विध्न विचारत भीरु जन, नहीं आरम्भे काम, विपति देख छोड़े तुरंत मध्यम मन कर श्याम।
पुरुष सिंह संकल्प कर, सहते विपति अनेक, 'बना' न छोड़े ध्येय को, रघुबर राखे टेक।।

रचितः मानव धर्म प्रणेता
सद्गुरु श्री रणछोड़दासजी महाराज

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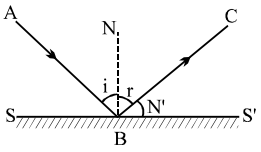
KEY CONCEPTS

1. LAWS OF REFLECTION :

(i) The incident ray (AB), the reflected ray (BC) and normal (NN') to the surface (SC') of reflection at the point of incidence (B) lie in the same plane. This plane is called the plane of incidence (also plane of reflection).

(ii) The angle of incidence (the angle between normal and the incident ray) and the angle of reflection (the angle between the reflected ray and the normal) are equal



$$\boxed{\angle i = \angle r}$$

2. OBJECT :

(a) **Real :** Point from which rays actually diverge.

(b) **Virtual :** Point towards which rays appear to converge

3. IMAGE :

Image is decided by reflected or refracted rays only. The point image for a mirror is that point

(i) Towards which the rays reflected from the mirror, actually converge (real image).

OR

(ii) From which the reflected rays appear to diverge (virtual image) .

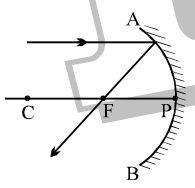
4. CHARACTERISTICS OF REFLECTION BY A PLANE MIRROR :

(a) The size of the image is the same as that of the object.

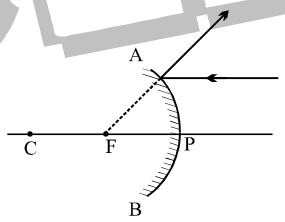
(b) For a real object the image is virtual and for a virtual object the image is real.

(c) For a fixed incident light ray, if the mirror be rotated through an angle θ the reflected ray turns through an angle 2θ.

5. SPHERICAL MIRRORS :



Concave



Convex

6. PARAXIAL RAYS : Rays which forms very small angle with axis are called paraxial rays.

7. SIGN CONVENTION :

We follow cartesian co-ordinate system convention according to which

(a) The pole of the mirror is the origin .

(b) The direction of the incident rays is considered as positive x-axis.

(c) Vertically up is positive y-axis.

Note : According to above convention radius of curvature and focus of concave mirror is negative and of convex mirror is positive.

8. MIRROR FORMULA : $\boxed{\frac{1}{f} = \frac{1}{v} + \frac{1}{u}.}$

f = x-coordinate of focus ; u = x-coordinate of object ;

v = x-coordinate of image

Note : Valid only for paraxial rays.

9. TRANSVERSE MAGNIFICATION : $\boxed{m = \frac{h_2}{h_1} = -\frac{v}{u}}$

h_2 = y co-ordinate of images h_1 = y co-ordinate of the object
(both perpendicular to the principle axis of mirror)

10. NEWTON'S FORMULA :

Applicable to a pair of real object and real image position only . They are called conjugate positions or foci. X,Y are the distance along the principal axis of the real object and real image respectively from the principal focus .

$$\boxed{XY = f^2}$$

11. OPTICAL POWER : Optical power of a mirror (in Diopters) $= -\frac{1}{f}$;

f = focal length (in meters) with sign .

REFRACTION -PLANE SURFACE

1. LAWS OF REFRACTION (AT ANY REFRACTING SURFACE) :

(i) The incident ray (AB), the normal (NN') to the refracting surface (II') at the point of incidence (B) and the refracted ray (BC) all lie in the same plane called the plane of incidence or plane of refraction .

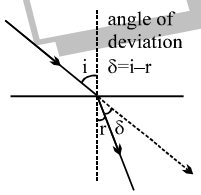
(ii) $\boxed{\frac{\text{Sin } i}{\text{Sin } r} = \text{Constant}}$:

for any two given media and for light of a given wave length. This is known as **SNELL'S LAW .**

$$\boxed{\frac{\text{Sin } i}{\text{Sin } r} = {}_1n_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}}$$

Note : Frequency of light does not change during refraction .

2. DEVIATION OF A RAY DUE TO REFRACTION :

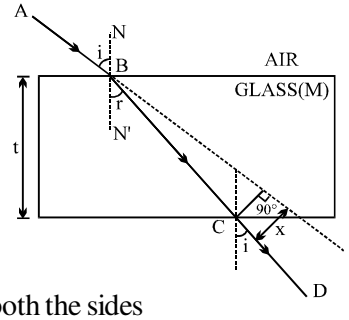


3. REFRACTION THROUGH A PARALLEL SLAB :

(i) Emerged ray is parallel to the incident ray, if medium is same on both sides.

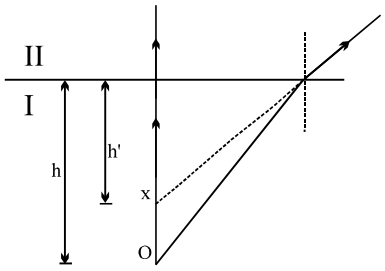
(ii) Lateral shift $\boxed{x = \frac{t \sin(i-r)}{\cos r}}$

t = thickness of slab



Note : Emerged ray will not be parallel to the incident ray if the medium on both the sides are different .

4. APPARENT DEPTH OF SUBMERGED OBJECT :

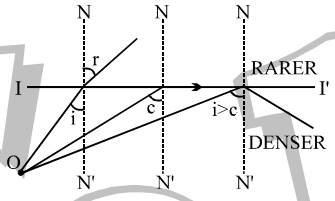


$(h' < h)$

at near normal incidence $\boxed{h' = \frac{\mu_2}{\mu_1} h}$

Note : h and h' are always measured from surface.

5. CRITICAL ANGLE & TOTAL INTERNAL REFLECTION (T. I. R.)



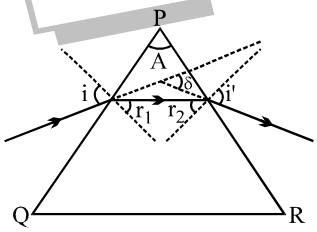
CONDITIONS OF T. I. R.

(i) Ray going from denser to rarer medium

(ii) Angle of incidence should be greater than the critical angle $(i > c)$.

