9 RAY OPTICS AND OPTICAL INSTRUMENTS

Ray Optics

- The branch of optics dealing with light as rays.

Reflection Of Light

When light rays strike the boundary of two media such as air and glass, a part of light turned back into the same medium. This is called Reflection of light.

Laws of Reflection

The regular reflection follows the two laws.

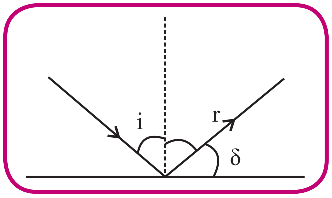
(i) The incident ray, the reflected ray and normal to surface at the point of incidence all lie in the same plane.

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

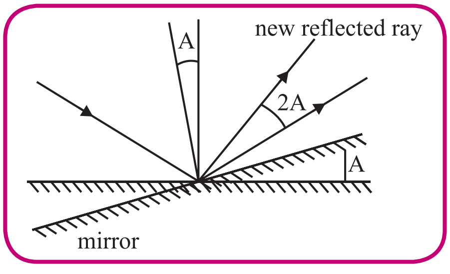
Deviation produced in Reflection is $\delta = 180^0 - (i + r)$

Since r = i

$\Rightarrow \delta = 180^0 - 2i$



Rotation of Plane Mirror



- If the plane mirror is rotated in its own plane then the incident ray, normal and reflected ray are fixed.
- If the plane mirror is rotated in the plane of incidence by an angle θ, then the reflected ray rotates by an angle 2θ, the normal rotates by an angle θ while the incident ray remains fixed.

Solved Example

Q. A plane mirror is rotated with 30° in its own plane. By what angle will the reflected ray turn?

Ans. Reflected ray will not get deflected as the mirror is getting rotated in the same plane.

Spherical Mirrors

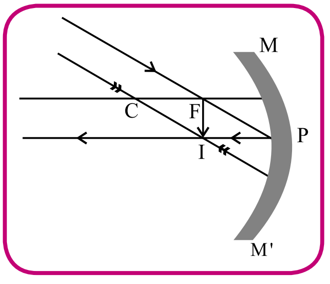
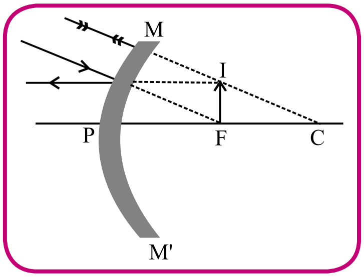


Image formation by a concave mirror:

No.	Position of object	Position of image	Nature of image	Size of image
1.	Infinity	At F	Real and inverted	Highly diminished
2.	Beyond C	Between F & C	Real and inverted	Diminished
3.	At C	At C	Real and inverted	Same size
4.	Between C & F	Beyond C	Real and inverted	Magnified

5.	At F	At infinity	Real and inverted	Highly magnified
6.	Between F & P	Behind the mirror	Virtual & erect	Magnified

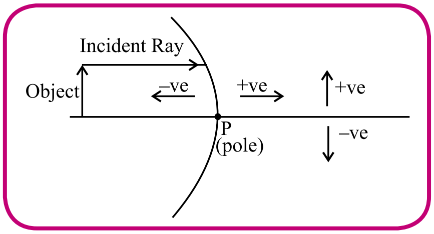
Image formation by a convex mirror:



No.	Position of object	Position of image	Nature of image	Size of image
1.	Infinity	At F	Virtual & erect	Highly diminished
2.	Between ∞ and P	Between P and F	Virtual & erect	Diminished

Sign Conventions For Mirrors And Lenses

1. All the distances are to be measured from the pole of the spherical mirror and from the optical centre in case of lenses
2. The distances measured in a direction opposite to the direction of incident light are taken as negative and vice versa.
3. The heights measured upward and perpendicular to the principal axis of mirror are taken as positive and vice versa.
4. Angle measured from the normal in the anticlock wise direction is positive and vice - versa



Spherical Mirror Formula

- The spherical mirror formula is $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ where u = object distance and v = image distance, both measured from the pole.

Magnification

- Linear or transverse magnification $= \frac{\text{height or size of the image}}{\text{height or size of the object}}$

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

If 'm' is +ve then image is virtual and erect.
If 'm' is –ve then image is real and inverted.

Axial or Longitudinal Magnification

$$m_{ax} = \frac{dv}{du} = \frac{x_2}{x_1} = \frac{v^2}{u^2} = m^2$$

where x_2 = size of image along principal axis.
x_2 = size of the object along principal axis.

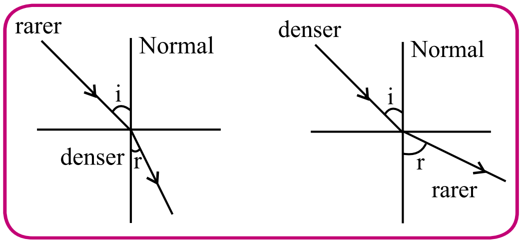
Solved Example

Q. If the linear magnification of a convex mirror is –0.5 then what will be its axial magnification?

Ans. Max = m^2
here m = –0.5

Refraction

- The phenomenon of bending up of light ray when it travels from one medium to another medium is called refraction.



- When a light ray suffers refraction its frequency remains the same but wavelength and speed changes

Laws of Refraction

1. The incident ray, the refracted ray and the normal at the point of incidence are coplanar.
2. For a given pair of media and for a given colour of light.

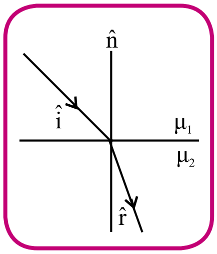
$$\frac{\sin i}{\sin r} = \mu = \text{constant}$$

Here, μ = refractive index

This is also called "law of sines" (or) **snell's law.**

From Snell's law

$\mu_1 \sin i = \mu_2 \sin r$



Refractive Index

Absolute refractive Index (μ):

$$\mu_{absolute} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}} = \frac{\lambda_o}{\lambda_m}$$

$$\mu = \frac{C}{V} = \frac{\frac{1}{\sqrt{\varepsilon_0\mu_0}}}{\frac{1}{\sqrt{\varepsilon\mu}}} = \sqrt{\frac{\varepsilon\mu}{\varepsilon_0\mu_0}} = \sqrt{\varepsilon_r\mu_r}$$

Relative Refractive Index

- When a ray of light passes from medium 1 to medium 2, the ratio of refractive index of medium 2 to that of medium 1 is called relative refractive index of medium 2 with respect to medium 1.

