CHAPTER 10 | *SIMPLE HARMONIC MOTION AND ELASTICITY*

CONCEPTUAL QUESTIONS

17. ***REASONING AND SOLUTION*** A trash compactor crushes empty aluminum cans, thereby reducing the total volume of the cans by 75%. The value given in Table 10.3 for the bulk modulus of aluminum cannot be used to calculate the change in pressure generated in the trash compactor. The value of the bulk modulus in Table 10.3 pertains to solid aluminum objects. Most of the 75% reduction in the total volume of the cans arises from collapsing the cans and forcing air out of them.

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18. ***REASONING AND SOLUTION*** Pressure is defined in terms of the magnitude of the force per unit area, where the force is applied perpendicular to the surface.

    Both sides of Equation 10.18, $F = S(DX / L_0)A$ can be divided by the area A to give F/A on the left side. This F/A term cannot be called a pressure, such as the pressure that appears in Equation 10.19, because the force F in the "F/A" term is a shear force that is parallel to the surface, not perpendicular to it.

CHAPTER 10 | SIMPLE HARMONIC MOTION AND ELASTICITY

PROBLEMS

28. ***REASONING*** As the block falls, only two forces act on it: its weight and the elastic force of the spring. Both of these forces are conservative forces, so the falling block obeys the principle of conservation of mechanical energy. We will use this conservation principle to determine the initial speed of the block.

SOLUTION

The conservation of mechanical energy states that the final total mechanical energy E_f is equal to the initial total mechanical energy E_0, or $E_f = E_0$ (Equation 6.9a). The expression for the total mechanical energy of an object is given by Equation 10.14. Thus, the conservation of total mechanical energy can be written as

$$\underbrace{\tfrac{1}{2}mv_f^2 + \tfrac{1}{2}Iw_f^2 + mgh_f + \tfrac{1}{2}kx_f^2}_{E_f} = \underbrace{\tfrac{1}{2}mv_0^2 + \tfrac{1}{2}Iw_0^2 + mgh_0 + \tfrac{1}{2}kx_0^2}_{E_0}$$

We can simplify this equation by noting which variables are zero. Since the block comes to a momentarily halt, $v_f = 0$ m/s. The block does not rotate, so its angular speed is zero, $w_f = w_0 = 0$ rad/s. Initially, the spring is unstretched, so that $x_0 = 0$ m. Setting these terms equal to zero in the equation above gives

$$mgh_f + \tfrac{1}{2}kx_f^2 = \tfrac{1}{2}mv_0^2 + mgh_0$$

Solving this equation for the initial speed v_0 of the block gives

$$v_0 = \sqrt{\frac{k\,x_\mathrm{f}^2}{m} - 2g\left(h_0 - h_\mathrm{f}\right)} = \sqrt{\frac{(58\ \mathrm{N/m})(0.15\ \mathrm{m})^2}{0.25\ \mathrm{kg}} - 2\left(9.8\ \mathrm{m/s^2}\right)(0.15\ \mathrm{m})} = \boxed{1.5\ \mathrm{m/s}}$$

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39. ***REASONING AND SOLUTION*** Applying Equation 10.16 and recalling that frequency and period are related by f = 1/T,

$$2\pi f = \frac{2\pi}{T} = \sqrt{\frac{g}{L}}$$

where L is the length of the pendulum. Thus,

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Solving for L gives

$$L = g\left(\frac{T}{2p}\right)^2 = \left(9.80\ \mathrm{m/s^2}\right)\left(\frac{9.2\ \mathrm{s}}{2p}\right)^2 = \boxed{21\ \mathrm{m}}$$

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42. ***REASONING*** As the ball swings down, it reaches it greatest speed at the lowest point in the motion. One complete cycle of the pendulum has four parts: the downward motion in which the ball attains its greatest speed at the lowest point, the subsequent upward motion in which the ball slows down and then momentarily comes to rest. The ball then retraces its motion, finally ending up where it originally began. The time it takes to reach the lowest point is one-quarter of the period of the pendulum, or $t = (1/4)T$. The period is related to the angular frequency w of the pendulum by Equation 10.4, $T = 2p/w$. Thus, the time for the ball to reach its lowest point is

$$t = \tfrac{1}{4}T = \frac{1}{4}\left(\frac{2p}{w}\right)$$

The angular frequency w of the pendulum depends on its length L and the acceleration g due to gravity through the relation $w = \sqrt{g/L}$ (Equation 10.16). Thus, the time is

$$t = \frac{1}{4}\left(\frac{2p}{w}\right) = \frac{1}{4}\left(\frac{2p}{\sqrt{\frac{g}{L}}}\right) = \frac{p}{2}\sqrt{\frac{L}{g}}$$