Critical angle $\boxed{C = \sin^{-1}\frac{n_r}{n_i}}$

6. REFRACTION THROUGH PRISM :



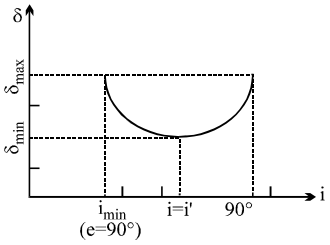
1. $\delta = (i + i') - (r + r')$

2. $r + r' = A$

3. Variation of δ versus i (shown in diagram) .

4. There is one and only one angle of incidence for which the angle of deviation is minimum.
When $\delta = \delta_m$ then $i = i'$ & $r = r'$, the ray passes symetrically about the prism, & then

$\boxed{n = \frac{\sin\left[\frac{A+\delta m}{2}\right]}{\sin\left[\frac{A}{2}\right]}}$, where n = absolute R.I. of glass .



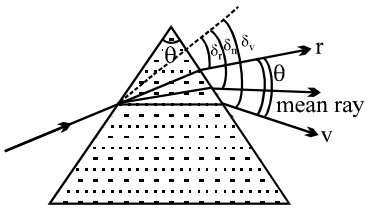
Note : When the prism is dipped in a medium then
n = R.I. of glass w.r.t. medium .

5. For a thin prism ($A \le 10^o$) ; $\delta = (n - 1) A$

6. **DISPERSION OF LIGHT :**

The angular spilitting of a ray of white light into a number of components when it is refracted in a medium other than air is called ***Dispersion of Light.***

7. **Angle of Dispersion :** Angle between the rays of the extreme colours in the refracted (dispersed) light is called ***Angle of Dispersion*** . $\theta = \delta_v - \delta_r$.



8. Dispersive power (ω) of the medium of the material of prism .

$$\omega = \frac{\text{angular dispersion}}{\text{deviation of mean ray (yellow)}}$$

For small angled prism ($A \le 10^o$)

$$\boxed{\omega = \frac{\delta_v - \delta_R}{\delta y} = \frac{n_v - n_R}{n - 1} \quad ; n = \frac{n_v + n_R}{2}}$$

n_v, n_R & n are R. I. of material for violet, red & yellow colours respectively .

9. **COMBINATION OF TWO PRISMS :**

(i) **ACHROMATIC COMBINATION :** It is used for deviation without dispersion .

Condition for this $(n_v - n_r) A = (n'_v - n'_r) A'$.

Net mean deviation $= \left[\frac{n_v + n_R}{2} - 1\right] A - \left[\frac{n'_v + n'_R}{2} - 1\right] A'$.

or $\omega\delta + \omega'\delta' = 0$ where ω, ω' are dispersive powers for the two prisms & δ, δ' are the mean deviation.

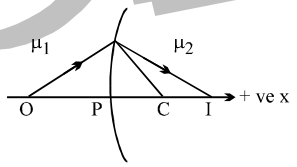
(ii) **DIRECT VISION COMBINATION :** It is used for producing disperion without deviation condition

for this $\left[\frac{n_v + n_R}{2} - 1\right] A = \left[\frac{n'_v + n'_R}{2} - 1\right] A'$.

Net angle of dispersion $= (n_v - n_r) A = (n'_v - n'_r) A'$.

REFRACTION AT SPERICAL SURFACE

1.(a) $\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}}$



v, u & R are to be kept with sign

as v = PI

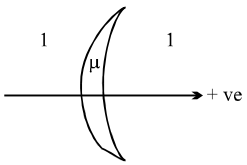
u = –PO

R = PC

(Note radius is with sign)

(b) $\boxed{m = \frac{\mu_1 v}{\mu_2 u}}$

2. **LENS FORMULA :**



(a) $\boxed{\frac{1}{v} - \frac{1}{u} = \frac{1}{f}}$

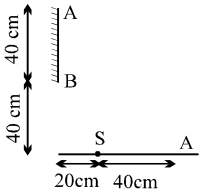
(b) $\boxed{\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$

(c) $\boxed{m = \frac{v}{u}}$

EXERCISE # I

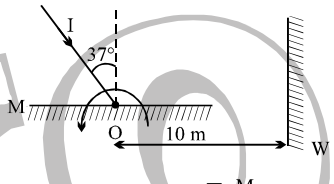
Q.1 A plane mirror 50 cm long , is hung parallel to a vertical wall of a room, with its lower edge 50 cm above the ground. A man stands infront of the mirror at a distance 2 m away from the mirror. If his eyes are at a height 1.8 m above the ground, find the length of the floor between him & the mirror, visible to him reflected from the mirror.

Q.2 In figure shown AB is a plane mirror of length 40cm placed at a height 40cm from ground. There is a light source S at a point on the ground. Find the minimum and maximum height of a man (eye height) required to see the image of the source if he is standing at a point A on ground shown in figure.

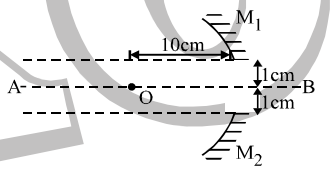


Q.3 A plane mirror of circular shape with radius r = 20 cm is fixed to the ceiling. A bulb is to be placed on the axis of the mirror. A circular area of radius R = 1 m on the floor is to be illuminated after reflection of light from the mirror. The height of the room is 3m. What is maximum distance from the center of the mirror and the bulb so that the required area is illuminated?

Q.4 A light ray I is incident on a plane mirror M. The mirror is rotated in the direction as shown in the figure by an arrow at frequency $\frac{9}{\pi}$ rev/sec. The light reflected by the mirror is received on the wall W at a distance 10 m from the axis of rotation. When the angle of incidence becomes 37° find the speed of the spot (a point) on the wall?



Q.5 A concave mirror of focal length 20 cm is cut into two parts from the middle and the two parts are moved perpendicularly by a distance 1 cm from the previous principal axis AB. Find the distance between the images formed by the two parts?

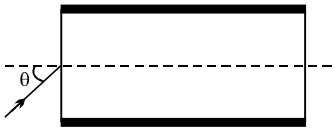


Q.6 A balloon is rising up along the axis of a concave mirror of radius of curvature 20 m. A ball is dropped from the balloon at a height 15 m from the mirror when the balloon has velocity 20 m/s. Find the speed of the image of the ball formed by concave mirror after 4 seconds? [Take : g=10 m/s^2]

Q.7 A thin rod of length d/3 is placed along the principal axis of a concave mirror of focal length = d such that its image, which is real and elongated, just touches the rod. Find the length of the image?

