

Ray Optics

Question1

A compound microscope has an objective of focal length 1.25 cm and an eyepiece of focal length 5 cm separated by a distance of 7.5 cm . The total magnification produced by the microscope when the final image forms at infinity is

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Options:

A.

6.25

B.

30

C.

120

D.

72.5

Answer: A

Solution:

Given, the focal length of the objective lens is $f_0 = 1.25$ cm

The focal length of the eyepiece is

$$f_e = 5 \text{ cm}$$

The separation between the objective and eyepiece is $L = 7.5$ cm



The distance of this image from the objective lens is

$$v_0 = L - f_e$$

$$v_0 = 7.5 \text{ cm} - 5 \text{ cm} = 2.5 \text{ cm}$$

The lens formula for the objective lens

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$$

$$\frac{1}{u_0} = \frac{1}{2.5 \text{ cm}} - \frac{1}{1.25 \text{ cm}}$$

$$u_0 = -2.5 \text{ cm}$$

The magnification of the objective lens is

$$M_0 = -\frac{v_0}{u_0} = \frac{-2.5 \text{ cm}}{-2.5 \text{ cm}} = 1$$

The magnification of the eyepiece when the final image is at infinity is $M_e = \frac{D}{f_e}$

$$M_e = \frac{25 \text{ cm}}{5 \text{ cm}} = 5$$

The total magnification is $M = M_0 \times M_e$

$$M = 1 \times 5 = 5$$

Question2

The property of light that explains the formation of coloured images due to thick lenses is

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Options:

A.

refraction

B.

dispersion

C.

reflection

D.

total internal reflection

Answer: B

Solution:

Dispersion is the property of light that causes the separation of light into its component colours when passing through a medium, such as thick lens. This happens because different colours(wavelengths) of light are refracted by different amount.

Question3

The angle of a prism made of a material of refractive index $\sqrt{2}$ is 90° . The angle of incidence for a light ray on the first face of the prism such that the light ray suffers total internal reflection at the second face is

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Options:

A.

0°

B.

90°

C.

60°

D.

45°

Answer: B

Solution:

$$\mu = \sqrt{2}, A = 90^\circ$$

For total internal reflection

$$\sin i_C = \frac{1}{\mu} = \frac{1}{\sqrt{2}} = \sin 45^\circ$$

$$\therefore i_C = 45^\circ$$

For total internal reflection to occur at the second face, the angle of incidence at the second face (r_2) must be greater than or equal to the critical angle. To ensure total internal reflection, we consider the limiting case where

$$r_2 = \theta_c = 45^\circ$$

The angle of the prism is related to the angles of refraction at the two faces by

$$A = r_1 + r_2$$

Since $A = 90^\circ$ and $r_2 = 45^\circ$

$$90^\circ = r_1 + 45^\circ$$

$$r_1 = 90^\circ - 45^\circ = 45^\circ$$

Applying Snell's law at the first face,

$$\mu_{\text{air}} \sin i = \mu_{\text{prism}} \sin r_1$$

$$1 \cdot \sin i = \sqrt{2} \sin 45^\circ$$

$$\sin i = \sqrt{2} \cdot \frac{1}{\sqrt{2}}$$

$$= 1 = \sin 90^\circ$$

$$\therefore i = 90^\circ$$

Question4

The total magnification produced by a compound microscope is 24 when the final image is formed at the least distance of distinct vision. If the focal length of the eyepiece is 5 cm , the magnification produced by the objective is

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Options:

A.

4



B.

4.8

C.

120

D.

6

Answer: A

Solution:

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

$$M = M_0 \cdot M_e$$

as we know, $M_e = 1 + \frac{D}{F_e}$

$$M_e = 1 + \frac{25}{5} = 6$$

$$S_o, 24 = M_0 \times 6$$

$$M_0 = 4$$

Question5

An object placed at a distance of 24 cm from a concave mirror forms an image at a distance of 12 cm from the mirror. If the object is moved with a speed of 12 ms^{-1} , then the speed of the image is

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Options:

A. 24 ms^{-1}

B. 3 ms^{-1}

C. 6 ms^{-1}

D. 12 ms^{-1}

Answer: B

Solution:

