GEOMETRICAL OPTICS

1. Two plane mirrors arc inclined to each other such that a ray of light incident on the first mirror (M_1) and parallel to the second mirror (M_2) is finally reflected from the second mirror (M_2) parallel to the first mirror (M_1). The angle between the two mirrors will be :

(1) 90° (2) 45° (3) 75° (4) 60°

2. A convex lens is put 10 cm from a light source and it makes a sharp image on a screen, kept 10 cm from the lens. Now a glass block (refractive index 1.5) of 1.5 cm thickness is placed in contact with the light source. To get the sharp image again, the screen is shifted by a distance d. Then d is :

(1) 0.55 cm away from the lens
(2) 1.1 cm away from the lens
(3) 0.55 cm towards the lens
(4) 0

3. The eye can be regarded as a single refracting surface . The radius of curvature of this surface is equal to that of cornea (7.8 mm). This surface separates two media of refractive indices 1 and 1.34. Calculate the distance from the refracting surface at which a parallel beam of light will come to focus.

(1) 2 cm (2) 1 cm
(3) 3.1 cm (4) 4.0 cm

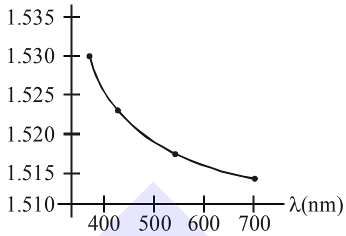
4. A plano convex lens of refractive index μ_1 and focal length f_1 is kept in contact with another plano concave lens of refractive index μ_2 and focal length f_2. If the radius of curvature of their spherical faces is R each and $f_1 = 2f_2$, then μ_1 and μ_2 are related as :

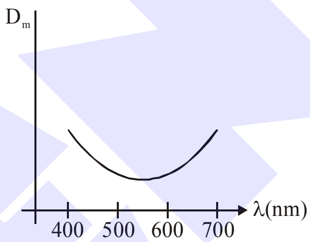
(1) $\mu_1 + \mu_2 = 3$ (2) $2\mu_1 - \mu_2 = 1$
(3) $2\mu_2 - \mu_1 = 1$ (4) $3\mu_2 - 2\mu_1 = 1$

5. A monochromatic light is incident at a certain angle on an equilateral triangular prism and suffers minimum deviation. If the refractive index of the material of the prism is $\sqrt{3}$, then the angle of incidence is :-

(1) 30° (2) 45° (3) 90° (4) 60°

6. The variation of refractive index of a crown glass thin prism with wavelength of the incident light is shown. Which of the following graphs is the correct one, if D_m is the angle of minimum deviation?



(1)


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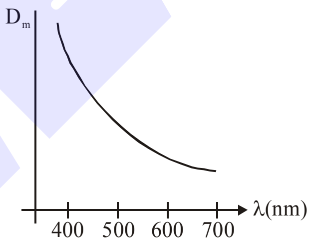

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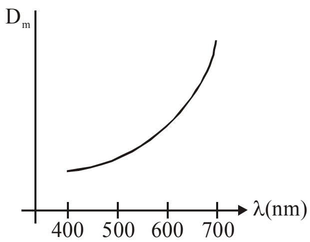

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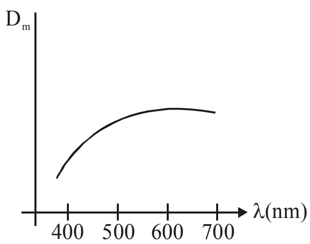


7. An object is at a distacen of 20 m from a convex lens of focal length 0.3 m. The lens forms an image of the object. If the object moves away from the lens at a speed of 5 m/s, the speed and direction of the image will be :

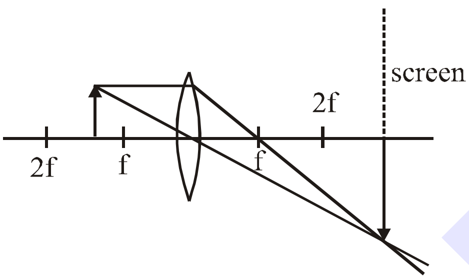
(1) 0.92×10^{-3} m/s away from the lens

(2) 2.26×10^{-3} m/s away from the lens

(3) 1.16×10^{-3} m/s towards the lens

(4) 3.22×10^{-3} m/s towards the lens

8. Formation of real image using a biconvex lens is shown below :



If the whole set up is immersed in water without disturbing the object and the screen position, what will one observe on the screen ?

