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Class: 12
Subject: Physics
Topic: Ray Optics
No. of Questions: 30

1. Why a diamond glitters in a brightly lit room, but not in a dark room?

   Sol.

   A diamond glitters in a brightly lit room because light entering the diamond from any face suffers multiple total internal reflections and does not come out. The diamond appears illuminated from inside. This would not happen in a dark room

2. Explain why a crack in a window pane appears silvery.

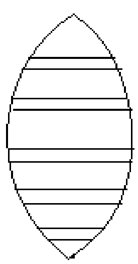
   Sol.
   A crack in a window pane appears silvery on account of total internal reflection of light in the crack.

3. Explain why the bubbles of air rising up in a water tank appear silvery when viewed from top.

   Sol.
   The bubbles of air rising up in a water tank appear silvery when viewed from top again on account of total internal reflection of light from the bubble.

4. A lens shown in Fig. is made of two different materials. A point object is placed on the principal axis of the lens. How many images will be obtained?

   Sol.



   As the lens is made of two different materials, it has two refractive indices and hence tow different focal lengths. Hence two distinct images will be obtained.

5. Why does a diamond shine?

   Sol.

   The brilliance of diamond is due to total internal reflection of light. μ for diamond is 2.42, so that cirtical angle for diamond air interface is $C = 24.4^{o}$(from $\sin C = 1/\mu$). The diamond is cut suitably so that light entering the diamond from any face suffers multiple total internal reflections at the various faces, and remains within the diamond. Hence the diamond sparkles.

6. A thin lens has focal length f and its aperture has diameter d. It forms an image of intensity I. Now the central part of the aperture up to diameter d/2 is blocked by an opaque paper. What will be the focal length and image intensity now?

Sol.

On blocking the central part of the lens, its focal length does not change. It remains f only.

Intensity of image is directly proportional to the area of the lens through which light passes. Now, initial area $A_1 = \pi\left(\frac{d}{2}\right)^2 = \pi d^2/4$

On blocking the central part of the aperture up to diameter d/2, the area left out is

$$A_2 = \pi\left(\frac{d}{2}\right) - \pi\left(\frac{d}{4}\right)^2 = \pi\frac{d^2}{4} - \frac{\pi d^2}{16} = \frac{3\pi d^2}{16}$$

As $\frac{I_2}{I_1} = \frac{A_2}{A_1} = \frac{3\pi d^2 4}{16\pi d^2} = \frac{12}{16} = \frac{3}{4}$ $\therefore I_2 = \frac{3}{4}I_1$

7. Why is there no dispersion of light refracted through a rectangular glass slab?

Sol.

After refraction at two parallel faces of a glass slab, a ray of light emerges in aa direction parallel to the direction of incidence of white light on the slab. As rays of all colours emerge in the same direction (of incidence of white light), hence there is no dispersion, but only lateral displacement.

8. What colour do you observe when white light passes through a blue and yellow filter?

Sol.

When white light passes through a blue and yellow filter, we get green colour with a tinge of blue and yellow. This is because blue and yellow colours transmitted from these filters mix to produce green colour.

9. List some advantages of a reflecting telescope, especially for high resolution astronomy.

Sol.

A. There is no chromatic aberration as the objective is a mirror.
B. Spherical aberration is reduced using mirror objective in the form of a paraboloid.
C. Image is brighter compared to that in a refracting telescope.
D. Mirror requires grinding and polishing of only one side.
E. High resolution is achieved by using a mirror of large aperture.

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10. A reflecting type telescope has a large mirror for its objective with radius of curvature equal to 80 cm. What is the magnifying power of telescope, especially for high resolution astronomy?

Sol. Here, R 80 cm.

Focal length of objective mirror $fo = \frac{R}{2} = \frac{80}{2} = 40\ cm$. and $f_e = 1.6\ cm$.