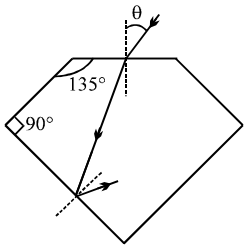
Q.8 A point object is placed 33 cm from a convex mirror of curvature radius = 40 cm. A glass plate of thickness 6 cm and index 2.0 is placed between the object and mirror, close to the mirror. Find the distance of final image from the object?

Q.9 A long solid cylindrical glass rod of refractive index 3/2 is immersed in a liquid of refractive index $\frac{3\sqrt{3}}{4}$. The ends of the rod are perpendicular to the central axis of the rod. a light enters one end of the rod at the central axis as shown in the figure. Find the maximum value of angle θ for which internal reflection occurs inside the rod?

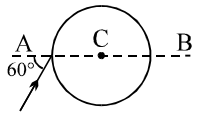


Q.10 A slab of glass of thickness 6 cm and index 1.5 is place somewhere in between a concave mirror and a point object, perpendicular to the mirror's optical axis. The radius of curvature of the mirror is 40 cm. If the reflected final image coincides with the object, then find the distance of the object from the mirror?

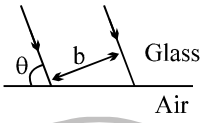
Q.11 A ray of light enters a diamond (n = 2) from air and is being internally reflected near the bottom as shown in the figure. Find maximum value of angle θ possible?



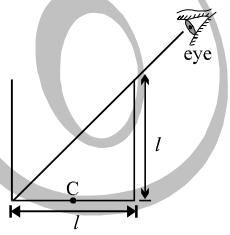
Q.12 A ray of light falls on a transparent sphere with centre at C as shown in figure. The ray emerges from the sphere parallel to line AB. Find the refractive index of the sphere.



Q.13 A beam of parallel rays of width b propagates in glass at an angle θ to its plane face . The beam width after it goes over to air through this face is _____ if the refractive index of glass is μ.

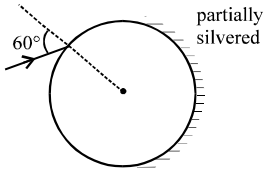


Q.14 A cubical tank (of edge *l*) and position of an observer are shown in the figure. When the tank is empty, edge of the bottom surface of the tank is just visible. An insect is at the centre C of its bottom surface. To what height a transparent liquid of refractive index $\mu = \sqrt{\frac{5}{2}}$ must be poured in the tank so that the insect will become visible?



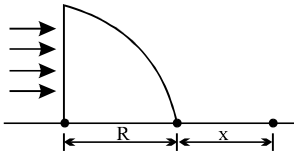
Q.15 Light from a luminous point on the lower face of a 2 cm thick glass slab, strikes the upper face and the totally reflected rays outline a circle of radius 3.2 cm on the lower face. What is the refractive index of the glass.

Q.16 A ray is incident on a glass sphere as shown. The opposite surface of the sphere is partially silvered. If the net deviation of the ray transmitted at the partially silvered surface is 1/3rd of the net deviation suffered by the ray reflected at the partially silvered surface (after emerging out of the sphere). Find the refractive index of the sphere.



Q.17 A narrow parallel beam of light is incident on a transparent sphere of refractive index 'n'. If the beam finally gets focussed at a point situated at a distance = 2 × (radius of sphere) from the centre of the sphere, then find n?

Q.18 A uniform, horizontal beam of light is incident upon a quarter cylinder of radius R = 5 cm, and has a refractive index $2/\sqrt{3}$. A patch on the table for a distance 'x' from the cylinder is unilluminated. find the value of 'x'?

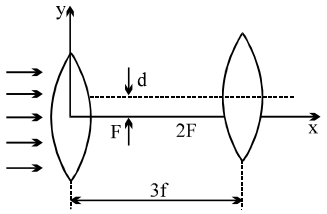


Q.19 A point object is placed at a distance of 25 cm from a convex lens of focal length 20 cm. If a glass slab of thickness t and refractive index 1.5 is inserted between the lens and object. The image is formed at infinity. Find the thickness t ?

Q.20 An object is kept at a distance of 16 cm from a thin lens and the image formed is real. If the object is kept at a distance of 6 cm from the same lens the image formed is virtual. If the size of the image formed are equal, then find the focal length of the lens?

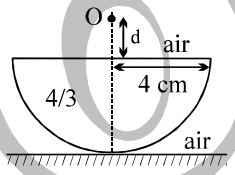
Q.21 A thin convex lens forms a real image of a certain object 'p' times its size. The size of real image becomes 'q' times that of object when the lens is moved nearer to the object by a distance 'a' find focal length of the lens ?

Q.22 In the figure shown, the focal length of the two thin convex lenses is the same = f. They are separated by a horizontal distance 3f and their optical axes are displaced by a vertical separation 'd' (d << f), as shown. Taking the origin of coordinates O at the centre of the first lens, find the x and y coordinates of the point where a parallel beam of rays coming from the left finally get focussed?



Q.23 A point source of light is kept at a distance of 15 cm from a converging lens, on its optical axis. The focal length of the lens is 10 cm and its diameter is 3 cm. A screen is placed on the other side of the lens, perpendicular to the axis of lens, at a distance 20 cm from it. Then find the area of the illuminated part of the screen?

Q.24 A glass hemisphere of refractive index 4/3 and of radius 4 cm is placed on a plane mirror. A point object is placed at distance 'd' on axis of this sphere as shown. If the final image be at infinity, find the value of 'd'.



Q.25 A double convex lens has focal length 25.0 cm in air. The radius of one of the surfaces is double of the other. Find the radii of curvature if the refractive index of the material of the lens is 1.5.

Q.26 A plano convex lens (μ=1.5) has a maximum thickness of 1 mm. If diameter of its aperture is 4 cm. Find

(i) Radius of curvature of curved surface

(ii) its focal length in air

Q.27 A plano-convex lens, when silvered on the plane side, behaves like a concave mirror of focal length 30 cm. When it is silvered on the convex side, it behaves like a concave mirror of focal length 10 cm. Find the refractive index of the material of the lens.

