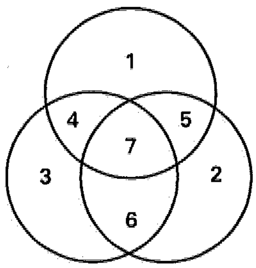
14 PHYSICS

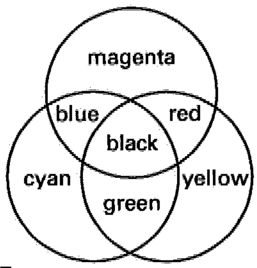
PHYSICS–1

The figure shown is used to indicate combinations of color primaries for subtractive mixing of colors. Which one of the following is true?



(A) 1 = green, 6 = magenta, 4 = yellow
(B) 1 = yellow, 4 = blue, 7 = white
(C) 1 = cyan, 5 = green, 7 = white
(D) 1 = magenta, 5 = red, 7 = black

This figure could be rotated so that 1 = magenta, yellow, or cyan. However, the only choice that has all three colors in the proper places is option (D).



The answer is (D).

PHYSICS–2

Which of the following statements is FALSE?

(A) wavelength of visible light > wavelength of microwaves
(B) frequency of radio waves < frequency of infrared waves
(C) wavelength of x-rays > wavelength of gamma rays
(D) frequency of ultraviolet > frequency of infrared

The electromagnetic spectrum is

radio waves	micro-waves	infrared	visible	ultraviolet	x-rays	gamma rays

increasing frequency ⟶

⟵ increasing wavelength

The wavelength of microwaves is greater than the wavelength of visible light. Therefore, option (A) is false.

The answer is (A).

PHYSICS–3

A light source emits a total luminous flux of 1000 lm distributed uniformly over a quarter of a sphere. What is most nearly the luminous intensity 2.5 m from the source?

(A) 42 lm/m^2 (B) 51 lm/m^2 (C) 58 lm/m^2 (D) 62 lm/m^2

Luminous intensity, I, is

$$I = \frac{L_o}{A}$$

In the preceding equation, L_o is the luminous flux and A is the surface area of sphere around the light source. The area of a quarter of a sphere is

$$A = \frac{4\pi r^2}{4} = \pi(2.5 \text{ m})^2$$

$$= 19.63 \text{ m}^2$$

$$I = \frac{1000 \text{ lm}}{19.63 \text{ m}^2} = 50.94 \text{ lm/m}^2 \quad (51 \text{ lm/m}^2)$$

The answer is (B).

PHYSICS–4

A 100 W lightbulb emits a total luminous flux of 1500 lm, distributed uniformly over a hemisphere. What is most nearly the illuminance at a distance of 2 m?

(A) 11 lm/m^2 (B) 21 lm/m^2 (C) 34 lm/m^2 (D) 60 lm/m^2

The illumination, E, is

$$E = \frac{\Phi}{A}$$

In the preceding equation, Φ is the luminous flux and A is the area.

$$\begin{aligned} A &= \frac{4\pi r^2}{2} \\ &= 2\pi(2 \text{ m})^2 \\ &= 25.13 \text{ m}^2 \end{aligned}$$

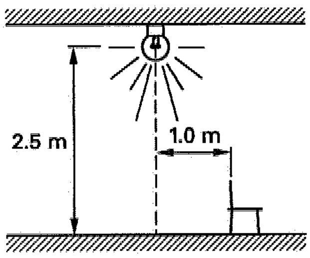
Therefore,

$$\begin{aligned} E &= \frac{1500 \text{ lm}}{25.13 \text{ m}^2} \\ &= 59.7 \text{ lm/m}^2 \quad (60 \text{ lm/m}^2) \end{aligned}$$

The answer is (D).

PHYSICS–5

A lightbulb is used to light a stage 2.5 m below. A chair sits on the stage 1.0 m from a spot directly below the bulb. If the bulb has a luminous intensity of 150 lm, what is most nearly the illumination on the floor around the chair?

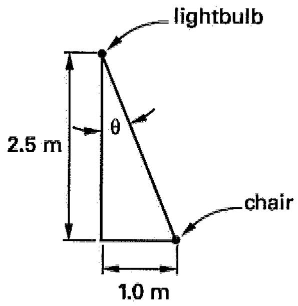


(A) 7.7 lm/m^2 (B) 19 lm/m^2 (C) 21 lm/m^2 (D) 51 lm/m^2

The illumination, E, is given by the following formula.

$$E = \frac{I \cos\theta}{r^2}$$

In the preceding equation, I is the luminous intensity of the source, θ is the angle from the normal to the surface the light strikes, and r is the distance from the light source.



$$\cos\theta = \frac{2.5 \text{ m}}{2.7 \text{ m}}$$

$$r = \sqrt{(2.5 \text{ m})^2 + (1 \text{ m})^2} = \sqrt{7.25 \text{ m}^2}$$

$$E = \frac{(150 \text{ lm})\left(\dfrac{2.5 \text{ m}}{2.7 \text{ m}}\right)}{7.25 \text{ m}^2}$$

$$= 19.2 \text{ lm/m}^2 \quad (19 \text{ lm/m}^2)$$

The answer is (B).

PHYSICS–6

Light of wavelength λ and intensity I_0 passes through a 0.05 m thick slab of glass whose absorption coefficient for that wavelength is 15 m^{-1}. What is most nearly the intensity, I, of the light after passing through the slab?

(A) $0.3I_0$ (B) $0.5I_0$ (C) $0.6I_0$ (D) $0.8I_0$

$$I = I_0 e^{-\alpha x}$$

The absorption coefficient, α, is 15 m^{-1}. Therefore,

$$I = I_0 e^{-(15/\text{m})(0.05 \text{ m})}$$

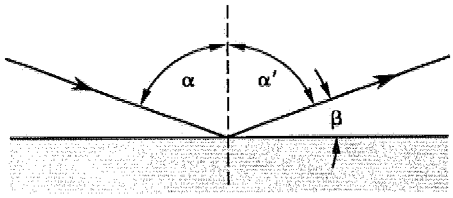
$$= 0.47I_0 \quad (0.5I_0)$$

The answer is (B).

PHYSICS–7

A light ray passing through air ($n = 1$) strikes a glass surface ($n_{\text{glass}} = 1.52$) at an angle of $\alpha = 60°$ from the normal to the surface. What is the angle, β, between the reflected light and the surface?

(A) 7.5° (B) 15° (C) 30° (D) 45°



The reflection law states that the angle of incidence is equal to the angle of reflection ($\alpha = \alpha'$). Therefore, $\alpha' = 60°$ and $\beta = 30°$.

The answer is (C).

PHYSICS–8

Which material type usually has a higher index of refraction?

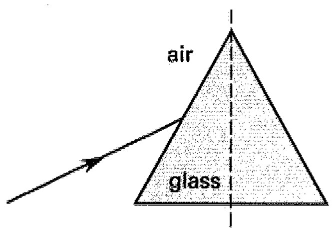
(A) lighter materials (B) heavier materials (C) denser materials (D) less-dense materials

In general, denser materials have higher indices of refraction.

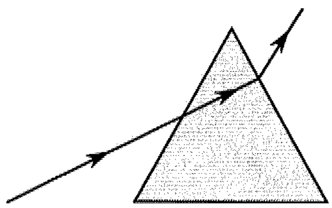
The answer is (C).

PHYSICS–9

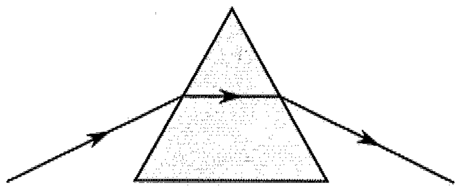
What is the path of the refracted ray in the following illustration?



