

Refraction of Light (Answers)

The wavelength of red helium–neon laser light in air is 632.8 nm. (a) What is its frequency? (b) What is its wavelength in glass that has an index of refraction of 1.50? (c) What is its speed in the glass?

$$(a) \quad f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{6.328 \times 10^{-7} \text{ m}} = \boxed{4.74 \times 10^{14} \text{ Hz}}$$

$$(b) \quad \lambda_{\text{glass}} = \frac{\lambda_{\text{air}}}{n} = \frac{632.8 \text{ nm}}{1.50} = \boxed{422 \text{ nm}}$$

$$(c) \quad v_{\text{glass}} = \frac{c_{\text{air}}}{n} = \frac{3.00 \times 10^8 \text{ m/s}}{1.50} = 2.00 \times 10^8 \text{ m/s} = \boxed{200 \text{ Mm/s}}$$

▲ A ray of light strikes a flat block of glass ($n = 1.50$) of thickness 2.00 cm at an angle of 30.0° with the normal. Trace the light beam through the glass and find the angles of incidence and refraction at each surface.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 : \quad \theta_2 = \sin^{-1} \left(\frac{n_1 \sin \theta_1}{n_2} \right)$$

$$\theta_2 = \sin^{-1} \left\{ \frac{1.00 \sin 30.0^\circ}{1.50} \right\} = \boxed{19.5^\circ}$$

θ_2 and θ_3 are alternate interior angles formed by the ray cutting parallel normals.

So,

$$\theta_3 = \theta_2 = \boxed{19.5^\circ}$$

$$1.50 \sin \theta_3 = 1.00 \sin \theta_4$$

$$\theta_4 = \boxed{30.0^\circ}$$

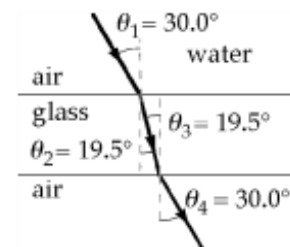


FIG. P35.19

● A room contains air in which the speed of sound is 343 m/s. The walls of the room are made of concrete in which the speed of sound is 1 850 m/s. (a) Find the critical angle for total internal reflection of sound at the concrete–air boundary. (b) In which medium must the sound be traveling if it is undergo total internal reflection? (c) “A bare concrete wall is a highly efficient mirror for sound.” Give evidence for or against this statement.

a) from Snell's law $n_1 \sin \theta_1 = n_2 \sin \theta_2$

this means that $\frac{c}{v_1} \sin \theta_1 = \frac{c}{v_2} \sin \theta_c$

$$\frac{\sin \theta_1}{v_1} = \frac{\sin 90}{v_2}$$

$$\frac{\sin \theta}{343} = \frac{1}{1850}$$

$$\sin \theta = \frac{343}{1850} = 0.185 \text{ hence, } \theta = \sin^{-1} \frac{343}{1850} = 10.7^\circ$$

b) Sound can be totally reflected if it is traveling in the medium where it travels slower: air)

c) Sound in air falling on the wall from most directions is 100% reflected , so the wall is a)
good mirror.

A converging lens has a focal length of 20.0 cm. Locate the image for object distances of (a) 40.0 cm, (b) 20.0 cm, and (c) 10.0 cm. For each case, state whether the image is real or virtual and upright or inverted. Find the magnification in each case.

For a converging lens, f is positive. We use $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$.

$$(a) \quad \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{40.0 \text{ cm}} = \frac{1}{40.0 \text{ cm}} \quad \boxed{q = 40.0 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{40.0}{20.0} = \boxed{-1.00}$$

The image is real, inverted, and located 40.0 cm past the lens.

$$(b) \quad \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{20.0 \text{ cm}} = 0 \quad \boxed{q = \text{infinity}}$$

No image is formed. The rays emerging from the lens are parallel to each other.

$$(c) \quad \frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{10.0 \text{ cm}} = -\frac{1}{20.0 \text{ cm}} \quad \boxed{q = -20.0 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{(-20.0)}{10.0} = \boxed{2.00}$$

The image is upright, virtual and 20.0 cm in front of the lens.

An object located 32.0 cm in front of a lens forms an image on a screen 8.00 cm behind the lens. (a) Find the focal length of the lens. (b) Determine the magnification. (c) Is the lens converging or diverging?

$$(a) \quad \frac{1}{p} + \frac{1}{q} = \frac{1}{f}; \quad \frac{1}{32.0 \text{ cm}} + \frac{1}{8.00 \text{ cm}} = \frac{1}{f}$$

so $f = 6.40 \text{ cm}$

$$(b) \quad M = -\frac{q}{p} = -\frac{8.00 \text{ cm}}{32.0 \text{ cm}} = \boxed{-0.250}$$

(c) Since $f > 0$, the lens is converging.

An object is located 20.0 cm to the left of a diverging lens having a focal length $f = -32.0$ cm. Determine (a) the location and (b) the magnification of the image. (c) Construct a ray diagram for this arrangement.

$$(a) \quad \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \quad \frac{1}{20.0 \text{ cm}} + \frac{1}{q} = \frac{1}{(-32.0 \text{ cm})}$$

so $q = -\left(\frac{1}{20.0} + \frac{1}{32.0}\right)^{-1} = \boxed{-12.3 \text{ cm}}$

The image is 12.3 cm to the left of the lens.

$$(b) \quad M = -\frac{q}{p} = -\frac{(-12.3 \text{ cm})}{20.0 \text{ cm}} = \boxed{0.615}$$

(c) See the ray diagram to the right.

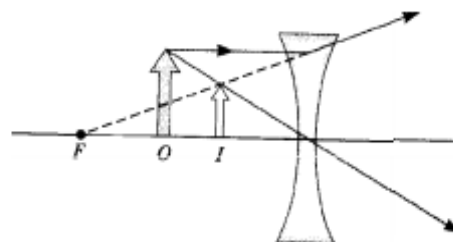


FIG. P36.37