Q35.2 Light travels through a vacuum at a speed of 300 000 km per second. Thus, an image we see from a distant star or galaxy must have been generated some time ago. For example, the star Altair is 16 light-years away; if we look at an image of Altair today, we know only what was happening 16 years ago. This may not initially seem significant, but astronomers who look at other galaxies can gain an idea of what galaxies looked like when they were significantly younger. Thus, it actually makes sense to speak of "looking backward in time."

Q35.6 The stealth fighter is designed so that adjacent panels are not joined at right angles, to prevent any retroreflection of radar signals. This means that radar signals directed at the fighter will not be channeled back toward the detector by reflection. Just as with sound, radar signals can be treated as *diverging* rays, so that any ray that is by chance reflected back to the detector will be too weak in intensity to distinguish from background noise. This author is still waiting for the automotive industry to utilize this technology.

Q35.9 Suppose the light moves into a medium of higher refractive index. Then its wavelength decreases. The frequency remains constant. The speed diminishes by a factor equal to the index of refraction.

Q35.13 The index of refraction of water is 1.33, quite different from 1.00 for air. Babies learn that the refraction of light going through the water indicates the water is there. On the other hand, the index of refraction of liquid helium is close to that of air, so it gives little visible evidence of its presence.

Q35.15 Diamond has higher index of refraction than glass and consequently a smaller critical angle for total internal reflection. A brilliant-cut diamond is shaped to admit light from above, reflect it totally at the converging facets on the underside of the jewel, and let the light escape only at the top. Glass will have less light internally reflected.

P35.6 (a) From geometry, $1.25\text{ m} = d\sin 40.0°$

so $d = \boxed{1.94\text{ m}}$.

(b) $\boxed{50.0° \text{ above the horizontal}}$

or parallel to the incident ray.

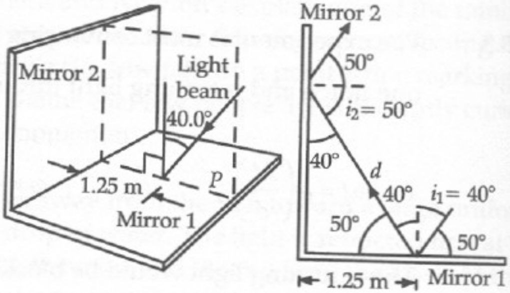

FIG. P35.6

P35.8 The incident light reaches the left-hand mirror at distance

$$(1.00 \text{ m})\tan 5.00° = 0.087\,5 \text{ m}$$

above its bottom edge. The reflected light first reaches the right-hand mirror at height

$$2(0.087\,5 \text{ m}) = 0.175 \text{ m}.$$

It bounces between the mirrors with this distance between points of contact with either.

Since $\dfrac{1.00 \text{ m}}{0.175 \text{ m}} = 5.72$

the light reflects $\boxed{\text{five times from the right-hand mirror and six times from the left}}$.

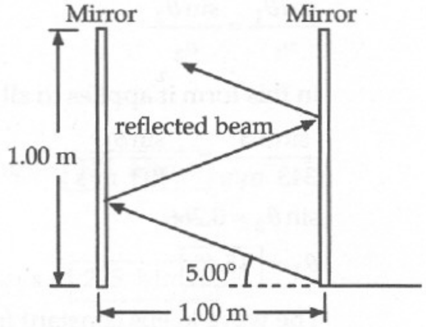

FIG. P35.8

P35.12 (a) $$f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}\ \text{m/s}}{6.328 \times 10^{-7}\ \text{m}} = \boxed{4.74 \times 10^{14}\ \text{Hz}}$$

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

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

P35.18 $\sin\theta_1 = n_w \sin\theta_2$

$$\sin\theta_2 = \frac{1}{1.333}\sin\theta_1 = \frac{1}{1.333}\sin(90.0° - 28.0°) = 0.662$$

$$\theta_2 = \sin^{-1}(0.662) = 41.5°$$

$$h = \frac{d}{\tan\theta_2} = \frac{3.00\text{ m}}{\tan 41.5°} = \boxed{3.39\text{ m}}$$

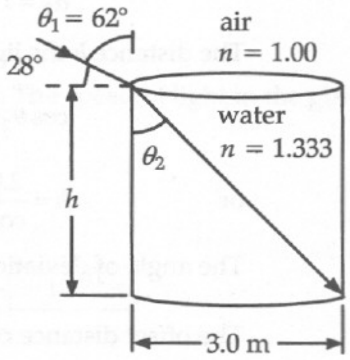

FIG. P35.18

P35.21 At entry, $n_1 \sin\theta_1 = n_2 \sin\theta_2$

or $1.00 \sin 30.0° = 1.50 \sin\theta_2$

$\theta_2 = 19.5°$.

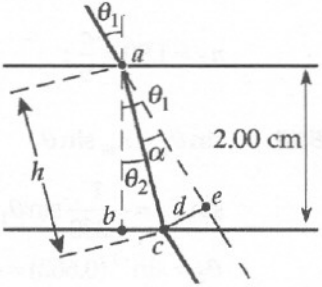

FIG. P35.21

The distance h the light travels in the medium is given by

$$\cos\theta_2 = \frac{2.00 \text{ cm}}{h}$$

or $h = \dfrac{2.00 \text{ cm}}{\cos 19.5°} = 2.12 \text{ cm}$.

The angle of deviation upon entry is $\alpha = \theta_1 - \theta_2 = 30.0° - 19.5° = 10.5°$.

The offset distance comes from $\sin\alpha = \dfrac{d}{h}$: $d = (2.21 \text{ cm}) \sin 10.5° = \boxed{0.388 \text{ cm}}$.

P35.38 $\sin\theta_c = \dfrac{n_{\text{air}}}{n_{\text{pipe}}} = \dfrac{1.00}{1.36} = 0.735$ $\theta_c = 47.3°$

Geometry shows that the angle of refraction at the end is
$\phi = 90.0° - \theta_c = 90.0° - 47.3° = 42.7°$.

Then, Snell's law at the end, $1.00\sin\theta = 1.36\sin 42.7°$

gives $\boxed{\theta = 67.2°}$.

The 2-μm diameter is unnecessary information.

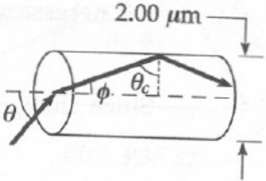

FIG. P35.38

*P35.40 (a) A ray along the inner edge will escape if any ray escapes. Its angle of incidence is described by $\sin\theta = \frac{R-d}{R}$ and by $n\sin\theta > 1\sin 90°$. Then

$$\frac{n(R-d)}{R} > 1 \qquad nR - nd > R \qquad nR - R > nd \qquad R > \boxed{\frac{nd}{n-1}}.$$

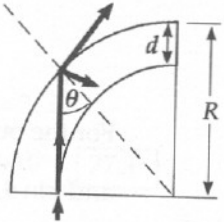

FIG. P35.40

(b) As $d \to 0$, $R_{\min} \to 0$. This is reasonable.

As n increases, $R_{\min}$ decreases. This is reasonable.

As n decreases toward 1, $R_{\min}$ increases. This is reasonable.

(c) $$R_{\min} = \frac{1.40\left(100\times10^{-6}\text{ m}\right)}{0.40} = \boxed{350\times10^{-6}\text{ m}}$$