ANSWERS TO EVEN-NUMBERED PROBLEMS

P9.2 1.14 kg; 22.0 m/s

P9.4 (a) $p_x = 9.00\ \text{kg}\cdot\text{m/s}$, $p_y = -12.0\ \text{kg}\cdot\text{m/s}$; (b) 15.0 kg · m/s

P9.6 (a) $v_{pi} = -0.346\ \text{m/s}$; (b) $v_{gi} = 1.15\ \text{m/s}$

P9.8 (a) 4.71 m/s East; (b) 717 J

P9.10 10^{-23} m/s

P9.12 (a) 3.22×10^3 N, 720 lb; (b) not valid; (c) These devices are essential for the safety of small children.

P9.14 (a) $\Delta\vec{p} = 3.38\ \text{kg}\cdot\text{m/s}\ \hat{j}$; (b) $\vec{F} = 7 \times 10^2\ \text{N}\hat{j}$

P9.16 (a) $(9.05\hat{i} + 6.12\hat{j})\ \text{N}\cdot\text{s}$; (b) $(377\hat{i} + 255\hat{j})$ N

P9.18 (a) $3.60\hat{i}$ N · s away from the racket; (b) −36.0 J

P9.20 (a) 981 N · s, up; (b) 3.43 m/s, down; (c) 3.83 m/s, up; (d) 0.748 m

P9.22 (a) 20.9 m/s East; (b) −8.68 × 103 J; (c) Most of the energy was transformed to internal energy with some being carried away by sound.

P9.24 (a) $v_f = \frac{1}{3}(v_1 + 2v_2)$; (b) $\Delta K = -\frac{m}{3}(v_1^2 + v_2^2 - 2v_1v_2)$

P9.26 (a) 2.50 m/s; (b) 37.5 kJ; (c) The event considered in this problem is the time reversal of the perfectly inelastic collision in Problem 9.25. The same momentum conservation equation describes both processes.

P9.28 7.94 cm

P9.30 $v = \frac{4M}{m}\sqrt{g\ell}$

P9.32 $v_c = \frac{(m+M)}{m}\sqrt{2\mu g d}$

P9.34 (a) 2.24 m/s toward the right; (b) No. Coupling order makes no difference to the final velocity.

P9.36 The driver of the northbound car was untruthful. His original speed was more than 35 mi/h.

P9.38 $v_O = 3.99\ \text{m/s}$ and $v_Y = 3.01\ \text{m/s}$

P9.40 $v = \frac{v_i}{\sqrt{2}}$, 45.0°, −45.0°

P9.42 The opponent grabs the fullback and does not let go, so the two players move together at the end of their interaction; (b) $\theta = 32.3°$, 2.88 m/s; (c) 786 J into internal energy

P9.44 $v_B = 5.89$ m/s; $v_C = 7.07$ m/s

P9.46 4.67×10^6 m from the Earth's center

P9.48 11.7 cm; 13.3 cm

P9.50 The center of mass of the molecule lies on the dotted line shown in ANS. FIG. P9.50, 0.006 73 nm below the center of the O atom.

P9.52 (a) See ANS. FIG. P8.42; (b) $(-2.00\hat{i} - 1.00\hat{j})$ m; (c) $(3.00\hat{i} - 1.00\hat{j})$ m/s; (d) $(15.0\hat{i} - 5.00\hat{j})$ kg · m/s

P9.54 (a) $(-2.89\hat{i} - 1.39\hat{j})$cm; (b) $(-44.5\hat{i} + 12.5\hat{j})$g · cm/s; (c) $(-4.94\hat{i} + 1.39\hat{j})$cm/s; (d) $(-2.44\hat{i} + 1.56\hat{j})\text{cm/s}^2$; (e) $(-220\hat{i} + 140\hat{j})\mu$N

P9.56 (a) Yes. $18.0\hat{i}$ kg · m/s; (b) No. The friction force exerted by the floor on each stationary bit of caterpillar tread acts over no distance, so it does zero work; (c) Yes, we could say that the final momentum of the card came from the floor or from the Earth through the floor; (d) No. The kinetic energy came from the original gravitational potential energy of the Earth-elevated load system, in the amount 27.0 J; (e) Yes. The acceleration is caused by the static friction force exerted by the floor that prevents the wheels from slipping backward.

