CHAPTER : 9

RAY OPTICS AND OPTICAL INSTRUMENTS

STUDY NOTES

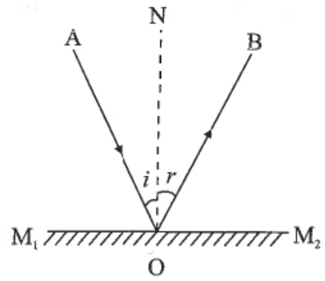
- **Laws of Reflection:**

  The reflection at a plane surface always takes place in accordance with the following two laws:

  (i) The incident ray, the reflected ray and normal to surface at the point of incidence all lie in the same plane

  (ii) The angle of incidence, i is equal to the angle of reflection r, i.e.,

  $$\angle i = \angle r$$



- **Formation of Image by the Plane Mirror:**

  The formation of image of a point object O by a plane mirror is represented in figure. The image formed I has the following characteristics:

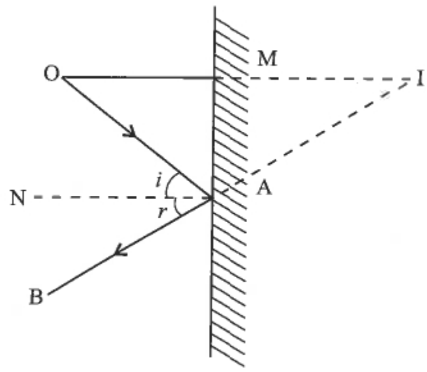
  (i) The size of image is equal to the size of object.

  (ii) The object distance = Image distance i.e.,

  OM = MI

  (iii) The image is virtual and erect.

  (iv) When a mirror is rotated through a certain angle, the reflected ray is rotated through twice this angle.



- **Reflectio of Light from Spherical Mirror:**

  (a) A spherical mirror is a part cut from a hollow sphere.

  (b) They are generally constructed from glass.

  (c) The reflection at spherical mirror also takes place in accordance with the laws of reflection.

- **Sign Convention:**

  Following sign conventions are the new cartesian sign convention:

  (i) All distances are measured from the pole of the mirror and direction of the incident light is taken as positive. In other words, the distances measured toward the right of the origin are positive.

  (ii) The distance measured against the direction of the incident light are taken as negative. In other words, the distances measured towards the left of origin are taken as negative.

  (iv) The distance measured in the upward direction, perpendicular to the principal axis of the mirror, are taken as postive and the distances measured in the downward direction are taken negative.

- **Focal Length of a Spherical Mirror:**

  (a) The distance between the focus and the pole of the mirror is called focal length of the mirror and is represented by f.

  (b) The focal length of the concave mirror is negative and that of a convex mirror is positive.

  (c) The focal length of a mirror (concave or convex) is equal to half of the radius of curvature of the mirror i.e., $f = \frac{R}{2}$.

- **Principal Axis of the Mirror:** The straight line joining the pole and the centre of curvature of spherical mirror extended on both sides is called principal axis of the mirror.
- **Mirror Formula:**

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

  Where u = distance of the object from the pole of mirror

  v = distance of the image from the pole of mirror

  f = focal length of the mirror

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

  Where r is the radius of curvature of the mirror.
- **Magnification:**

  It is defined as the ratio of the size of the image to that of the object.

  Linear magnification,

  $$\text{m}=\frac{\text{I}}{O}=-\frac{\text{v}}{u}=\frac{f-v}{f}=\frac{f}{f-u}$$

  Where I size of image and O = size of object.
- Magnification, m is positive, implies that the image is real and inverted.
- Magnification, m is negative, implies that the image is virtual and erect.
- **Refraction:**

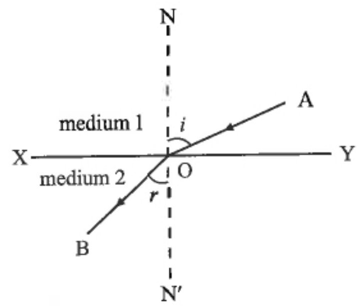
  When a ray of light falls on the boundary separating the two media, there is a change in direction of ray. This phenomenon is called refraction.
- **Laws of Refraction:**

  (i) The incident ray, normal at the point of incidence and refracted ray all lie in one plane.

  (ii) For the same pair of media and the same colour of light, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant i.e.,

  $$\frac{\sin i}{\sin r}={}_a\mu_b$$

  Where ${}_a\mu_b$ is a constant known as refractive index of the medium b with respect to the medium a; i is the angle of incidence in medium a and r is the angle of refraction in medium b.



- **Principle of Reversibility of Light:**

  As light follows a reversible path,

  $$\frac{\sin r}{\sin i}={}_b\mu_a$$

  Multiplying we get,

  $${}_a\mu_b \times {}_b\mu_a=\frac{\sin i}{\sin r}\times\frac{\sin r}{\sin i}=1$$

  $${}_a\mu_b=\frac{1}{{}_b\mu_a}$$
- **Methods to Determine Refractive Index of a Medium:**

  Refractive index of a medium can also be determined from the following:

  (i) $\mu=\dfrac{\text{Velocity of light in air}}{\text{Velocity of light in the medium}}$

(ii) $\mu = \frac{1}{\sin C}$

Where C is the critical angle.

- **Critical Angle:** The Critical angle is the angle of incidence in a denser medium coresponding to which the refracted ray just grazes the surface of separation.

- **Apparent Depth of a Liquid:** If the object be placed at the bottom of a transparent medium, say water, and viewed from above, it will appear higher thant it actually is.

  The refractive index μ in this case is:

$$\text{Refractive index of the medium, } \mu = \frac{\text{Real Depth}}{\text{Apparent Depth}}$$

- **Refraction through a Single Surface:** If μ_1, μ_2 are refractive indices of first and second media, R the radius of curvature of spherical surface, formula is

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

  where u and v are the distances of the object and the image from the centre of the refracting surface of radius of curvature R respectively.

