P16.18 (a) Let us write the wave function as $y(x,\ t) = A\sin(kx + \omega t + \phi)$

$$y(0,\ 0) = A\sin\phi = 0.020\ 0\ \text{m}$$

$$\left.\frac{dy}{dt}\right|_{0,\ 0} = A\omega\cos\phi = -2.00\ \text{m/s}$$

Also, $$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.025\ 0\ \text{s}} = 80.0\pi/\text{s}$$

$$A^2 = x_i^2 + \left(\frac{v_i}{\omega}\right)^2 = (0.020\ 0\ \text{m})^2 + \left(\frac{2.00\ \text{m/s}}{80.0\pi/\text{s}}\right)^2$$

$$A = \boxed{0.021\ 5\ \text{m}}$$

(b) $$\frac{A\sin\phi}{A\cos\phi} = \frac{0.020\ 0}{\frac{-2}{80.0\pi}} = -2.51 = \tan\phi$$

Your calculator's answer $\tan^{-1}(-2.51) = -1.19\ \text{rad}$ has a negative sine and positive cosine, just the reverse of what is required. You must look beyond your calculator to find

$$\phi = \pi - 1.19\ \text{rad} = \boxed{1.95\ \text{rad}}$$

(c) $$v_{y,\ \max} = A\omega = 0.021\ 5\ \text{m}(80.0\pi/\text{s}) = \boxed{5.41\ \text{m/s}}$$

(d) $$\lambda = v_x T = (30.0\ \text{m/s})(0.025\ 0\ \text{s}) = 0.750\ \text{m}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.750\ \text{m}} = 8.38/\text{m} \qquad \omega = 80.0\pi/\text{s}$$

$$\boxed{y(x,\ t) = (0.021\ 5\ \text{m})\sin(8.38x\ \text{rad/m} + 80.0\pi t\ \text{rad/s} + 1.95\ \text{rad})}$$

P16.19 (a) $f = \dfrac{v}{\lambda} = \dfrac{(1.00\ \text{m/s})}{2.00\ \text{m}} = \boxed{0.500\ \text{Hz}}$

$\omega = 2\pi f = 2\pi(0.500/\text{s}) = \boxed{3.14\ \text{rad/s}}$

(b) $k = \dfrac{2\pi}{\lambda} = \dfrac{2\pi}{2.00\ \text{m}} = \boxed{3.14\ \text{rad/m}}$

(c) $y = A\sin(kx - \omega t + \phi)$ becomes

$y = \boxed{(0.100\ \text{m})\sin(3.14x/\text{m} - 3.14t/\text{s} + 0)}$

(d) For $x = 0$ the wave function requires

$\boxed{y = (0.100\ \text{m})\sin(-3.14t/\text{s})}$

(e) $\boxed{y = (0.100\ \text{m})\sin(4.71\ \text{rad} - 3.14\,t/\text{s})}$

(f) $v_y = \dfrac{\partial y}{\partial t} = 0.100\ \text{m}(-3.14/\text{s})\cos(3.14x/\text{m} - 3.14t/\text{s})$

The cosine varies between +1 and –1, so

$v_y \le (0.314\ \text{m/s})$

P16.22 The mass per unit length is: $\mu = \dfrac{0.060\ 0\ \text{kg}}{5.00\ \text{m}} = 1.20 \times 10^{-2}\ \text{kg/m}$.

The required tension is: $T = \mu v^2 = (0.012\ 0\ \text{kg/m})(50.0\ \text{m/s})^2 = \boxed{30.0\ \text{N}}$.

P16.34 $f = \dfrac{v}{\lambda} = \dfrac{30.0}{0.500} = 60.0\ \text{Hz}$ $\qquad \omega = 2\pi f = 120\pi\ \text{rad/s}$

***P16.44** The linear wave equation is $\dfrac{\partial^2 y}{\partial x^2} = \dfrac{1}{v^2}\dfrac{\partial^2 y}{\partial t^2}$

If $y = e^{b(x - vt)}$

then $\dfrac{\partial y}{\partial t} = -bve^{b(x - vt)}$ and $\dfrac{\partial y}{\partial x} = be^{b(x - vt)}$

$\dfrac{\partial^2 y}{\partial t^2} = b^2v^2e^{b(x - vt)}$ and $\dfrac{\partial^2 y}{\partial x^2} = b^2e^{b(x - vt)}$

Therefore, $\dfrac{\partial^2 y}{\partial t^2} = v^2\dfrac{\partial^2 y}{\partial x^2}$, demonstrating that $e^{b(x - vt)}$ is a solution

P17.3 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 before the pot strikes. $0.300\text{ s} + 5.32 \times 10^{-2}\text{ s} = 0.353\text{ s}$

Since the whole time of fall is given by $y = \frac{1}{2}gt^2$: $18.25\text{ m} = \frac{1}{2}(9.80\text{ m/s}^2)t^2$

$t = 1.93\text{ s}$

the warning needs to come $1.93\text{ s} - 0.353\text{ s} = 1.58\text{ s}$

into the fall, when the pot has fallen $\frac{1}{2}(9.80\text{ m/s}^2)(1.58\text{ s})^2 = 12.2\text{ m}$

to be above the ground by $20.0\text{ m} - 12.2\text{ m} = \boxed{7.82\text{ m}}$

P17.12 (a) $\Delta P = (1.27\text{ Pa})\sin\left(\frac{\pi x}{\text{m}} - \frac{340\pi t}{\text{s}}\right)$ (SI units)

The pressure amplitude is: $\Delta P_{max} = \boxed{1.27\text{ Pa}}$.