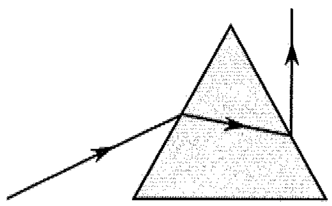
(A)



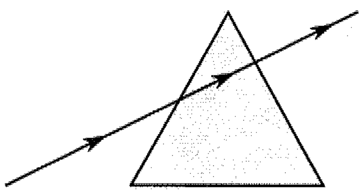
(B)



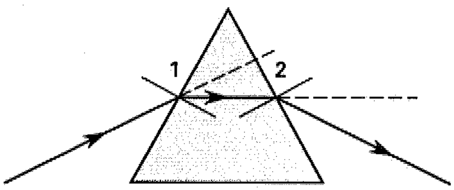
(C)



(D)



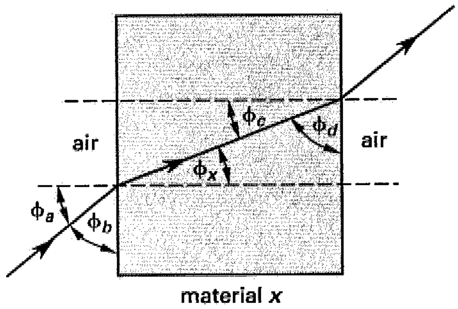
The light ray is refracted at interface 1. It is not normal to the surface of the glass, so its path changes direction. This eliminates options (A) and (D). Since $n_{glass} > n_{air}$, the ray is bent toward the normal to the surface of the glass at interface 1, and away from the normal to the surface at interface 2. Thus, option (B) is the correct path of the ray.



The answer is (B).

PHYSICS–10

How can the index of refraction of material x be defined?



(A) $n_x = \frac{\sin\phi_a}{\sin\phi_b}$ (B) $n_x = \frac{\sin\phi_a}{\sin\phi_c}$ (C) $n_x = \frac{\sin\phi_c}{\sin\phi_d}$ (D) $n_x = \frac{\sin\phi_b}{\sin\phi_c}$

Indices of refraction are defined such that $n_a \sin\phi_a = n_x \sin\phi_x$, where n_a and n_x are the indices of refraction of materials a and x, and ϕ_a and ϕ_b are the angles between the light ray and the normal to the interface between the two materials.

The reference index for air, n_a, is 1. Therefore,

$$n_x = \frac{\sin\phi_a}{\sin\phi_x}$$

From the illustration,

$$\phi_x = \phi_c$$

$$n_x = \frac{\sin\phi_a}{\sin\phi_c}$$

The answer is (B).

PHYSICS–11

What is the index of refraction of a material if the speed of light through the material is 2.37×10^8 m/s?

(A) 1.10 (B) 1.19 (C) 1.27 (D) 1.34

The index of refraction of a material is

$$n = \frac{c}{\mathrm{v}}$$

$$n = \frac{3 \times 10^8 \ \frac{\mathrm{m}}{\mathrm{s}}}{2.37 \times 10^8 \ \frac{\mathrm{m}}{\mathrm{s}}} = 1.27$$

The answer is (C).

PHYSICS–12

What is most nearly the speed of light through glass that has an index of refraction of 1.33?

(A) 1.1×10^8 m/s (B) 2.3×10^8 m/s (C) 2.5×10^8 m/s (D) 2.8×10^8 m/s

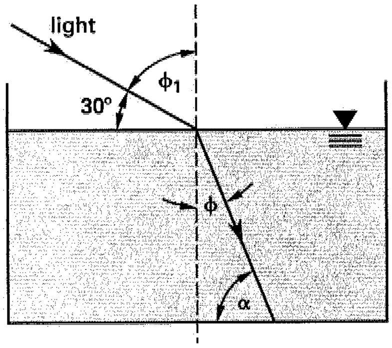
$$n = \frac{c}{\mathrm{v}}$$

$$\mathrm{v} = \frac{c}{n} = \frac{3.0 \times 10^8 \ \frac{\mathrm{m}}{\mathrm{s}}}{1.33} = 2.26 \times 10^8 \ \mathrm{m/s} \quad (2.3 \times 10^8 \ \mathrm{m/s})$$

The answer is (B).

PHYSICS–13

Light hits the surface of a trough of water at an angle of 30° from horizontal. The index of refraction of water is 1.333. What is most nearly the angle, α, in the illustration?



(A) 30° (B) 34° (C) 41° (D) 50°

First, use Snell's law to find ϕ. Then, use ϕ to find α. Since $n_a = 1$ for air,

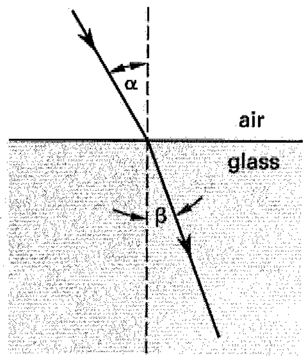
$$n_a \sin \phi_1 = n_w \sin \phi$$
$$\sin \phi_1 = n \sin \phi$$
$$\phi_1 = 90^\circ - 30^\circ$$
$$= 60^\circ$$
$$\sin \phi = \frac{\sin 60^\circ}{1.333}$$
$$= 0.650$$
$$\phi = 40.5^\circ$$
$$\alpha = 90^\circ - \phi$$
$$= 90^\circ - 40.5^\circ$$
$$= 49.5^\circ \quad (50^\circ)$$

The answer is (D).

PHYSICS–14

A light ray in air ($n_{air} = 1$) is incident on a glass surface ($n_{glass} = 1.52$) at an angle of 30° from the normal. What is most nearly the angle between the refracted light ray and the normal?

(A) 16° (B) 19° (C) 30° (D) 45°



$$n_a \sin\alpha = n_g \sin\beta$$

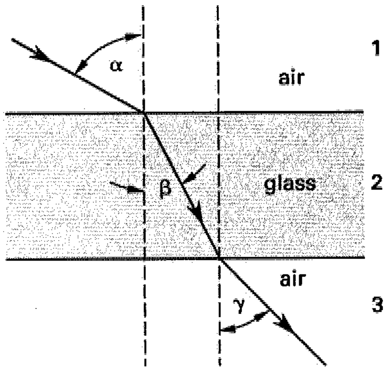
$$\sin\beta = \frac{n_a \sin\alpha}{n_g} = \frac{1 \sin 30°}{1.52} = 0.3289$$

$$\beta = 19.2° \quad (19°)$$

The answer is (B).

PHYSICS–15

Given that $\alpha = 60°$, $n_{air} = 1$, and $n_{glass} = 1.52$, find the angle, γ, in the illustration.



(A) 15° (B) 30° (C) 45° (D) 60°

Use Snell's law at each interface.

$$n_{air} \sin\alpha = n_{glass} \sin\beta$$
$$n_{glass} \sin\beta = n_{air} \sin\gamma$$

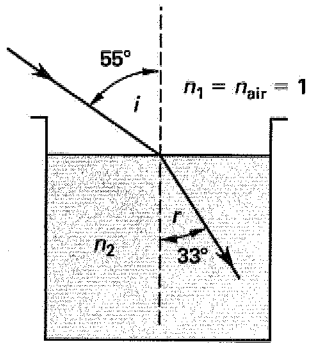
Therefore,

$$n_{air} \sin\alpha = n_{air} \sin\gamma$$
$$\sin\gamma = \sin\alpha$$
$$= \sin 60°$$
$$\gamma = 60°$$

The answer is (D).

PHYSICS–16

A student has a beaker of unknown liquid. When a beam of light of wavelength $\lambda = 0.59$ Å shines into the liquid at an angle of 55° from the normal to the surface, the refracted beam continues at an angle of 33° from the normal to the surface. What is the liquid?



