of the slit formed by the reflection at the face *AC* coincides with the vertical cross wire. The readings are again noted.
- The difference between these two readings gives the angle rotated by the telescope, which is twice the angle of the prism. Half of this value gives the angle of the prism *A*.

(ii) Angle of minimum deviation (D)

- The prism is placed on the prism table so that the light from the collimator falls on a refracting face, and the refracted image is observed through the telescope.
- The prism table is now rotated so that the angle of deviation decreases.
- A stage comes when the image stops for a moment and if we rotate the prism table further in the same direction, the image is seen to recede and the angle of deviation increases. The vertical cross wire of the telescope is made to coincide with the image of the slit where it turns back. This gives the minimum deviation position

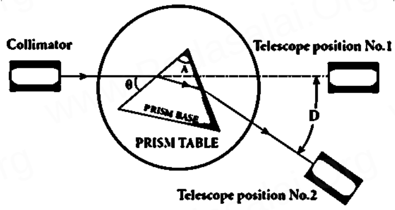


Figure 6.91 Angle of minimum deviation

- The readings of the verniers are noted. Now, the prism is removed and the telescope is turned to receive the direct ray and the vertical cross wire is made to are noted.
- The difference between the two readings gives the angle of minimum deviation *D*. The refractive index of the material of the prism n is calculated using the formula,

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Numerical Problems

1. An object is placed at a certain distance from a convex lens of focal length 20 cm. Find the distance of the object if the image obtained is magnified 4 times.

Given:

$f = -20cm\,, v = -4u$

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

$\frac{1}{(-20)} = \frac{1}{(-4u)} + \frac{1}{u}$

$= \frac{1}{u}\left(-\frac{1}{4} + \frac{1}{1}\right)$

$= \frac{1}{u}\left(\frac{3}{4}\right)$

$= -\frac{3\times20}{4} = \mathbf{-15}\boldsymbol{cm}$

2. A compound microscope has a magnification of 30. The focal length of eye piece is 5 cm. Assuming the final image to be at least distance of distinct vision, find the magnification produced by the objective.

Given:

M = 30 , f = 5cm , least distance D = 25cm

$M = M_o\left(1 + \frac{D}{f_e}\right)$

$30 = M_o\left(1 + \frac{25}{5}\right)$

$M_o = \frac{30}{6} = 5$

3. An object is placed in front of a concave mirror of focal length 20 cm. The image formed is three times the size of the object. Calculate two possible distances of the object from the mirror.

Given;

$m = +3\,, m = -3\ \&\ f = -20cm$

m = 3

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

$3 = -\frac{v}{u}$

$v = -3u$

By mirror equation

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

$\frac{1}{(-20)} = \frac{1}{(-3u)} + \frac{1}{u}$

$= \frac{1}{u}\left(-\frac{1}{3} + \frac{1}{1}\right)$

$= \frac{1}{u}\left(\frac{2}{3}\right)$

$= -\frac{\mathbf{40}}{\mathbf{3}}\,\boldsymbol{cm}$

m = -3

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

$-3 = -\frac{v}{u}$

$v = 3u$

By mirror equation

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

$\frac{1}{(-20)} = \frac{1}{(3u)} + \frac{1}{u}$

$= \frac{1}{u}\left(\frac{1}{3} + \frac{1}{1}\right)$

$= \frac{1}{u}\left(\frac{4}{3}\right)$

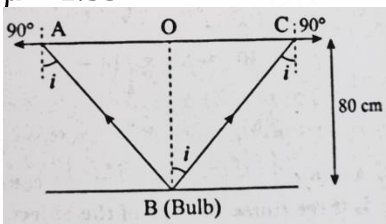
$= -\frac{\mathbf{80}}{\mathbf{3}}\,\boldsymbol{cm}$

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

Given

d_1 = 80cm = 0.8m

μ = 1.33



Bulb is a point source , the emergent light can be considered as circle of radius

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

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

$\sin i = \frac{\sin 90°}{1.33} = 0.75$

$i = \sin^{-1}(0.75)$= 48.75°

From the given figure

$\tan i = \frac{OC}{OB} = \frac{r}{d}$

$r = \tan i \times d$

$= \tan 48.15° \times 0.8 = 0.91m$

Area of surface of water = πr^2

= $3.14\times(0.91)^2$

= 2.61 m^2

5. A thin converging glass lens made of glass with refractive index 1.5 has a power of + 5.0 *D*. When this lens is immersed in a liquid of refractive index *n*, it acts as a divergent lens of focal length 100 cm. What must be the value of *n*?