$$_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{C_1}{C_2} = \frac{\lambda_1}{\lambda_2} = \frac{\sin i}{\sin r}$$

☑ Solved Example

Q. If active index of water is 4/3 and that of glass is 3/2. Find the refractive index of glass w.r.t. water.

Ans. $\mu_w = 4/3$, $\mu_g = 3/2$

Refractive index of glass w.r.t. water $({}^w\mu_g) = {}^a\mu_g / {}^a\mu_w$

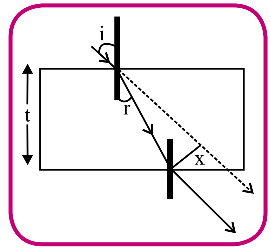
$$= \frac{3/2}{4/3}$$

$$= \frac{3}{2} \times \frac{3}{4}$$

$= 9/8$

Refraction Through Parallel Sided Glass Slab

- Whenever a light ray passes through a glass slab the incident and emergent rays will be parallel to each other. But the emergent ray is displaced laterally.



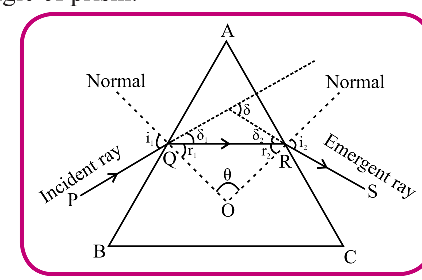
The lateral displacement (x) $= \frac{t}{\cos r}\sin(i - r)$

The length of the path travelled by light inside the glass slab $= \frac{t}{\cos r} = t \sec r$

Prism

(i) It is a transparent material the surface on which light is incident & the surface from where light emerge should be plane but not parallel.

(ii) The angle between these two surfaces is known as angle of prism.



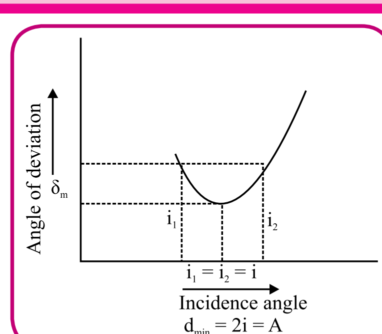
Total angle of deviation

$$\boxed{\delta = i_1 + i_2 - (r_1 + r_2)}$$

$$\boxed{r_1 + r_2 = A}$$

SCAN (Special Cases Asked in NEET)

Condition of Minimum Deviation



If angle of prism (A) and angle of minimum deviation (δ_{min}) is given the refraction index of the prism can be given by

$$\mu = \frac{\sin\left[\frac{A+\delta_{min}}{2}\right]}{\sin\frac{A}{2}}$$

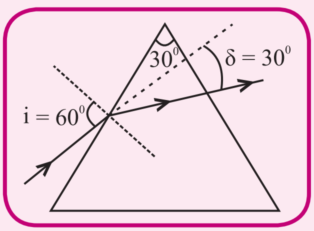
If angle of prism is small $A < 10^o$, $\sin\theta \approx \theta$

$\delta_{min} = (\mu - 1)A$ for thin prism

Q. The angle of minimum deviation measured with a prism is 30° and the angle of prism is 60°. The refractive index of prism material is –

a. $\sqrt{2}$ b. 2 c. $\frac{3}{2}$ d. $\frac{4}{3}$

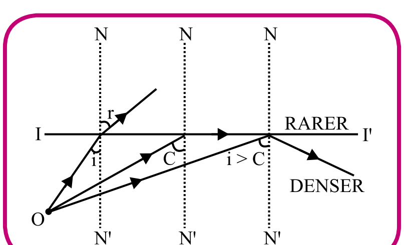
Ans. (a) $\mu = \dfrac{\sin\left(\frac{\delta_{min}+A}{2}\right)}{\sin\frac{A}{2}}$



$$\mu = \frac{\sin\left(\frac{30+60}{2}\right)}{\sin\frac{60}{2}}$$

$$\mu = \frac{\sin 45°}{\sin 30°} = \sqrt{2}$$

Critical Angle & Total Internal Reflection (TIR)



Conditions . Ray is going from denser to rarer medium

SCAN (Special Cases Asked in NEET)

For TIR . Angle of incidence should be greater than the critical angle (i > C). If refractive index of two medium is known critical angle can be given by

Critical angle :

$$(C) = \sin^{-1}\frac{\mu_R}{\mu_D} = \sin^{-1}\frac{v_D}{v_R} = \sin^{-1}\frac{\lambda_D}{\lambda_R}$$

Q. In vacuum, to travel distance d, light takes time t and in medium to travel 5d, it takes time T. The critical angle of the medium is:

a. $\sin^{-1}\left(\frac{5T}{t}\right)$ b. $\sin^{-1}\left(\frac{6t}{T}\right)$

c. $\sin^{-1}\left(\frac{6t}{T}\right)$ d. $\sin^{-1}\left(\frac{5t}{3T}\right)$

Ans. (b) In vacuum c = d/t

In medium $v = \frac{5d}{T}$

$$\mu = \frac{c}{v} = \frac{T}{5t}$$

Also, $\sin C = \frac{1}{\mu}$ (C is critical angle)

$$\therefore C = \sin^{-1}\left(\frac{5t}{T}\right)$$

Optical fibers typically include a core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by the phenomenon of total internal reflection which causes the **fiber** to act as a waveguide.

Optical-fiber systems have many advantages over metallic-based communication systems. These advantages include interference, attenuation, and bandwidth characteristics.

Refraction Through Spherical Surface

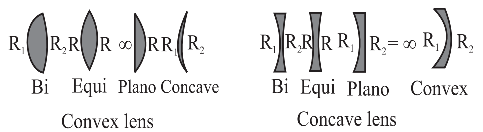
For both concave and convex refracting surfaces

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

Only appropriate sign conventions are to be used for a particular kind of surface.

Lens

- Lenses give both real and virtual images
- The nature of the image formed by a lens depends on the position of object and nature of lens.