P9.58 (a) yes; (b) no; (c) 103 kg·m/s, up; (d) yes; (e) 88.2 J; (f) no, the energy came from chemical energy in the person's leg muscles

P9.60 (a) 787 m/s; (b) 138 m/s

P9.62 (a) 3.90×10^7 N; (b) 3.20 m/s^2

P9.64 (a) $-v_e \ln\left(1 - \frac{t}{T_p}\right)$; (b) See ANS. FIG. P9.64(b); (c) $\frac{v_e}{T_p - t}$; (d) See ANS. FIG. P9.64(d); (e) $v_e(T_p - t)\ln\left(1 - \frac{t}{T_p}\right) + v_e t$; (f) See ANS. FIG. P9.64(f)

P9.66 (a) $-\left(\frac{m}{M-m}\right)\vec{\mathbf{v}}_{\text{gloves}}$; (b) As she throws the gloves and exerts a force on them, the gloves exert an equal and opposite force on her that causes her to accelerate from rest to reach the velocity $\vec{\mathbf{v}}_{\text{girl}}$.

P9.68 (a) $K_E/K_A = m_1/(m_1+m_2)$; (b) 1.00; (c) See P9.68(c) for argument.

P9.70 (a) –3.54 m/s; (b) 1.77 m; (c) 3.54×10^4 N; (d) No

P9.72 (a) See P9.72(a) for description; (b) $v_i = \frac{m+M}{m}\sqrt{2gh}$

P9.74 (a) See P9.74 for complete statement; (b) The final velocity of the seat is $-0.055\,6\hat{\mathbf{i}}$ m/s. That of the sleigh is $7.94\hat{\mathbf{i}}$ m/s; (c) –453 J

P9.76 In order for his motion to reverse under these conditions, the final mass of the astronaut and space suit is 30 kg, much less than is reasonable.

P9.78 (a) $2.58\times10^3\ \text{kg}\cdot\text{m}/(80\ \text{kg}+m)$; (b) 32.2 m; (c) $m \to 0$; (d) See P9.78(d) for complete answer; (e) See P9.78(e) for complete answer.

P9.80 (a) –0.667 m/s; (b) h = 0.952 m

P9.82 $\left(\frac{M+m}{m}\right)\sqrt{\frac{gd^2}{2h}}$

P9.84 (a) 6.81 m/s; (b) s = 1.00 m

P9.86 (a) 6.29 m/s; (b) 6.16 m/s; (c) Most of the 2% difference between the values for speed could be accounted for by air resistance.

P9.88 0.179 m/s

P9.90 (a) $(20.0\hat{\mathbf{i}}+7.00\hat{\mathbf{j}})$ m/s; (b) $4.00\hat{\mathbf{i}}$ m/s^2; (c) $4.00\hat{\mathbf{i}}$ m/s^2; (d) $(50.0\hat{\mathbf{i}}+35.0\hat{\mathbf{j}})$ m; (e) 600 J; (f) 674 J; (g) 674 J; (h) The accelerations computed in different ways agree. The kinetic energies computed in different ways agree. The three theories are consistent.

P9.92 $0.063\,5L$

P9.94 (a) 3.75 N; (b) 3.75 N; (c) 3.75 N; (d) 2.81 J; (e) 1.41 J/s; (f) One-half of the work input becomes kinetic energy of the moving sand and the other half becomes additional internal energy. The internal energy appears when the sand does not elastically bounce under the hopper, but has friction eliminate its horizontal motion relative to the belt. By contrast, all of the impulse input becomes momentum of the moving sand.

P9.96 $\frac{3Mgx}{L}$

ANSWERS TO EVEN-NUMBERED PROBLEMS

P10.2 (a) 0.209 rad/s^2; (b) yes

P10.4 144 rad

P10.6 -2.26×10^2 rad/s^2

P10.8 (a) 3.5 rad; (b) increase by a factor of 4

P10.10 Because the disk's average angular speed does not match the average angular speed expressed as $(\omega_i + \omega_f)/2$ in the model of a rigid object under constant angular acceleration, the angular acceleration of the disk cannot be constant.

P10.12 50.0 rev

P10.14 (a) $\boxed{\omega h^{3/2}\left(\frac{2}{g}\right)^{1/2}}$; (b) 1.16 cm; (c) The deflection is only 0.02% of the original height, so it is negligible in many practical cases; (d) Decrease

P10.16 ~10^7 rev/yr

P10.18 (a) 0.605 m/s; (b) 17.3 rad/s; (c) 5.82 m/s; (d) We did not need to know the length of the pedal cranks.