(A) acetic acid, $n = 1.30$
(B) water, $n = 1.33$
(C) nitric acid, $n = 1.40$
(D) benzene, $n = 1.50$

$$n_1 \sin i = n_2 \sin r$$

In the preceding equation, i is the angle of incidence, and r is the angle of refraction.

$$\begin{aligned} n_2 &= n_1 \frac{\sin i}{\sin r} \\ &= (1)\left(\frac{\sin 55^\circ}{\sin 33^\circ}\right) \\ &= 1.50 \end{aligned}$$

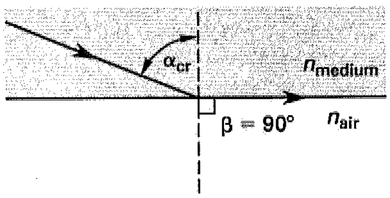
The only liquid listed with an index of refraction of 1.50 is benzene.

$\boxed{\text{The answer is (D).}}$

PHYSICS–17

A light ray in a medium ($n_{\text{medium}} = 1.7$) is totally reflected when it strikes the interface between the medium and air. In order for this phenomenon to occur, what should most nearly be the critical (i.e., minimum) angle between the light ray and the normal to the surface?

(A) 0° (B) 15° (C) 18° (D) 36°



Since the index of refraction is greater for the medium than for air, total internal reflection may occur. For total internal reflection to occur, the angle of refraction, β, must be at least 90°.

$$n_{\text{medium}} \sin \alpha_{\text{cr}} = n_{\text{air}} \sin \beta$$

$$\sin \alpha_{\text{cr}} = \frac{n_{\text{air}} \sin 90°}{n_{\text{medium}}}$$

$$= \frac{(1)(1)}{1.7}$$

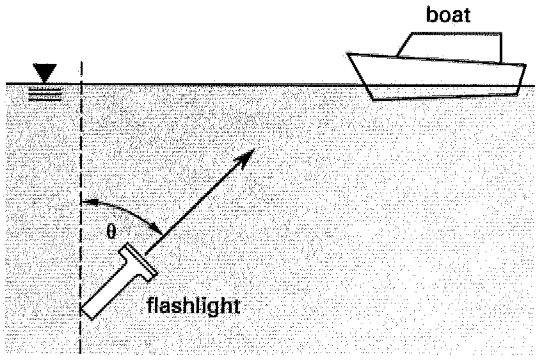
$$= 0.5882$$

$$\alpha_{\text{cr}} = 36°$$

The answer is (D).

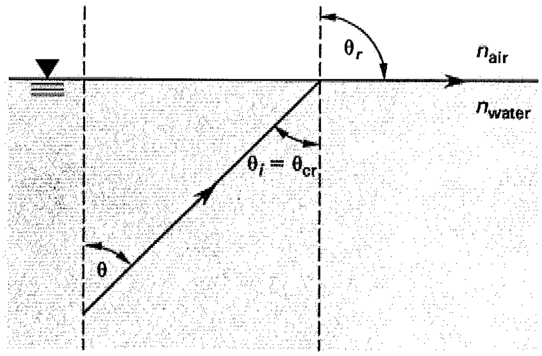
PHYSICS–18

An underwater diver signals his partner in a boat using a very bright flashlight. Assuming the water is crystal clear and the surface is perfectly calm, at what angle from vertical, θ, can the diver hold his flashlight and still have its beam visible above the surface? (The indices of refraction are $n_{water} = 1.33$ and $n_{air} = 1.00$.)



(A) 32.5° (B) 41.2° (C) 45.0° (D) 48.8°

Since $n_{air} < n_{water}$, total internal reflection can occur. This happens when the incident angle, θ, is large enough so that the refracted angle is at least 90°. The incident angle for which the refracted angle is exactly 90° is called the critical angle, θ_{cr}. The critical angle can be found from Snell's law.



$$\theta = \theta_i$$

$$\begin{aligned}\sin\theta_{cr} &= \frac{n_{air}}{n_{water}}\sin 90^\circ \\ &= \frac{n_{air}}{n_{water}} \\ &= \frac{1.00}{1.33} \\ \theta_{cr} &= 48.8^\circ\end{aligned}$$

For the light to be seen above the surface, θ must be less than θ_{cr}.

$\boxed{\text{The answer is (D).}}$

PHYSICS–19

The radius of curvature of a convex spherical mirror is 48 cm. What are the focal length and focal type?

(A) −12 cm, virtual focus
(B) −24 cm, virtual focus
(C) 12 cm, real focus
(D) 24 cm, real focus

For a convex mirror, the radius of curvature, R, is negative. The equation for the focal length of a spherical mirror is

$$\begin{aligned}\frac{1}{f} &= \frac{2}{R} \\ f &= \frac{R}{2} \\ &= \frac{-48 \text{ cm}}{2} \\ &= -24 \text{ cm}\end{aligned}$$

The negative sign indicates that the mirror has a virtual focus. The focal length is −24 cm.

$\boxed{\text{The answer is (B).}}$

PHYSICS–20

An object 6 cm high is placed 12 cm away from a concave mirror whose focal length is 36 cm. What is the height of the image?

(A) 2 cm (B) 4 cm (C) 5 cm (D) 9 cm

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

In the preceding equation, q is the image distance, p is the object distance, and f is the focal length.

$$\begin{aligned} q &= \frac{pf}{p-f} \\ &= \frac{(12\text{ cm})(36\text{ cm})}{12\text{ cm} - 36\text{ cm}} \\ &= -18\text{ cm} \end{aligned}$$

$$\begin{aligned} \frac{I}{O} &= \left|\frac{q}{p}\right| \\ &= \frac{18\text{ cm}}{12\text{ cm}} \\ &= 1.5 \end{aligned}$$

In the preceding equation, I is the image size and O is the object size.

$$\begin{aligned} I &= (1.5)O \\ &= (1.5)(6\text{ cm}) \\ &= 9\text{ cm} \end{aligned}$$

The answer is (D).

PHYSICS–21

An object is placed 10 cm away from a concave mirror with a focal length of 30 cm. What image is formed?

(A) a real image 10 cm in front of the mirror
(B) a virtual image 15 cm behind the mirror
(C) a real image 20 cm in front of the mirror
(D) a virtual image 25 cm behind the mirror

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

In the preceding equation, p is the object distance, q is the image distance, and f is the focal length.

$$\begin{aligned} q &= \frac{pf}{p-f} \\ &= \frac{(10\ \text{cm})(30\ \text{cm})}{10\ \text{cm}-30\ \text{cm}} \\ &= -15\ \text{cm} \end{aligned}$$

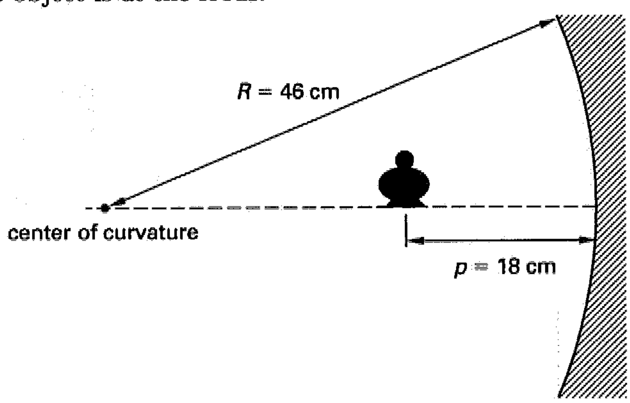
The negative sign indicates that this is a virtual image, 15 cm behind the mirror.

The answer is (B).

PHYSICS–22

A chess piece is placed 18 cm in front of a concave mirror that has a radius of curvature of 46 cm. Which of the following statements about the image is/are true?

I. The image is larger than the object.
II. The image is real.
III. The image is upright.
IV. The image is beyond the center of curvature.
V. The object is at the focus.



(A) V only (B) I and III (C) II and IV (D) I, III, and IV

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

In the preceding equation, p is the object distance, q is the image distance, and f is the focal length.

$$\begin{aligned} f &= \frac{R}{2} \\ &= \frac{46 \text{ cm}}{2} \\ &= 23 \text{ cm} \end{aligned}$$

$$\begin{aligned} q &= \frac{pf}{p - f} \\ &= \frac{(18 \text{ cm})(23 \text{ cm})}{18 \text{ cm} - 23 \text{ cm}} \\ &= -82.8 \text{ cm} \end{aligned}$$

Thus, the image is virtual and behind the mirror. Statements II, IV, and V are incorrect.