Sign conventions:

For a converging lens, the focal length is positive

For a diverging lens, the focal length is negative

Image formation by a convex lens

No.	Position of object	Position of image	Nature of image	Size of image
1.	Infinity	At F	Real and inverted	Highly diminished
2.	Beyond 2F	Between F & 2F	Real and inverted	Diminished
3.	At 2F	AT 2F	Real and inverted	Same size
4.	Between 2F & F	Beyond 2F	Real and inverted	Magnified
5.	At F	At infinity	Real and inverted	Highly magnified
6.	Between F & O	Same side	Virtual & erect	Magnified

Image formation by a concave lens:

No.	Position of object	Position of image	Nature of image	Size of image
1.	Infinity	At F	Virtual & erect	Highly diminished
2.	Between ∞ and O	Same side	Virtual & erect	Diminished

Lens Maker's Formula

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

SCAN (Special Cases Asked in NEET)

- When a lens is immersed in a liquid its focal length changes and the new focal length can be given as:

$$\frac{1}{f'} = \left(\frac{\mu_g}{\mu_l} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where μ_g = refractive index of lens

μ_l = refractive index of liquid.

f = focal length of lens in air

f' = focal length of the lens in liquid

Q. A convex lens of refractive index 1.5 has a focal length of 18 cm in air. Calculate the change in its focal length when it is immersed in water of refractive index 4/3.

Ans. Given, a convex lens

Refractive index of lens, ${}^{a}\mu_0 = 1.5$

Focal length of lens in air, $f_a = 18$

Refractive index of water, ${}^{a}\mu_w = 4/3$

For the lens in air,

$$\frac{1}{f_a} = \left({}_{a}\mu_g - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{17} = (1.5 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{R_1} - \frac{1}{R_2} = \frac{1}{4}$$

When the lens is immersed in water

$$\frac{1}{f_w} = \left(\frac{{}^{a}\mu_g}{{}_{a}\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= \left(\frac{1.5}{4/9} - 1\right) \times \frac{1}{4}$$

$$= \frac{1}{8} \times \frac{1}{4} = \frac{1}{32}$$

Thus, $f_w = 32$ cm

Hence, focal length changes from 18 to 32.

- $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ (appropriate sign conventions are to be applied)

Linear magnification: (m)

- Magnification $m = \frac{v}{u} = \frac{\text{size of image}}{\text{size of object}}$

  If 'm' is +ve image is virtual erect.

  If 'm' is –ve image is real, inverted.

- For real image produced by convex lens

(a) $u = f\left[1 + \frac{1}{m}\right]$

(b) $v = f(1 + m)$

Areal Magnification :

$$m_{ar} = \frac{A_1}{A_0} = \frac{v^2}{u^2} = m^2$$

Where A_1 = Area of Image;

A_0 = Area of Object

Thin Lenses in Contact

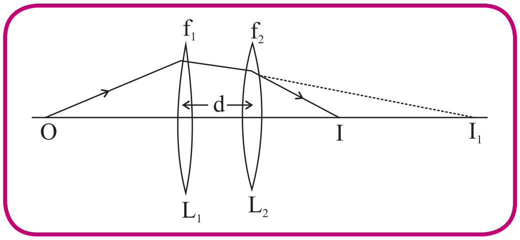
If number of thin lenses of focal lengths f_1, f_2, f_3... are in contact with each other, the equivalent focal length "f" is given by

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

The equivalent focal power is $P = P_1 + P_2 + P_3 + ..$

SCAN (Special Cases Asked in NEET)

Lenses Separated by a Distance



- When two lenses of focal lengths f_1 and f_2 are kept apart by a distance d, the effective focal length f is given by $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

  The combined focal power 'P' of the system is $P = P_1 + P_2 - dP_1P_2$

Q. Two thin lenses (one convex and the other concave lens) of focal length 60 cm and 20 cm respectively placed in contact. Find the focal length of combination.

Ans. F_1 = 60 cm, F_2 = 20 cm,

Focal length of combination (F) will be given by

$1/F = 1/F_1 + 1/F_2$

$1/F = 1/60 - 1/20$

$= (1-3)/60$

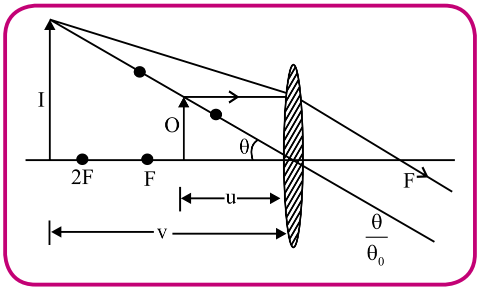
$= -2/60$

$1/F = -1/30$

$F = -30$ cm.

Optical Instruments

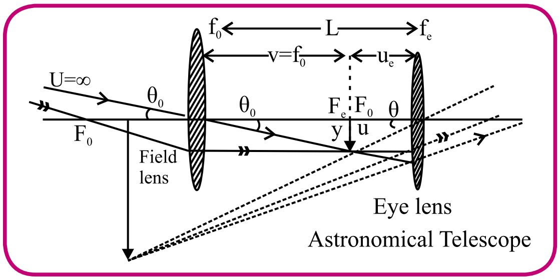
For Simple microscope



Magnifying power when image is formed at least distance distinct vision (D): $MP = 1 + \frac{D}{f}$

When image is formed at infinity: $MP = \frac{D}{f}$

Astronomical Telescope : $MP = -\frac{f_0}{u_e}$



F_0 - focal length of objective lens

F_e - focal length of eye piece

u_e - Object distance from eye piece

Magnifying power when final image is formed at D:

$$MP = -\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$$

Tube length: $L = f_0 + |u_e|$

SCAN (Special Cases Asked in NEET)

When final image of astronomical telescope is formed at infinity and the focal length of the eye piece and objective lenses is known then magnifying power (MP) and tube length (L) can be find out with the help of following equation

$$MP = -\frac{f_0}{f_e} \text{ and } L = f_0 + f_e$$

Q. An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and eyepiece is 36 cm and the final image is formed at infinity. The focal lengths of objective and eye piece :