Q.28 A prism of refractive index $\sqrt{2}$ has a refracting angle of 30°. One of the refracting surfaces of the prism is polished. For the beam of monochromatic light to retrace its path, find the angle of incidence on the refracting surface.

Q.29 An equilateral prism deviates a ray through 23° for two angles of incidence differing by 23°. Find μ of the prism?

Q.30 A equilateral prism provides the least deflection angle 46° in air. Find the refracting index of an unknown liquid in which same prism gives least deflection angle of 30°.

List of recommended questions from I.E. Irodov.

5.13 to 17, 5.21 to 24, 5.26, 5.27, 5.31, 5.34 to 37

EXERCISE # II

Q.1 An observer whose least distance of distinct vision is 'd', views his own face in a convex mirror of radius of curvature 'r'. Prove that magnification produced can not exceed $\frac{r}{d+\sqrt{d^2+r^2}}$.

Q.2 A thief is running away in a car with velocity of 20 m/s. A police jeep is following him, which is sighted by thief in his rear view mirror which is a convex mirror of focal length 10 m. He observes that the image of jeep is moving towards him with a velocity of 1 cm/s. If the magnification of the mirror for the jeep at that time is 1/10. Find

(a) actual speed of jeep

(b) rate at which magnification is changing.

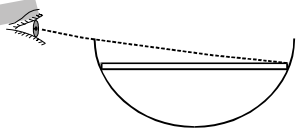
Assume that police jeep is on axis of the mirror.

Q.3 A luminous point P is inside a circle. A ray enters from P and after two reflections by the circle, return to P. ,, θ be the angle of incidence, a the distance of P from the centre of the circle and b the distance of the centre from the point where the ray in its course crosses the diameter through P, prove that $\tan\theta = \sqrt{\frac{a-b}{a+b}}$.

Q.4 An object is kept on the principal axis of a convex mirror of focal length 10 cm at a distance of 10 cm from the pole. The object starts moving at a velocity 20 mm/sec towards the mirror at angle 30° with the principal axis. What will be the speed of its image and direction with the principal axis at that instant?

Q.5 A surveyor on one bank of canal observed the image of the 4 inch and 17 ft marks on a vertical staff, which is partially immersed in the water and held against the bank directly opposite to him, coincides. If the 17ft mark and the surveyor's eye are both 6ft above the water level, estimate the width of the canal, assuming that the refractive index of the water is 4/3.

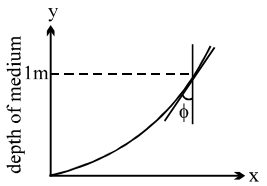
Q.6 A circular disc of diameter d lies horizontally inside a metallic hemispherical bowl radius a. The disc is just visible to an eye looking over the edge. The bowl is now filled with a liquid of refractive index μ. Now, the whole of the disc is just visible to the eye in the same position. Show that $d = 2a\frac{(\mu^2-1)}{(\mu^2+1)}$.



Q.7 A ray of light travelling in air is incident at grazing angle (incidence angle = 90°) on a medium whose refractive index depends on the depth of the medium. The trajectory of the light in the medium is a parabola, $y = 2x^2$. Find, at a depth of 1 m in the medium.

(i) the refractive index of the medium and

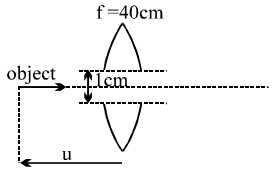
(ii) angle of incidence ϕ.



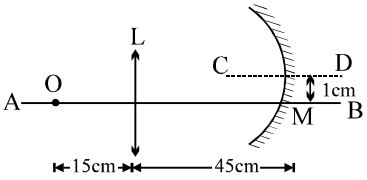
Q.8 Two thin similar watch glass pieces are joined together, front to front, with rear portion silvered and the combination of glass pieces is placed at a distance $a = 60$ cm from a screen. A small object is placed normal to the optical axis of the combination such that its two times magnified image is formed on the screen. If air between the glass pieces is replaced by water ($\mu = 4/3$), calculate the distance through which the object must be displaced so that a sharp image is again formed on the screen.

Q.9 A concave mirror has the form of a hemisphere with a radius of R = 60 cm. A thin layer of an unknown transparent liquid is poured into the mirror. The mirror-liquid system forms one real image and another real image is formed by mirror alone, with the source in a certain position. One of them coincides with the source and the other is at a distance of $l = 30$ cm from source. Find the possible value(s) refractive index μ of the liquid.

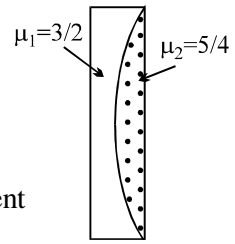
Q.10 In the figure shown, find the relative speed of approach/separation of the two final images formed after the light rays pass through the lens, at the moment when u = 30 cm. The speed object = 4 cm/s. The two lens halves are placed symmetrically w.r.t. the moving object.



Q.11 In the figure shown L is a converging lens of focal length 10cm and M is a concave mirror of radius of curvature 20cm. A point object O is placed in front of the lens at a distance 15cm. AB and CD are optical axes of the lens and mirror respectively. Find the distance of the final image formed by this system from the optical centre of the lens. The distance between CD & AB is 1 cm.



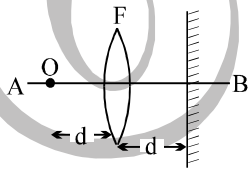
Q.12 A thin plano-convex lens fits exactly into a plano concave lens with their plane surface parallel to each other as shown in the figure. The radius of curvature of the curved surface R = 30 cm. The lens are made of difference material having refractive index $\mu_1 = \frac{3}{2}$ and $\mu_2 = \frac{5}{4}$ as shown in figure.



(i) if plane surface of the plano-convex lens is silvered, then calculate the equivalent focal length of this system and also calculate the nature of this equivalent mirror.

(ii) An object having transverse length 5 cm in placed on the axis of equivalent mirror (in part 1), at a distance 15 cm from the equivalent mirror along principal axis. Find the transverse magnification produced by equivalent mirror.

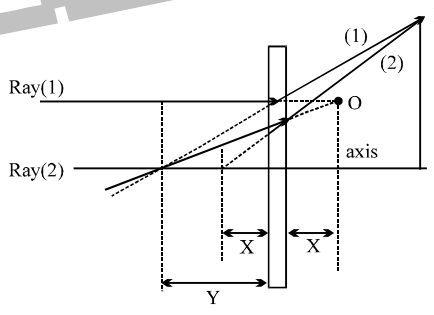
Q.13 In the figure shown 'O' is point object. AB is principal axis of the converging lens of focal length F. Find the distance of the final image from the lens.