As Magnifying power, $m = \frac{f_o}{f_e}$ $\therefore m = \frac{40}{1.6} = 25$

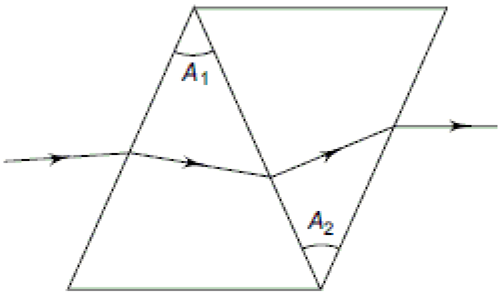
11. A thin prism P_1 with angle 4° is made from a glass of refractive index 1.54 combined with another thin prism P_2 made from a glass of refractive index 1.72 to produce dispersion without deviation. The angle of prism P_2 is

A. 5.33°
B. 4°
C. 3°
D. 2.6°

Right Answer Explanation:

For a prism with a very small refracting angle A, the deviation is given by (Fig.)

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



$\therefore$ Deviation produced by the first prism is

$$\delta_1 = (\mu_1 - 1) A_1$$

and that produced by the second prism is

$$\delta_2 = (\mu_2 - 1) A_2$$

The total deviation will be zero if $\delta_1 + \delta_2 = 0$. The emergent ray will then be parallel to the incident ray (see figure). Thus

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

The negative sign shows that the refracting angles of the two prisms are in opposite directions. Thus

$$|A_2| = \frac{(\mu_1 - 1) A_1}{(\mu_2 - 1)} = \frac{(1.54 - 1) \times 4°}{(1.72 - 1)} = 3°,$$

which is choice (3).

12. When a ray of light enters a glass slab from air,

A. its wavelength decreases
B. its wavelength increases
C. its frequency increases
D. neither wavelength nor frequency changes

Right Answer Explanation:
Since the refractive index of glass is greater than that of air, the speed of light is less in glass than in air. The frequency of light never changes due to reflection or refraction. Since v = $\nu\lambda$ or λ = v/ν, wavelength λ decreases because speed v decreases.
Hence the correct choice is (1).

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13. Spherical aberration in a thin lens can be reduced by

A. using a monochromatic light
B. using a doublet combination
C. using a circular annular mask over the lens
D. increasing the size of the lens

Right Answer Explanation:
Using monochromatic light eliminates chromatic aberration. Using a doublet combination minimizes chromatic aberration. Increasing the size of the lens increases its resolving power. To reduce spherical aberration, the aperture (i.e. exposed portion of the lens) must be decreased. Hence the correct choice is (3).

14. A real image of a distant object is formed by a plano-convex lens on its principal axis. The spherical aberration

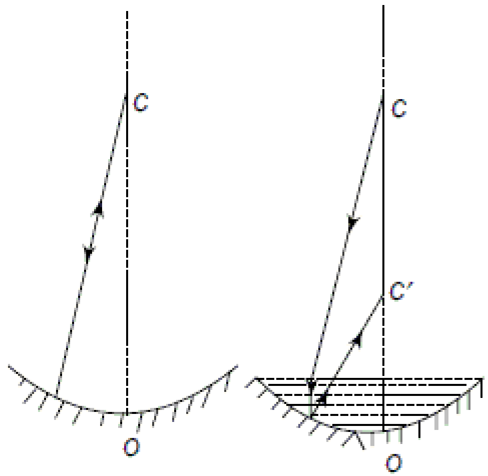
A. is absent
B. is smaller if the curved surfaces of the lens faces the object
C. is smaller if the plane surface of the lens faces the object
D. is the same whichever side of the lens faces the object

Right Answer Explanation:
Spherical aberration is reduced if the total deviation is distributed over the two surfaces of the lens. If the plane surface of the lens faces the object, all the deviation takes place at the curved surface. Hence spherical aberration is not reduced. Hence the correct choice is (2).