a. 30 cm   b. 15 cm

c. 20 cm   d. 40 cm

Ans. (a) Here $M = \frac{f_0}{f_e}$

or $\frac{f_0}{f_e} = 5$ or $f_0 = 5f_e$

Also $f_0 + f_e = 36$

$\therefore$ $6f_e = 36$ or $f_e = 6$ cm

$\therefore$ $f_0 = 5 \times 6 = 30$ cm

Lens camera : $\text{Time of exposure} \propto \frac{1}{(\text{aperture})^2}$

$$f - \text{mumber} = \frac{\text{focal length}}{\text{aperture}}$$

For myopia or short-sightedness or near sightedness

$$\frac{1}{F.P} - \frac{1}{\text{object}} = \frac{1}{f} = P; f = -F.P.$$

Where F.P is the far point

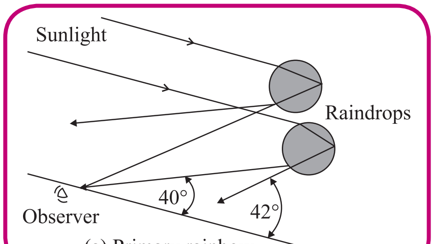
For long-sightedness or hypermetropia

$$\frac{1}{N.P} - \frac{1}{\text{object}} = \frac{1}{f} = P$$

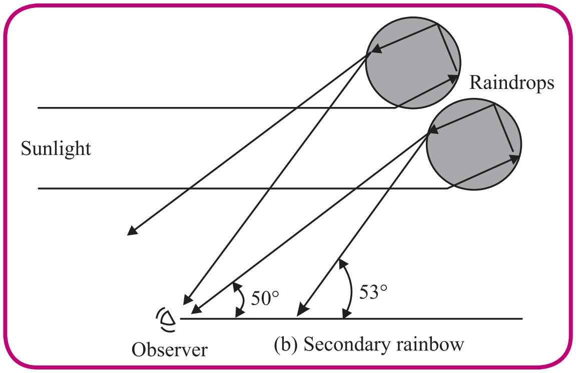
Where N.P is the near point.

Formation of Rainbow

Primary Rainbow Secondary Rainbow



(a) Primary rainbow



(b) Secondary rainbow

- The primary rainbow is a result of three-step process, that is, refraction, reflection and refraction.
- A secondary rainbow is formed as shown in Fig. (b). It is due to four-step process. The intensity of light is reduced at the second reflection and hence the secondary rainbow is fainter than the primary rainbow. Further, the order of the colours is reversed in it as is clear from Fig. (b).
- Rainbows are visible only when the altitudes of the sun is less than 42°.
- A complete rainbow can be seen in an aeroplane at high altitudes.

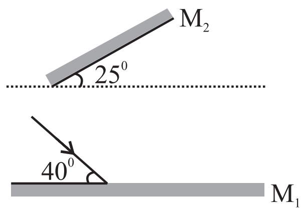
NEET REPLICA

1. A ray is incident at 30° angle on plane mirror. What will be deviation after reflection from mirror.

a. 120° b. 60°

c. 30° d. 45°

2. By what angle should M_2 be rotated, so that the light ray after reflection from both the mirror become horizontal? (as shown in figure)



a. 5° clockwise

b. 75° anticlockwise

c. 5° Clockwise

d. 15° anticlockwise

3. A point object is placed at a distance of 10 cm and its real image is formed at a distance of 20 cm from a concave mirror. If the object is moved by 0.1 cm towards the mirror, the image will shift by about.

a. 0.4 cm away from the mirror

b. 0.4 cm towards the mirror

c. 0.8 cm away from the mirror

d. 0.8 cm towards the mirror

4. An object of height 7.5 cm is placed in front of a convex mirror of radius of curvature 25 cm at a distance of 40 cm. The height of the image should be -

a. 2.3 cm b. 1.78 cm

c. 1 cm d. 0.8 cm

5. A square of side 9 cm is placed at a distance of 25 cm from a concave mirror of focal length 10 cm. The centre of the square is at the axis of the mirror and the plane is normal to the axis. The area enclosed by the image of the square is

a. 4 cm^2 b. 6 cm^2

c. 16 cm^2 d. 36 cm^2

6. Match the corresponding entries of column-1 with column-2. [where m is the magnification produced by the mirror]

Column-1	Column-2
(A) $m = -2$	(1) Convex mirror
(B) $m = -\frac{1}{2}$	(2) Concave mirror
(C) $m = +2$	(3) Real image
(D) $m = \sqrt{2}/\sqrt{3}$	(4) Virtual image

a. A → 2 and 3; B → 2 and 3; C → 2 and 4; D → 1 and 4

b. A → 1 and 3; B → 1 and 4; C → 1 and 2; D → 3 and 4

c. A → 1 and 4; B → 2 and 3; C → 2 and 4; D → 2 and 3

d. A → 3 and 4; B → 2 and 4; C → 2 and 3; D → 1 and 4

7. A lens of refractive index n is put in a liquid of refractive index (n'), if focal length of lens in air is 'f', its focal length in liquid will be:

a. $\frac{-fn'(n-1)}{n'-n}$ b. $\frac{-f(n'-n)}{n'(n-1)}$

c. $\frac{-n'(n-1)}{f(n'-n)}$ d. $\frac{fn'n}{n-n'}$

8. A fish is a little away below the surface of a lake. If the critical angle is 49^0, then the fish could see things above the water surface within an angular range of θ where:

a. $\theta = 49^0$ b. $\theta = 90^0$

c. $\theta = 98^0$ d. $\theta = 24\frac{1}{2}^0$

9. A ray of light is incident at an angle of 45^0 on one face of a rectangular glass slab of thickness 10cm and refractive index 3/2. Calculate the lateral shift produced:

a. 0.33 m b. 0.45 cm

c. 0.033 m d. 0.045 m

10. A thin prism P_1 with angle 4° and made from glass of refractive index 1.54 is combined with another prism P_2 made of glass of refractive index 1.72 to produce dispersion without deviation. The angle of prism P_2 is:

a. 5.33° b. 4°

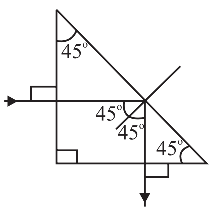
c. 2.6° d. 3°

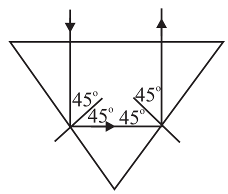
11. A thin prism of angle 15° made of glass of refractive index $\mu_1 = 1.5$ is combined with another prism of glass of refractive index ($\mu_2 = 1.75$). The combination of the prisms produces dispersion without deviation. The angle of the second prism should be:

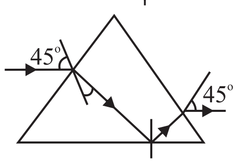
a. 7° b. 10°

c. 12° d. 5°

12. Show with the help of ray diagrams that a right angled isosceles prism can produce a deviation of 90° If the refractive index is greater than $\sqrt{2}$.