Q.14 The rectangular box shown is the place of lens. By looking at the ray diagram, answer the following questions:

(i) If X is 5 cm then what is the focal length of the lens?

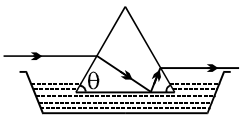
(ii) If the point O is 1 cm above the axis then what is the position of the image? Consider the optical center of the lens to be the origin.



Q.15 Two identical convex lenses L_1 and L_2 are placed at a distance of 20 cm from each other on the common principal axis. The focal length of each lens is 15 cm and the lens L_2 is to the right of lens A. A point object is placed at a distance of 20 cm on the left of lens L_1, on the common axis of two lenses. Find, where a convex mirror of radius of curvature 5 cm should be placed so that the final image coincides with the object?

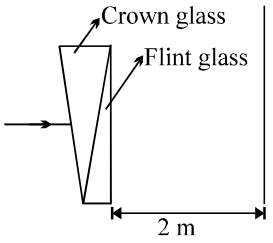
Q.16 An isosceles triangular glass prism stands with its base in water as shown. The angles that its two equal sides make with the base are θ each. An incident ray of light parallel to the water surface internally reflects at the glass-water interface and subsequently re-emerges into the air. Taking the refractive indices of glass and water to be 3/2 and 4/3 respectively, show that θ must be at least

$\tan^{-1}\frac{2}{\sqrt{17}}$ or 25.9°.



Q.17 A parallel beam of light falls normally on the first face of a prism of small angle. At the second face it is partly transmitted and partly reflected, the reflected beam striking at the first face again, and emerging from it in a direction making an angle 6°30' with the reversed direction of the incident beam. The refracted beam is found to have undergone a deviation of 1°15' from the original direction. Find the refractive index of the glass and the angle of the prism.

Q.18 The refractive indices of the crown glass for violet and red lights are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. A prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other thin flint glass prism is combined with the crown glass prism such that the net mean deviation is 1.5° anticlockwise.

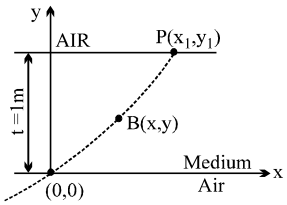


(i) Determine the angle of the flint glass prism.

(ii) A screen is placed normal to the emerging beam at a distance of 2m from the prism combination. Find the distance between red and violet spot on the screen. Which is the topmost colour on screen.

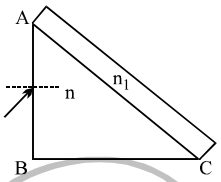
EXERCISE # III

Q.1 A ray of light travelling in air is incident at grazing angle (incident angle = 90°) on a long rectangular slab of a transparent medium of thickness t = 1.0 (see figure). The point of incidence is the origin A (O, O). The medium has a variable index of refraction n(y) given by : $n(y) = [ky^{3/2} + 1]^{1/2}$, where $k = 1.0\ m^{-3/2}$.
The refractive index of air is 1.0 .



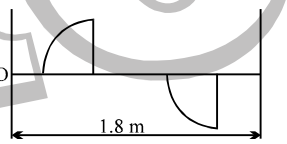
(i) Obtain a relation between the slope of the trajectory of the ray at a point B (x , y) in the medium and the incident angle at that point.
(ii) Obtain an equation for the trajectory y(x) of the ray in the medium.
(iii) Determine the coordinates (x_1 , y_1) of the point P, where the ray the ray intersects the upper surface of the slab-air boundary .
(iv) Indicate the path of the ray subsequently . [JEE '95]

Q.2 A right angle prism (45°–90°–45°) of refractive index n has a plate of refractive index n_1 ($n_1 < n$) cemented to its diagonal face. The assembly is in air. a ray is incident on AB (see the figure) .



(i) Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.
(ii) Assuming n = 1.352 . Calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated . [JEE '96]

Q.3 A thin plano–convex. Lens of focal length F is split into two halves, one of the halves is shifted along the optical axis. The separation between object and image planes is 1.8 m. The magnification of the image formed by one of the half lenses is 2. Find the focal length of the lens and separation between the two halves. Draw the ray diagram for image formation. [JEE '96]

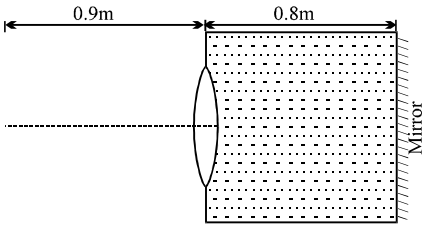


Q.4 Which of the following form(s) a virtual & erect image for all positions of the real object ?
(A) Convex lens (B) Concave lens (C) Convex mirror (D) Concave mirror
[JEE '96]

Q.5 A small fish, 0.4 m below the surface of a lake, is viewed through a simple converging lens of focal length 3 m . The lens is kept at 0.2m above the water surface such that the fish lies on the optical axis of the lens. Find the image of the fish seen by the observer . The refractive index of the water is 4/3.
[REE '96]

Q.6(i) An eye specialist prescribes spectacles having a combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm . The power of this lens combination in diopters is :
(A) + 1.5 (B) – 1.5 (C) + 6.67 (D) – 6.67
[JEE '97]

(ii) A thin equiconvex lens of glass of refractive index $\mu=3/2$ & of focal length 0.3 m in air is sealed into an opening at one end of a tank filled with water ($\mu = 4/3$). On the opposite side of the lens, a mirror is placed inside the tank on the tank wall perpendicular to the lens axis, as shown in figure . The separation between the lens and the mirror is 0.8 m . A small object is placed outside the tank in front of the lens at a distance of 0.9 m from the lens along its axis . Find the position (relative to the lens) of the image of the object formed by the system. [JEE ' 97]



Q.7 Select the correct alternative(s) : [JEE '98]

(i) A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the pole of the mirror & C its centre of curvature . A point object is placed at C . It has a real image, also located at C . If the mirror is now filled with water, the image will be:

(A) real, & will remain at C

(B) real, & located at a point between C & ∞

(C) virtual, & located at a point between C & O

(D) real, & located at a point between C & O .