Determine the magnification, m.

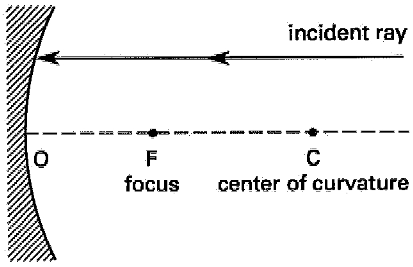
$$\begin{aligned} m &= -\frac{q}{p} \\ &= -\left(\frac{-82.8 \text{ cm}}{18 \text{ cm}}\right) \\ &= +4.6 \end{aligned}$$

The positive sign indicates that the image is upright. Therefore, III is true. Since $m > 1$, the image is larger than the object. Thus, I is also true.

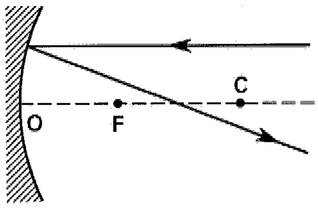
$\boxed{\text{The answer is (B).}}$

PHYSICS–23

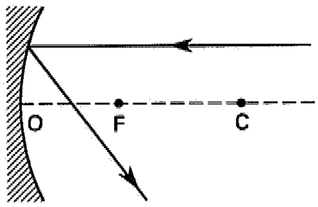
Consider the concave spherical mirror in the illustration. What is the path of the reflected ray?



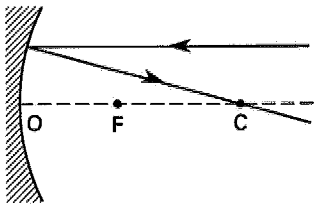
(A)



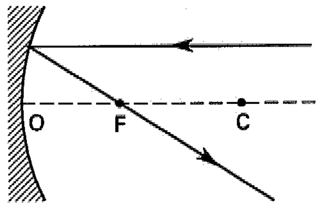
(B)



(C)



(D)

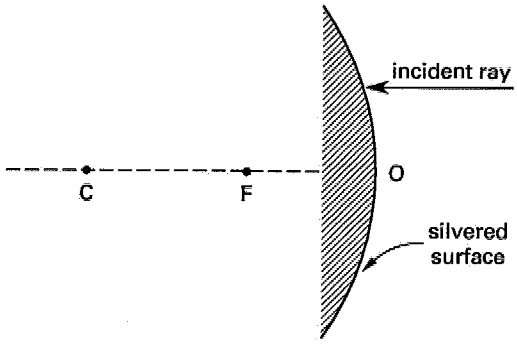


If an incident ray is parallel to the principal axis of a concave mirror, the reflected ray will pass through the focus point, F. Therefore, option (D) is correct.

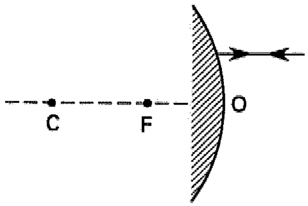
The answer is (D).

PHYSICS–24

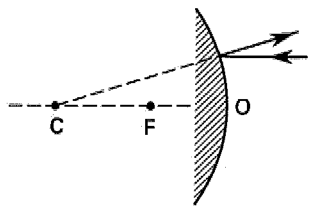
Consider the convex spherical mirror shown. What is the path of the reflected ray?



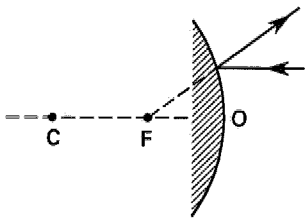
(A)



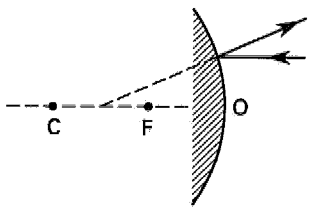
(B)



(C)



(D)

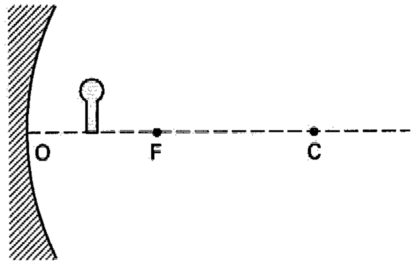


If the incident ray is parallel to the principal axis of a convex mirror, the reflected ray follows a path such that its extension passes through the focus. Therefore, option (C) is correct.

The answer is (C).

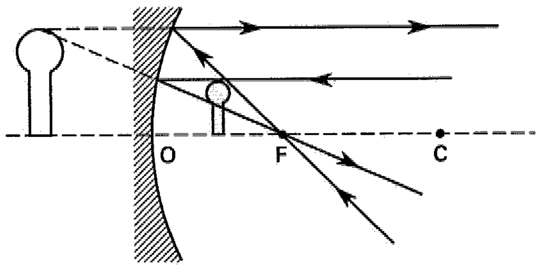
PHYSICS–25

Which of the following describes the image of an object that is placed between the focus and the concave spherical mirror?



(A) real, larger, inverted
(B) virtual, larger, not inverted
(C) virtual, smaller, not inverted
(D) real, smaller, inverted

Construct a ray diagram to find the image.

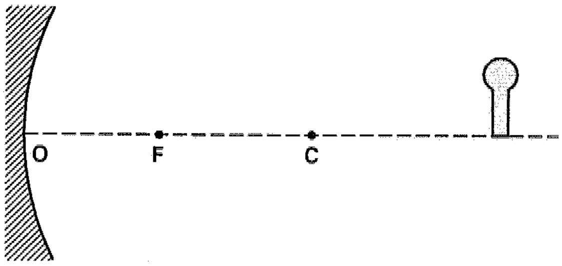


The image is virtual, behind the mirror, larger, and not inverted. Therefore, option (B) is the correct answer.

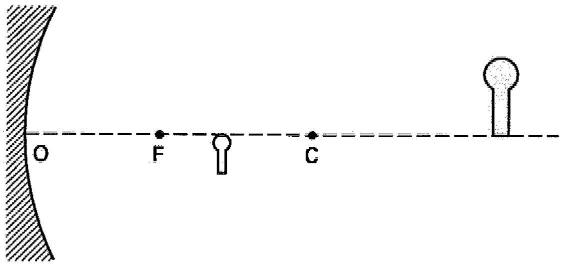
The answer is (B).

PHYSICS–26

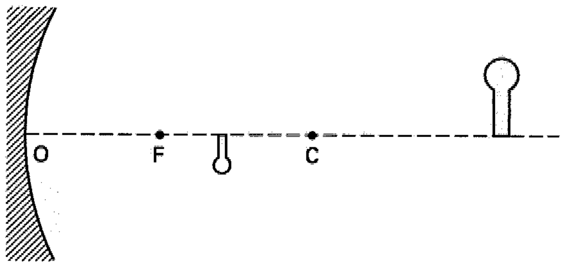
Which of the following options correctly depicts the image of the object as shown in the concave spherical mirror?



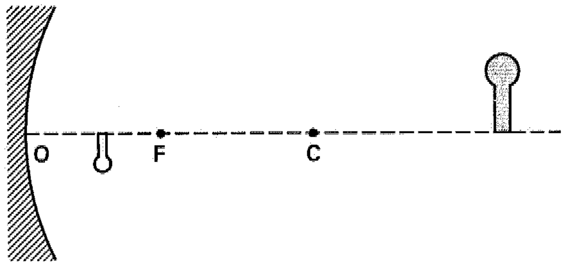
(A)



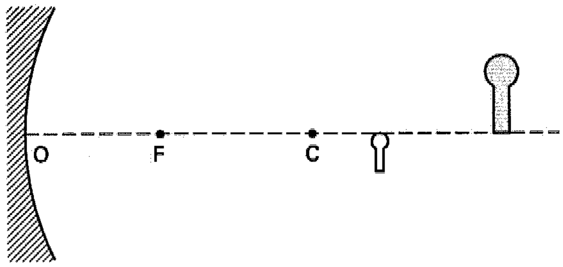
(B)



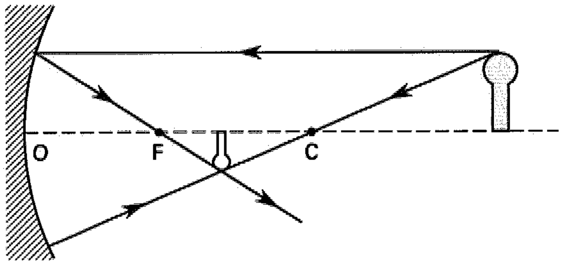
(C)



(D)



Construct a ray diagram to find the image.