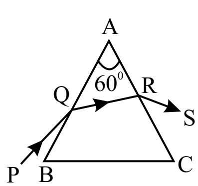
a. 

b. 

c. 

d. None of these

13. A ray *PQ* incident on the refracting face *BA* is refracted in the prism *BAC* as shown in the figure and emerges from the other refracting face *AC* as *RS*, such that *AQ* = *AR*. If the angle of prism *A* = 60° and the refractive index of the material of prism is $\sqrt{3}$, then the angle of deviation of the ray is:



a. 60° b. 45°

c. 30° d. None of these

14. The angle of minimum deviation for prism of angle π/3 is π/6. Calculate the velocity in the material of the prism if the velocity of light in vacuum is 3×10^8 m/s?

a. 2.12×10^8 m/s b. 4×10^8 m/s

c. 5×10^8 m/s d. 3.12×10^8 m/s

15. A person can see clearly objects only when they lie between 50 cm and 400 cm from his eyes. In order to increase the maximum distance of distinct vision to infinity, the type and power of the correcting lens, the person has to use, will be:

a. Concave, – 0.2 diopter

b. Convex, + 0.15 diopter

c. Convex, + 2.25 diopter

d. Concave, – 0.25 diopter

16. The ratio of angle of minimum deviation of a prism in air and when dipped in water will be (${}_a\mu_g = 3/2$ and ${}_a\mu_w = 4/3$) if prism angle is very small.

a. 1/8 b. 1/2

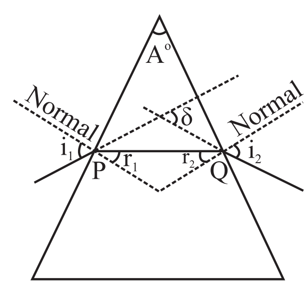
c. 3/4 d. 1/4

17. Prism angle of glass prism is 10°. It's refractive index of red and violet colour is 1.51 and 1.52 respectively. Then its dispersive power will be .

a. 0.015 b. 0.020

c. 0.011 d. 0.019

18. For the ray diagram shown in the adjoining figure, the false statement is:



a. $\delta = (i_1 + i_2) - (r_1 + r_2)$

b. $A = r_1 + r_2$

c. $(\sin i_1)(\sin r_2) = (\sin i_2)(\sin r_1)$

d. $(\sin i_1)(\sin r_1) = (\sin i_2)(\sin r_2)$

19. When light of wavelength λ is incident on an equilateral prism kept in its minimum deviation position, it is found that the angle of deviation equals the angle of the prism itself. The refractive index of the material of the prism for the wavelength λ is then:

a. $\sqrt{3}$ b. $\frac{\sqrt{3}}{2}$

c. 2 d. $\sqrt{2}$

20. Angle of prism is A and its one surface is silvered. Light rays falling at an angle of incidence 2A on first surface return back through the same path after suffering reflection at second silver surface. Refractive index of the material of prism is

a. 2 sin A b. 2 cos A

c. $\frac{\cos A}{2}$ d. tan A

21. A ray of light is incident at 60^0 on the one face of a prism of angle 30^0 and the emergent ray makes 30^0 with the incident ray. The refractive index of the prism is:

a. 1.732 b. 1.414

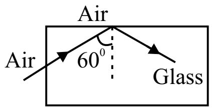
c. 1.5 d. 1.33

22. Light of wavelength 4000 Å is incident at small angle on a prism of apex angle 4º. The prism has $n_v = 1.5$ & $n_r = 1.48$. The angle of dispersion produced by the prism in this light is:

a. 0.2º b. 0.08º

c. 0.192º d. None of these

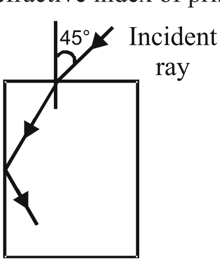
23. A light ray going from air is incident (as shown in figure) at one end of a glass fibre (refractive index μ = 1.5) making an incidence angle of 60^0 on the lateral surface, so that it undergoes a total internal reflection. How much time would it take to traverse the straight fibre of length 1 km?



a. 3.3 μs b. 6.6 μs

c. 5.7 μs d. 3.85 μs

24. For the given incident ray as shown in figure, the condition of total internal refraction of this ray the minimum refractive index of prism will be :



a. $\frac{\sqrt{3}+1}{2}$ b. $\frac{\sqrt{2}+1}{2}$

c. $\sqrt{\frac{3}{2}}$ d. $\sqrt{\frac{7}{6}}$

25. A ray of light traveling in transparent medium of refractive index μ falls on a surface separating the medium from air at an angle of incidence of 45°. For which of the following value of μ the ray can undergo total internal reflection?

a. μ > 1.33 b. μ > 1.4

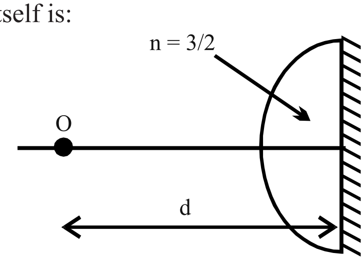
c. μ > 1.5 d. μ > 1.25

26. A thin plano-convex lens acts like a concave mirror of focal length 0.2 m, when silvered from its plane surface. The refractive index of the material of the lens is 1.5. The radius of curvature of the convex surface of the lens will be:

a. 0.1 m b. 0.75 m

c. 0.4 m d. 0.2 m

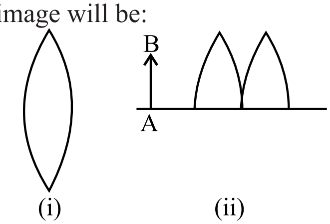
27. A plano-convex lens of focal length 10 cm is silvered at its plane face. The distance d at which an object must be placed in order to get its image on itself is:



a. 5 cm b. 20 cm

c. 10 cm d. 2.5 cm

28. In the figure (i) a thin lens of focal length 10 cm is shown. The lens is cut into two equal parts, and the parts are arranged as shown in the figure (ii). An object AB of height 1 cm is placed at distance of 7.5 cm from the arrangement. The height of the final image will be:



a. 0.5 cm b. 2 cm

c. 1 cm d. 4 cm

29. A double convex lens made of glass (refractive index *n* = 1.5) has both radii of curvature of magnitude 20 cm incident light rays parallel to the axis of the lens will converge at a distance *L* such that:

a. $L = 20$ cm b. $L = 10$ cm

c. $L = 40$ cm d. $L = \frac{20}{3}$ cm

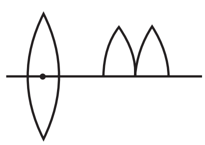
30. A plano-convex lens has a maximum thickness of 6 cm. When placed on a horizontal table with the curved surface in contact with the table surface, the apparent depth of the bottom most point of the lens is found to be 4 cm. If the lens is inverted such that the plane face of the lens is in contact with the surface of the table, the apparent depth of the centre of the plane face is found to be $\frac{17}{4}$ cm. The radius of curvature of the lens is:

a. 68 cm
b. 75 cm
c. 128 cm
d. 34 cm

31. The focal length of a convex lens is 20 cm and its refractive index is 1.5. If the radius of curvature of one surface is 7.5 cm, the radius of curvature of the second surface will be

a. 7.5 cm
b. 30.0 cm
c. 75 cm
d. 5.0 cm

32. A lens is cut from the optical centre along the principal axis and the two parts of the lens are placed sideways as shown in figure. Then the new focal length of the combination:



a. Remains the same
b. Becomes double
c. Becomes half
d. Becomes triple

33. Two lenses are placed in contact with each other and the focal length of combination is 80 cm. If the focal length of one is 20 cm, then the power of the other will be:

a. 1.66 D
b. 4.00 D
c. –1.00 D
d. –3.75 D

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

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

35. A person can see clearly only upto a distance of 25 cm. He wants to read a book placed at a distance of 50 cm. What kind of lens does he required for his spectacles and what must be its power ?

a. Concave, – 1.0 D
b. Convex, + 1. 5 D
c. Concave, – 2.0 D
d. Convex, + 2.0 D

36. An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and the eyepiece is 36 cm. The final image is formed at infinity. The focal lengths f_0 of the objective and f_e of the eyepiece are -

a. 45 cm and –9 cm respectively
b. 50 cm and 10 cm respectively
c. 7.2 cm and 5 cm respectively
d. 30 cm and 6 cm respectively

37. The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and eyepiece is 20 cm. the focal length of lenses are:

a. 10 cm, 10 cm
b. 15 cm, 5 cm
c. 18 cm, 2 cm
d. 11 cm, 9 cm

38. A telescope has an objective lens of 10 cm diameter and is situated at a distance of one kilometre from two objects. The minimum distance between these two objects, which can be resolved by the telescope, when the mean wavelength of light is 5000 Å, of the order of :

a. 0.5 m
b. 5 m
c. 5 mm
d. 5 cm

39. A compound microscope has magnifying power as 32 and magnifying power of eye-piece is 4, then the magnifying power of objective is -

a. 8
b. 10
c. 6
d. 12

40. In a compound microscope the objective and eye-piece have focal lengths of 0.95 cm and 5 cm respectively and are kept at distance of 20 cm. The last image is at ∞. Calculate magnifying power.

a. 95
b. 94
c. 94/6
d. None of these

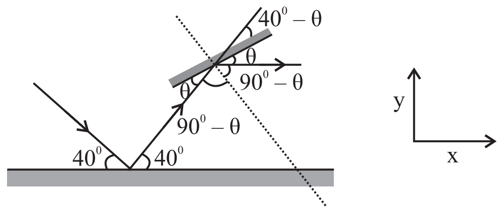
41. A passenger in an aeroplane shall:

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

EXPLANATIONS

1. (a) $\delta = 180 - 2i = 180° - 60° = 120°$

2. (a)



$\theta = 40^0 - \theta \Rightarrow \theta = 20°$

$\Rightarrow$ 5^0 clockwise

In this case the ray will become horizontal and will be reflected along - $\hat{i}$

3. (a) $(\Delta V) = -m^2(\Delta U)$

$$m = \frac{f}{f-v} = \frac{-20}{-20+40} = 2$$

$\Delta V = (2)^2(0.1\text{cm})$

$\Delta V = -0.4\text{cm}$

– sign represent object & image are moving opposite to each other

4. (b) $f = \frac{R}{2} = \frac{25}{2} = 12.5\text{cm}$

u = –40 cm

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

$$\frac{h_2}{7.5} = \frac{12.5}{12.5+40}$$

$h_2 = 1.78$ cm

5. (d) $A_I = m^2 A_0 = \left(\frac{f}{f-u}\right)^2 \times (9)^2 = \left(\frac{-10}{-10+25}\right)^2 \times 81$

$= 36\ \text{cm}^2$

6. (a) *Ref. NCERT, Class XII, Ch-9, Pg. 313*

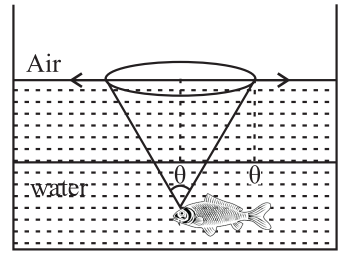
A → 2 and 3; B → 2 and 3; C → 2 and 4; D → 1 and 4.

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

$$\frac{1}{f_l} - \left(\frac{n}{n'} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{f_l}{f} = \frac{(n-1)n'}{n-n'} \quad \text{or} \quad f_l = \frac{-fn'(n-1)}{n'-n}$$

8. (c) According to the question



θ = c + c (as by the figure)

θ = 2c

θ = 2 × 49°

$\theta = 98^0$

9. (c) Here $i = 45^0$, t = 10 cm =0.1 m, μ = 1.5, lateral shift = ?

As, $\mu = \frac{\sin i_1}{\sin r_1}$

$$\therefore\ \sin r_1 = \frac{\sin i_1}{\mu} = \frac{\sin 45^0}{1.5}$$

$$\sin r_1 = \frac{0.707}{1.5}$$

$r_1 = 28.14^0$

$$lateral\ shift = \frac{t \sin(i_1 - r_1)}{\cos r_1}$$

Lateral shift = 0.033 m

10. (d) For a thin prism, angle of minimum deviation is given by

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

Where, μ is refractive index of the prism and *A* the angle of prism. For dispersion without deviation

$\delta_1 = \delta_2 \Rightarrow (\mu_1 - 1) A_1 = (\mu_2 - 1) A_2$

$$\Rightarrow A_2 = \frac{(\mu_1 - 1)}{(\mu_2 - 1)} A_1$$

Given, $\mu_1 = 1.54$, $A_1 = 4°$ and $\mu_2 = 1.72$

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

11. (b) *Ref. NCERT, Class XII, Ch-9, Pg. 331*

For condition dispersion without deviation in prism

$\delta_1 = \delta_2$

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

$\Rightarrow (1.5 - 1)15° - (1.75 - 1)A_2 = 0$

$\Rightarrow 7.5° - 0.75A_2 = 0$

$\Rightarrow A_2 = 10°$

12. (a) $\mu > \sqrt{2} \Rightarrow \frac{1}{\mu} < \frac{1}{\sqrt{2}}$

$\Rightarrow \sin C < \sin 45° \Rightarrow C < 45°$

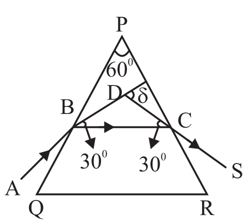
Hence a ray striking a glass-air surface from inside the prism will be reflected back if angle of incidence is not less than 45°.