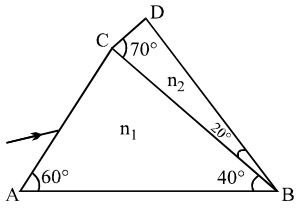
(ii) A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence of 45º . The ray undergoes total internal reflection . If n is the refractive index of the medium with respect to air, select the possible value(s) of n from the following :

(A) 1.3 (B) 1.4 (C) 1.5 (D) 1.6

(iii) A spherical surface of radius of curvature R separates air (refractive index 1.0) from glass (refractive index 1.5) . The centre of curvature is in the glass . A point object P placed in air is found to have a real image Q in the glass . The line PQ cuts the surface at a point O and PO = OQ . The distance PO is equal to :

(A) 5R (B) 3R (C) 2R (D) 1.5R

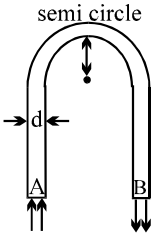
Q.8 A prism of refractive index n_1 & another prism of refractive index n_2 are stuck together without a gap as shown in the figure. The angles of the prisms are as shown . n_1 & n_2 depend on λ, the wavelength of light according to $n_1 = 1.20 + \frac{10.8\times10^4}{\lambda^2}$ & $n_2 = 1.45 + \frac{1.80\times10^4}{\lambda^2}$ where λ is in nm .



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

(ii) For light of wavelength λ_0, find the angle of incidence i on the face AC such that the deviation produced by the combination of prisms is minimum . [JEE '98]

Q.9 A rod made of glass ($\mu = 1.5$) and of square cross-section is bent into the shape shown in figure. A parallel beam of light falls perpendicularly on the plane flat surface A. Referring to the diagram, d is the width of a side & R is the radius of inner semicircle. Find the maximum value of ratio $\frac{d}{R}$ so that all light entering the glass through surface A emerge from the glass through surface B. [REE '98]



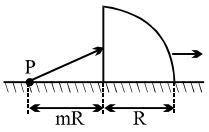
Q.10 A concave lens of glass, refractive index 1.5, has both surfaces of same radius of curvature R. On immersion in a medium of refractive index 1.75, it will behave as a [JEE '99]

(A) convergent lens of focal length 3.5R (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

Q.11 The x-y plane is the boundary between two transparent media. Medium-1 with $z > 0$ has refractive index $\sqrt{2}$ and medium – 2 with $z < 0$ has a refractive index $\sqrt{3}$. A ray of light in medium –1 given by the vector $A = 6\sqrt{3}\,\hat{i} + 8\sqrt{3}\,\hat{j} - 10\hat{k}$ is incident on the plane of separation. Find the unit vector in the direction of refracted ray in medium -2. [JEE '99]

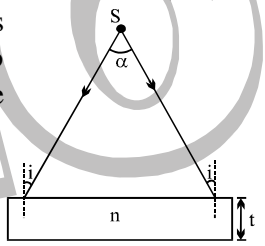
Q.12 A quarter cylinder of radius R and refractive index 1.5 is placed on a table. A point object P is kept at a distance of mR from it. Find the value of m for which a ray from P will emerge parallel to the table as shown in the figure. [JEE '99]



Q.13 Two symmetric double-convex lenses L_1 and L_2 with their radii of curvature 0.2m each are made from glasses with refractive index 1.2 and 1.6 respectively. The lenses with a separation of 0.345 m are submerged in a transparent liquid medium with a refractive index of 1.4. Find the focal lengths of lens L_1 and L_2. An object is placed at a distance of 1.3m from L_1, find the location of its image while the whole system remains inside the liquid. [REE '99]

Q.14 Select the correct alternative. [JEE '2000 (Scr)]

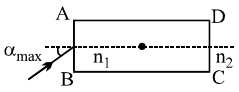
(a) A diverging beam of light from a point source S having divergence angle α, falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is t and the refractive index n, then the divergence angle of the emergent beam is



(A) zero (B) α

(C) $\sin^{-1}(1/n)$ (D) $2\sin^{-1}(1/n)$

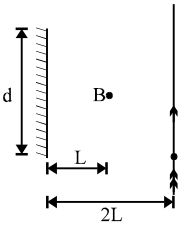
(b) A rectangular glass slab ABCD, of refractive index n_1, is immersed in water of refractive index $n_2 (n_1 > n_2)$. A ray of light is incident at the surface AB of the slab as shown. The maximum value of the angle of incidence α_{max}, such that the ray comes out only from the other surface CD is given by



(A) $\sin^{-1}\left[\frac{n_1}{n_2}\cos\left(\sin^{-1}\frac{n_2}{n_1}\right)\right]$ (B) $\sin^{-1}\left[n_1\cos\left(\sin^{-1}\frac{1}{n_2}\right)\right]$

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

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



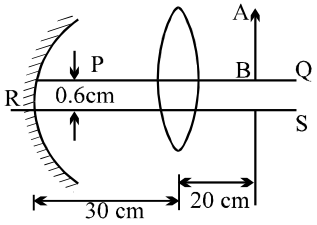
(A) d/2 (B) d (C) 2d (D) 3d

(d) A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 or L_2 having refractive indices n_1 and n_2 respectively ($n_2 > n_1 > 1$). The lens will diverge a parallel beam of light if it is filled with

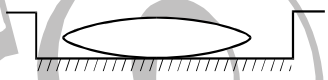
(A) air and placed in air. (B) air and immersed in L_1.

(C) L_1 and immersed in L_2. (D) L_2 and immersed in L_1.