Given :

P = +5.0 D where $P = \frac{1}{f} = \frac{1}{5} \times 100 = 20cm$

$n = 1.5$

$$\frac{1}{f} = [n-1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{20} = [1.5-1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$\frac{1}{20} = [0.5]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$.........(1)

$f = -100cm \; n_2 = 1.5 \quad n_1 = n$

$\frac{1}{-100} = \left[\frac{1.5}{n} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$......(2)

Divide (2) by (1)

$$\frac{1}{-5} = \frac{\left(\frac{1.5}{n} - 1\right)}{0.5}$$

On solving

$$n = \frac{1.5}{0.9} = \frac{5}{3}$$

6. If the distance *D* between an object and screen is greater than 4 times the focal length of a convex lens, then there are two positions of the lens for which images are formed on the screen. This method is called conjugate foci method. If *d* is the distance between the two positions of the lens, obtain the equation for focal length of the convex lens.

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

Sub $v = D - u$ in (1)

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

Equation will be

$u^2 - Du + fD = 0$

Quadratic equation

$$u = \frac{D \pm \sqrt{D^2 - 4fD}}{2}$$

When $u_1 = \frac{D - \sqrt{D^2-4fD}}{2}$

$$v_1 = D - u_1 = \frac{D + \sqrt{D^2 - 4fD}}{2}$$

When $u_2 = \frac{D + \sqrt{D^2-4fD}}{2}$

$$v_2 = D - u_2 = \frac{D - \sqrt{D^2 - 4fD}}{2}$$

Displacement x = $v_1 - u_1 - u_2 - v_2$

Hence we get focal length

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

7. A beam of light of wavelength 600 nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. What is the distance between the first dark fringe on either side of the central bright fringe?

Given;

$\lambda = 600nm = 600 \times 10^{-9} m$

Distance between screen and slit D = 2m

Width of slit d = 1mm = 1×10^{-3}m

Fringe width $\beta = \frac{2D\lambda}{d}$

$= \frac{2\times2\times600\times10^{-9}}{1\times10^{-3}}$

$= 2.4 \times 10^{-3} = 2.4mm$

8. In Young's double slit experiment, the slits are 2 mm apart and are illuminated with a mixture of two wavelength λ_0 = 750 nm and λ = 900 nm. What is the minimum distance from the common central bright fringe on a screen 2 m from the slits where a bright fringe from one interference pattern coincides with a bright fringe from the other?

$n_1\lambda_1 = n_2\lambda_2$

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{900}{750}$$

$$\frac{n_1}{n_2} = \frac{6}{5}$$

5^{th} and 6^{th} fringe coincide

$$X_{min} = \frac{n_2 \times \lambda_2 \times D}{d}$$
$$= \frac{5 \times 900 \times 10^{-9} \times 2}{2 \times 10^{-3}}$$
$$= 4.5mm$$

9. In Young's double slit experiment, 62 fringes are seen in visible region for sodium light of wavelength 5893 Å. If violet light of wavelength 4359 Å is used in place of sodium light, then what is the number of fringes seen?

Given

$n_1 = 62 , \lambda_1 = 5893 \text{ Å} , \lambda_2 = 4359\text{Å}$

$n_1\lambda_1 = n_2\lambda_2$

$$n_2 = \frac{n_1\lambda_1}{\lambda_2}$$
$$= \frac{62 \times 5893}{4359} = 84$$

10. A compound microscope has a magnifying power of 100 when the image is formed at infinity. The objective has a focal length of 0.5 cm and the tube length is 6.5 cm. What is the focal length of the eyepiece.

Given

f_o = 0.5cm , m = 100 D=25cm

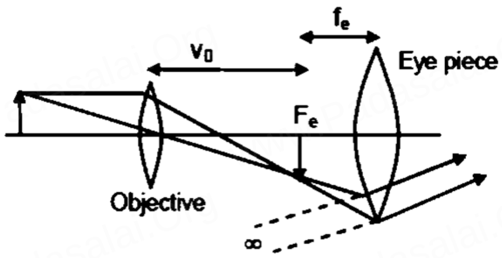


Image is formed at infinity , the real image produced by the objective lens should lie on the focus of the eye piece

$V_o + f_e$ = 6.5cm ……(1)

$$m = \frac{v_o}{u_0} \times \frac{D}{f_e}$$
$$= -\left[1 - \frac{v_o}{f_0}\right]\frac{D}{f_e} \quad \text{since } \frac{v_o}{u_0} = 1 - \frac{v_o}{f_0}$$
$$100 = -\left[1 - \frac{v_o}{0.5}\right]\frac{25}{f_e}$$
$$100f_e = -(1 - 2v_o)25$$
$2v_o - 4f_e = 1$……….(2)

Solving (1) & (2)

v_o = 4.5 cm and f_e = 2cm