90° deviation is produced if the ray strikes on one of the sides normally as shown.

Here, I = 45° and hence reflection takes place.

13. (a) For a given prism, the angle of deviation depends upon the angle of incidence of the light rays falling on the prism. Taking triangle *DBC*, we have

$$\delta = \angle DBC + \angle DCB$$



Since, Δ *PBC* is an equilateral triangle, therefore

$$\angle DBC = \frac{60°}{2} = 30° \Rightarrow \delta = 30° + 30° = 60°$$

Hence, angle of deviation of the ray is 60°.

14. (a) We know, $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$

$$\frac{c}{v} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$$

$$\frac{c \times \sin A/2}{\sin\left(\frac{A+\delta_m}{2}\right)}$$

$$v = \frac{3\times10^8 \sin 30°}{\sin 45°} \Rightarrow v = \frac{3\times10^8 \times 0.500}{0.707}$$

$v = 2.12 \times 10^8$ m/s

15. (d) *Ref. NCERT, Class XII, Ch-9*

Lens formula and sign convention $= \frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

As we want to correct myopia. So, far point must go to infinity.

$v = -4$m, $u = -\infty$, P = ?

$$P = \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-4} - \frac{1}{\infty}$$

$$P = \frac{-1}{4} \times \frac{25}{25} = -0.25 \text{ dioptre}$$

(–) Implies concave mirror

16. (d) $\frac{\delta_w}{\delta_a} = \frac{({}_w\mu_g - 1)}{({}_a\mu_g - 1)} = \frac{\left(\frac{9}{8} - 1\right)}{\left(\frac{3}{2} - 1\right)} = \frac{1}{4}$

17. (d) $\mu_r = \frac{\mu_R + \mu_v}{2} = 1.515$

$$\omega = \frac{(\mu_v - \mu_R)}{(\mu_r - 1)} = \frac{1.52 - 1.51}{1.515 - 1} = \frac{0.01}{0.515} = 0.019$$

18. (d) $\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2}$

19. (a) According to the relation

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2} = \frac{\sin\left(\frac{60° + 60°}{2}\right)}{\sin\frac{60°}{2}}$$

$$\mu = \frac{\sin 60°}{\sin 30°} = \frac{\sqrt{3}}{2} \times \frac{2}{1} = \sqrt{3}$$

$\mu = \sqrt{3}$

20. (b) According to the relation

$A = r_1 + r_2$

$A = r + o$

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

$$\mu = \frac{\sin 2A}{\sin A} \Rightarrow \mu = \frac{2\sin A \cos A}{\sin A}$$

$\mu = 2 \cos A$

21. (a) i = 60°, A = 30°, δ = 30°

As we known

$i + e = A + \delta$

$e = A + \delta - i$

$= A + \delta - i$

$= 30^o + 30^o - 60^o$

$e = 0^o, r_2 = 0^o$

As, $r_1 + r_2 = A$

$\therefore r_1 = 30^o$

$$\mu = \frac{\sin i}{\sin r} \Rightarrow \frac{\sin 60^o}{\sin 30^o} = \sqrt{3} = 1.732$$

$\mu = 1.732$

22. (d) Dispersion will not occur for a light of wave length (λ) = 4000 Å.

23. (d) When total internal reflection just takes place form lateral surface $i = c$, i.e. $60° = c$

$$\Rightarrow \quad \sin 60° = \sin c = \frac{1}{\mu} \Rightarrow \mu = \frac{2}{\sqrt{3}}$$

Time taken by light to traverse some distance in a medium

$$t = \frac{\mu x}{c} = \frac{\frac{2}{\sqrt{3}} \times 10^3}{3 \times 10^8} 3.85 \mu s$$

24. (c) $\mu_2 = \sqrt{\mu_1 + \sin^2 i}$

$\mu_2 = \sqrt{1 + \sin^2 45}$

$\mu_2 = \sqrt{\frac{3}{2}}$

25. (b) For total internal reflection, $i > c$

$$\Rightarrow \sin i > \sin c \Rightarrow \sin 45° > \frac{1}{\mu} \Rightarrow \mu > \sqrt{2} \Rightarrow \mu > 1.4$$

26. (d) After silvering the plane surface, planoconvex lens behaves as a concave mirror of focal length

$$\frac{1}{f'} = \frac{2}{f_{lens}}$$

but $f' = 0.2$ m $\Rightarrow f_{lens} = 2f' = 2 \times 0.2 = 0.4$ m

Now, from lens maker's formula,

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

$$\therefore \quad \frac{1}{0.4} = (1.5 - 1) \times \frac{1}{R_1} \quad (\because R_2 = \infty)$$

$\Rightarrow R_1 = 0.5 \times 0.4 = 0.2$ m

27. (c) $\frac{1}{10} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{R} - \frac{1}{\infty}\right) \Rightarrow \frac{1}{2R} = \frac{1}{10} \Rightarrow R = 5$ cm

Rays should retrace the path

$\Rightarrow$ incident rays on mirror should be normal

$$\Rightarrow \frac{3/2}{\infty} - \frac{1}{-d} = \left(\frac{1}{-d} - \frac{1/2}{5}\right)$$

[u = – d, as lens is their]

$$\Rightarrow \frac{1}{d} = \frac{1}{10} \Rightarrow d = 10 \text{ cm}$$

28. (b) The effective focal length is 5 cm.

The height of final images is

$$= \frac{v}{u} \times O = \frac{f}{u+f} = \frac{5}{-7.5+5} \times 1 = 2\,cm$$

29. (a) $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (1.5-1)\left[\frac{1}{(+20)} - \frac{1}{(-20)}\right]$

$\Rightarrow f = +20$ cm

Incident rays travelling parallel to the axis of lens will converge at its principal focus.