Given, for concave mirror

$$u = -24 \text{ cm}$$

$$v = -12 \text{ cm}$$

Using the mirror equation,

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

$$\frac{1}{f} = \frac{1}{-12} - \frac{1}{24}$$

$$\frac{1}{f} = \frac{-2-1}{24}$$

$$f = -8 \text{ cm}$$

Magnification m is given by,

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

$$m = \frac{-12}{-24} = \frac{1}{2}$$

The speed of the image v_i is related to the speed of object v_0 by the magnification.

$$v_i = m^2 \cdot v_0$$

$$v_i = \left(\frac{1}{2}\right)^2 \times 12$$

$$v_i = \frac{12}{4} \Rightarrow v_i = 3 \text{ m/s}$$

Question6

When the object and the screen are 90 cm apart, it is observed that a clear image is formed on the screen when a convex lens is placed at two positions separated by 30 cm between the object and the screen. The focal length of the lens is

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Options:

A. 21.4 cm



- B. 20 cm
- C. 30 cm
- D. 30.8 cm

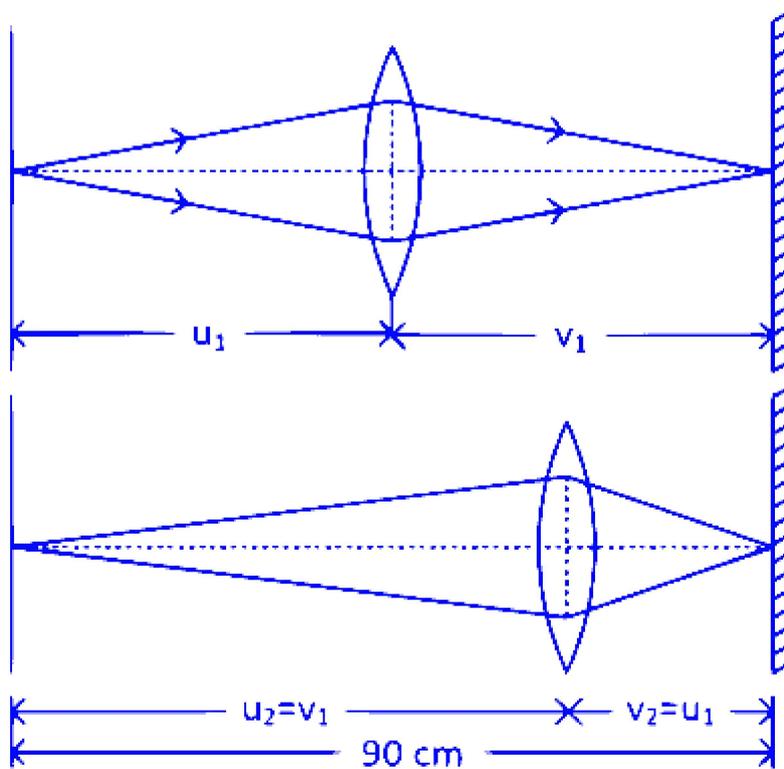
Answer: B

Solution:

The image of the object can be located on the screen for two-positions of convex lens such that u and v are exchanged.

The separation between two positions of the lens is,

$$d = 30 \text{ cm}$$



From the figure,

$$u_1 + v_1 = 90 \text{ cm}$$

$$v_1 - u_1 = 30 \text{ cm}$$

On solving Eq. (i) and Eq. (ii), we get

$$v_1 = 60 \text{ cm}$$

$$u_1 = 30 \text{ cm}$$

From lens formula,

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

$$\frac{1}{f} = \frac{1}{60} - \frac{1}{-30}$$

$$\frac{1}{f} = \frac{1+2}{60} \Rightarrow f = 20 \text{ cm}$$

Question7

When a monochromatic light is incident on a surface separating two media, both the reflected and refracted lights have the same

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Options:

- A. frequency
- B. wavelength
- C. velocity
- D. amplitude

Answer: A

Solution:

When monochromatic light strikes a surface that separates two different media, both the reflected and refracted light will have the same frequency as the original light.

This phenomenon occurs because the reflection and refraction processes involve the interaction of light with the atoms at the boundary. These atoms act like oscillators and are compelled to vibrate at the frequency of the incoming light. Consequently, the light emitted by these oscillating atoms—whether reflected or refracted—retains the same frequency as the incident light.