15. A concave mirror is placed on a horizontal table, with its axis directed vertically upwards. Let O be the pole of the mirror and 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 and will remain at C
B. real and located at a point between C and infinity
C. virtual and located at a point between C and O
D. real and located at a point between C and O

Right Answer Explanation:
The figure below shows the ray diagram for the image formation in the two cases. When the mirror is filled with water, the image is real and located at C’ which is between O and C. Hence the correct choice is (4).



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

A. convergent lens of focal length 3.5R
B. convergent lens of focal length 3R
C. divergent lens of focal length 3.5R
D. divergent lens of focal length 3R

Right Answer Explanation:

The focal length f of a lens of refractive index μ_2 surrounded by a medium of refractive index μ_1 is given by

$$\frac{1}{f} = \left(\frac{\mu_2 - \mu_1}{\mu_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Now, for a concave lens, $f = -f$. Given $R_1 = R$ and $R_2 = -R_1 = -R$. Also $\mu_2 = 1.5$ and $\mu_1 = 1.75$. Hence, we have

$$-\frac{1}{f} = \left(\frac{1.5 - 1.75}{1.75}\right)\left(\frac{1}{R} + \frac{1}{R}\right) = \left(\frac{-0.25}{1.75}\right)\left(\frac{2}{R}\right)$$

which gives $f = 3.5\,R$. Since the focal length is positive, the lens acts like a convergent lens. Hence the correct choice is (1).

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17. In a compound microscope, the intermediate image is

    A. real, inverted and magnified
    B. real, erect and magnified
    C. virtual, erect and magnified
    D. virtual, erect and reduced

Right Answer Explanation:
In a compound microscope, the object is placed just beyond the focus of the objective. Hence the image formed by the object is real, inverted and highly magnified. Thus the correct choice is (1).

18. A hollow double concave lens is made of a very thin transparent material. It can be filled with air or either of the 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

Right Answer Explanation:
Since the lens is concave, $f = -f$. Also $R_2 = -R_1$.
Therefore, we have

$$-\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

where n_2 is the refractive index of the liquid filling the lens and n_1 that of the liquid in which the lens is immersed. It will act as a divergent lens (i.e. f will remain negative) if $n_2 > n_1$.
Hence the correct choice is (4).

19. When a glass prism of refracting angle 60° is immersed in a liquid, its angle of minimum deviation is 30°. The critical angle of glass with respect to the liquid medium is

    A. 42°
    B. 45°
    C. 50°
    D. 52°

Right Answer Explanation:

The refractive index of the prism with respect to the liquid in which it is immersed is given by

$$\mu = \frac{\sin\left\{\frac{1}{2}(A+\delta_m)\right\}}{\sin\frac{1}{2}(A)}$$

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

$$= \frac{\sin 45^\circ}{\sin 30^\circ} = \sqrt{2}$$

The critical angle i_c is given by

$\sin i_c = \frac{1}{\sqrt{2}}$, which give $i_c = 45^\circ$. Hence the correct choice is (2).

20. A prism is made of a material of refractive index $\sqrt{3}$. The angle of the prism is A. If the angle of minimum deviation is equal to the angle of the prism, then the value of A is

A. 30°
B. 45°
C. 60°
D. 75°

Right Answer Explanation:

Given $\mu = \sqrt{3}$ and $\delta_m = A$. Now

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

$$= \frac{\sin\left(\frac{A}{2}\right)\cos\left(\frac{A}{2}\right)}{\sin\left(\frac{A}{2}\right)} = 2\cos\left(\frac{A}{2}\right)$$

$$\therefore\ 2\cos\left(\frac{A}{2}\right) = \mu = \sqrt{3} \text{ or } \cos\left(\frac{A}{2}\right) = \frac{\sqrt{3}}{2}$$

or $\frac{A}{2} = 30^\circ$ or $A = 60^\circ$

Hence the correct choice is (3).