(1) Image disappears

(2) No change

(3) Erect real image

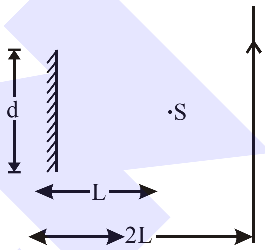
(4) Magnified image

9. A plano-convex lens (focal length f_2, refractive index μ_2, radius of curvature R) fits exactly into a plano-concave lens (focal length f_1, refractive index μ_1, radius of curvature R). Their plane surfaces are parallel to each other. Then, the focal length of the combination will be :

(1) $f_1 - f_2$ (2) $f_1 + f_2$

(3) $\frac{R}{\mu_2 - \mu_1}$ (4) $\frac{2f_1f_2}{f_1 + f_2}$

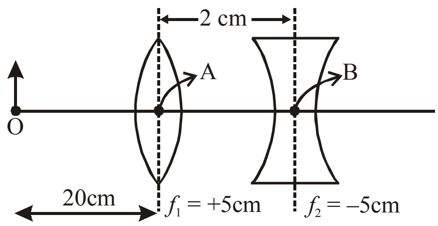
10. A point source of light, S is placed at a distance L in front of the centre of plane mirror of width d which is hanging vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror, at a distance 2L as shown below. The distance over which the man can see the image of the light source in the mirror is :



(1) 3d (2) $\frac{d}{2}$

(3) d (4) 2d

11. What is the position and nature of image formed by lens combination shown in figure? (f_1, f_2 are focal lengths)



(1) 70 cm from point B at left; virtual

(2) 40 cm from point B at right; real

(3) $\frac{20}{3}$ cm from point B at right , real

(4) 70 cm from point B at right, real

12. A convex lens (of focal length 20 cm) and a concave mirror, having their principal axes along the same lines, are kept 80 cm apart from each other. The concave mirror is to the right of the convex lens. When an object is kept at a distance of 30 cm to the left of the convex lens, its image remains at the same position even if the concave mirror is removed. The maximum distance of the object for which this concave mirror, by itself would produce a virtual image would be :-

(1) 20 cm (2) 10 cm (3) 25 cm (4) 30 cm

13. An upright object is placed at a distance of 40 cm in front of a convergent lens of focal length 20 cm. A convergent mirror of focal length 10 cm is placed at a distance of 60 cm on the other side of the lens. The position and size of the final image will be :

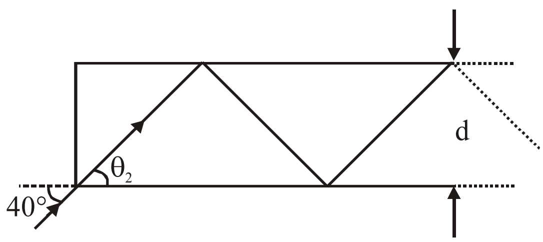
(1) 40 cm from the convergent mirror, same size as the object

(2) 20 cm from the convergent mirror, same size as the object

(3) 20 cm from the convergent mirror, twice the size of the object

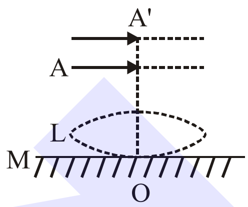
(4) 40 cm from the convergent lens, twice the size of the object

14. In figure, the optical fiber is ℓ = 2m long and has a diameter of d = 20 μm. If a ray of light is incident on one end of the fiber at angle θ_1 = 40°, the number of reflection it makes before emerging from the other end is close to: (refractive index of fibre is 1.31 and sin 40° = 0.64)



(1) 55000 (2) 57000
(3) 66000 (4) 45000

15. A thin convex lens L (refractive index = 1.5) is placed on a plane mirror M. When a pin is placed at A, such that OA = 18 cm, its real inverted image is formed at A itself, as shown in figure. When a liquid of refractive index μ_1 is put between the lens and the mirror, The pin has to be moved to A', such that OA' = 27 cm, to get its inverted real image at A' itself. The value of μ_1 will be :-



(1) $\sqrt{2}$ (2) $\frac{4}{3}$ (3) $\sqrt{3}$ (4) $\frac{3}{2}$

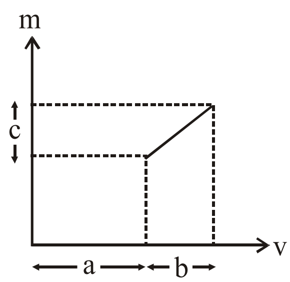
16. A convex lens of focal length 20 cm produces images of the same magnification 2 when an object is kept at two distances x_1 and x_2 ($x_1 > x_2$) from the lens. The ratio of x_1 and x_2 is:-