Q.15 A convex lens of focal length 15 cm and a concave mirror of focal length 30 cm are kept with their optic axes PQ and RS parallel but separated in vertical direction by 0.6 cm as shown. The distance between the lens and mirror is 30 cm. An upright object AB of height 1.2 cm is placed on the optic axis PQ of the lens at a distance of 20 cm from the lens . If A′ B′ is the image after refraction from the lens and reflection from the mirror, find the distance A′B′ from the pole of the mirror and obtain its magnification. Also locate positions of A′ and B′ with respect to the optic axis RS. [JEE 2000]



Q.16 A thin equi biconvex lens of refractive index 3/2 is placed on a horizontal plane mirror as shown in the figure. The space between the lens and the mirror is then filled with water of refractive index 4/3. It is found that when a point object is placed 15cm above the lens on its principal axis, the object coincides with its own image. On repeating with another liquid, the object and the image again coincide at a distance 25cm from the lens. Calculate the refractive index of the liquid. [JEE 2001]

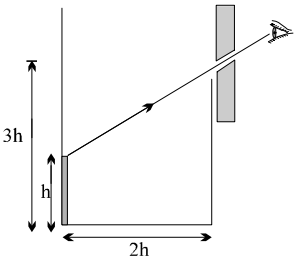


Q.17 The refractive indices of the crown glass for blue and red lights are 1.51 and 1.49 respectively and those of the flint glass are 1.77 and 1.73 respectively. An isosceles prism of angle 6° is made of crown glass. A beam of white light is incident at a small angle on this prism. The other flint glass isosceles prism is combined with the crown glass prism such that there is no deviation of the incident light. Determine the angle of the flint glass prism. Calculate the net dispersion of the combined system. [JEE 2001]

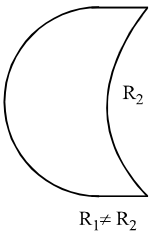
Q.18 An observer can see through a pin-hole the top end of a thin rod of height h, placed as shown in the figure. The beaker height is 3h and its radius h. When the beaker is filled with a liquid up to a height 2h, he can see the lower end of the rod. Then the refractive index of the liquid is

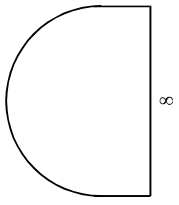
(A) 5/2 (B) $\sqrt{5/2}$

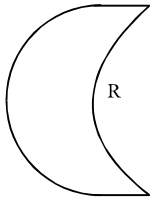
(C) $\sqrt{3/2}$ (D) 3/2 [JEE 2002 (Scr)]

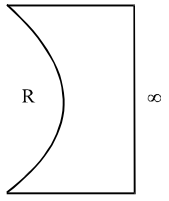


Q.19 Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams. [JEE 2002 (Scr)]

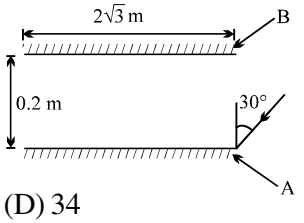
(A) 

(B) 

(C) 

(D) 

Q.20 Two plane mirrors A and B are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle of 30° at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is [JEE 2002 (Scr)]

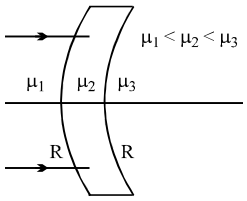


(A) 28 (B) 30 (C) 32 (D) 34

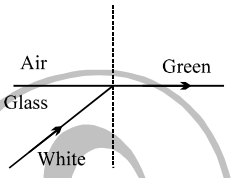
Q.21 A convex lens of focal length 30 cm forms an image of height 2 cm for an object situated at infinity. If a convcave lens of focal length 20 cm is placed coaxially at a distance of 26 cm in front of convex lens then size image would [JEE 2003 (Scr)]

(A) 2.5 cm (B) 5.0 (C) 1.25 (D) None

Q.22 A meniscus lens is made of a material of refractive index μ_2. Both its surfaces have radii of curvature R. It has two different media of refractive indices μ_1 and μ_3 respectively, on its two sides (see figure). Calculate its focal length for $\mu_1 < \mu_2 < \mu_3$, when light is incident on it as shown. [JEE 2003]

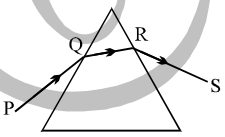


Q.23 White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging ray in air contains



(A) yellow, orange, red (B) violet, indigo, blue
(C) all colours (D) all coloure except green
[JEE 2004 (Scr)]

Q.24 A ray of light is incident on an equilateral glass prism placed on a horizontal table. For minimum deviation which of the following is true ? [JEE 2004 (Scr)]

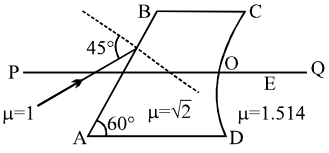


(A) PQ is horizontal (B) QR is horizontal
(C) RS is horizontal (D) Either PQ or RS is horizontal.

Q.25 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 [JEE 2004 (Scr)]

(A) 2 cm (B) 4 cm (C) 6 cm (D) 12 cm

Q.26 Figure shows an irregular block of material of refractive index $\sqrt{2}$. A ray of light strikes the face AB as shown in the figure. After refraction it is incident on a spherical surface CD of radius of curvature 0.4 m and enters a medium of refractive index 1.514 to meet PQ at E. Find the distance OE upto two places of decimal. [JEE 2004]

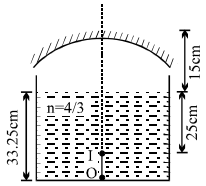


Q.27 An object is approaching a thin convex lens of focal length 0.3 m with a speed of 0.01 m/s. Find the magnitudes of the rates of change of position and lateral magnification of image when the object is at a distance of 0.4 m from the lens. [JEE 2004]

Q.28 The ratio of powers of a thin convex and thin concave lens is $\frac{3}{2}$ and equivalent focal length of their combination is 30 cm. Then their focal lengths respectively are [JEE' 2005 (Scr)]

(A) 75, – 50 (B) 75, 50 (C) 10, – 15 (D) – 75, 50

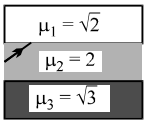
Q.29 Figure shows object O. Final image I is formed after two refractions and one reflection is also shown in figure. Find the focal length of mirror. (in cm) :



(A) 10 (B) 15 (C) 20 (D) 25

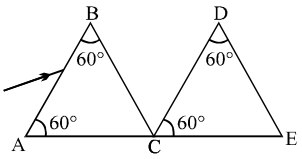
[JEE' 2005 (Scr)]

Q.30 What will be the minimum angle of incidence such that the total internal reflection occurs on both the surfaces?



[JEE 2005]

Q.31 Two identical prisms of refractive index $\sqrt{3}$ are kept as shown in the figure. A light ray strikes the first prism at face AB. Find,

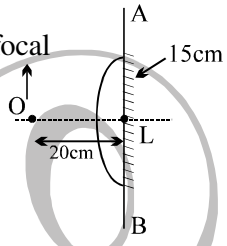


(a) the angle of incidence, so that the emergent ray from the first prism has minimum deviation.

(b) through what angle the prism DCE should be rotated about C so that the final emergent ray also has minimum deviation.