- **Lens:** A lens is a piece of a refracting medium bounded by two surfaces, at least one of which is a curved surface. Lenses are of two types :
  - (i) **Convex or converging lens:** It is thicker at the centre than at the edges. It converges a parallel beam of light on refraction through it. It has a real focus.
  - (ii) **Concave or diverging lens:** It is thinner at the centre than at the edges. It diverges a parallel beam of light on refraction through it. It has a virtual focus.

- **Definitions in connection with spherical lenses:**
  - (i) **Centre of curvature:** The centre of curvature of the surface of a lens is centre of the sphere of which it forms a part. Because a lens has two surfaces, so it has two centres of curvature.
  - (ii) **Radius of curvature:** The radius of the surface of a lens is the radius of the sphere of which the surface forms a part.
  - (iii) **Principal axis:** It is the line passing through the two centres of curvature of the lens.
  - (iv) **Principal focus:** A narrow beam of light parallel to the principal axis either converges to a point or appears to diverge from a point on the principal axis after refraction through the lens. This point is called principal focus. A lens has two principal focii.
  - (v) **Optical Centre:** It is the point situated within the lens through which a ray of light passes undeviated.
  - (vi) **Focal length:** It is the distance between the principal focus and the optical centre of the lens.
  - (vii) **Aperture:** It is the diameter of the circular boundary of the lens.

- **New Cartesian sign convention for spherical lenses:**
  - (i) All distances are measured from the optical centre of the lens.
  - (ii) The distances measured in the direction of incident light are taken as positive.
  - (iii) The distances measured in the opposite direction of incident light are taken as negative.
  - (iv) Heights measured upwards and perpendicular to the principal axis are taken as positive.
  - (v) Heights measured downwards and perpendicular to the principal axis are taken as negative. In this sign convention, the focal length of a converging lens is positive and that of a diverging lens is negative.

- **Refraction through a spherical surface:**

  A surface which forms part of a sphere of a transparent refracting material is called a spherical refracting surface.
  - (i) **Refraction from rarer to denser medium:** When a ray of light travels from a rarer medium of refractive index μ_1 to a denser medium of refractive index μ_2 of a spherical surface of radius of curvature R, the relation between object distance u and image distance v is

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

If the rarer medium is air, then $\mu_1 = 1$ and $\mu_2 = \mu$, we have

$$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$$

(ii) **Refraction from denser to rarer medium:** When the object is placed in a denser medium, the relation between u and v can be obtained by interchanging μ_1, and μ_2,

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

- **Power of a spherical refracting surface:** It is given by

$$P = \frac{\mu_2 - \mu_1}{R} = \frac{\mu - 1}{R} \text{ (for air)}$$

where R is measured in metre. The power of a convex surface is positive and that of a concave surface is negative.

- **Lens maker's formula:** This formula relates the focal length f to the refractive index μ and the radii of curvature R_1, R_2 of its spherical surfaces.

$$\frac{1}{f} = \left[\frac{\mu_2 - \mu_1}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

When lens is replaced in air $\mu_1 = 1$ and $\mu_2 = \mu$. The lens maker formula takes the form, $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

- **Thin lens formula:** This formula gives relationship between object distance u, image distance v and focal length f a spherical lens (convex or concave) of small aperture.

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

- **Linear magnification produced by a lens:** It is the ratio of the size of the image formed by a lens to the size of the object.

$$M = \frac{h_2}{h_1} = \frac{v}{u} = \frac{f}{f + u} = \frac{f - v}{f}$$

When M is positive (or v is negative), the image is virtual and erect. When M is negative (or v is positive), the image is real and inverted.

- **Power of a lens:** The power of a lens is defined as the reciprocal of its focal length, expressed in metres.

$$P = \frac{1}{f(\text{m})}$$

SI unit of power is m^{-1}, also called dioptre (D).

One dioptre is the power of a lens whose principal focal length is 1 metre.

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

- **Lens combinations:** When lenses are used in combination, each lens magnifies the image formed by the preceding lens. The total magnification is equal to the product of the magnifications produced by the individual lenses.

$$m = m_1 \times m_2 \times m_3 \ldots.$$

The combined focal length f of two thin lenses of focal lengths f_1 and f_2 placed in contact is given by

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

- **Refraction through a prism:** When a ray of light is refracted through a prism, the sum of the angle of incidence i and the angle of emergence i' is equal to the sum of the angle of the prism A and the angle of deviation δ

$$A + \delta = i + i'$$

$$\text{and } A = r + r'$$

where r and r' are the corresponding angles of refraction at the two faces.

- **Relation between the refractive index and angle of minimum deviation:** The minimum value of the angle of deviation suffered by a ray on passing through a prism is called the angle of minimum deviation and is denoted by δ. When a ray of light suffers minimum deviation.

$$i = i', r = r' \text{ and } \delta = \delta_m$$

$$A + \delta_m = i + i = 2i \text{ or } i = \frac{A + \delta_m}{2}$$

And

$$A = r + r = 2r \text{ or } r = \frac{A}{2}$$

$$\text{Refractive index, } \mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\left(\sin\frac{A}{2}\right)}$$

- **Deviation produced by a prism of small angle:** It does not depend on the angle of incidence and is given by

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

- **Dispersion:** The splitting of white light into its constituent colours when it passes through a glass prism is called dispersion. The dispersion of light occurs because refractive index of prism material is different for different wavelengths.
- **Angular dispersion:** The angular separation between the two extreme colours (violet and red) in the spectrum is called angular dispersion. Angular dispersion

$$= \delta_V - \delta_r = (\mu_V - 1) A - (\mu_r - 1) A = (\mu_V - \mu_r) A$$

- **Dispersion power:** It is the ability of the prism material to cause dispersion and is defined as the ratio of the angular dispersion to the mean deviation.

