1. The wave speed is given by $v = \lambda f$. The period is 3.0 seconds, and the wavelength is 8.0 m.

$$v = \lambda f = \lambda / T = (8.0\,\text{m})/(3.0\,\text{s}) = \boxed{2.7\,\text{m/s}}$$

22. (a) The only difference is the direction of motion.

$$D(x,t) = 0.015\sin(25x + 1200t)$$

(*b*) The speed is found from the wave number and the angular frequency, Eq. 15-12.

$$v = \frac{\omega}{k} = \frac{1200\,\text{rad/s}}{25\,\text{rad/m}} = \boxed{48\,\text{m/s}}$$

24. The traveling wave is given by $D = 0.22\sin(5.6x + 34t)$.

(*a*) The wavelength is found from the coefficient of *x*.

$$5.6\,\text{m}^{-1} = \frac{2\pi}{\lambda} \quad \rightarrow \quad \lambda = \frac{2\pi}{5.6\,\text{m}^{-1}} = 1.122\,\text{m} \approx \boxed{1.1\,\text{m}}$$

(*b*) The frequency is found from the coefficient of *t*.

$$34\,\text{s}^{-1} = 2\pi f \quad \rightarrow \quad f = \frac{34\,\text{s}^{-1}}{2\pi} = 5.411\,\text{Hz} \approx \boxed{5.4\,\text{Hz}}$$

(*c*) The velocity is the ratio of the coefficients of *t* and *x*.

$$v = \lambda f = \frac{2\pi}{5.6\,\text{m}^{-1}}\frac{34\,\text{s}^{-1}}{2\pi} = 6.071\,\text{m/s} \approx \boxed{6.1\,\text{m/s}}$$

Because both coefficients are positive, the velocity is in the $\boxed{\text{negative } x \text{ direction}}$.

(*d*) The amplitude is the coefficient of the sine function, and so is $\boxed{0.22\,\text{m}}$.

(*e*) The particles on the cord move in simple harmonic motion with the same frequency as the

wave. From Chapter 14, $v_{\text{max}} = D\omega = 2\pi fD$.

$$v_{\text{max}} = 2\pi fD = 2\pi\left(\frac{34\,\text{s}^{-1}}{2\pi}\right)(0.22\,\text{m}) = \boxed{7.5\,\text{m/s}}$$

The minimum speed is when a particle is at a turning point of its motion, at which time the speed is 0.

$$v_{\text{min}} = \boxed{0}$$

43. The fundamental frequency of the full string is given by $f_{\text{unfingered}} = \frac{v}{2l} = 441\,\text{Hz}$. If the length is reduced to 2/3 of its current value, and the velocity of waves on the string is not changed, then the new frequency will be as follows.

$$f_{\text{fingered}} = \frac{v}{2\left(\frac{2}{3}l\right)} = \frac{3}{2}\frac{v}{2l} = \left(\frac{3}{2}\right)f_{\text{unfingered}} = \left(\frac{3}{2}\right)(441\,\text{Hz}) = \boxed{662\,\text{Hz}}$$

46. Four loops is the standing wave pattern for the 4th harmonic, with a frequency given by $f_4 = 4f_1 = 280$ Hz. Thus $\boxed{f_1 = 70\text{ Hz}, f_2 = 140\text{ Hz}, f_3 = 210\text{ Hz, and } f_5 = 350\text{ Hz}}$ are all other resonant frequencies.

48. Adjacent nodes are separated by a half-wavelength, as examination of Figure 15-26 will show.

$$\lambda = \frac{v}{f} \quad \rightarrow \quad \Delta x_{\text{node}} = \tfrac{1}{2}\lambda = \frac{v}{2f} = \frac{96\,\text{m/s}}{2(445\,\text{Hz})} = \boxed{0.11\,\text{m}}$$

$\boxed{49.}$ Since $f_n = nf_1$, two successive overtones differ by the fundamental frequency, as shown below.

$$\Delta f = f_{n+1} - f_n = (n+1)f_1 - nf_1 = f_1 = 320\,\text{Hz} - 240\,\text{Hz} = \boxed{80\,\text{Hz}}$$

51. The speed of the wave is given by Eq. 15-2, $v = \sqrt{F_T/\mu}$. The wavelength of the fundamental is $\lambda_1 = 2l$. Thus the frequency of the fundamental is $f_1 = \frac{v}{\lambda_1} = \frac{1}{2l}\sqrt{\frac{F_T}{\mu}}$. Each harmonic is present in a vibrating string, and so $f_n = nf_1 = \boxed{\frac{n}{2l}\sqrt{\frac{F_T}{\mu}}}$, $n = 1, 2, 3, \ldots$.