SOLUTION After the ball is released, the time that has elapsed before it attains its greatest speed is

$$t = \frac{p}{2}\sqrt{\frac{L}{g}} = \frac{p}{2}\sqrt{\frac{0.65\ \mathrm{m}}{9.80\ \mathrm{m/s^2}}} = \boxed{0.40\ \mathrm{s}}$$

CHAPTER 16 | *WAVES AND SOUND*

CONCEPTUAL QUESTIONS

3. ***REASONING AND SOLUTION*** A longitudinal wave moves along a Slinky at a speed of 5 m/s. We *cannot* conclude that one coil of the Slinky moves through a distance of 5 m in one second. The quantity 5 m/s is the longitudinal wave speed, v_{speed}; it specifies how fast the *disturbance* travels along the spring. The wave speed depends on the properties of the spring. Like the transverse wave speed, the longitudinal wave speed depends upon the tension *F* in the spring and its linear mass density *m*/*L*. As long as the tension and the linear mass density remain the same, the disturbance will travel along the spring at constant speed.

The particles in the Slinky oscillate longitudinally in simple harmonic motion with the same amplitude and frequency as the source. As with all particles in simple harmonic motion, the particle speed is not constant. The particle speed is a maximum as the particle passes through its equilibrium position and reaches zero when the particle has reached its maximum displacement from the equilibrium position. The particle speed depends upon the amplitude and frequency of the particle's motion. Thus, the particle speed, and therefore the longitudinal speed of a single coil, depends upon the properties of the source that causes the disturbance.

CHAPTER 16 | *WAVES AND SOUND*

Problems

2. ***REASONING AND SOLUTION*** The "wavelength" of the magnetized regions is

$$\lambda = v/f = (0.048 \text{ m/s})/(15\ 000 \text{ Hz}) = \boxed{3.2 \times 10^{-6} \text{ m}}$$

6. ***REASONING*** The speed of a Tsunamis is equal to the distance *x* it travels divided by the time *t* it takes for the wave to travel that distance. The frequency *f* of the wave is equal to its speed divided by the wavelength λ, $f = v/\lambda$ (Equation 16.1). The period *T* of the wave is related to its frequency by Equation 10.5, $T = 1/f$.

SOLUTION

a. The speed of the wave is (in m/s)

$$v = \frac{x}{t} = \frac{3700 \times 10^3 \text{ m}}{5.3 \text{ h}}\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = \boxed{190 \text{ m/s}}$$

b. The frequency of the wave is

$$f = \frac{v}{l} = \frac{190 \text{ m/s}}{750 \times 10^3 \text{ m}} = \boxed{2.5 \times 10^{-4} \text{ Hz}} \qquad (16.1)$$

c. The period of any wave is the reciprocal of its frequency:

$$T = \frac{1}{f} = \frac{1}{2.5 \times 10^{-4} \text{ Hz}} = \boxed{4.0 \times 10^3 \text{ s}} \qquad (10.5)$$

16. ***REASONING*** Each pulse travels a distance that is given by vt, where v is the wave speed and t is the travel time up to the point when they pass each other. The sum of the distances traveled by each pulse must equal the 50.0-m length of the wire, since each pulse starts out from opposite ends of the wires.

SOLUTION Using v_A and v_B to denote the speeds on either wire, we have

$$v_A\, t + v_B\, t = 50.0 \text{ m}$$

Solving for the time t and using Equation 16.2 $\left(v = \sqrt{\dfrac{F}{m/L}} \right)$, we find

$$t = \frac{50.0 \text{ m}}{v_A + v_B} = \frac{50.0 \text{ m}}{\sqrt{\dfrac{F_A}{m/L}} + \sqrt{\dfrac{F_B}{m/L}}} = \frac{50.0 \text{ m}}{\sqrt{\dfrac{6.00 \times 10^2 \text{ N}}{0.020 \text{ kg/m}}} + \sqrt{\dfrac{3.00 \times 10^2 \text{ N}}{0.020 \text{ kg/m}}}} = \boxed{0.17 \text{ s}}$$