(1) 5 : 3 (2) 2 : 1
(3) 4 : 3 (4) 3 : 1

17. A concave mirror for face viewing has focal length of 0.4 m. The distance at which you hold the mirror from your face in order to see your image upright with a magnification of 5 is :

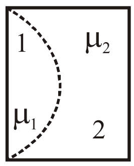
(1) 1.60 m (2) 0.24 m
(3) 0.16 m (4) 0.32 m

18. The graph shows how the magnification m produced by a thin lens varies with image distance v. What is the focal length of the lens used ?



(1) $\frac{b^2c}{a}$ (2) $\frac{b^2}{ac}$ (3) $\frac{a}{c}$ (4) $\frac{b}{c}$

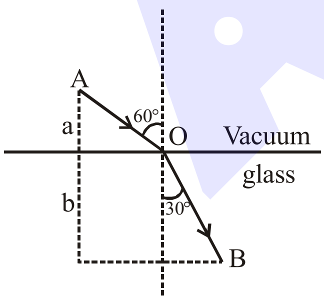
19. One plano-convex and one plano-concave lens of same radius of curvature 'R' but of different materials are joined side by side as shown in the figure. If the refractive index of the material of 1 is μ_1 and that of 2 is μ_2, then the focal length of the combination is :



(1) $\dfrac{R}{2-(\mu_1-\mu_2)}$ (2) $\dfrac{2R}{\mu_1-\mu_2}$

(3) $\dfrac{R}{2(\mu_1-\mu_2)}$ (4) $\dfrac{R}{\mu_1-\mu_2}$

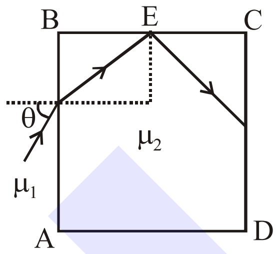
20. A ray of light AO in vacuum is incident on a glass slab at angle 60° and refracted at angle 30° along OB as shown in the figure. The optical path length of light ray from A to B is:



(1) 2a + 2b (2) $2a+\dfrac{2b}{3}$

(3) $\dfrac{2\sqrt{3}}{a}+2b$ (4) $2a+\dfrac{2b}{\sqrt{3}}$

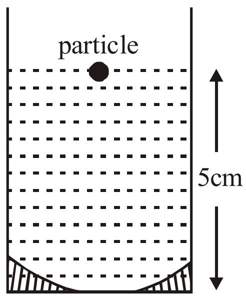
21. A transparent cube of side d, made of a material of refractive index μ_2, is immersed in a liquid of refractive index $\mu_1(\mu_1<\mu_2)$. A ray is incident on the face AB at an angle θ(shown in the figure). Total internal reflection takes place at point E on the face BC. The θ must satisfy :



(1) $\theta<\sin^{-1}\dfrac{\mu_1}{\mu_2}$ (2) $\theta<\sin^{-1}\sqrt{\dfrac{\mu_2^2}{\mu_1^2}-1}$

(3) $\theta>\sin^{-1}\dfrac{\mu_1}{\mu_2}$ (4) $\theta>\sin^{-1}\sqrt{\dfrac{\mu_2^2}{\mu_1^2}-1}$

22. A concave mirror has radius of curvature of 40 cm. It is at the bottom of a glass that has water filled up to 5 cm (see figure). If a small particle is floating on the surface of water, its image as seen, from directly above the glass, is at a distance d from the surface of water. The value of d is close to : (Refractive index of water = 1.33)

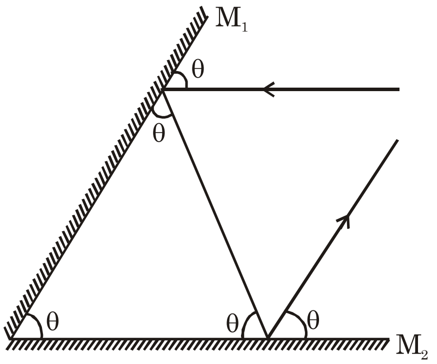


(1) 8.8 cm (2) 11.7 cm

(3) 6.7 cm (4) 13.4 cm

SOLUTION

1. Ans. (4)



Assuming angles between two mirrors be θ

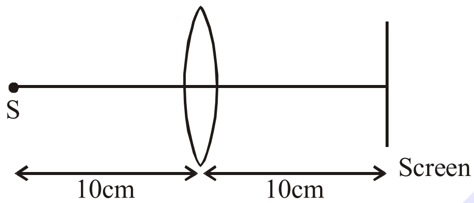
as per geometry,

sum of anlges of Δ

3θ = 180°

θ = 60°

2. Ans. (1)



$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{10}-\frac{1}{-10}=\frac{1}{f}\Rightarrow f=5\text{cm}$$