21. Light is incident at an angle α on one planar end of a transparent cylindrical rod of refractive index **n**. The least value of **n** so that the light entering the rod does not emerge from the curved suface of the rod for any value of α is

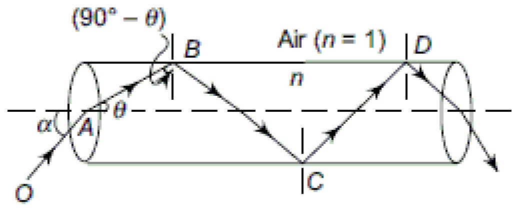
A. $\frac{4}{3}$
B. $\sqrt{2}$
C. 1.5
D. $\sqrt{3}$

Right Answer Explanation:

Refer to Fig.

Ray OA is incident at an angle α at the planar face of the cylindrical rod. Let θ be the angle of refraction. From Snell's law, we have

$$n = \frac{\sin\alpha}{\sin\theta} \quad \text{or} \quad \sin\theta = \frac{\sin\alpha}{n} \qquad (1)$$



The ray AB is incident at point B of the curved surface of the cylinder at an angle $(90° - \theta)$. This ray is travelling in a denser medium of refractive index n and is incident at the cylinder-air interface at point B. The ray will not emerge from the curved surface if it suffers total internal reflection at B. For this to happen $(90° - \theta) \geq i_c$, the critical angle or

$$\sin(90° - \theta) \geq \sin i_c \text{ or } \cos\theta \geq \sin i_c$$

or $$(1 - \sin^2\theta)^{1/2} \geq \sin i_c$$

or $$1 - \sin^2\theta \geq \sin^2 i_c \qquad (2)$$

The critical angle is given by

$$\sin i_c = \frac{1}{n} \qquad (3)$$

Using Eqs. (1) and (3) in Eq. (2) we get

$$1-\frac{\sin^2\alpha}{n^2}\geq\frac{1}{n^2}\text{ or } n^2-\sin^2\alpha\geq 1$$

or $$n^2\geq(1+\sin^2\alpha)$$

Since the maximum value of $\sin^2\alpha=+1$, it follows that

$$n_{\min}^2\geq 2 \quad\text{or}\quad n_{\min}\geq\sqrt{2}$$

This is the minimum value of refractive index of the cylindrical rod for the ray AB to suffer total internal reflection at point B. By symmetry, ray BC will be totally reflected along CD suffering another total internal reflection at D and so on until the ray finally emerges from the opposite planar face of the rod.

22. A square wire of side 3.0 m is placed 25 cm from a concave mirror of focal length 10 cm. The area enclosed by the image of the wire is

A. 1 cm^2
B. 4 cm^2
C. 16 cm^2
D. 25 cm^2

Right Answer Explanation:

$u = -25$ cm and $f = -10$ cm. The distance of the image is given by

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-10} - \frac{1}{-25} \quad \text{or} \quad v = -\frac{3}{50} \text{ cm}$$

Area of the object wire is $3.0 \times 3.0 = 9.0$ cm^2. The area magnification is given by

$$\frac{\text{area of image}}{\text{area of object}} = (\text{linear magnification})^2$$

$$= \frac{v^2}{u^2} = \left(\frac{50}{3 \times 25}\right)^2 = \frac{4}{9}$$

Therefore, the area enclosed by image is

$$\frac{4}{9} \times 9 \text{ cm}^2 = 4 \text{ cm}^2,$$

which is choise (2).