Thus, option (B) gives the correct location and type of the image.

$\boxed{\text{The answer is (B).}}$

PHYSICS–27

A thin lens is made from glass with $n = 1.5$. It has a convex face with a 25 cm radius of curvature and a concave face with a 35 cm radius of curvature. What are the focal length and type of the lens?

(A) diverging lens, virtual focus, focal length of 100 cm
(B) converging lens, real focus, focal length of 125 cm
(C) diverging lens, virtual focus, focal length of 150 cm
(D) converging lens, real focus, focal length of 175 cm

The radius of curvature for the convex face, R_1, is positive, but for the concave face, R_2, it is negative.

$$\begin{aligned}\frac{1}{f} &= (n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)\\ &= (1.5-1)\left(\frac{1}{25\text{ cm}}-\frac{1}{35\text{ cm}}\right)\\ &= \frac{1}{175\text{ cm}}\\ f &= 175\text{ cm}\end{aligned}$$

The focal length is positive, indicating a real focus and, therefore, a converging lens with a focal length of 175 cm.

$\boxed{\text{The answer is (D).}}$

PHYSICS–28

An object 0.31 m tall is placed 0.61 m from a converging lens whose focal length is 0.46 m. Most nearly where is the image formed?

(A) 0.61 m from the lens
(B) 0.92 m from the lens
(C) 1.2 m from the lens
(D) 1.9 m from the lens

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

In the preceding equation, f is the focal length, p is the object distance, and q is the image distance.

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$q = \frac{pf}{p-f}$$

$$= \frac{(0.61 \text{ m})(0.46 \text{ m})}{0.61 \text{ m} - 0.46 \text{ m}}$$

$$= 1.87 \text{ m} \quad (1.9 \text{ m})$$

The answer is (D).

PHYSICS–29

What is the image position of an object placed 15 cm away from a thin, spherical converging lens with a focal length of 10 cm?

(A) 15 cm beyond the lens
(B) 20 cm beyond the lens
(C) 25 cm beyond the lens
(D) 30 cm beyond the lens

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

In the preceding equation, p is the object distance, q is the image distance, and f is the focal length.

$$\frac{1}{q} = \frac{p-f}{pf}$$

$$q = \frac{pf}{p-f}$$

$$= \frac{(15 \text{ cm})(10 \text{ cm})}{15 \text{ cm} - 10 \text{ cm}}$$

$$= 30 \text{ cm}$$

The positive value of q means that there is a real image on the opposite side of the lens from the object (beyond the lens).

The answer is (D).

PHYSICS–30

For of an object placed 25 cm from a diverging lens with a focal length of 15 cm, most nearly where is the image? What type of image is it?

(A) 9.4 cm behind the lens; virtual image
(B) 13 cm behind the lens; real image
(C) 15 cm behind the lens; virtual image
(D) 18 cm behind the lens; real image

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

In the preceding equation, p is the object distance, q is the image distance, and f is the focal length. Determine the focal length.

$$\begin{aligned}
f &= -15\ \text{cm} \quad [f \text{ is negative for a diverging lens}] \\
\frac{1}{q} &= \frac{p-f}{pf} \\
q &= \frac{pf}{p-f} \\
&= \frac{(25\ \text{cm})(-15\ \text{cm})}{25\ \text{cm} - (-15\ \text{cm})} \\
&= -9.375\ \text{cm} \quad (-9.4\ \text{cm})
\end{aligned}$$

This is a virtual image, located about 9.4 cm behind the lens.

$\boxed{\text{The answer is (A).}}$

PHYSICS–31

A magnifying glass has a plastic lens with an index of refraction of $n = 5.4$ and radii of curvature of 0.9 m and 1.3 m for the two faces. What is the magnification of the lens when it is held 0.1 m from an object being viewed?

(A) 1.5 (B) 4.5 (C) 6.0 (D) 6.5

A magnifying glass uses a biconvex lens. If f is the focal length of the lens, R_1 and R_2 are the radii of curvature, and n is the index of refraction, then

$$\begin{aligned}\frac{1}{f} &= (n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)\\ &= (5.4-1)\left(\frac{1}{0.9\ \text{m}}+\frac{1}{1.3\ \text{m}}\right)\\ &= 8.3\ \text{m}^{-1}\\ f &= \frac{1}{8.3\ \frac{1}{\text{m}}} = 0.12\ \text{m}\end{aligned}$$

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

In the preceding equation, p is the object distance, and q is the image distance.

$$\begin{aligned}\frac{1}{q} &= \frac{1}{f}-\frac{1}{p}\\ q &= \frac{pf}{p-f}\\ &= \frac{(0.1\ \text{m})(0.12\ \text{m})}{0.1\ \text{m}-0.12\ \text{m}}\\ &= -0.6\ \text{m}\end{aligned}$$

The magnification, m, is

$$\begin{aligned}m &= -\frac{q}{p}\\ &= -\frac{-0.6\ \text{m}}{0.1\ \text{m}}\\ &= 6\end{aligned}$$

$\boxed{\text{The answer is (C).}}$

PHYSICS–32

An astronomer observing the night sky has a telescope with an 0.2 m objective lens. If two stars 700 ly away are barely resolved by the telescope, approximately how far apart are they? Assume the light from both stars has a wavelength of $\lambda = 5500$ Å.

(A) 2.2×10^9 m (B) 1.1×10^{10} m (C) 2.2×10^{10} m (D) 2.2×10^{13} m

The minimum resolvable distance, d_0, between two objects is

$$d_0 = 1.22\frac{\lambda L}{D}$$

In the preceding equation, λ is the wavelength of light, L is the distance of the objects from the lens, and D is the diameter of the lens.

In the above problem,

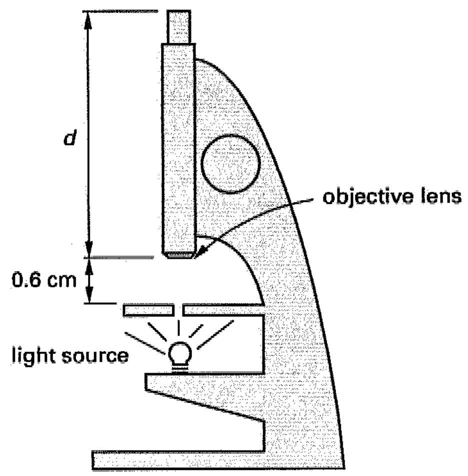
$$\lambda = (5500\ \text{Å})\left(1.0 \times 10^{-10}\ \frac{\text{m}}{\text{Å}}\right)$$
$$= 5.5 \times 10^{-7}\ \text{m}$$
$$L = 700\ \text{ly}$$
$$D = 0.2\ \text{m}$$

$$d_0 = \frac{(1.22)(5.5 \times 10^{-7}\ \text{m})(700\ \text{ly})\left(9.44 \times 10^{15}\ \frac{\text{m}}{\text{ly}}\right)}{0.2\ \text{m}}$$
$$= 2.22 \times 10^{13}\ \text{m} \quad (2.2 \times 10^{13}\ \text{m})$$

The answer is (D).