$$\text{Dispersion power} = \frac{\text{Angular dispersion}}{\text{Mean deviation}}$$

$$\omega = \frac{\delta v - \delta r}{\delta} = \frac{(\mu_V - \mu_r)}{\mu - 1}$$

Hence, $\delta = \frac{\delta v + \delta r}{2}$ and $\mu = \frac{(\mu_V + \mu_r)}{2}$

- **Spherical aberration:** It is the inability of a lens or a spherical mirror of large aperture to bring the paraxial and marginal rays of a wide beam of light to focus at a single point.
- **Chromatic aberration:** The inability of lens to bring the light rays of different colours to focus at a single point.
- **Blue colour of the sky:** According to Rayleigh's law of scattering, the intensity of light of wavelength present in the scattered light is inversely proportional to the fourth power of wavelength.

  As the blue colour of sunlight is scattered more by the atmospheric molecules, due to which the sky appears blue.
- **Rainbow:** It is a spectacular display of the spectrum of light produced by refraction, dispersion and total internal reflection of sunlight by several raindrops. An observer standing with his back towards the sun observes it in the form of concentric circular arcs of different colours in the horizon.
- **Human eye:** It is most important and sensitive sense organ. The essential parts of a human eye are sclerotic, cornea, choroid, iris, pupil, crystalline lens, ciliary muscles, aqueous humour, vitreous humour and retina. It is a convex lens of focal length about 2.5 cm.
- **Visual angle:** The angle subtended by an object on the eye is called visual angle. Larger the visual angle, larger is the apparent size of an object.
- **Simple microscope:** It is a convex lens of short focal length. When the object is placed between the lens and its focus and the eye is held just behind the lens, a virtual, erect and enlarged image is seen. When the final image is formed at the least distance of distinct vision (D), the magnifying power of the simple microscope is the ratio of angle subtended by the image at the least distance of distinct vision and the angle subtended by the object at the least distance of distinct vision

$$\text{Or } m = \frac{\beta}{\alpha} = 1 + \frac{D}{f}$$

When the final image is formed at infinity, $m = \frac{D}{f}$, viewing is more comfortable when the eye is focussed at infinity.

- **Compound microscope:** It is an optical device used to see magnified images of tiny objects. The objective is a convex lens of very short focal length and of small aperture. The eyepiece is a convex lens of relatively larger focal length and of larger aperture. The difference between the focal lengths of the eyepiece and the objective is small. Its magnifying power is given by

$$m = m_o \times m_e$$

When the final image is formed at the least distance of distinct vision,

$$m = \frac{\beta}{\alpha} = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

- **Astronomical telescope:** It is used to view heavenly bodies. The objective is a convex lens of large focal length and large aperture. The eyepiece is convex lens of small focal length and small aperture. The difference in the focal lengths of the two lenses is large. The eyepiece forms a real, inverted and diminished image. The eyepiece magnifies this image. The final image is inverted with respect to the object.

When the final image is formed at the least distance of distinct vision,

$$m = \frac{\beta}{\alpha} = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

When the final image is formed at infinity (normal adjustment),

$$m = \frac{\beta}{\alpha} = -\frac{f_o}{f_e}$$

For large magnifying power of a telescope, clearly

$$f_o >> f_e$$

- **Reflecting telescope:** It uses a concave paraboidal mirror of large aperture to view the distant object. Both spherical and chromatic aberrations are minimum.

When the final image is formed at the least distance of distinct vision, $m = \frac{\beta}{\alpha} = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

When the final image is formed at infinity, $m = \frac{f_o}{f_e}$

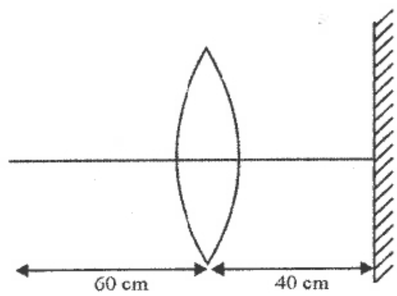
QUESTION BANK

MULTIPLE CHOICE QUESTIONS

1. Image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from 25/3 m to 50/7 m in 30 seconds. What is the speed of the object in km per hour?

(a) 3 (b) 2 (c) 3.5 (d) 3.2

2. A point object is placed at a distance of 60 cm from a convex lens of focal length 30 cm. If a plane mirror were put perpendicular to the principal axis of the lens and at a distance of 40 cm from it, the final image would be formed at a distance of –



(a) 20 cm from the plane mirror, it would be virtual image
(b) 20 cm from the lens, it would be a real image
(c) 30 cm from the lens, it would be a real image
(d) 30 cm from the plane mirror it would be a virtual image

3. A ray is incident at an angle of incidence i on one surace of a small angle prism (with angle of prism A) and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ, then the angle of incidence is nearly equal to:

(a) $\frac{2A}{\mu}$ (b) μA (c) $\frac{\mu A}{2}$ (d) $\frac{A}{2\mu}$

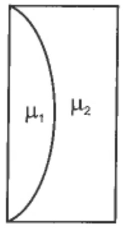
4. Assume that light of wavelength 600 nm is coming from a star. The limit of resolution of telescope whose objective has a diameter of 2 m is:

(a) 1.83×10^{7} rad (b) 7.32×10^{-7} rad (c) 6.00×10^{7} rad (d) 3.66×10^{-7} rad

5. A plano-convex of refractive index 1.5 and radius of curvature 30 cm is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens, an object be placed in order to have a real image of the size of the object?