23. A convex lens and a concave lens are placed in contact. The ratio of the magnitude of the power of the convex lens to that of the concave lens is 4 : 3. If the focal length of the convex lens is 12 cm, the focal length of the combination will be

A. 16 cm
B. 24 cm
C. 32 cm
D. 48 cm

Right Answer Explanation:

Given $f_1 = +12$ cm and $\frac{|P_1|}{|P_2|} = \frac{4}{3}$ or $\frac{|f_2|}{|f_1|} = \frac{4}{3}$

Since f_2 is negative, $\frac{f_2}{f_1} = -\frac{4}{3}$. Hence

$$f_2 = -\frac{4}{3} f_1 = -\frac{4}{3} \times 12 = -16 \text{ cm}$$

The focal length F of the combination is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{12} + \frac{1}{-16} = \frac{1}{48}$$

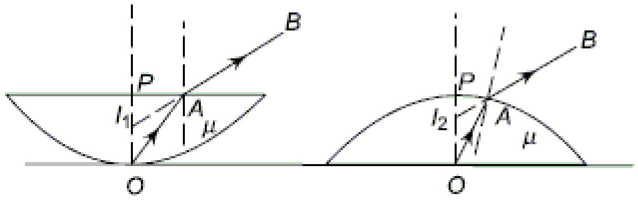
which gives $F = 48$ cm. Hence the correct choice is (4).

24. A plano-convex lens has thickness 4 cm. When placed on a horizontal table with the curved face in contact with it, the apparent depth of the bottom-most point of the lens is found to be 3 cm. If the lens is inverted such that the plane face is in contact with the table, the apparent depth of the centre of the plane face of the lens is found to be $\frac{25}{8}$ cm. The focal length of the lens is

A. 25 cm
B. 50 cm
C. 75 cm
D. 100 cm

Right Answer Explanation:

Refer to Fig.



(1) (2)

When the curved face of the lens is in contact with the table, the virtual image of the bottom-most point O of the lens is formed at I_1 due to refraction at the plane surface as shown in Fig. (1).

Real depth = 4 cm and apparent depth = 3 cm. Hence

$$\mu = \frac{4}{3}$$

When the plane face of the lens is in contact with the table, the image of the centre O of the plane face of the lens is formed at I_2 due to refraction at the curved face as shown in Fig. (2). For refraction at this face, we have

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

where $\mu_1 = 1, \mu_2 = \mu, u = OP = -4$ cm, and $v = OI_2 = -\frac{25}{8}$ cm. Putting these values, we get

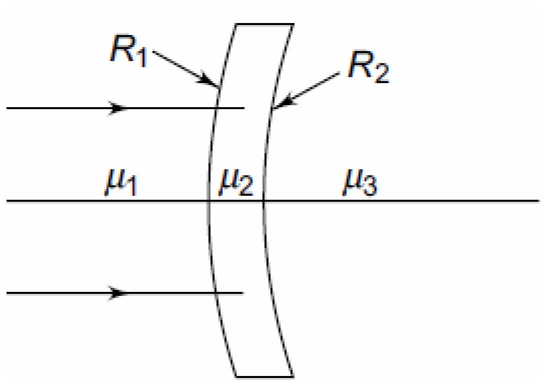
$$-\frac{8}{25} - \frac{\mu}{-4} = \frac{1-\mu}{R}$$

Putting $\mu = \frac{4}{3}$ and solving we get $R = 25$ cm. Now, the focal length of the plano-convex lens is given by

$$\frac{1}{f} = (\mu - 1)\frac{1}{R} = \left(\frac{4}{3} - 1\right) \times \frac{1}{25} = \frac{1}{75}$$

or $\qquad f = 75$ cm.

25. The figure below shows a lens having radii of curvature R_1 and R_2 and $\mu_1 < \mu_2 < \mu_3$. If the thickness of the lens is negligible and $R_1 = R_2 = R$, the focal length of the lens will be