PHYSICS–33

A microscope has an eyepiece with a focal length, f_e, of 2.5 cm and a magnification of 5. If the objective lens is 0.6 cm from the object being viewed and has a magnification of 10, what is the distance, d, between the two lenses?



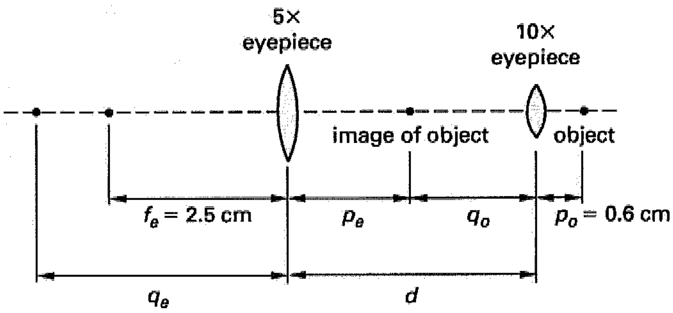
(A) 2.0 cm (B) 2.5 cm (C) 8.0 cm (D) 8.5 cm

For a lens with p as the object distance, q as the image distance, and f as the focal length, the lens equation is

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

The magnification, m, is

$$m=-\frac{q}{p}$$



The sign of m indicates whether or not the image is inverted. From the illustration, it can be seen that $d = |p_e| + |q_o|$. The subscripts denote the eyepiece, e, and the objective lens, o. First, find the distance between the image of the object and the objective lens.

$$m = -\frac{q_o}{p_o}$$

$$\begin{aligned} q_o &= -mp_o \\ &= -(10)(0.6 \text{ cm}) \\ &= -6.0 \text{ cm} \end{aligned}$$

$$|q_o| = 6.0 \text{ cm}$$

Next, find p_e for the eyepiece.

$$\frac{1}{p_e} + \frac{1}{q_e} = \frac{1}{f_e}$$

$$m_e = -\frac{q_e}{p_e}$$

$$|q_e| = m_e p_e$$

$$\frac{1}{p_e} - \frac{1}{m_e p_e} = \frac{1}{f_e}$$

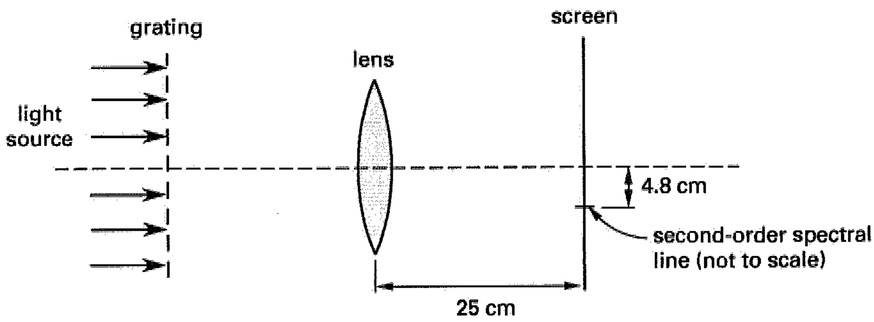
$$\begin{aligned} p_e &= f_e - \frac{f_e}{m_e} \\ &= 2.5 \text{ cm} - \frac{2.5 \text{ cm}}{5} \\ &= 2.0 \text{ cm} \end{aligned}$$

$$\begin{aligned} d &= |q_o| + |p_e| \\ &= 6.0 \text{ cm} + 2.0 \text{ cm} \\ &= 8.0 \text{ cm} \end{aligned}$$

The answer is (C).

PHYSICS–34

A diffraction grating set up as shown is used to find the wavelength of a light source. If the grating has 4000 lines/cm, the lens used to focus the light from the grating is 25 cm from the screen where the light is focused, and the second-order spectral line is 4.8 cm from the center position, what is the wavelength of the light?

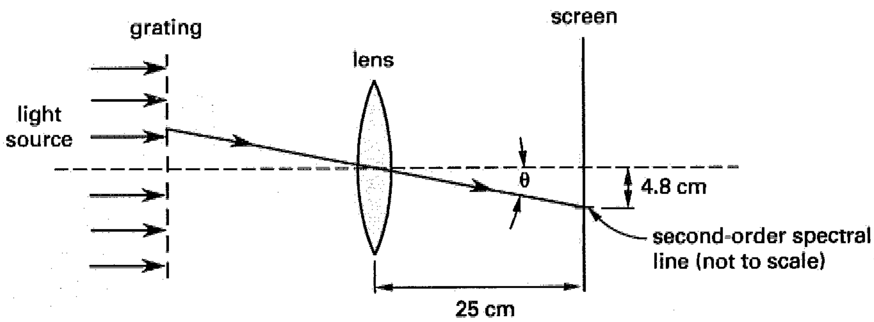


(A) 2000 Å (B) 2400 Å (C) 3200 Å (D) 7300 Å

The relationship between the wavelength, the position of the spectral line, and the diffraction grating is determined by the sine of the angle of two lines drawn from the center of the lens straight to the screen and the spectral line.

$$\sin\theta = \frac{n\lambda}{d}$$

In the preceding equation, n is the order of spectral line and d is the spacing of the grating.



The following information can be determined from the diagram.

$$\sin\theta = \frac{4.8 \text{ cm}}{\sqrt{(25 \text{ cm})^2 + (4.8 \text{ cm})^2}}$$
$$= 0.189$$
$$d = \frac{1 \text{ line}}{4000 \ \frac{\text{lines}}{\text{cm}}}$$
$$= 2.5 \times 10^{-4} \text{ cm}$$
$$n = 2 \quad \text{[for a second-order spectral line]}$$
$$\lambda = \frac{d \sin\theta}{n}$$
$$= \frac{(2.5 \times 10^{-4} \text{ cm})(0.189)}{2}$$
$$= 2.36 \times 10^{-5} \text{ cm} \quad (2400 \text{ Å})$$

The answer is (B).

PHYSICS–35

What is the photon energy associated with green-blue light of wavelength 500 nm? ($\hbar = 6.626 \times 10^{-34}$ J·s, and $c = 3.0 \times 10^{8}$ m/s.)

(A) 1×10^{-19} J (B) 2×10^{-19} J (C) 3×10^{-19} J (D) 4×10^{-19} J

$$E = \hbar f$$
$$= \frac{\hbar c}{\lambda}$$
$$\lambda = (500 \text{ nm})\left(1.0 \times 10^{-9} \ \frac{\text{m}}{\text{nm}}\right)$$
$$= 5.00 \times 10^{-7} \text{ m}$$
$$E = \frac{(6.626 \times 10^{-34} \text{ J·s})\left(3 \times 10^{8} \ \frac{\text{m}}{\text{s}}\right)}{5 \times 10^{-7} \text{ m}}$$
$$= 3.98 \times 10^{-19} \text{ J} \quad (4 \times 10^{-19} \text{ J})$$

The answer is (D).

PHYSICS–36

What is most nearly the energy of a photon of wavelength 0.1 nm?

(A) 0.090×10^{-14} J (B) 0.11×10^{-14} J (C) 1.6×10^{-15} J (D) 2.0×10^{-15} J

$$\begin{aligned} E &= \hbar f \\ &= \frac{\hbar c}{\lambda} \\ &= \frac{(6.626 \times 10^{-34}\ \text{J·s})\left(3.0 \times 10^{8}\ \frac{\text{m}}{\text{s}}\right)}{1 \times 10^{-10}\ \text{m}} \\ &= 1.99 \times 10^{-15}\ \text{J} \quad (2.0 \times 10^{-15}\ \text{J}) \end{aligned}$$

The answer is (D).

PHYSICS–37

Light at wavelength 6493 Å is visible red light. It is, however, very close to the limits of the human eye. What is most nearly the energy of this light?