(a) 20 cm (b) 30 cm (c) 60 cm (d) 80 cm

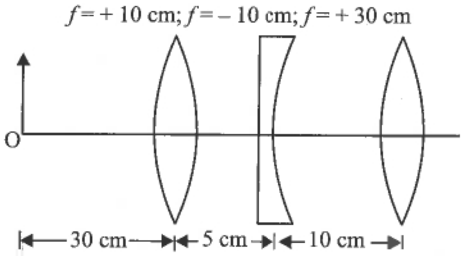
6. Curved surfaces of a plano-convex lens of refractive index μ_1 and a plano-concave lens of refractors index μ_2 have equal radius of curvature as shown in figure. Find the ratio of radius of curvature to the focal length of the combined lenses.



(a) $\frac{1}{\mu_2 - \mu_1}$ (b) $\mu_1 - \mu_2$ (c) $\frac{1}{\mu_1 - \mu_2}$ (d) $\mu_2 - \mu_1$

7. Find the distance of the image from object O, formed by the combination of lenses in the figure:

(a) 75 cm
(b) 10 cm
(c) 20 cm
(d) infinity



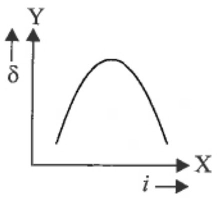
8. An object is placed beyond the centre of curvature C of the given concave mirror. If the distance of the object is d_1 from C, the distance of the image formed is d_2 from C, the radius of curvature of this mirror is:

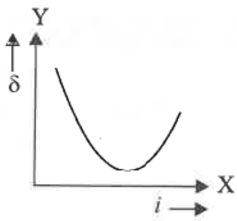
(a) $\frac{2d_1d_2}{d_1 - d_2}$ (b) $\frac{2d_1d_2}{d_1 + d_2}$ (c) $\frac{d_1d_2}{d_1 + d_2}$ (d) $\frac{d_1d_2}{d_1 - d_2}$

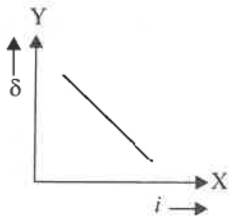
9. Car B overtakes another car A at a relative speed of 40 ms^{-1}. How fast will the image of car B appear to move in the mirror of focal length 10 cm fitted in car A, when the car B is 1.9 m away from the car A?

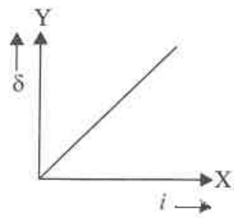
(a) 4 ms^{-1} (b) 0.2 ms^{-1} (c) 40 ms^{-1} (d) 0.1 ms^{-1}

10. Which one from the below plots represents expected graphical representation of the angle of deviation δ with angle of incidence i in a prism

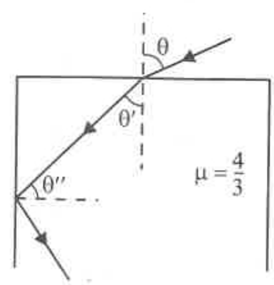
(a)


(b)


(c)


(d)


11. A ray of light entering from air into a denser medium of refractive index 4/3, as shown in figure. The light ray suffers total internal reflection at the adjacent surface as shown. The maximum value of angle θ should be equal to :



(a) $\sin^{-1}\frac{\sqrt{7}}{3}$ (b) $\sin^{-1}\frac{\sqrt{5}}{4}$

(c) $\sin^{-1}\frac{\sqrt{7}}{4}$ (d) $\sin^{-1}\frac{\sqrt{5}}{3}$

12. A prism of refractive index μ and angle of prism A is placed in the position of minimum angle of deviation. If minimum angle of deviation is also A, then in terms of refractive index

(a) $2\ \text{ccos}^{-1}\left(\frac{\mu}{2}\right)$ (b) $\sin^{-1}\left(\frac{\mu}{2}\right)$ (c) $\sin^{-1}\left(\sqrt{\frac{\mu-1}{2}}\right)$ (d) $\cos^{-1}\left(\frac{\mu}{2}\right)$

13. An astronomical refracting telescope will have large angular magnification and high angular resolution, when it has an objective lens of

(a) small focal length and large diameter (b) large focal length and small diameter

(c) large focal length and large diameter (d) small focal length and small diameter

14. A square wire of side 3.0 cm is placed 25 cm away from a concave mirror of focal length 10 cm. Thus the area enclosed by the image of the wire is: (The centre of the wire is on the axis of the mirror, with its two sides normal to the axis).

(a) 75 cm^2 (b) 4 cm^2 (c) 25 cm^2 (d) 16 cm^2

15. To a fish under water, viewing obliquely a fisherman standing on the bank of a lake, the man looks

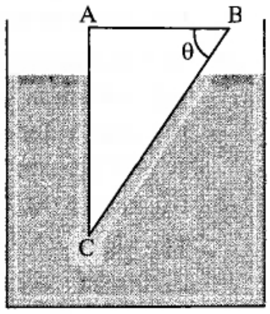
(a) taller than what he actually is (b) shorter than what he actually is

(c) the same height as he actually is (d) depends on the obliquity

16. A transparent cube of 0.21 m edge contains a small air bubble. Its apparent distance when viewed through one face of the cube is 0.10 m and when viewed from the opposite face is 0.04 m. The actual distance of the bubble from the second face of the cube is

(a) 0.06 m (b) 0.17 m (c) 0.05 m (d) 0.04 m

17. A glass prism of refractive index 1.5 is immersed in water as shown in the figure. A beam of light incident normally on the face AB is totally reflected from the face AC if



(a) $\sin\theta \geq \frac{8}{9}$

(b) $\frac{2}{3} < \sin\theta \geq \frac{8}{9}$

(c) $\sin\theta \leq \frac{2}{3}$

(d) $\sin\theta \leq \frac{8}{9}$

18. In a concave mirror, an object is placed at a distance d, from the focus and the image is formed at a distance d, from the focus. Then the focal length of the mirror is