A. $f = \frac{\mu_3 R}{(\mu_3 - \mu_1)}$

B. $f = \frac{\mu_2 R}{(\mu_3 - \mu_1)}$

C. $f = \frac{\mu_1 R}{(\mu_3 - \mu_2)}$

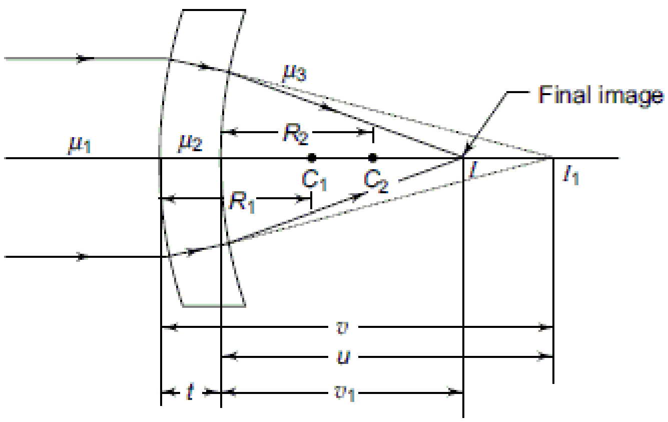
D. $f = \frac{(\mu_2 - \mu_1) R}{(\mu_3 - \mu_1)}$

Right Answer Explanation:

Refer to Fig.

Refraction at the first surface: $u = -\infty$, $v = +v$ and $R = +R_1$. We have

$$\frac{\mu_2}{v} - \frac{\mu_1}{-\infty} = \frac{\mu_2 - \mu_1}{R_1}$$



or $$\frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R_1} \quad \text{(i)}$$

Refraction at the second surface: $u = v - t = v$ ($\because t$ is negligible),

$v = +v_1$ and $R = +R_2$. We have

$$\frac{\mu_3}{v_1} - \frac{\mu_2}{v} = \frac{\mu_3 - \mu_2}{R_2} \quad \text{(ii)}$$

Since the incident ray is parallel to the principal axis, $v_1 = f$, the focal length of the lens and using $v_1 = f$ (i) in (ii), we get

$$\frac{\mu_3}{f} - \frac{\mu_2 - \mu_1}{R_1} = \frac{\mu_3 - \mu_2}{R_2}$$

or $$\frac{1}{f} = \left(\frac{\mu_2 - \mu_1}{\mu_3}\right) \cdot \frac{1}{R_1} + \left(\frac{\mu_3 - \mu_2}{\mu_3}\right) \cdot \frac{1}{R_2} \quad \text{(iii)}$$

This is the expression for the focal length. If $R_1 = R_2$ we get [put $R_1 = R_2 = R$ in (iii)]

$$\frac{1}{f} = \left(\frac{\mu_3 - \mu_1}{\mu_3}\right)\frac{1}{R}$$

So the correct choice is (1).

26. 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 point O and PO = OQ. The distance PO is equal to

A. 5 R
B. 3 R
C. 2 R
D. 1.5 R

Right Answer Explanation:

Using the formula for a spherical surface

$$\frac{\mu_a}{u}+\frac{\mu_g}{v}=\frac{\mu_g-\mu_a}{R}$$

we have $\frac{1.0}{u}+\frac{1.5}{u}=\frac{1.5-1.0}{R}$ (since $v = u$)

which gives $u = 5R$. Hence the correct choice is (1).

27. An eye specialist prescribes spectacles having a combination of a convex lens of focal length 40 cm in contact with a concave lens of local length 25 cm. The power of this lens combination is

A. + 1.5 D
B. 1.5 D
C. + 6.67 D
D. 6.67 D

Right Answer Explanation:

Power of the lens combination is

$$P = P_1 + P_2 = \frac{1}{f_1\,(\text{in m})}+\frac{1}{f_2\,(\text{in m})}$$

$$= \frac{1}{+0.40\text{ m}}+\frac{1}{-0.25\text{ m}}$$

$$= -1.5\text{ m}^{-1} = -1.5\text{ D},$$

which is choice (2).