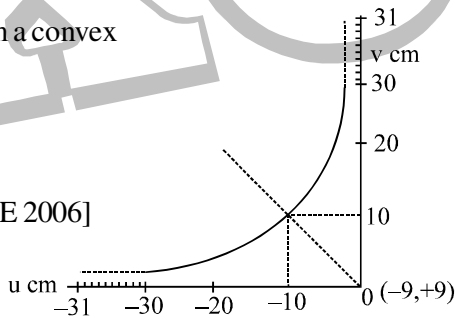
[JEE 2005]

Q.32 A point object is placed at a distance of 20 cm from a thin plano-convex lens of focal length 15 cm, if the plane surface is silvered. The image will form at



(A) 60 cm left of AB
(B) 30 cm left of AB
(C) 12 cm left of AB
(D) 60 cm right of AB [JEE 2006]

Q.33 Graph of position of image vs position of point object from a convex lens is shown. Then, focal length of the lens is



(A) 0.50 ± 0.05 cm
(B) 0.50 ± 0.10 cm
(C) 5.00 ± 0.05 cm
(D) 5.00 ± 0.10 cm [JEE 2006]

Q.34 Parallel rays of light from Sun falls on a biconvex lens of focal length f and the circular image of radius r is formed on the focal plane of the lens. Then which of the following statement is correct?

(A) Area of image πr^2 directly proportional to f
(B) Area of image πr^2 directly proportional to f^2
(C) Intensity of image increases if f is increased.
(D) If lower half of the lens is covered with black paper area of image will become half. [JEE 2006]

Q.35 A simple telescope used to view distant objects has eyepiece and objective lens of focal lengths f_e and f_0, respectively. Then [JEE 2006]

Column 1	**Column 2**
(A) Intensity of light received by lens	(P) Radius of aperture (R)
(B) Angular magnification	(Q) Dispersion of lens
(C) Length of telescope	(R) focal length f_0, f_e
(D) Sharpness of image	(S) spherical aberration

ANSWER KEY

EXERCISE # I

Q.1 1.23 m Q.2 160cm; 320cm Q.3 75 cm Q.4 1000 m/s

Q.5 2 cm Q.6 80 m/s Q.7 d/2 Q.8 42 cm

Q.9 $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$ Q.10 42 cm Q.11 $\sin^{-1}\left(\frac{\sqrt{3}-1}{\sqrt{2}}\right)$ Q.12 $\sqrt{3}$

Q.13 $\frac{b(1-\mu^2\cos^2\theta)^{1/2}}{\sin\theta}$ Q.14 $h = l$ Q.15 $\frac{\sqrt{41}}{4}$ Q.16 $\sqrt{3}$

Q.17 4/3 Q.18 5 cm Q.19 15 cm Q.20 11 cm

Q.21 $\frac{apq}{(q-p)}$ Q.22 (5f, 2d) Q.23 $(\pi/4)$ cm^2 Q.24 3 cm

Q.25 75/4 cm, 75/2 cm Q.26 (i) 0.2 m ,(ii) 0.4 m Q.27 1.5

Q.28 45° Q.29 $\frac{\sqrt{43}}{5}$ Q.30 $\frac{8}{5\sqrt{2}}$

EXERCISE # II

Q.2 (a) 21 m/s, (b) 1×10^{-3} /sec Q.4 $\tan^{-1}\frac{2}{\sqrt{3}}$ with the principal axis, $\frac{\sqrt{7}}{4}$ cm/sec

Q.5 16 feet Q.7 $\mu = 3$, $\sin^{-1}(1/3)$ Q.8 15 cm towards the combination

Q.9 1.5 or $(\sqrt{5}-1)$ Q.10 8/5 cm/s Q.11 $6\sqrt{26}$ cm Q.12 + 60, + 4/5

Q.13 $l = \left|\frac{(3f-2d)fd}{4fd-2d^2-f^2}\right|$ Q.14 10cm, 10,2 Q.15 5.9 cm,10.9 cm

Q.17 $\mu = \frac{13}{8}$, A = 2° Q.18 (i) 2° ,(ii) $\frac{4\pi}{9}$ mm

EXERCISE # III

Q.1 (a) $\tan\theta = \frac{dy}{dx} = \cot i$ (b) $y = k^2\left(\frac{x}{4}\right)^4$ (c) 4.0, 1 (d) It will become parallel to x-axis

Q.2 (i) $\sin^{-1}\left[\frac{1}{\sqrt{2}}\left(\sqrt{n^2 - n_1^2} - n_1\right)\right]$ (ii) $r_1 = \sin^{-1}(n \sin 45°) = 72.94°$

Q.3 f = 0.4 m, separation = 0.6 m Q.4 B, C Q.5 On the object itself

Q.6 (i) B, (ii) 90 cm from the lens towards right Q.7 (i) D, (ii) C, D, (iii) A

Q.8 (i) $\lambda_0 = 600$ nm, n = 1.5 (ii) $i = \sin^{-1}(0.75) = 48.59°$ Q.9 $\left(\frac{r}{R}\right)_{max} = \frac{1}{2}$ Q.10 A

Q.11 $\vec{r} = \frac{3}{5\sqrt{2}}\hat{i} + \frac{2\sqrt{2}}{5}\hat{j} - \frac{1}{\sqrt{2}}\hat{k}$ (angle of incidence $= 60^0$; $r = 45^0$) Q.12 m = 4/3

Q.13 $f_1 = -70cm$, $f_2 = 70cm$, V= 560 cm to the right of L_2 Q.14 (a) B (b) A (c) D (d) D

Q.15 A′B′ at 15 cm to the right of mirror . B′ is 0.3 cm above RS and A′ is 1.5 cm below RS. Magnification is 1.5

Q.16 1.6 Q.17 4^0 and -0.04^0 Q.18 B Q.19 C Q.20 B

Q.21 A Q.22 $f = v = \frac{\mu_3 R}{\mu_3 - \mu_1}$ Q.23 A Q.24 B

Q.25 C Q.26 $\frac{1.514 \times 0.4}{0.1} = 6.06\,m$ correct upto two places of decimal.

Q.27 0.09 m/s ; Magnitude of the rate of change of lateral magnification is 0.3 s^{-1}. Q.28 C

Q.29 C Q.30 60° Q.31 (a) i = 60°, (b) 60° (anticlockwise)

Q.32 C Q.33 C Q.34 B

Q.35 (A) P ; (B) R; (C) R; (D) P, Q, S