RAY OPTICS

In order to understand the nature of light, various theories have been given from time to time. We now believe that light has dual nature – it propagates as a wave but interacts with matter as a particle.

REFLECTION OF LIGHT

When a beam of light strikes an object or a surface separating two media, a part of it is reflected back into the same medium.

LAWS OF REFLECTION:

FIRST LAW: The incident ray, the reflected ray and the normal at the point of incidence all must lie in the same plane.

SECOND LAW: The angle of incidence is equal to the angle of reflection.

SOME IMPORTANT RESULTS CONCERNING REFLECTION FROM PLANE MIRROR:

1. The image formed by a plane mirror is virtual, erect and laterally inverted.
2. The size of the image is equal to the size of the object.
3. The image is as far behind as the object is in front of the mirror.
4. If the image is moved through a distance x towards or away from the object, the image moves through a distance 2x.If the speed of the mirror is v, that of the image is 2v.
5. If the image is turned through an angle α, the reflected ray turns through an angle 2α.
6. The deviation of a ray produced by a plane mirror is π-2i, where I is the angle of incidence.
7. Number of images of an object in two mirrors inclined to each other at an angle α, {let k =$\frac{360}{\alpha}$} n is k if k is odd and n is k-1 if k is even.

REFRACTION OF LIGHT

When a ray of light is incident on the boundary between two transparent media, a part of it passes into the second medium with change in direction. This phenomenon is called Refraction of Light.

*If the ray travels from rarer to denser medium, it bends towards the normal and vice versa.

Refractive index ${}_1\mu_2$ (Refractive Index of medium 2 w.r.t to medium 1) = $\frac{\sin i}{\sin r}$ [Snell's Law}

$$\mu = \frac{speed\ of\ light \in medium\,1}{speed\ of\ light \in medium\,2} = \frac{v1}{v2} = ¿\ \frac{C}{v} = \frac{\lambda 1}{\lambda 2}$$

REVERSIBILITY PRINCIPLE OF LIGHT:

$${}_1\mu_2 = \frac{1}{{}_2\mu_1}$$ **or 1μ2 x 2μ1 = 1**

APPARENT DEPTH AND REAL DEPTH:

REFRACTIVE INDEX OF DENSER MEDIUM WRT RARER MEDIUM = ${}_1\mu_2 = \frac{Real\ Depth}{Apparent\ Depth}$

Apparent Depth $= \frac{t}{n}$; where t is the thickness of the slab.

CRITICAL ANGLE AND TOTAL INTERNAL REFLETION:

When a ray of light goes from a denser medium to a rarer medium , it bends away from the normal. The angle of incidence (c) for which the angle of reflection becomes 90^0, is called critical angle.

We have ${}_1\mu_2 = \frac{1}{\sin c}$ (Necessary Condition For TIR to Take place that angle of incidence must be greater than the Critical angle and μ2 > μ1)

Optical Fibres: Optical Fibres consists of thousands of very long and fine quality glass fibres, coated with a thin layer of a material of lower refractive index. Typical values are; thickness of strands = 10^{-4} cm, μ (of fibre material) = 1.7, μ (of coating) = 1.5.When light enters from one end of Optical Fibre, it suffers multiple internal reflections and finally comes out from the other end. The necessary conditions of TIR are always met. Thus light can be transmitted to very long distances even without any loss of intensity; even when the fibre is twisted.

USES: As Light Pipes in medical diagnosis and for optical signal transmission.

REFRACTION THROUGH A PRISM:

If A is the refracting angle of the Prism and D is the angle of deviation then for a glass prism

$$A + D = I + e$$

Where i – Angle of incidence and and e = Angle of emergence

Refractive index of the material of the prism **μ =** $\frac{\sin}{\sin}\frac{\left(A+\frac{D}{2}\right)}{A/2}$

It can be shown that the deviation produced by the small angled prism D = (μ-1) A

DISPERSION OF LIGHT:

Dispersion takes place because the refractive index of the medium depends on the wavelength of the light as per the following relation **μ = A +**$\frac{B}{\lambda 2}$ **.** This shows that smaller the wavelength, larger is the value of μ.Thus μ is maximum for violet and least for Red colour.Hence Violet deviates most and Red deviates least.

The Mirror Equation: $\frac{1}{f}$ = $\frac{1}{u}$ + $\frac{1}{v}$; where u & V represent object & image distance respectively. Also R = 2 f, where R is the radius of curvature of the mirror and f is the focal length.

Magnification Produced by a mirror is the ratio of the size of the image to that size of the object.