Shift due to slab = $t\left(1-\frac{1}{\mu}\right)$ in the direction of incident ray

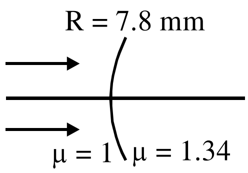
$$=1.5\left(1-\frac{2}{3}\right)=0.5$$

again, $\frac{1}{v}-\frac{1}{-9.5}=\frac{1}{5}$

$$\Rightarrow\frac{1}{u}=\frac{1}{5}-\frac{2}{19}=\frac{9}{95}$$

$$\Rightarrow v=\frac{95}{9}=10.55\text{cm}$$

3. Ans. (3)



$$\frac{1.34}{V}-\frac{1}{\infty}=\frac{1.34-1}{7.8}$$

∴ V = 30.7 mm

4. Ans. (2)

$$\frac{1}{2f_2}=\frac{1}{f_1}=(\mu_1-1)\left(\frac{1}{\infty}-\frac{1}{-R}\right)$$

$$\frac{1}{f_2}=(\mu_2-1)\left(\frac{1}{-R}-\frac{1}{\infty}\right)$$

$$\frac{(\mu_1-1)}{R}=\frac{(\mu_2-1)}{2R}$$

$2\mu_2 - \mu_2 = 1$

5. Ans. (4)

i = e

$$r_1=r_2=\frac{A}{2}=30^{\circ}$$

by Snell's law

$$1\times\sin i=\sqrt{3}\times\frac{1}{2}=\frac{\sqrt{3}}{2}$$

i = 60

6. Ans. (2)

Since $D_m = (\mu - 1)A$

& on increasing the wavelength, μ decreases & hence D_m decreases. Therefore correct answer is (2)

7. Ans. (3)

From lens equation

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

$$\frac{1}{v}-\frac{1}{(-20)}=\frac{1}{(.3)}=\frac{10}{3}$$

$$\frac{1}{v}=\frac{10}{3}-\frac{1}{20}$$

$$\frac{1}{v}=\frac{197}{60};v=\frac{60}{197}$$

$$m=\left(\frac{v}{u}\right)=\frac{\left(\frac{60}{197}\right)}{20}$$

velocity of image wrt. to lens is given by

$v_{I/L} = m^2 v_{O/L}$

direction of velocity of image is same as that of object

$v_{O/L} = 5$ m/s

$$v_{I/L}=\left(\frac{60\times1}{197\times20}\right)^2(5)$$

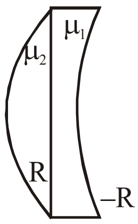
$= 1.16 \times 10^{-3}$ m/s towards the lens

8. Ans. (1)

From $\frac{1}{f} = (\mu_{rel} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

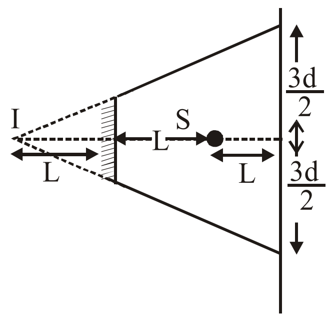
Focal length of lens will change hence image disappears from the screen.

9. Ans. (3)



$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1-\mu_1}{R} + \frac{\mu_2 - 1}{R}$$

10. Ans. (1)



3d

11. Ans. (4)

For first lens

$$\frac{1}{V} - \frac{1}{-20} = \frac{1}{5}$$

$$V = \frac{20}{3}$$

For second lens

$$V = \frac{20}{3} - 2 = \frac{14}{3}$$

$$\frac{1}{V} - \frac{1}{\frac{14}{3}} = \frac{1}{-5}$$

V = 70cm

12. Ans. (2)

Sol.