(b) $\omega = 2\pi f = 340\pi/\text{s}$, so $f = \boxed{170\text{ Hz}}$

(c) $k = \frac{2\pi}{\lambda} = \pi/\text{m}$, giving $\lambda = \boxed{2.00\text{ m}}$

(d) $v = \lambda f = (2.00\text{ m})(170\text{ Hz}) = \boxed{340\text{ m/s}}$

P17.20 (a) $70.0\text{ dB} = 10\log\left(\frac{I}{1.00 \times 10^{-12}\text{ W/m}^2}\right)$

Therefore, $I = (1.00 \times 10^{-12}\text{ W/m}^2)10^{(70.0/10)} = \boxed{1.00 \times 10^{-5}\text{ W/m}^2}$.

(b) $I = \frac{\Delta P_{max}^2}{2\rho v}$, so

$$\Delta P_{max} = \sqrt{2\rho v I} = \sqrt{2(1.20\text{ kg/m}^3)(343\text{ m/s})(1.00 \times 10^{-5}\text{ W/m}^2)}$$

$$\Delta P_{max} = \boxed{90.7\text{ mPa}}$$

***P17.26** (a) We have $\lambda = \frac{v}{f}$ and f is the same for all three waves. Since the speed is smallest in air, λ is smallest in air. It is larger by $\frac{1\,493\text{ m/s}}{331\text{ m/s}} = \boxed{4.51\text{ times}}$ in water and by $\frac{5\,950}{331} = \boxed{18.0\text{ times in iron}}$.

(b) From $I = \frac{1}{2}\rho v \omega^2 s_{\max}^2$; $s_{\max} = \sqrt{\frac{2I_0}{\rho v \omega_0^2}}$, $s_{\max}$ is smallest in iron, larger in water by

$$\sqrt{\frac{\rho_{\text{iron}} v_{\text{iron}}}{\rho_{\text{water}} v_{\text{water}}}} = \sqrt{\frac{7\,860 \cdot 5\,950}{1\,000 \cdot 1\,493}} = \boxed{5.60\text{ times}}$$, and larger in air by $\sqrt{\frac{7\,860 \cdot 5\,950}{1.29 \cdot 331}} = \boxed{331\text{ times}}$.

(c) From $I = \frac{\Delta P_{\max}^2}{2\rho v}$; $\Delta P_{\max} = \sqrt{2I\rho v}$, $\Delta P_{\max}$ is smallest in air, larger in water by

$$\sqrt{\frac{1\,000 \cdot 1\,493}{1.29 \cdot 331}} = \boxed{59.1\text{ times}}$$, and larger in iron by $\sqrt{\frac{7\,860 \cdot 5\,950}{1.29 \cdot 331}} = \boxed{331\text{ times}}$.

(d)

$$\lambda = \frac{v}{f} = \frac{v 2\pi}{\omega} = \frac{(331\text{ m/s})2\pi}{2\,000\pi/\text{s}} = \boxed{0.331\text{ m}}\text{ in air}$$

$$\lambda = \frac{1\,493\text{ m/s}}{1\,000/\text{s}} = \boxed{1.49\text{ m}}\text{ in water} \qquad \lambda = \frac{5\,950\text{ m/s}}{1\,000/\text{s}} = \boxed{5.95\text{ m}}\text{ in iron}$$

$$s_{\max} = \sqrt{\frac{2I_0}{\rho v \omega_0^2}} = \sqrt{\frac{2 \times 10^{-6}\text{ W/m}^2}{(1.29\text{ kg/m}^3)(331\text{ m/s})(6\,283\text{ 1/s})^2}} = \boxed{1.09 \times 10^{-8}\text{ m}}\text{ in air}$$

$$s_{\max} = \sqrt{\frac{2 \times 10^{-6}}{1\,000(1\,493)}\frac{1}{6\,283}} = \boxed{1.84 \times 10^{-10}\text{ m}}\text{ in water}$$

$$s_{\max} = \sqrt{\frac{2 \times 10^{-6}}{7\,860(5\,950)}\frac{1}{6\,283}} = \boxed{3.29 \times 10^{-11}\text{ m}}\text{ in iron}$$

$$\Delta P_{\max} = \sqrt{2I\rho v} = \sqrt{2(10^{-6}\text{ W/m}^2)(1.29\text{ kg/m}^3)331\text{ m/s}} = \boxed{0.029\,2\text{ Pa}}\text{ in air}$$

$$\Delta P_{\max} = \sqrt{2 \times 10^{-6}(1\,000)1\,493} = \boxed{1.73\text{ Pa}}\text{ in water}$$

$$\Delta P_{\max} = \sqrt{2 \times 10^{-6}(7\,860)(5\,950)} = \boxed{9.67\text{ Pa}}\text{ in iron}$$

P17.37 $f' = f\frac{(v \pm v_O)}{(v \pm v_S)}$

(a) $$f' = 320\frac{(343 + 40.0)}{(343 + 20.0)} = \boxed{338\text{ Hz}}$$

(b) $$f' = 510\frac{(343 + 20.0)}{(343 + 40.0)} = \boxed{483\text{ Hz}}$$