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

Sigh Convention : We shall use "Real is positive and virtual is negative' i.e. the distances of real objects and real images are taken as positive and those of virtual objects and virtual images are taken as negative.

The Lens Maker's formula: $\frac{1}{f}$ **= (μ-1) [**$\frac{1}{R1}$ **-** $\frac{1}{R2}$**]**

Where R1 & R2 are the Radii of curvature of the first and the second surface respectively.

The lens equation: $\frac{1}{f}$ = $\frac{1}{v}$ - $\frac{1}{u}$; where u & V represent object & image distance respectively. Also R = 2 f, where R is the radius of curvature of the lens and f is the focal length.

Magnification Produced by a lens is the ratio of the size of the image to that size of the object.

M = $\frac{v}{u}$ **=** $\frac{v-f}{f}$ **=** $\frac{f}{u-f}$

<u>Power of a Lens</u>: The Reciprocal of the focal length $P = \frac{1}{f}$, when f is measured in metres.SI unit of Power is Dioptre (D).

<u>Equivalent Focal length of two thin lenses in contact</u>:

If two thin lenses having focal lengths f1 and f2 are placed in contact, and then the equivalent focal length F of the combination is given by

$$\frac{1}{F} = \frac{1}{f1} + \frac{1}{f2}$$

Power $P = P_1 + P_2$

<u>OPTICAL INSTRUMENTS</u>: A simple microscope is a convex lens of short focal length.

Magnifying power of Simple microscope is given by $\mathbf{M = 1 + \frac{D}{f}}$, where D = 25 cm.If the final image is formed at infinity then $\mathbf{M} = \frac{D}{f}$. In this case the image can be seen with relaxed eye.

<u>COMPOUND MICROSCOPE</u>: It consists of two converging lenses, an objective of small focal length and an eye piece of large focal length.

The Magnifying Power $M = m_0 \times m_e = \frac{v}{u}\left(1 + \frac{D}{fe}\right) = \frac{L}{fo}\left(1 + \frac{D}{fe}\right)$ where L is the length of the microscope.

If the final image is formed at infinity

$$\mathbf{M} = \frac{D}{fe} \mathbf{X} \frac{v}{u}$$

<u>ASTRONOMICAL TELESCOPE</u>:

It consists of two converging lenses, objective of large focal length f_0 and eyepiece of small focal length f_e.

Magnifying power $\mathbf{M = f_0/f_e.}$

If the final image is formed at the least distance of distinct vision D, then

$$\mathbf{M = f_0/f_e.\ (1 + \frac{fe}{D})}$$

MULTIPLE CHOICE QUESTIONS

1. A convex mirror of focal length f forms an image which is 1/n times the object. The distance of the object from the mirror is :

   (a) (1-n) f (b)($\frac{n-1}{n}$) f (c) $\left(\frac{n+1}{n}\right)f$ (d) (n+1) f

2. A light bulb is placed between two plane mirrors inclined at an angle 60^0. The number of images formed are :

   (a) 6 (b) 2 (c) 5 (d) 4

3. The focal length of convex mirror is f and the distance from the object to the principal focus is x.The ratio of the size of the image to the size of the object is :

   (a) $\frac{f+x}{f}$ (b) $\frac{f}{x}$ (c) $\sqrt{¿¿}$/x) (d) f^2/x^2

4. A light wave has a frequency of 4 X 10^{14} Hz and a wavelength of 5 X 10^{-7} meters in a medium. The refractive index of the medium is:

   (a) 1.5 (b) 1.33 (c) 1 (d) 0.66

5. A convex lens of focal length 40 cm is in contact with a concave lens of focal length 25 cm. The power of the combination is :

   (a) – 1.5 D (b) -6.5 D (c) 6.5 D (d) + 6.67 D

6. An object is placed 9 cm from a magnifying lens of focal length 24 cm. What is magnitude of the magnification?

   (a) 1.2 (b) 1.6 (c) 2 (d) 2.4

7. The condition that the image is not formed on the screen placed on the other side of the lens, when the object is placed before the lens:

   (a) At F (b) Between 2F & ∞ (c)) Between 2F & Optical Centre (f) Between 2F & F

8. A glass convex lens (μ=1.5) has a focal length of 8 cm in air. What would be the focal length of the lens when it is immersed in water (μ = 1.33):