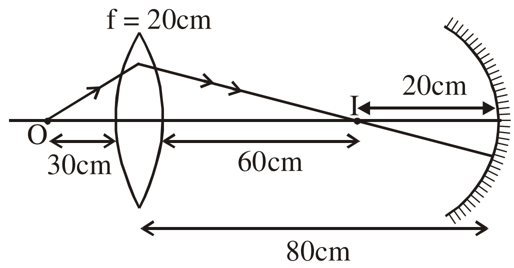


Image formed by lens

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

$$\frac{1}{v} + \frac{1}{30} = \frac{1}{20}$$

v = +60 cm

If image position does not change even when mirror is removed it means image formed by lens is formed at centre of curvature of spherical mirror.

Radius of curvature of mirror = 80 – 60 = 20 cm

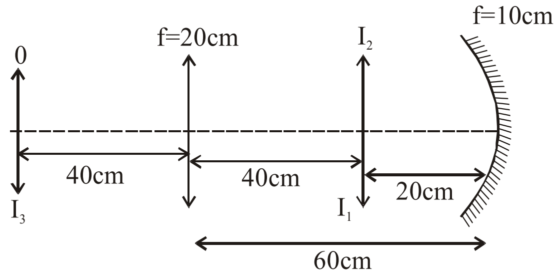
⇒ focal length of mirror f = 10 cm

for virtual image, object is to be kept between focus and pole.

⇒ maximum distance of object from spherical mirror for which virtual image is formed, is 10cm.

13. Allen Ans. is BONUS
Final Ans. by NTA (2)

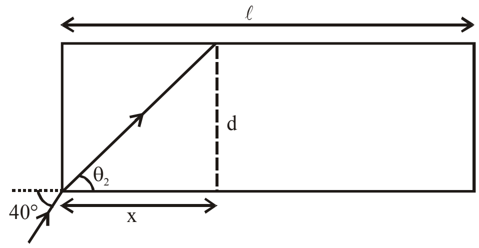
Sol. Note :
There will be 3 phenomenon
(i) Refraction from lens
(ii) Reflection from mirror
(iii) Refraction from lens
After these phenomena. Image will be on object and will have same size.
None of the option depicts so this question is Bonus



1^{st} refraction $u = -40cm; f = +20cm$
$\Rightarrow v = +40$ cm (image I_1)
and $m_1 = -1$
for reflection
$u = -20cm; f = -10cm$
$\Rightarrow v = -20cm$ (image I_2)
and $m_2 = -1$
2^{nd} refraction
$u = -40cm; f = +20cm$
$\Rightarrow v = +40cm$ (image I_3)
and $m_3 = -1$
Total magnification $= m_1 \times m_2 \times m_3 = -1$
and final image is formed at distance 40cm from convergent lens and is of same size as the object

14. Allen Ans. is 1 or 2
Final Ans. by NTA (2)

Sol. Note :
If we approximate the angle θ_2 as 30° initially then answer will be closer to 57000. But if we solve thorougly, answer will be close to 55000.
So both the answers must be awarded.
Detailed solution is as following.



Exact solution
by Snells' law $1.\sin 40° = (1.31)\sin\theta_2$

$$\sin\theta_2 = \frac{.64}{1.31} = \frac{64}{131} \approx .49$$

Now $\tan\theta_2 = \frac{64}{\sqrt{(131)^2 - (64)^2}} = \frac{64}{\sqrt{13065}} \approx \frac{64}{114.3} = \frac{d}{x}$

Now no. of reflections

$$= \frac{2 \times 64}{114.3 \times 20 \times 10^{-6}} = \frac{64 \times 10^5}{114.3}$$

$\approx 55991 \approx 55000$

Approximate solution
By Snells' law $1.\sin 40° = (1.31)\sin\theta_2$

$$\sin\theta_2 = \frac{.64}{1.31} = \frac{64}{131} \approx .49$$

If assume $\Rightarrow \theta_2 \approx 30°$

$$\tan 30° = \frac{d}{x} \Rightarrow x = \sqrt{3}d$$

Now number of reflections

$$= \frac{\ell}{\sqrt{3}d} = \frac{2}{\sqrt{3} \times 20 \times 10^{-6}} = \frac{10^5}{\sqrt{3}}$$

$\approx 57735 \approx 57000$

15. Ans. (2)

Sol. $\frac{1}{f_1} = \frac{1}{2} \times \frac{2}{18} = \frac{1}{18}$

$$\frac{1}{f_2} = \frac{(\mu_1 - 1)}{-18}$$

when μ_1 is filled between lens and mirror

$$P = \frac{2}{18} - \frac{2}{18}(\mu_1 - 1) = \frac{2 - 2\mu_1 + 2}{18}$$

$$= F_m = -\left(\frac{18}{2 - \mu_1}\right)$$

$2 = 6 - 3\mu_1$
$3\mu_1 = 4$
$\mu_1 = 4/3.$

16. Ans. (4)

Sol. Magnification is 2

If image is real, $x_1 = \dfrac{3f}{2}$

If image is virtual, $x_2 = \dfrac{f}{2}$

$\dfrac{x_1}{x_2} = 3:1.$

17. Ans. (4)

Sol. $m = \dfrac{f}{f-u}$

$5 = \dfrac{-40}{-40-u}$

$u = -32$ cm

Option (4)