Question8

The power of a thin convex lens placed in air is +4 D . The refractive index of the material of the convex lens is $\frac{3}{2}$. If this convex lens is immersed in a liquid of refractive index $\frac{5}{3}$, then

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Options:

- A. it behaves like a convex lens of focal length 75 cm .
- B. it behaves like a convex lens of focal length 125 cm .
- C. it behaves like a concave lens of focal length 125 cm .
- D. it behaves like a concave lens of focal length 75 cm .

Answer: C

Solution:

The power of a thin convex lens when placed in air is given as +4 D, with the refractive index of the lens material being $\frac{3}{2}$. Let's explore how the lens behaves when immersed in a liquid with a refractive index of $\frac{5}{3}$.

Lens in Air

Power Formula:

$$P_{\text{air}} = \frac{1}{f}$$

Here, the power $P_{\text{air}} = 4 \text{ D}$, thus:

$$f = \frac{1}{4} \text{ m} = 25 \text{ cm}$$

Lens Maker's Formula in Air:

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

Substituting values:

$$\frac{1}{f} = \left(\frac{3}{2} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$4 = \frac{1}{2} \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{R_1} - \frac{1}{R_2} = 8$$

Lens in Liquid

When the lens is immersed in a liquid of refractive index $\frac{5}{3}$, the effective focal length f' changes:

Refractive Index Ratio:

$$\frac{\mu_g}{\mu_w} = \frac{\frac{3}{2}}{\frac{5}{3}} = \frac{9}{10}$$



Modified Lens Maker's Formula in Liquid:

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

Substituting values:

$$\frac{1}{f'} = \left(\frac{9}{10} - 1 \right) \times 8$$

$$\frac{1}{f'} = (-0.1) \times 8 = -0.8$$

New Focal Length:

$$f' = -\frac{1}{0.8} = -125 \text{ cm}$$

The negative focal length indicates that the lens behaves like a concave lens of focal length 125 cm when immersed in this liquid.

Question9

The refractive index of the material of a small angled prism is 1.6. If the angle of minimum deviation is 4.2° , the angle of the prism is

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Options:

A. 4.2°

B. 7°

C. 4.8°

D. 9°

Answer: B

Solution:

Given:

Refractive index, $\mu = 1.6$

Angle of minimum deviation, $\delta_D = 4.2^\circ$

We wish to find the angle of the prism, denoted as A .

The formula for the angle of minimum deviation is:

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



Rearranging this formula to solve for A , we have:

$$A = \frac{\delta_D}{\mu - 1}$$

Substituting the known values:

$$A = \frac{4.2}{1.6 - 1}$$

$$A = \frac{4.2}{0.6}$$

Thus, the angle of the prism A is:

$$A = 7^\circ$$

Question10

The Brewster angle for air to glass transition of light is (Refractive index of glass = 1.5)

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Options:

A. $\sin^{-1} \left(\frac{3}{2} \right)$

B. $\cos^{-1} \left(\frac{3}{2} \right)$

C. $\tan^{-1} \left(\frac{3}{2} \right)$

D. $\cos^{-1} \left(\frac{2}{3} \right)$

Answer: C

Solution:

To determine the Brewster angle for the transition of light from air to glass, we start by noting the refractive index of glass, which is given as 1.5.

The Brewster angle θ is related to the refractive index μ through the following relationship:

$$\mu = \tan \theta$$

Substituting the given refractive index into the equation:

$$1.5 = \tan \theta$$

This can also be expressed as:

$$\frac{3}{2} = \tan \theta$$

Therefore, we find the Brewster angle by taking the inverse tangent:

$$\theta = \tan^{-1}\left(\frac{3}{2}\right)$$

Question11

When an object of height 12 cm is placed at a distance from a convex lens, an image of height 18 cm is formed on a screen. Without changing the positions of the object and the screen. If the lens is moved towards the screen, another clear image is formed on the screen. The height of this image is

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Options:

- A. 4 cm
- B. 6 cm
- C. 8 cm
- D. 10 cm

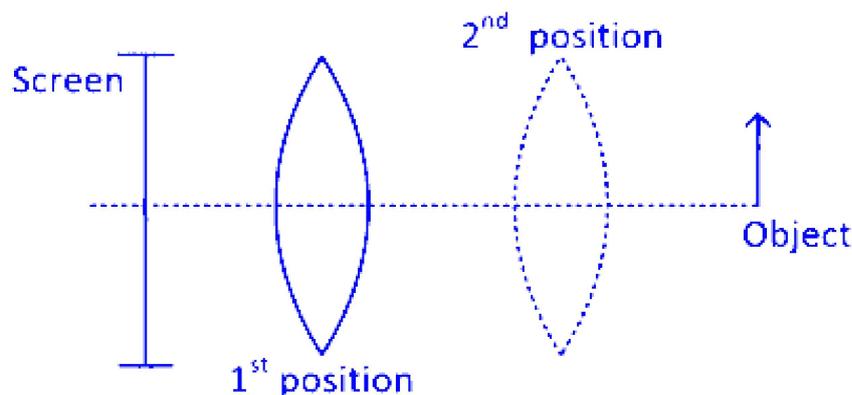
Answer: C

Solution:

Given,

Object height, $O = 12$ cm

First image height, $I_1 = 18$ cm



We know that product of magnification

$$m_1 m_2 = 1$$



(where m_1 = when image height is I_1 and m_2 = when image height is I_2)

$$m_1 = \frac{I_1}{O} = \frac{18}{12} = \frac{3}{2}$$

$$m_1 m_2 = 1$$

$$\frac{3}{2} m_2 = 1$$

$$\Rightarrow m_2 = \frac{2}{3}$$

$$\text{Now, } m_2 = \frac{I_2}{O}$$

$$\frac{2}{3} = \frac{I_2}{12}$$

$$I_2 = \frac{2 \times 12}{3}$$

$$I_2 = 8 \text{ cm}$$

New height of image.

Question12

A thin plano-convex lens of focal length 73.5 cm has a circular aperture of diameter 8.4 cm . If the refractive index of the material of the lens is $\frac{5}{3}$, then the thickness of the lens is nearly

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Options:

A. 2.4 cm

B. 2.4 mm

C. 1.8 mm

D. 1.8 cm

Answer: C

Solution:

Focal length of plano-convex



$$= 73.5 \text{ cm}$$

Diameter of circular aperture = 8.4 cm

$$r = 4.2 \text{ cm}$$

Refractive index, $\mu = \frac{5}{3} = 1.66$

Radius of curvature and focal length relation is

$$f = \frac{R}{\mu - 1}$$

$$\Rightarrow R = f(\mu - 1)$$

$$R = 73.5 \times 0.66$$

$$R = 48.5$$

Now using the relation

$$R = \frac{r^2}{2x} [x = \text{thickness of lens}]$$

$$48.5 = \frac{(4.2)^2}{2x}$$

$$x = \frac{17.64}{97} \text{ cm}$$

$$x = 0.181 \text{ cm}$$

$$x = 1.8 \text{ mm}$$

Question13

A small angled prism is made of a material of refractive index $\frac{3}{2}$. The ratio of the angles of minimum deviations when the prism is placed in air and in water of refractive index $\frac{4}{3}$ is

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Options:

A. 4 : 1

B. 3 : 4



C. 2 : 3

D. 1 : 3

Answer: A

Solution:

Given, $\mu_{\text{glas}} = (3/2)$

As we know that, $\delta_m = (\mu - 1)A$

Here, A is prism angle

Now, $\delta_{m_2} = \left(\frac{3}{2} - 1\right)A = \frac{1}{2}A$

$$\delta_{m_2} = \left(\frac{\frac{3}{2}}{\frac{4}{3}} - 1\right)A = \frac{1}{8}A$$

$$\Rightarrow \frac{\delta_{m_m}}{\delta_{m_2}} = \frac{\frac{1}{2}}{\frac{1}{8}} = \frac{1}{2} \times 8 = 4 : 1$$

Question14

If you are using eye glasses of power 2 D, your near point is

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Options:

A. 25 cm

B. 50 cm

C. 43 cm

D. 32 cm

Answer: B

Solution:

Given, power of lens = 2D

Focal length = $\frac{1}{2}$ m



$$= 0.5 \text{ m} = 50 \text{ cm}$$

Hence, near point will also be 50 cm .