(a) $\sqrt{d_1 d_2}$ (b) $d_1 d_2$ (c) $(d_1 + d_2)/2$ (d) $\sqrt{\frac{d_1}{d_2}}$

19. A short linear object of length L lies on the axis of a spherical mirror of focal length f at a distance u from the mirror. Its image has an axial length L equal to:

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

20. The apparent depth of water in cylindrical water tank of diameter 2R cm is reducing at the rate of x cm/minute when water is being drained out at a constant rate. The amount of water drained in c.c, per minute is : (n_1 = refractive index of air, n_2 = refractive index of water)

(a) $\frac{x\pi R^2 n_1}{n_2}$ (b) $\frac{x\pi R^2 n^2}{n_1}$ (c) $\frac{2\pi R n_1}{n_2}$ (d) $\pi r^2 x$

21. A lens is made of flint glass (refractive index = 1.5). When the lens is immersed in a liquid of refractive index 1.25, the focal length

(a) increases by a factor of 1.25 (b) increases by a factor of 2.5

(c) increases by a factor of 1.2. (d) decreases by a factor of 1.2.

22. A leaf which contains only green pigments is illuminated by a laser light of wavelength 0.6328 μm. It would appear to be

(a) brown (b) black (c) red (d) green

23. 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

24. A passenger in an aeroplane shall

(a) never see a rainbow

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

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

(d) shall never see a secondary rainbow

25. The radius of curvature of the curved surface of a plano-convex lens is 20 cm. If the refractive index of the material of the lens be 1.5, it will

(a) act as a convex lens only for the objects that lie on its curved side

(b) act as a concave lens for the objects that lies on its curved side

(c) act as a convex lens irrespective of the side on which object lies

(d) act as a concave lens irrespective of side on which the object lies

26. The phenomena involved in the reflection of radiowaves by ionosphere is similar to

(a) reflection of light by plane mirror

(b) total internal reflection of light in air during a mirage

(c) dispersion of light by water molecules during the formation of a rainbow

(d) scattering of light by the particles of air.

27. The plane face of a planoconvex lens is silvered. If u be the refractive index and R, the radius of curvature of curved surface, then the system will behave like a concave mirror of radius of curvature

(a) μR (b) $\frac{R}{(\mu - 1)}$ (c) $\frac{R^2}{\mu}$ (d) $\left[\frac{(\mu + 1)}{(\mu - 1)}\right]R$

28. Which of the following is a wrong statement?

(a) $D = \frac{1}{f}$, where f is the focal length and D is called the refractive power of a lens

(b) power is expressed in dioptre when f is in metres

(c) power is expressed in dioptre and does not depend on the system of unit used to measure f

(d) D is positive for convergent lens and negative for divergent lens

29. For compound microscope $f_0 = 1$ cm , $f_e = 2.5$ cm. An object is placed at distance 1.2 cm from objective lens. What should be length of microscope for normal adjustment?

(a) 8.5 cm (b) 8.3 cm (c) 6.5 cm (d) 6.3 cm

30. One cannot see through fog, because

(a) fog absorbs the light (b) light suffers total reflection at droplets

(c) refractive index of the fog is infinity (d) light is scattered by the droplets.

31. Flash light equipped with a new set of batteries, produces bright white light. As the batteries wear out,

(a) the light intensity gets reduced with no change in its colour

(b) light colour changes first to yellow and then red with no change in intensity

(c) it stops working suddenly, while giving white light

(d) colour changes to red and also intensity gets reduced.

32. The focal length of the objective and eye lenses of a microscope are 1.6 cm and 2.5 cm respectively. The distance between the two lenses is 21.7 cm. If the final image is formed at infinity, what is the linear magnification?

(a) 11 (b) 110 (c) 1.1 (d) 44

33. Focal length of a planoconvex lens is whose convex surface is silvered is :

(a) $\frac{R}{\mu}$ (b) $\frac{R}{2\mu}$ (c) $\frac{R}{2(\mu-1)}$ (d) $\frac{R}{\mu}$

34. A small telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, what is the height of the final image when it is formed 25 cm away from the eyepiece?

(a) 30 cm (b) 30 m (c) –30 cm (d) –30 m

35. A convex lens is made of glass of refractive index 1.5. If the radius of curvature of each of the two surfaces is 20 cm find the ratio of the powers of the lens, when placed in air to its power, when immersed in a liquid of refractive index 1.25.

(a) 5:2 (b) 2:5 (c) 1: 1 (d) 1:5

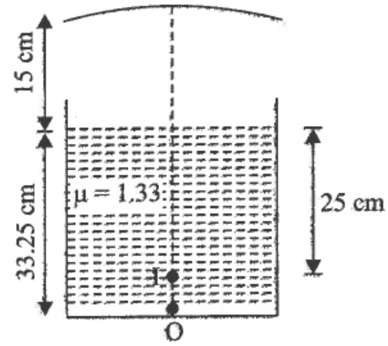
36. A double convex lens of 5 D made of glass of refractive index 1.5 with both faces of equal radii, curvature. Find the value of curvature.

(a) 5 cm (b) 20 cm (c) 25 cm (d) 0.2 cm

37. A source emits a sound of frequency 600 Hz inside water. The frequency heard in air (velocity of sound in water 1500 m/s, velocity of sound in air = 300 m/s) will be

(a) 300 Hz (b) 120 Hz (c) 600 Hz (d) 6000 Hz

38. A container is filled with water (μ = 1.33) upto height of 33.25 cm. A concave mirror is placed 15 cm above the water level and the image of an object placed at the bottom is formed 25 cm below the water level.