18. Ans. (4)

Sol. $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

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

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

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

At $v = a$, $m_1 = 1 - \dfrac{a}{f}$

At $v = a + b$, $m_2 = 1 - \dfrac{a+b}{f}$

$m_2 - m_1 = c = \left[1 - \dfrac{a+b}{f}\right] - \left[1 - \dfrac{a}{f}\right]$

$c = \dfrac{b}{f}$

$f = \dfrac{b}{c}$

19. Ans. (4)

Sol. For 1st lens $\dfrac{1}{f_1} = \left(\dfrac{\mu_1 - 1}{1}\right)\left(\dfrac{1}{\infty} - \dfrac{1}{-R}\right) = \dfrac{\mu_1 - 1}{R}$

for 2nd lens $\dfrac{1}{f_2} = \left(\dfrac{\mu_2 - 1}{1}\right)\left(\dfrac{1}{-R} - 0\right) = -\dfrac{\mu_2 - 1}{R}$

$\dfrac{1}{f_{eq}} = \dfrac{1}{f_1} + \dfrac{1}{f_2}$

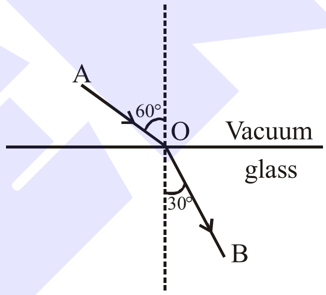
$\dfrac{1}{f_{eq}} = \dfrac{R}{\mu_1 - 1} + \dfrac{R}{-(\mu_2 - 1)} \Rightarrow \dfrac{1}{f_{eq}} = \dfrac{R}{\mu_1 - \mu_2}$

Hence $f_{eq} = \dfrac{\mu_1 - \mu_2}{R}$

20. Ans. (1)

Sol. From Snell's law

$1.\sin 60° = \mu \sin 30°$



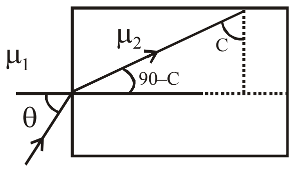
$\Rightarrow \mu = \sqrt{3}$

Optical path = AO + μ(OB)

$= \dfrac{a}{\cos 60°} + \sqrt{3}\dfrac{b}{\cos 30°}$

21. Ans. (2)

Sol.



$\sin c = \dfrac{\mu_1}{\mu_2}$

$\mu_1 \sin\theta = \mu_2 \sin(90° - C)$

$\sin\theta = \dfrac{\mu_2\sqrt{1 - \dfrac{\mu_1^2}{\mu_2^2}}}{\mu_1}$

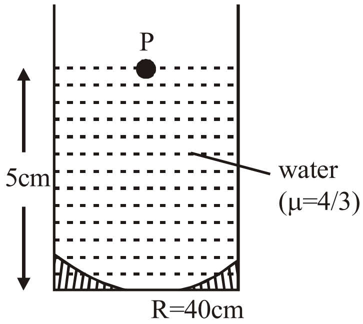
$\theta = \sin^{-1}\sqrt{\dfrac{\mu_2^2 - \mu_1^2}{\mu_1^2}}$

For TIR

$\theta < \sin^{-1}\sqrt{\dfrac{\mu_2^2}{\mu_1^2} - 1}$

22. Ans. (1)

Sol. Light incident from particle P will be reflected at mirror



$$u = -5\text{cm},\ f = -\frac{R}{2} = -20\text{cm}$$

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

$$\boxed{v_1 = +\frac{20}{3}\text{cm}}$$

This image will act as object for light getting refracted at water surface

So, object distance $d = 5 + \frac{20}{3} = \frac{35}{3}\text{cm}$

below water surface.

After refraction, final image is at

$$d' = d\left(\frac{\mu_2}{\mu_1}\right)$$

$$= \left(\frac{35}{3}\right)\left(\frac{1}{4/3}\right)$$

$$= \frac{35}{4} = 8.75\text{cm}$$

$$\approx 8.8\text{cm}$$