28. The size of the image of an object, which is at infinity, as formed by a convex lens of focal length 30 cm is 1.6 cm. If a concave lens of focal length 20 cm is placed between the convex lens and the image at a distance of 26 cm from the convex lens, the size of the final image will be

A. 0.8 cm
B. 1.2 cm
C. 2.0 cm
D. 2.4 cm

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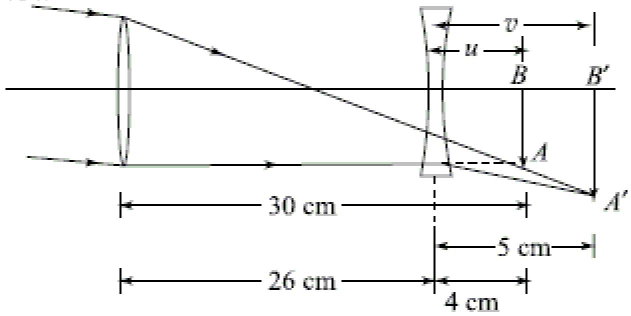
Right Answer Explanation:

Refer to the Fig. AB is the image of size 1.6 cm formed by the convex lens at its focal plane. It serves as the virtual object for the concave lens. $A'B'$ is the final image.

For concave lens, $f = -20$ cm, $u = +4$ cm; $v = ?$. Now



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

or $$\frac{1}{v} - \frac{1}{4} = -\frac{1}{20}$$

which gives $v = 5$ cm. Thus the final image at a distance of 5 cm from the concave lens. Now

$$\frac{A'B'}{AB} = \frac{v}{u}$$

or $$\frac{A'B'}{1.6\text{ cm}} = \frac{5\text{ cm}}{4\text{ cm}}$$

or $A'B' = 2.0$ cm. Hence the correct choice is (3).

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29. In the visible region, the dispersive powers and the mean angular deviations for crown and flint glass prisms are ω and $\omega\Gamma$ and d and d' respectively. When the two prisms are combined, the condition of zero dispersion by the combination is

A. $\sqrt{\omega d} + \sqrt{\omega' d'} = 0$
B. $\omega' d + \omega d' = 0$
C. $\omega d - \omega d' = 0$
D. $(\omega d)^2 + (\omega' d')^2 = 0$

Right Answer Explanation:

Mean angular deviations produced by crown and flint glass prisms respectively are

$$d = (\mu - 1) A \text{ and } d' = (\mu' - 1) A'$$

Their dispersive powers are

$$\omega = \frac{(\mu_v - \mu_r)}{(\mu - 1)} \text{ and } \omega' = \frac{(\mu'_v - \mu'_r)}{(\mu' - 1)}$$

Their angular dispersions respectively are

$$D = (\mu_v - \mu_r) A \text{ and } D' = (\mu'_v - \mu'_r) A'$$

When the prisms are combined, the dispersion by the combination will be zero if

$$D + D' = 0$$

or $$(\mu_v - \mu_r) A + (\mu'_v - \mu'_r) A' = 0$$

or $$\frac{(\mu_v - \mu_r)}{(\mu - 1)} (\mu - 1) A + \frac{(\mu'_v - \mu'_r)}{(\mu' - 1)} (\mu' - 1) A' = 0$$

or $\omega d + \omega' d' = 0$, which is choice (3).

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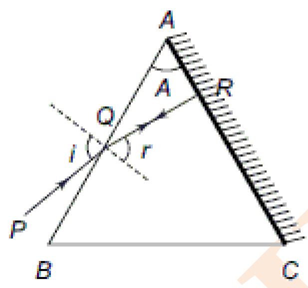
30. One face of a glass prism is silver polished. A light ray falls at an angle of 45° on the other face. After refraction, it is subsequently reflected from the silvered face and then it retraces its path. The refracting angle of the prism is 30°. The refractive index of the material of the prism is

A. $\frac{3}{2}$
B. $\sqrt{2}$
C. $\frac{\sqrt{3}}{2}$
D. $\sqrt{3}$

Right Answer Explanation:

The refracted ray QR will retrace its path if it falls normally on the silvered face AB (see adjoining figure). It follows from Fig. that



$$r = A = 30° \text{ (given)}$$

Also $\quad i = 45°$ (given). Hence

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

which is choice (2).