(A) 1.9×10^{-19} J (B) 2.5×10^{-19} J (C) 2.9×10^{-19} J (D) 3.1×10^{-19} J

$$\begin{aligned} E &= \hbar f \\ &= \frac{\hbar c}{\lambda} \end{aligned}$$

Planck's constant, $\hbar$, is

$$\begin{aligned} \hbar &= 6.626 \times 10^{-34}\ \text{J·s} \\ \lambda &= 6.493 \times 10^{-10}\ \text{m} \\ E &= \frac{(6.626 \times 10^{-34}\ \text{J·s})\left(3.0 \times 10^{8}\ \frac{\text{m}}{\text{s}}\right)}{6493 \times 10^{-10}\ \text{m}} \\ &= 3.06 \times 10^{-19}\ \text{J} \quad (3.1 \times 10^{-19}\ \text{J}) \end{aligned}$$

The answer is (D).

PHYSICS–38

To be effective, an omnidirectional alarm must have a minimum loudness of 70 dB. If it is to be effective 60 m away, what is most nearly the minimum power required?

(A) 0.1 W (B) 0.2 W (C) 0.3 W (D) 0.5 W

The intensity level, I, is related to distance and power according to

$$I = \frac{W}{4\pi r^2}$$

In the preceding equation, W is power and r is the distance from the source.

In decibels,

$$\begin{aligned} I &= 10 \log \frac{I}{I_0} \\ I_0 &= 1 \times 10^{-12}\ \mathrm{W/m^2} \\ I &= I_0 10^{I/10} \\ W &= I_0 10^{I/10}(4\pi r^2) \\ &= \left(1 \times 10^{-12}\ \frac{\mathrm{W}}{\mathrm{m^2}}\right)(10^{70/10})(4\pi)(60\ \mathrm{m})^2 \\ &= 0.45\ \mathrm{W} \quad (0.5\ \mathrm{W}) \end{aligned}$$

The answer is (D).

PHYSICS–39

A stationary observer hears a siren approaching. The siren has a sound frequency of 700 Hz and is approaching the observer at 80 km/h. What is the frequency heard by the observer? Assume the velocity of sound in air is 332 m/s.

(A) 600 Hz (B) 650 Hz (C) 700 Hz (D) 750 Hz

The frequency heard by the observer, f_o, is

$$f_o = f_s \left(\frac{\mathrm{v} + \mathrm{v}_o}{\mathrm{v} - \mathrm{v}_s}\right)$$

In the preceding equation, f_s is the frequency of the source, v is the velocity of wave transmission in the medium, v_o is the component of observer velocity directed toward the source, and v_s is the component of source velocity directed toward the observer.

$$v_s = \left(80\ \frac{\text{km}}{\text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(1000\ \frac{\text{m}}{\text{km}}\right)$$
$$= 22.2\ \text{m/s}$$
$$f_o = (700\ \text{Hz})\left(\frac{332\ \frac{\text{m}}{\text{s}} + 0\ \frac{\text{m}}{\text{s}}}{332\ \frac{\text{m}}{\text{s}} - 22.2\ \frac{\text{m}}{\text{s}}}\right)$$
$$= 750\ \text{Hz}$$

The answer is (D).

PHYSICS–40

A policeman waiting at a speed trap hears a car going by honking its horn. Being an amateur musician with perfect pitch, the policeman recognizes that the pitch of the horn is G♯ (f = 415.30 Hz), a half-step lower than its normal pitch of A (f = 440.00 Hz). The velocity of sound in the air is 332 m/s. At what speed was the car traveling?

(A) 35 km/h (B) 67 km/h (C) 71 km/h (D) 83 km/h

The change in pitch is due to the Doppler effect. The frequency heard by the observer, f_o, is

$$f_o = f_s\left(\frac{v + v_o}{v - v_s}\right)$$

In the preceding equation, f_s is the frequency of source, v is the velocity of sound, v_o is the velocity of the observer, and v_s is the velocity of the source.

$$v = 332\ \text{m/s}$$
$$v_o = 0\ \text{m/s}$$

Solve for v_s.

$$\begin{aligned} v_s &= v - \frac{f_s}{f_o}(v + v_o) \\ &= \left(332\ \frac{m}{s} - \left(\frac{440.00\ \text{Hz}}{415.30\ \text{Hz}}\right)\left(332\ \frac{m}{s} + 0\ \frac{m}{s}\right)\right)\left(3600\ \frac{s}{h}\right)\left(\frac{1\ \text{km}}{1000\ \text{m}}\right) \\ &= -71\ \text{km/h} \quad [71\ \text{km/h away from the policeman}] \end{aligned}$$

The answer is (C).

PHYSICS–41

Solar collectors generate 1 kW/m^2 of thermal energy using the sun's energy. A collector with an area of 1 m^2 heats water. The water flow rate is 30 L/min. What is most nearly the temperature rise in the water? The specific heat of water is 4200 J/kg·°C.

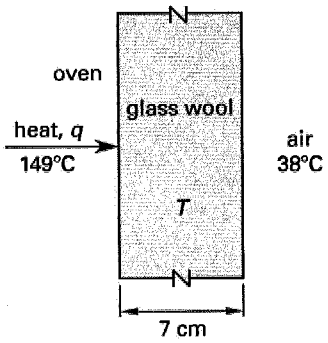
(A) 0.1°C (B) 0.5°C (C) 5°C (D) 30°C

$$\begin{aligned} P &= \left(1\ \frac{\text{kW}}{\text{m}^2}\right)(1\ \text{m}^2)\left(1000\ \frac{\text{W}}{\text{kW}}\right) \\ &= 1000\ \text{W} \\ P &= \rho Q c_p \Delta T \\ 1000\ \text{W} &= \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(30\ \frac{\text{L}}{\text{min}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right)\left(\frac{1\ \text{m}^3}{1000\ \text{L}}\right)\left(4200\ \frac{\text{J}}{\text{kg}\cdot{}^\circ\text{C}}\right)\Delta T \\ &= \left(2100\ \frac{\text{W}}{{}^\circ\text{C}}\right)\Delta T \\ \Delta T &= \frac{1000\ \text{W}}{2100\ \frac{\text{W}}{{}^\circ\text{C}}} \\ &= 0.48^\circ\text{C} \quad (0.5^\circ\text{C}) \end{aligned}$$

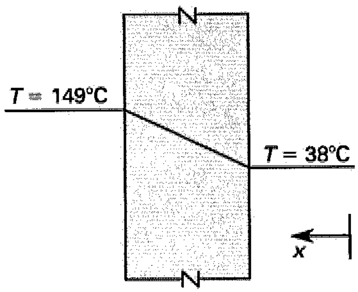
The answer is (B).

PHYSICS–42

A sketch of an oven wall is shown. What is most nearly the temperature in the center of the glass wool?



(A) 46°C (B) 54°C (C) 94°C (D) 98°C



For steady-state flow, the temperature profile is linear.

$$\frac{dT}{dx} = A$$

$$T = Ax + B$$

$$A = \frac{149°\text{C} - 38°\text{C}}{7 \text{ cm}} = 15.86°\text{C/cm}$$

$$B = 38°\text{C}$$

$$T = \left(15.86 \ \frac{°\text{C}}{\text{cm}}\right) x + 38°\text{C}$$

At the center,

$$x = 3.5 \text{ cm}$$

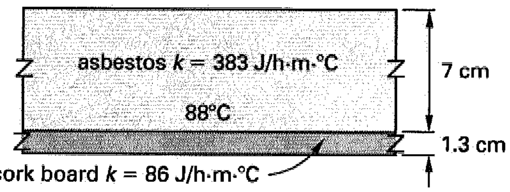
$$T = \left(15.86\ \frac{^\circ\text{C}}{\text{cm}}\right)(3.5 \text{ cm}) + 38^\circ\text{C}$$

$$= 93.5^\circ\text{C} \quad (94^\circ\text{C})$$

The answer is (C).

PHYSICS-43

As a measure to reduce the outer wall temperature of an oven, an extra layer of cork insulation is added as shown. What is most nearly the temperature of the outer wall if the temperature between the asbestos and cork is 88°C?



