17.1 Since $v_{light} >> v_{sound}$, $d \approx (343 \text{ m/s})(16.2 \text{ s}) = \boxed{5.56 \text{ km}}$

Goal Solution

G: There is a common rule of thumb that lightning is about a mile away for every 5 seconds of delay between the flash and thunder (or ~3 s/km). Therefore, this lightning strike is about 3 miles (~5 km) away.

O: The distance can be found from the speed of sound and the elapsed time. The time for the light to travel to the observer will be much less than the sound delay, so the speed of light can be ignored.

A: Assuming that the speed of sound is constant through the air between the lightning strike and the observer,

$$v_s = \frac{d}{\Delta t} \quad \text{or} \quad d = v_s \Delta t = (343 \text{ m/s})(16.2 \text{ s}) = 5.56 \text{ km}$$

L: Our calculated answer is consistent with our initial estimate, but we should check the validity of our assumption that the speed of light could be ignored. The time delay for the light is

$$t_{light} = \frac{d}{c} = \frac{5560 \text{ m}}{3.00 \times 10^8 \text{ m/s}} = 1.85 \times 10^{-5} \text{ s}$$

and $\Delta t = t_{sound} - t_{light} = 16.2 \text{ s} - 1.85 \times 10^{-5} \text{ s} \approx 16.2 \text{ s}$ (when properly rounded)

Since the travel time for the light is much smaller than the uncertainty in the time of 16.2 s, t_{light} can be ignored without affecting the distance calculation. However, our assumption of a constant speed of sound in air is probably not valid due to local variations in air temperature during a storm. We must assume that the given speed of sound in air is an accurate *average* value for the conditions described.

17.3 Sound takes this time to reach the man:

$$\frac{(20.0 \text{ m} - 1.75 \text{ m})}{343 \text{ m/s}} = 5.32 \times 10^{-2} \text{ s}$$

so the warning should be shouted no later than

$$0.300 \text{ s} + 5.32 \times 10^{-2} \text{ s} = 0.353 \text{ s} \quad \text{before the pot strikes.}$$

17.5 (a) At 9000 m, $\Delta T = \left(\frac{9000}{150}\right)(-1.00°\text{C}) = -60.0°\text{C}$ so $T = -30.0°\text{C}$

Using the chain rule:

$$\frac{dv}{dt} = \frac{dv}{dT}\frac{dT}{dx}\frac{dx}{dt} = v\frac{dv}{dT}\frac{dT}{dx} = v(0.607)\left(\frac{1}{150}\right) = \frac{v}{247}, \text{ so } dt = (247 \text{ s})\frac{dv}{v}$$

$$\int_0^t dt = (247 \text{ s})\int_{v_i}^{v_f}\frac{dv}{v}$$

$$t = (247 \text{ s})\ln\left(\frac{v_f}{v_i}\right) = (247 \text{ s})\ln\left[\frac{331.5 + 0.607(30.0)}{331.5 + 0.607(-30.0)}\right]$$

$t = \boxed{27.2 \text{ s}}$ for sound to reach ground

(b) $t = \frac{h}{v} = \frac{9000}{[331.5 + 0.607(30.0)]} = \boxed{25.7 \text{ s}}$

It takes longer when the air cools off than if it were at a uniform temperature.

17.9 (a) $A = \boxed{2.00\ \mu m}$ $\lambda = \frac{2\pi}{15.7} = 0.400\ m = \boxed{40.0\ cm}$

$$v = \frac{\omega}{k} = \frac{858}{157} = \boxed{54.6\ m/s}$$

(b) $s = 2.00 \cos[(15.7)(0.0500) - (858)(3.00 \times 10^{-3})] = \boxed{-0.433 \mu m}$

(c) $v_{max} = A\omega = (2.00\ \mu m)(858\ s^{-1}) = \boxed{1.72\ mm/s}$

17.27 $40.0\ dB = 10\ dB \log\left(\frac{I}{10^{-12}\ W/m^2}\right)$

$$4.00 = \log \frac{I}{10^{-12}}$$

$$I = 10^{-12}(1.00 \times 10^4) = 1.00 \times 10^{-8}\ W/m^2$$

$$\wp = 4\pi r^2 I = (4\pi)(9.00)(1.00 \times 10^{-8}) = \boxed{1.13\ \mu W}$$

17.34 (a) $f' = \frac{f(v + v_O)}{(v + v_S)}$ where from observer to source is positive.

$$f' = 2500\frac{(343 + 25.0)}{(343 - 40.0)} = \boxed{3.04\ kHz}$$

(b) $f' = 2500\frac{(343 - 25.0)}{(343 + 40.0)} = \boxed{2.08\ kHz}$

(c) $f' = 2500\frac{(343 - 25.0)}{(343 - 40.0)} = \boxed{2.62\ kHz}$ while police car overtakes

$f' = 2500\frac{(343 + 25.0)}{(343 + 40.0)} = \boxed{2.40\ kHz}$ after police car passes

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17.66 $\wp_2 = \frac{1}{20.0}\wp_1$ $\beta_1 - \beta_2 = 10 \log\frac{\wp_1}{\wp_2}$

$$80.0 - \beta_2 = 10 \log 20.0 = +13.0$$

$$\beta_2 = \boxed{67.0\ dB}$$