Question15

For a combination of two convex lenses of focal lengths f_1 and f_2 to act as a glass slab, the distance of separation between them is

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Options:

A.

$$t_1 + t_2$$

B.

$$f_1 \sim f_2$$

C.

$$\frac{t_1+t_2}{2}$$

D.

$$\frac{f_1 \sim f_2}{2}$$

Answer: A

Solution:

Given that,

Lens 1 has focal length = f_1

Lens 2 has focal length = f_2 ,

Here, when two convex lenses are combine to act as a glass lab, the distance of separation between them is the sum of their focal length, so the correct representation of the formula is $f_1 + f_2$.



Question16

If a ray of light passes through an equilateral prism such that the angle of incidence and the angle of emergence are both equal to 70% of the angle of the prism, then the angle of minimum deviation is

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Options:

A. 36°

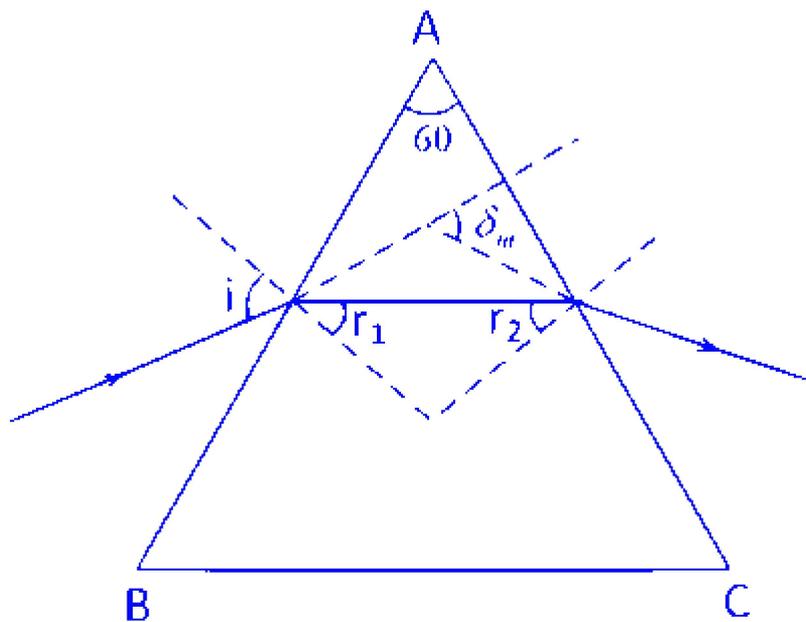
B. 18°

C. 42°

D. 24°

Answer: D

Solution:



For an equilateral prism, the angle of the prism (A) is 60° .

If angles of incidence (i) and emergence

(e) are both 70% of A , then

$$i = e = 0.7 \times A = 0.7 \times 60^\circ = 42^\circ$$

The angle of minimum deviation (δ_m) occurs when the light path inside the prism is parallel to the base, which implies that $i = e$

Since, $i = e$, we have



$$\begin{aligned}\delta_m &= i + e - A \\ &= 42^\circ + 42^\circ - 60^\circ \\ &= 84^\circ - 60^\circ\end{aligned}$$

$$\delta_m = 24^\circ$$

The angle of minimum deviation is 24° .

Question17

The angles of incidence and emergence of a light ray passing through a prism of angle A are i and e respectively. The total deviation produced by the prism is

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Options:

- A. $i + e + A$
- B. $i + e - A$
- C. $i + e - 2A$
- D. $i + e + 2A$

Answer: B

Solution:

Given,

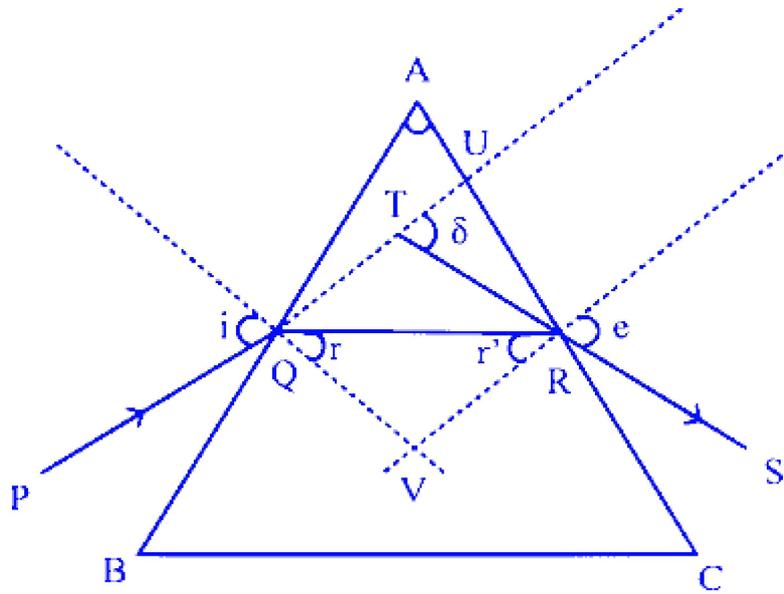
Angle of incidence = i

Angle of emergence = e

Angle of prism = A

Let angle of deviation = δ





PQ = incident ray
 RS = emergent ray

Angle of deviation = the angle between the direction of incident ray and the emergent ray.

$$\begin{aligned} \delta &= \angle UTS = \angle TQR + \angle TRQ \text{ [From } \triangle TQR] \\ \delta &= (\angle TQV - \angle RQV) + (\angle TRV - \angle QRV) \\ \delta &= (i - r) + (e - r) \quad \dots (i) \end{aligned}$$

Now sum of angle of quadrilateral $AQVR = 360^\circ$

$$\angle AQV = \angle ARV = 90^\circ$$

$$\text{So, } \angle A + \angle QVR = 180^\circ$$

From $\triangle QRV$

$$\begin{aligned} r + r' + \angle QVR &= 180^\circ \\ r + r' &= A \quad \dots (ii) \end{aligned}$$

From Eq. (i)

$$\delta = i + e - (r + r') \quad \dots (iii)$$

Put the value of $(r + r')$ in Eq. (iii)

$$\delta = i + e - A$$

Question 18

An empty tank has concave mirror as its bottom. When sunlight falls normally on the mirror, it is focussed at a height of 32 cm from the mirror. If the tank is filled with water upto a height of 20 cm, then the sunlight focusses at (refractive index of water = $\frac{4}{3}$)

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Options:

- A. 16 cm above water level
- B. 9 cm above water level
- C. 16 cm below water level
- D. 9 cm below water level

Answer: B

Solution:

Given,

Image distance, $v = -32$ cm

Object (sun) distance, $u = \infty$

Tank is filled upto = 20 cm

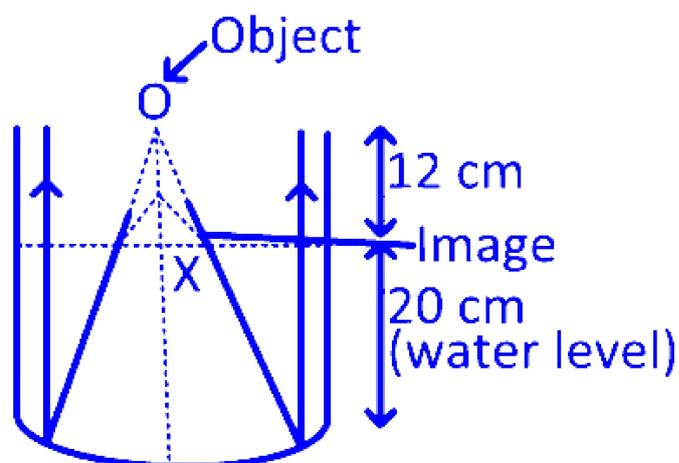
Refractive index of water = $\frac{4}{3}$

Using mirror formula,

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{-1}{32} + \frac{1}{\infty}$$
$$f = -32 \text{ cm}$$

When water is filled upto a height ($h = 20$ cm), the image formed by mirror will act as virtual object for water surface.

The image formed by virtual object.



$$\frac{\mu_{\text{water}}}{\mu_{\text{air}}} = \frac{\text{Actual height}}{\text{Apparent height}}$$
$$\frac{4}{3} = \frac{XO}{XI} \Rightarrow XO = 12 \text{ cm}$$
$$\frac{4}{3} = \frac{12}{XI} = 9 \text{ cm}$$

Sunlight will focus at 9 cm above water level.