   (a) 2 m (b) 4 cm (c) 16 cm (d) 32 cm

9. The minimum distance between an object and its real image formed by a convex lens is :

   (a) 1.5 f (b) 2 f (c) 2.5 f (d) 4 f

10. Focal length of a convex lens will be maximum for:

    (a) Blue Light (b) yellow Light (c) Green Light (d) Red Light

11. In the formation of a rainbow, the light from the sun on water droplets undergoes

    (a) Dispersion only (b) TIR Only (c) Dispersion & TIr both (d) None of the above

12. A convex lens of focal length f produces an image 1/n times the size of the object. The distance of the object from the lens is :

    (a) nf (b) f/n (c) (n+1) f (d) (n-1) f

13. What is the time taken (in seconds) to cross a glass of thickness 4 mm and refractive Index 3 by light:

    (a) 4 X 10^{-11} (b) 2 X 10^{-11} (c) 16 X 10^{-11} (d) 8 X 10^{-11}

14. A concave mirror of focal length f (in air) is immersed in water (μ = 1.33). The focal length of the mirror in water will be:

(a) f (b) $\frac{4}{3}$f (c)) $\frac{3}{4}$f (d) $\frac{7}{3}$f

15. An equicovex lens of glass of focal length 0.1 m is cut along a plane perpendicular to principal axis into two equal parts. The ratio of focal length of new lenses is:

(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 2 : 0.5

16. A convex lens is dipped into a liquid whose refractive Index is equal to the refractive Index of lens. Then its focal length will:

(a) Becomes zero (b) becomes infinite (c) reduces (d) increases

17. Which of the following is used in optical fibres?

(a) Total Internal Reflection (b) Scattering (c) Diffraction (d) refraction

18. The focal length of an equiconvex lens in air is equal to either of its radii of curvature. The refractive Index of the material of the prism is:

(a) 4/3 (b) 2.5 (c) 0.8 (d) 1.5

19. To a fish in water, a bird in air appears to be at 30 cm from the surface. If ${}_a\mu_g$ = 4/3, then the true distance of the bird from the surface is :

(a) 40 cm (b) 22.5 cm (c) 80 cm (d) **none of the above**

20. A Plano convex lens has a curved surface of radius 100 cm.If μ = 1.5, then the focal length of the lens is:

(a) 50 cm (b) 100 cm (c) 200 cm (d) 500 cm

21. Up to what height the water be filled into a vessel of height 21 cm such that it appears half filled when viewed from above?

(a) 8 cm (b) 10.5 cm (c) 12 cm (d) 14 cm

22. If the critical angle for TIR from a medium to vacuum is 300, the velocity of light in the medium is :

(a) 3×10^8 m/s (b) 1.5×10^8 m/s (c) 6×10^8 m/s (d) $\sqrt{3} \times 10^8$ m/s

23. An astronomical telescope has a large aperture to

(a) Reduce spherical aberration (b) have high resolution

(c)increase span of observation (d) have low dispersion

24. An object and a screen are fixed at a distance d apart. When a lens of focal length f is moved between the object and the screen, sharp image s of the object are formed on the screen for two p[positions of the lens. The magnification produced at these two positions is M_1 and M_2, then:

(a) d > 2f (b) d > 4f (c) $M_1 M_2 = 1$ (d) None

25. A point object P moves towards a convex mirror with a constant speed V, along its optic axis. The speed of the image is:

(a) Always less than V

(b) May be >,= or < V depending on the position of P

(c) Increases as P comes closer to the mirror
(d) Decreases as P comes closer to the mirror

26. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm below the surface, the radius of the circle in cm is :
(a) $36/\sqrt{7}$ (b) $36\sqrt{7}$ (c) $4\sqrt{5}$ (d) None

27. A thin glass lens has optical power -5 D in air. Its optical power in a liquid medium with refractive index 1.6 will be:
(a) – 1 D (b) 1 D (c) -25 D (d) 25 D

28. To get three images of a single object, one should have two plane mirrors inclined at an angle of:
(a) 30^0 (b) 60^0 (c) 90^0 (d) 120^0

29. The image formed by an objective of a compound microscope is :
(a) Real & enlarged (b) virtual & enlarged
(c) Real & diminished (d) virtual & diminished

30. A person having the nearest distance of distinct vision of 32 cm uses a reading lens of focal length 8 cm. The magnification of his reading lens is:
(a) 5 (b) 4 (c) 3 (d) 2

31. Consider telecommunication through optical fibres. Which of the following statements is not true?
(a) Optical fibres can be of graded Refractive Index
(b) Optical fibres have extremely low transmission loss
(c) They are subject to electromagnetic interference from outside
(d) They may have homogeneous core with a suitable cladding.