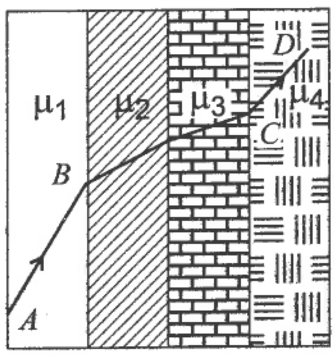


The focal length of the mirror is

(a) 10 cm (b) 15 cm

(c) 20 cm (d) 25 cm

39. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3, and μ_4 as shown in the figure. The surface of all media are parallel



If the emerged ray CD is parallel to the incident ray AB, we must have

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

40. A ray of light travelling in water is incident on its surface open to air. The angle of incidence is θ, which is less than the critical angle. Then there will be

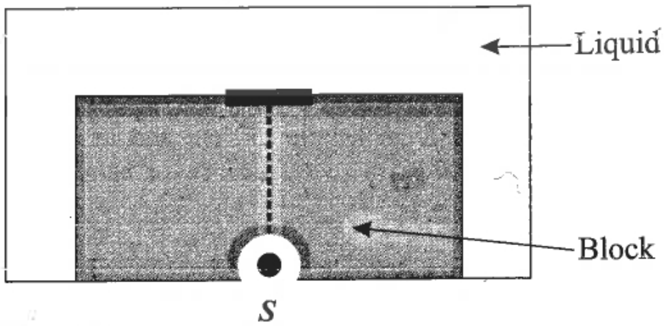
(a) only a reflected ray and no refracted ray

(b) only a refracted ray and no reflected ray

(c) a reflected ray and a refracted ray and the angle between them would be less than $180° - 2\theta$

(d) a reflected ray and a refracted ray and the angle between them would be greater than $180° - 2\theta$

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



The refractive index of the liquid is

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

42. A point object is placed at the centre of a glass sphere of radius 6 cm and refractive index 1.5. The distance of the virtual image from the surface of the sphere is

(a) 2 cm (b) 4 cm (c) 6 cm (d) 12 cm

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

(a) 1.25 cm (b) 2.5 cm (c) 1.05 cm (d) 2 cm

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

(a) convergent lens of focal length 3.5 R

(b) convergent lens of focal length 3.0 R

(c) divergent lens of focal length 3.5 R

(d) divergent lens of focal length 3.0 R

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

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

46. The image of an object, formed by a plano–convex lens at a distance 8 m behind the lens, is real and is one third the size of the object. The wavelength of light inside the lens is 2/3 times the wavelength in free space. The radius of the curved surface of the lens is

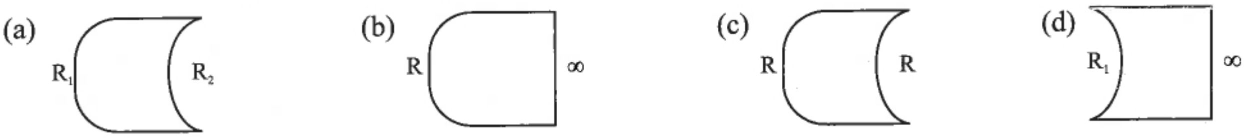
(a) 1 m (b) 2 m (c) 3 m (d) 6 m

47. In a thin lens, spherical aberration can be reduced by

(a) using a monochromatic light (b) using a doublet combination

(c) using a circular annular mask over the lens (d) increasing the size of the lens.

48. Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams.



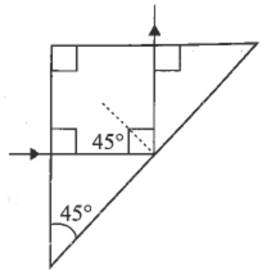
49. A car is fitted with a convex side-view mirror of focal length 20 cm. A second car 2.8 m behind the first car is overtaking the first car at a relative speed of 15 ms^{-1}. The speed of the image of the second car as seen in the mirror of the first one is

(a) $\frac{1}{10}$ m/s (b) $\frac{1}{15}$ m/s (c) $\frac{1}{20}$ m/s (d) 15 m/s

50. Let the x-z plane be the boundary between two transparent media. Medium 1 in $z \geq 0$ has a refractive index of $\sqrt{2}$ and medium 2 with $z<0$ has a refractive index of $\sqrt{3}$. A ray of light in medium 1 given by the vector $\vec{A} = 6\sqrt{3}\,\hat{i}\,\text{Å} + 8\sqrt{3}\,\hat{j} - 10\,\hat{k}$ is incident on the plane of separation. The angle of refraction in medium 2 is

(a) 30° (b) 45° (c) 60° (d) 75°

51. A light ray is incident perpendicular to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index,



(a) $\mu < 1/\sqrt{2}$ (b) $\mu > \sqrt{2}$

(c) $\mu > 1/\sqrt{2}$ (d) $\mu < \sqrt{2}$

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

(a) Total internal reflection (b) Scattering

(c) Diffraction (d) Refraction.

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

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

54. A plano-convex lens of refractive index 1.5 and radius of curvature 30 cm is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens, an object be placed in order to have a real image of the size of the object?

(a) 20 cm (b) 30 cm (c) 60 cm (d) 80 cm.

55. The image formed by an objective of a compound microscope is

(a) virtual and diminished (b) real and diminished

(c) real and enlarged (d) virtual and enlarged.

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

(a) $f_1 = f_2 < f$ (b) $f_1 > f$ and f_2 becomes negative

(c) $f_2 > f$ and f_1 becomes negative (d) f_1 and f_2 both becomes negative

57. 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.