(A) 14°C (B) 22°C (C) 31°C (D) 37°C

$$q_{\text{oven to asbestos}} = q_{\text{asbestos to cork}}$$

$$= -kA\frac{\Delta T}{\Delta x}$$

$$-k_{\text{asbestos}}A\left(\frac{88^\circ\text{C} - 177^\circ\text{C}}{\dfrac{7 \text{ cm}}{100\ \dfrac{\text{cm}}{\text{m}}}}\right) = -k_{\text{cork}}A\left(\frac{T_{\text{out}} - 88^\circ\text{C}}{\dfrac{1.3 \text{ cm}}{100\ \dfrac{\text{cm}}{\text{m}}}}\right)$$

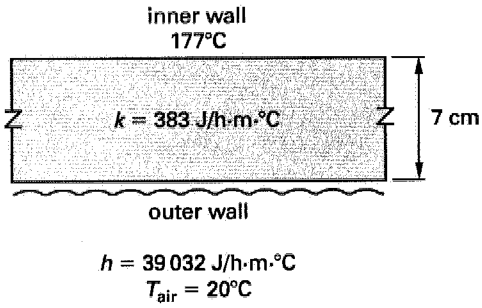
$$-\left(383\ \frac{\text{J}}{\text{h·m·°C}}\right)\left(\frac{(-89^\circ\text{C})(100 \text{ cm})}{7 \text{ cm}}\right) = -\left(86\ \frac{\text{J}}{\text{h·m·°C}}\right) \times \left(\frac{(T_{\text{out}} - 88^\circ\text{C})(100 \text{ cm})}{1.3 \text{ cm}}\right)$$

$$T_{\text{out}} = 14.4^\circ\text{C} \quad (14^\circ\text{C})$$

The answer is (A).

PHYSICS–44

An oven has an inner wall temperature of 177°C. The insulation is 7 cm thick and has a thermal conductivity of 383 J/h·m·°C. If the film coefficient of the outer wall is 39 032 J/h·m²·°C, and the air is at 20°C, what is most nearly the temperature of the outer wall surface?



(A) 22°C (B) 32°C (C) 39°C (D) 42°C

$$q_{\text{oven to insulation}} = q_{\text{outer wall to air}}$$

$$-k\frac{(T_{\text{outer}} - T_{\text{inner}})}{t_{\text{insul}}}A = hA(T_{\text{outer}} - T_{\text{air}})$$

Rearrange to solve for T_{outer}.

$$T_{\text{outer}} = \frac{\left(\dfrac{k}{t_{\text{insul}}h}\right)T_{\text{inner}} + T_{\text{air}}}{1 + \dfrac{k}{t_{\text{insul}}h}}$$

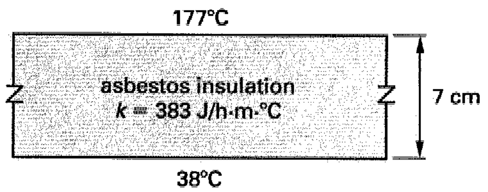
$$= \frac{\left(\dfrac{\left(383\ \dfrac{\text{J}}{\text{h·m·°C}}\right)}{(7\ \text{cm})\left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right) \times \left(39\,032\ \dfrac{\text{J}}{\text{h·m}^2\text{·°C}}\right)}\right)(177°\text{C}) + 20°\text{C}}{1 + \dfrac{383\ \dfrac{\text{J}}{\text{h·m·°C}}}{(7\ \text{cm})\left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right)\left(39\,032\ \dfrac{\text{J}}{\text{h·m}^2\text{·°C}}\right)}}$$

$$= 39.3°\text{C} \quad (39°\text{C})$$

The answer is (C).

PHYSICS–45

A 0.03 m^3 (interior capacity) oven is modeled as a six-sided cubical box. The inside and outside wall temperatures at steady state are shown. The insulating material is asbestos with a thermal conductivity of 383 J/h·m·°C. What is most nearly the power dissipated by the oven? Neglect heat transfer through the corners and edges.



(A) 2.5×10^5 J/h (B) 3.7×10^5 J/h (C) 3.9×10^5 J/h (D) 4.4×10^5 J/h

The heat transfer, Q, is

$$Q = -kA\frac{dT}{dx}$$

At steady state, the temperature profile is linear.

$$dx = 0.07 \text{ m}$$

Therefore,

$$\begin{aligned}\frac{dT}{dx} &= \frac{177°\text{C} - 38°\text{C}}{0.07 \text{ m}} \\ &= 1986 \text{ °C/m}\end{aligned}$$

The oven is modeled as a cubical box with equal sides.

$$\begin{aligned} s &= \sqrt[3]{V} \\ &= \sqrt[3]{0.03 \text{ m}^3} \\ &= 0.31 \text{ m} \\ A &= ns^2 = (6)(0.31 \text{ m})(0.31 \text{ m}) \\ &= 0.58 \text{ m}^2 \end{aligned}$$

$$Q = -\left(383\ \frac{\text{J}}{\text{h}\cdot\text{m}\cdot{}^\circ\text{C}}\right)(0.58\ \text{m}^2)\left(1986\ \frac{{}^\circ\text{C}}{\text{m}}\right)$$
$$= -4.41\times 10^5\ \text{J/h}\quad (4.4\times 10^5\ \text{J/h})$$

The negative value indicates that heat is lost to the surroundings.

The answer is (D).

PHYSICS–46

A copper sphere 0.3 m in diameter radiates power through a vacuum to an environment at 273K. The emissivity of copper is 0.15, and the sphere is at 60°C. The power radiated is most nearly

(A) 28 W (B) 30 W (C) 37 W (D) 53 W

The emitted energy rate is

$$E = \epsilon\sigma T^4 A = \epsilon\sigma T^4 4\pi r^2$$
$$= (0.15)\left(5.67\times 10^{-8}\ \frac{\text{W}}{\text{m}^2\cdot\text{K}^4}\right)(60^\circ\text{C} + 273^\circ)^4(4\pi)\left(\frac{0.30\ \text{m}}{2}\right)^2$$
$$= 29.6\ \text{W}\quad (30\ \text{W})$$

The answer is (B).

PHYSICS–47

An oxidized copper sphere 0.3 m in diameter with an emissivity of 0.78 is filled with water. If the water temperature is 88°C, and the environment is at 273K, what is most nearly the instantaneous rate of cooling of the water? At 88°C, the density of water is 966.6 kg/m^3, and the specific heat is 4190 J/kg·°C.

(A) 10°C/h (B) 11°C/h (C) 12°C/h (D) 13°C/h

The radiated energy is

$$\begin{aligned} E &= \epsilon\sigma T^4 A \\ &= \epsilon\sigma T^4 4\pi r^2 \end{aligned}$$

The heat lost from the water is

$$\begin{aligned} Q &= mc_p\frac{dT}{dt} = V\rho c_p\frac{dT}{dt} \\ &= \frac{4\pi r^3}{3}\rho c_p\frac{dT}{dt} \\ E &= Q \\ 4\pi\epsilon r^2\sigma T^4 &= \frac{4\pi\rho r^3 c_p\frac{dT}{dt}}{3} \\ \frac{dT}{dt} &= \frac{3\epsilon\sigma T^4}{rc_p\rho} \\ &= \left(\frac{(3)(0.78)\left(5.67\times10^{-8}\ \frac{\text{W}}{\text{m}^2{\cdot}\text{K}^4}\right)(88^\circ\text{C}+273^\circ)^4}{\left(\frac{0.3\ \text{m}}{2}\right)\left(4190\ \frac{\text{J}}{\text{kg}{\cdot}^\circ\text{C}}\right)\left(966.6\ \frac{\text{kg}}{\text{m}^3}\right)}\right) \\ &\quad\times\left(3600\ \frac{\text{s}}{\text{h}}\right) \\ &= 13.4^\circ\text{C/h}\quad(13^\circ\text{C/h}) \end{aligned}$$

$\boxed{\text{The answer is (D).}}$