32. A double convex lens of refractive index μ_2 is immersed in a liquid of refractive index μ_1. this lens will act as converging lens if :
(a) $\mu_1 > \mu_2$ (b)) $\mu_1 < \mu_2$ (c)) $\mu_1 = \mu_2$ (d)) $\mu_1 = \mu_2 = 0$

33. A Convex lens is in contact with a concave lens. The magnitude of the ratio of their focal lengths is 2/3. Their equivalent focal length is 30 cm. Their individual focal lengths are:
(a) -75, 50 (b) -10, 15 (c) 75, 50 (d) -15, 10

34. A ray of light is incident at the glass-water interface at an angle i. If it emerges finally parallel to the surface of water, and then the value of μ_g would be:
(a) (4/3) sin i (b) 1/ sin i (c) 4/3 (d) 1

35. Which of the following form (s) a virtual and erect image for all positions of object/
(a) Convex lens (b) concave lens (c) convex mirror (d) concave mirror

36. A concave lens of glass(refractive index 1.5) has both surfaces of same radius of curvature R. On immersion in a medium of refractive Index 1.75, it will behave as a :
(a) Convergent lens of f = 3.5 R (b) convergent lens of f = 3.0 R
(c) Divergent lens of f = 3.5 R (d) divergent lens of f = 3.0 R

37. A lens is placed between a source of light and a wall. It forms images of areas A1 and A2 on the wall for its two different positions. The area of the source of light is
(a) $\sqrt{A1A2}$ (b) $(A_1 + A_2)/2$ (c) $(A_1 - A_2)/2$ (d) $(1/A_1) + (1/A_2)$

38. A thin prism P_1 with angle 4^0 and made of glass of refractive index 1.54 is combined with another prism P_2 made of refractive index 1.72 to produce dispersion without deviation. The angle of the prism P_2 is:
(a) 5.33^0 (b) 4^0 (c) 3^0 (d) 2.6^0

39. When a ray of light enters a glass slab from air:
(a) Its wavelength increases
(b) Neither its wavelength nor its frequency changes
(c) Its frequency increases
(d) Its wavelength decreases

40. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen:
(a) Half the image will disappear
(b) Complete image will be formed
(c) Intensity of the image will increase
(d) Intensity of the image will decrease

41. Two plane mirrors are inclined at 70^0. A ray incident on one mirror at an angle , after reflection falls on the second mirror and is reflected from there parallel to the first mirror. The value of θ is (a) 50 degrees (b) 45 degrees (c) 30 degrees (d) 55 degrees

42. A number of images of a candle frame are seen in a thick mirror. Which of the following statement is correct?
(a) The first image is the brightest (b) The second image is the brightest
(c) The last image is the brightest (d) all images are equally bright

43. The critical angle of light going from medium A into Medium B is θ.the speed of light in medium A is v.The speed of light in medium B is
(a) $v/\sin\theta$ (b) $v \sin\theta$ (c) v / (tanθ¿ (d) $v \tan\theta$

44. The critical angle is maximum when light travels from
(a) Water to air (b) glass to air (c) glass to water (d) air to water

45. An air bubble inside a glass slab appears to be 6 cm deep when viewed from one side and 4 cm deep when viewed from the opposite side. The thickness of the slab is
(a) 10 cm (b) 6.67 cm (c) 15 cm (d) 20 cm

46. A convex lens A of focal length 20 cm and a concave lens of focal length 5 cm are kept along the same axis with distance d between them. If a parallel beam of light falling on A leaves B as parallel beam, then value of d is (in cm)
(a) 25 (b) 15 (c) 30 (d) 50

47. The blue colour of sky is due to the phenomenon of
(a) Scattering (b) dispersion (c) reflection (d) refraction

48. Two beams of red and violet colors are made to pass separately through a prism($A=60^0$).In the position of minimum deviation , the angle of refraction will be
(a)30^0 for both (b) more for violet (c) more for red (d) equal for both colors

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

(a) Virtual at a distance of 16 cm from the mirror (b) real, at a distance of 16 cm from mirrors
(c) Virtual at a distance of 20 cm from the mirror (d) real, at a distance of 20 cm from the mirror

50. Image of an object approaching a concave mirror of radius of curvature 20 cm along its optics axis is observed to move from 27/3 m to 50/7 m in 30 seconds. The speed of the object in km/h
(a) 2km/h (b) 6km/h (c) 5 km/h (d) 3 km/h

ANSWER KEY

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