58. A telescope has an objective lens of focal length 150 cm and an eyepiece of focal length 5 cm. If a 50 m tall tower at a distance of 1 km is observed through this telescope in normal setting, the angle formed by the image of the tower is θ, then θ is close to

(a) 15° (b) 60° (c) 30° (d) 1°

59. Ray optics is valid, when characteristic dimensions are

(a) much smaller than the wavelength of light (b) much larger than the wavelength of light

(c) of the same order as the wavelength of light (d) of the order of one millimetre.

60. 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

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

61. The refractive index of water is 1.33. What will be the speed of light in water?

(a) 3×10^8 m/s (b) 2.26×10^8 m/s (c) 4×10^8 m/s (d) 1.33×10^8 m/s

62. The refractive index of air w.r.t. glass is 2/3. The refractive index of diamond w.r.t. air is 12/5. Then, the refractive index of glass w.r.t. diamond will be

(a) 5/8 (b) 8/9 (c) 5/18 (d) 18/5

63. A bubble in glass slab (u-15) when viewed from one side appears at 5 cm arid 2 cm from other side, then thickness of slab is

(a) 3.75 cm (b) 3 cm (c) 10.5 cm (d) 2.5 cm.

64. A ray of light travelling in a transparent medium of fractive index μ, falls on a surface separating the medium from air at an angle of incidene of 45°. For which of the following value of μ the ray can undergo total internal reflection?

(a) $\mu = 1.33$ (b) $\mu = 1.40$ (c) $\mu = 1.50$ (d) $\mu = 1.25$

65. A convex lens is dipped in a liquid, whose refractive index is equal to the refractive index of the lens. Then, its focal length will

(a) become zero
(b) become infinite
(c) remain unchanged
(d) become small, but non-zero.

66. A planoconvex lens is made of refractive index 1.6. If the radius of curvature of the curved surface is 60 cm, then focal length of the lens is

(a) 50 cm (b) 100 cm (c) 200 cm (d) 400 cm

67. 24 A bulb is located on a wall. Its image of equal size is to be obtained on a parallel wall with the help of a convex lens. The lens is placed at a distance *d* ahead of second wall.Then the required focal length will be

(a) only *d*/4
(b) only *d*/2
(c) more than *d*/4 but less than *d*/2
(d) less than *d*/4

68. If a convex lens of focal length 80 cm and a concave lens of focal length 50 cm are combined together, what will be their resulting power?

(a) + 6.5D (b) – 6.5D (c) + 7.5D (d) – 0.75 D

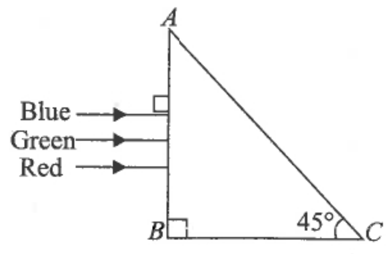
69. A plano-convex lens fits exactly into a plano-concave lens. Their plane surfaces are parallel to each other. If lenses are made of diferent materials of refractive indices μ_1 and μ_2 and R is the radius of curvature of the curved surface of the lenses, then the focal length of the combination is

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

70. A thin prism of angle 15° made of glass of refractive index, $\mu_1 = 1.5$ is combined with another prism of glass of refractive index $\mu_2 = 1.75$. The combination of the prisms produces dispersion without deviation. The angle of the second prism should be

(a) 12° (b) 5° (c) 7° (d) 10°

71. A beam of light consisting of red, green and blue colours is incident on a right angled prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47, respectively.



The prism will

(a) separate the red colour part from the green and blue colours.
(b) separate the blue colour part from the red and green colours.
(c) separate all the three colours from one another.
(d) not separate the three colours at all.

72. Rainbow is formed due to combination of

(a) refraction and scattering
(b) refraction and absorption
(c) dispersion and total internal reflection
(d) dispersion and focusing.

73. The blue colour of the sky is due to the phenomenon of

(a) scattering (b) dispersion (c) reflection (d) refraction

74. An astronomical telescope of ten fold angular magnification has a length of 44 cm. The focal length of the object is

(a) 4 cm (b) 40 cm (c) 44 cm (d) 440 cm

75. A lens having focal length f and aperture of diameter d forms an image of intensity I. Aperture of d diameter $d/2$ in central region of lens is covered by a black paper. Focal length of lens and intensity of image now will be respectively

(a) f and $\frac{I}{4}$ (b) $\frac{3f}{4}$ and $\frac{I}{2}$ (c) f and $\frac{3I}{4}$ (d) $\frac{f}{2}$ and $\frac{I}{2}$

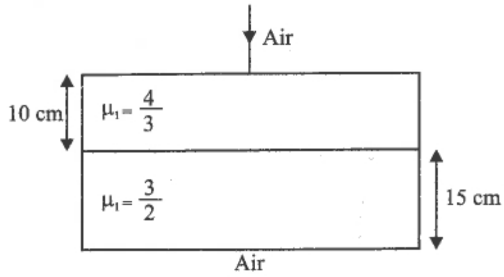
76. A ray of light is incident on the surface separation of a medium with velocity of light at an angle 30°. What will be the velocity of light in the medium?