$\therefore L = +20$ cm

30. (d) $n = \frac{\text{Real depth}}{\text{Apparent depth}}$

$$n_1 = \frac{6}{4} = \frac{3}{2} = 1.5$$

$$\Rightarrow \frac{n_1}{u} - \frac{n_2}{v} = \frac{n_1 \sim n_2}{R} \Rightarrow \frac{1.5}{6} - \frac{4}{17} = \frac{1.5-1}{R}$$

$\Rightarrow R = 34$ cm

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

$$\frac{1}{20} = (1.5-1)\left(\frac{1}{7.5} - \frac{1}{R_2}\right)$$

$R_2 = 30$ cm

32. (c) Focal length of the two half remains same and when placed sideways the focal length of combination become half.

33. (d) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow \frac{1}{80} = \frac{1}{20} + \frac{1}{f_2}$

$$= \frac{1}{f_2} = \frac{1}{80} - \frac{1}{20}$$

$$\frac{1}{f_2} = \frac{1-4}{80} = f_2 = -\frac{80}{3}\text{cm}$$

$\therefore$ power of second lens

$$P_2 = \frac{100}{f_2} = \frac{100}{\frac{-80}{3}} = -3.75\,D$$

34. (c) Focal length of the combination

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \quad \ldots\text{(i)}$$

We have, $f_1 = \frac{R}{(\mu_1 - 1)}$ and $f_2 = \frac{-R}{(\mu_2 - 1)}$

On putting these values in Eq. (i), we get

$$\frac{1}{f} = \frac{(\mu_1 - 1)}{R} - \frac{(\mu_2 - 1)}{R}$$

$$f = \frac{R}{\mu_1 - \mu_2}$$

35. (c) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{-25} - \frac{1}{-50} = \frac{1}{f}$$

$f = -50$ cm

$$P_L = \frac{1}{f_L} = -2D$$

36. (d) Magnification $= 5 = \frac{f_0}{f_e}$

Tube length $= 36 = f_0 + f_e$

37. (c) Given, $M = \frac{f_o}{f_e} = 9$ and $f_o + f_e = 20$

$f_o = 9 f_e$

So, $9f_e + f_e = 20 \Rightarrow f_e = 2$ cm

$\therefore f_o = 9 \times 2 = 18$ cm

38. (c) Resolving limit of telescope is

$$\theta \propto \frac{x}{D} = \frac{\lambda}{d}$$

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

Given, $\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m,

D = 1 km = 1000 m

d = 10 cm = 0.1 m

Hence, $x = \frac{5000 \times 10^{-10} \times 1000}{0.1}$

$= 5 \times 10^{-3}$ m

= 5 mm

39. (a) M.P. $= m_0 \times m_e$

$32 = m_0 \times 4$

$\therefore m_0 = 8$

40. (d) If final image is at ∞

then $u_e = 5$ cm, $v_0 = 20 - 5 = 15$ cm

$$MP = m_0 \times m_e = \left(\frac{f_0 - v_0}{f_0}\right)\left(\frac{D}{f_e}\right)$$

$$= \left(\frac{0.95 - 15}{0.95}\right)\left(\frac{25}{5}\right) \approx -74$$

41. (b) A passenger in an aeroplane may see a primary and a secondary rainbow like concentric circles.

NEET Past 5 Year Questions

Rotation of Plane Mirror

1. A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source L. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle θ is given by: (2017-Delhi)

a. $\frac{y}{x}$ b. $\frac{x}{2y}$

c. $\frac{x}{y}$ d. $\frac{y}{2x}$

Spherical Mirror Formula

2. An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be: (2018)

a. 30 cm towards the mirror

b. 36 cm away from the mirror

c. 30 cm away the mirror

d. 36 cm towards the mirror

Prism (Dispersion Without Derivation)

3. A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be: (2017-Delhi)

a. 6° b. 8°

c. 10° d. 4°

Condition of Minimum Deviation

4. The angle of incidence for a ray of light at a refracting surface of a prism is 45°. The angle of prism is 60°. If the ray suffers minimum deviation through the prism, the angle of minimum deviation and refractive index of the material of the prism respectively, are: (2016 - I)

a. $45°; \frac{1}{\sqrt{2}}$ b. $30°; \sqrt{2}$

c. $45°; \sqrt{2}$ d. $30°; \frac{1}{\sqrt{2}}$

5. The refracting angle of a prism is A, and refractive index of the material of the prism is cot(A/2). The angle of minimum deviation is: (2015)

a. $180° - 2A$ b. $90° - A$

c. $180° + 2A$ d. $180° - 3A$

Reflection and Refraction at the Interface

6. The refractive index of the material of a prism is $\sqrt{2}$ and the angle of the prism is 30º. One of the two refracting surfaces of the prism is made a mirror inwards, by silver coating. A beam of monochromatic light entering the prism from the other face will retrace its path (after reflection from the silvered surface) if its angle of incidence on the prism is: (2018)

a. 30º b. 45º

c. 60º d. Zero

Applications of T.I.R

7. In total internal reflection when the angle of incidence is equal to the critical angle for the pair of media in contact, what will be angle of refraction? (2019)

a. 180°

b. 0°

c. Equal to angle of incidence

d. 90°

Thin Lenses in Contact

8. Two similar thin equi-convex lenses, of focal length f each, are kept coaxially in contact with each other such that the focal length of the combination is F_1. When the space between the two lenses is filled with glycerine (which has the same refractive index

($\mu = 1.5$) as that of glass) then the equivalent focal length is F_2 . The ratio $F_1 : F_2$ will be: (2019)

a. 2 : 1
b. 1 : 2
c. 2 : 3
d. 3 : 4

9. Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the center. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is: (2015)

a. –25 cm
b. –50 cm
c. 50 cm
d. –20 cm

Astronomical Telescope: (Refracting Type)

10. An astronomical telescope has objective and eyepiece of focal length 40 cm and 4 cm respectively. To view an object 200 cm away from the objective, the lenses must be separated by a distance: (2016 - I)

a. 37.3 cm
b. 46.0 cm
c. 50.0 cm
d. 54.0 cm

Formation of Rainbow

11. Pick the wrong answer in the context with rainbow. (2019)

a. When the light rays undergo two internal reflections in a water drop, a secondary rainbow is formed
b. The order of colours is reversed in the secondary rainbow
c. An observer can see a rainbow when his front is towards the sun
d. Rainbow is a combined effect of dispersion refraction and reflection of sunlight

ANSWER KEY

1	2	3	4	5	6	7	8	9	10	11
d	b	a	b	a	b	d	b	b	d	c