54. The standing wave is given by $D = (2.4\,\text{cm})\sin(0.60x)\cos(42t)$.

(a) The distance between nodes is half of a wavelength.

$$d = \tfrac{1}{2}\lambda = \tfrac{1}{2}\frac{2\pi}{k} = \frac{\pi}{0.60\,\text{cm}^{-1}} = 5.236\,\text{cm} \approx \boxed{5.2\,\text{cm}}$$

(b) The component waves travel in opposite directions. Each has the same frequency and speed, and each has half the amplitude of the standing wave.

$$A = \tfrac{1}{2}(2.4\,\text{cm}) = \boxed{1.2\,\text{cm}}\ ;\ f = \frac{\omega}{2\pi} = \frac{42\,\text{s}^{-1}}{2\pi} = 6.685\,\text{Hz} \approx \boxed{6.7\,\text{Hz}}\ ;$$

$$v = \lambda f = 2d_{\text{node}}f = 2(5.236\,\text{cm})(6.685\,\text{Hz}) = 70.01\,\text{cm/s} \approx \boxed{70\,\text{cm/s}}\ \ (2\text{ sig. fig.})$$

(c) The speed of a particle is given by $\frac{\partial D}{\partial t}$.

$$\frac{\partial D}{\partial t} = \frac{\partial}{\partial t}\left[(2.4\,\text{cm})\sin(0.60x)\cos(42t)\right] = (-42\,\text{rad/s})(2.4\,\text{cm})\sin(0.60x)\sin(42t)$$

$$\frac{\partial D}{\partial t}(3.20\,\text{cm},\ 2.5\text{s}) = (-42\,\text{rad/s})(2.4\,\text{cm})\sin\left[(0.60\,\text{cm}^{-1})(3.20\,\text{cm})\right]\sin\left[(42\,\text{rad/s})(2.5\,\text{s})\right]$$

$$= \boxed{92\,\text{cm/s}}$$

57. The frequency is given by $f = \frac{v}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{F}{\mu}}$. The wavelength and the mass density do not change when the string is tightened.

$$f = \frac{v}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{F}{\mu}} \quad \rightarrow \quad \frac{f_2}{f_1} = \frac{\frac{1}{\lambda}\sqrt{\frac{F_2}{\mu}}}{\frac{1}{\lambda}\sqrt{\frac{F_1}{\mu}}} = \sqrt{\frac{F_2}{F_1}} \quad \rightarrow \quad f_2 = f_1\sqrt{\frac{F_2}{F_1}} = (294\,\text{Hz})\sqrt{1.15} = \boxed{315\,\text{Hz}}$$

60. (*a*) The maximum swing is twice the amplitude of the standing wave. Three loops is 1.5 wavelengths, and the frequency is given.

$$A = \tfrac{1}{2}(8.00\,\text{cm}) = 4.00\,\text{cm} \;;\; \omega = 2\pi f = 2\pi(120\,\text{Hz}) = 750\,\text{rad/s} \;;$$

$$k = \frac{2\pi}{\lambda} \quad \rightarrow \quad ; \; \tfrac{3}{2}\lambda = 1.64\,\text{m} \quad \rightarrow \quad \lambda = 1.09\,\text{m} \;;\; k = \frac{2\pi}{1.09\,\text{m}} = 5.75\,\text{m}^{-1}$$

$$D = A\sin(kx)\cos(\omega t) = \boxed{(4.00\,\text{cm})\sin\left[\left(5.75\,\text{m}^{-1}\right)x\right]\cos\left[(750\,\text{rad/s})t\right]}$$

(*b*) Each component wave has the same wavelength, the same frequency, and half the amplitude of
the standing wave.

$$\boxed{\begin{aligned} D_1 &= (2.00\,\text{cm})\sin\left[\left(5.75\,\text{m}^{-1}\right)x - (750\,\text{rad/s})t\right] \\ D_2 &= (2.00\,\text{cm})\sin\left[\left(5.75\,\text{m}^{-1}\right)x + (750\,\text{rad/s})t\right] \end{aligned}}$$