(a) 1.96×10^8 m/s (b) 3.18×10^8 m/s (c) 2.12×10^8 m/s (d) 3.33×10^8 m/s

77. The time taken by the light to cross a glass of thickness 4 mm and refractive index 3, will be

(a) 4×10^{-11} sec (b) 16×10^{-11} sec
(c) 8×10^{-11} sec (d) 24×10^{-10} sec

78. Considering normal incidence of ray, the equivalent refractive index of combination of two slabs shown in the figure is



(a) 1.8 (b) 1.43
(c) 2 (d) none of these

79. The focal length of a biconvex lens of radii of each surfaces 50 cm and refractive index 1.5, is

(a) 40.4 cm (b) 75 cm (c) 50 cm (d) 80 cm

80. A prism is filled with liquid of refractive index of $\sqrt{2}$. If angle of minimum deviation

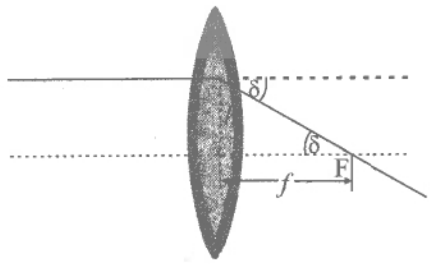
(a) 75° (b) 60° (c) 45° (d) 30°

INPUT TEXT BASED MCQ'S

1. *Power of a lens is a measure of the convergence or divergence, which a lens introduces in the light falling on it. Clearly, a lens of shorter focal length bends the incident light more, while converging it in case of a convex lens and diverging it in case of a concave lens. The power P of a lens is defined as the tangent of the angle by which it converges or diverges a beam of light parallel to the principal axis falling at unit distance from the optical centre.*

$\tan\delta = \frac{h}{f}$; if $h = 1$, $\tan\delta = \frac{1}{f}$ or $\delta = \frac{1}{f}$ for small value of δ. Thus,

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



The SI unit for power of a lens is dioptre (D): 1D = $1m^{-1}$. If several thin lenses of focal length f_1, f_2, f_3,.... are in contact, the effective focal length of their combination is given by

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$$

In terms of power we can be written as

$$P = P_1 + P_2 + P_3 + ...$$

(i) A convex and a concave lens separated by distance d are then put in contact. The focal length of the combination

(a) beomes 0 (b) remains the same (c) decreases (d) increases

(ii) If two lenses of power +15 D and +1.0 D are placed in contact, then the effective power of combination will be
(a) 2.5 D (b) 1.5 D (c) 0.5 D (d) 3.25 D

(iii) If the power of a lens is +5 dioptre, what is the focal length of the lens?
(a) 10 cm (b) 20 cm (c) 15 cm (d) 5 cm

(iv) Two thin lenses of focal lengths +10 cm and –5 cm are kept in contact. The power of the combination is
(a) –10 D (b) –20 D (c) 10 D (d) 15 D

(v) A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm. The system will be
(a) converging in nature (b) diverging in nature
(c) can be converging or diverging (d) none of these

2. *The lens maker's formula relates the focal length of a lens to the refractive index of the lens material and the radii of curvature of its two surfaces. This formula is called so because it is used by manufacturers to design lenses of required focal length from a glass of given refractive index.*

If the object is placed at infinity, the image will be formed at focus for both double convex lens and double concave lens. Therefore, lens maker's formula is, $\frac{1}{f} = \left[\frac{\mu_2-\mu_1}{\mu_1}\right]\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$

When lens is replaced in air $\mu_1 = 1$ *and* $\mu_2 = \mu$. *The lens maker formula takes the form,* $\frac{1}{f} = (\mu-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$

(i) The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. Its focal length is 12 cm. What is the refractive index of glass?
(a) 1.5 (b) 1.78 (c) 2.0 (d) 2.52

(ii) A convex lens has 20 cm focal length in air. What is focal length in water? (Refractive index of air-water = 1.33, refractive index for air-glass = 1.5.)
(a) 12 cm (b) 78.2 cm (c) 15 cm (d) 75 cm

(iii) An under-water swimmer cannot see very clearly even in absolutely clear water because of
(a) absorption of light in water (b) scattering of light in water
(c) reduction of speed of light in water (d) change in the focal length of eye-lens

(iv) A thin lens of glass (μ = 1.5) of focal length 10 cm is immersed in water (μ = 1.33). The new focal length is
(a) 20 cm (b) 40 cm (c) 48 cm (d) 12 cm

(v) An object is immersed in a fluid. In order that the object becomes invisible, it should
(a) behave as a perfect reflector (b) absorb all light falling on it
(c) have refractive index one
(d) have refractive index exactly matching with that of the surrounding fluid.

ANSWERS

1. (a)	**2.** (a)	**3.** (b)	**4.** (d)	**5.** (a)	**6.** (b)	**7.** (a)	**8.** (a)	**9.** (d)	**10.** (b)
11. (a)	**12.** (a)	**13.** (c)	**14.** (b)	**15.** (a)	**16.** (a)	**17.** (a)	**18.** (a)	**19.** (d)	**20.** (b)
21. (b)	**22.** (b)	**23.** (c)	**24.** (b)	**25.** (c)	**26.** (b)	**27.** (b)	**28.** (c)	**29.** (a)	**30.** (d)
31. (a)	**32.** (b)	**33.** (b)	**34.** (a)	**35.** (a)	**36.** (b)	**37.** (c)	**38.** (a)	**39.** (d)	**40.** (c)
41. (c)	**42.** (c)	**43.** (b)	**44.** (a)	**45.** (d)	**46.** (c)	**47.** (c)	**48.** (c)	**49.** (b)	**50.** (b)
51. (b)	**52.** (a)	**53.** (d)	**54.** (a)	**55.** (c)	**56.** (b)	**57.** (b)	**58.** (b)	**59.** (b)	**60.** (d)
61. (b)	**62.** (a)	**63.** (c)	**64.** (c)	**65.** (b)	**66.** (b)	**67.** (b)	**68.** (d)	**69.** (c)	**70.** (d)
71. (a)	**72.** (c)	**73.** (a)	**74.** (b)	**75.** (c)	**76.** (c)	**77.** (a)	**78.** (b)	**79.** (c)	**80.** (d)

Input Text Based MCQs

1. **(i)** (d), **(ii)** (a), **(iii)** (b), **(iv)** (a), **(v)** (b) **2.** **(i)** (a), **(ii)** (b), **(iii)** (d), **(iv)** (b), **(v)** (d)