P10.20 (a) 54.3 rev; (b) 12.1 rev/s

P10.22 (a) 5.77 cm; (b) Yes. See P10.20 for full explanation.

P10.24 $\frac{a}{g}\sqrt{1+\pi^2}$

P10.26 (a) $(-2.73\hat{i}+1.24\hat{j})$ m; (b) It is in the second quadrant, at 156°; (c) $(-1.85\hat{i}-4.10\hat{j})$ m/s; (d) It is moving toward the third quadrant, at 246°; (e) $(6.15\hat{i}-2.78\hat{j})$ m/s^2; (f) See ANS. FIG. P10.26; (g) $(24.6\hat{i}-11.1\hat{j})$ N

P10.28 168 N · m

P10.30 (a) 1.03 s; (b) 10.3 rev

P10.32 (a) See ANS. FIG. P10.32; (b) 0.309 m/s^2; (c) T_1 = 7.67 N, T_2 = 9.22 N

P10.34 (a) For F = 25.1 N, R = 1.00 m. For F = 10.0 N, R = 25.1 m; (b) No. Infinitely many pairs of values that satisfy this requirement may exist: for any $F \le 50.0$ N, R = 25.1 N · m/F, as long as $R \le 3.00$ m.

P10.36 (a) 1.95 s; (b) If the pulley were massless, the acceleration would be larger by a factor 35/32.5 and the time short by the square root of the factor 32.5/35. That is, the time would be reduced by 3.64%.

P10.38 $10^0\ \text{kg}\cdot\text{m}^2 = 1\ \text{kg}\cdot\text{m}^2$

P10.40 (a) See P10.40(a) for full description; (b) See P10.40(b) for full description

P10.42 $I_{y'} = \int_{\text{all mass}} r^2 dm = \int_0^L x^2 \frac{M}{L} dx = \frac{M}{L}\frac{x^3}{3}\Big|_0^L = \frac{1}{3}ML^2$

P10.44 (a) 92.0 kg·m^2; (b) 184 J; (c) 6.00 m/s, 4.00 m/s, 8.00 m/s; (d) 184 J; (e) The kinetic energies computed in parts (b) and (d) are the same.

P10.46 $\frac{13}{24}MR^2\omega^2$

P10.48 276 J

P10.50 $v = \sqrt{\frac{2(m_1 - m_2)gh}{m_1 + m_2 + \frac{I}{R^2}}}$ and $\omega = \sqrt{\frac{2(m_1 - m_2)gh}{m_1R^2 + m_2R^2 + I}}$

P10.52 The situation is impossible because the range is only 3.86 km, not city-wide.

P10.54 (a) 6.90 J; (b) 8.73 rad/s; (c) 2.44 m/s; (d) The speed it attains in swinging is greater by 1.043 2 times

P10.56 $mr^2\left(\frac{2gh}{v^2} - 1\right)$

P10.58 (a) 74.3 W; (b) 401 W

P10.60 rolling: $v_f = \sqrt{10gh/7}$; sliding: $v_f = \sqrt{2gh}$; The time to roll is longer by a factor of $(0.7/0.5)^{1/2} = 1.18$

P10.62 (a) the cylinder; (b) $v^2/4g\sin\theta$; (c) The cylinder does not lose mechanical energy because static friction does not work on it. Its rotation means that it has 50% more kinetic energy than the cube at the start, and so it travels 50% farther up the incline.

P10.64 (a) 2.38 m/s; (b) The centripetal acceleration at the top is $\frac{v_2^2}{r} = \frac{(2.38\ \text{m/s})^2}{0.450\ \text{m}} = 12.6\ \text{m/s}^2 > g$. Thus, the ball must be in contact with the track, with the track pushing downward on it; (c) 4.31 m/s; (d) $\sqrt{-1.40\ \text{m}^2/\text{s}^2}$; (e) never makes it to the top of the loop

P10.66 $\frac{1}{3}$ the length of the chimney

P10.68 (a) $d = (1890 + 80n)\left(\frac{0.459\text{ m}}{80n - 150}\right)$; (b) 94.1 m; (c) 1.62 m; (d) –5.79 m; (e) The rising car will coast to a stop only for $n \geq 2$; (f) For $n = 0$ or $n = 1$, the mass of the elevator is less than the counterweight, so the car would accelerate upward if released; (g) 0.459 m

P10.70 $\omega(t) = \omega + At + \frac{1}{2}Bt^2$; (b) $\omega t + \frac{1}{2}At^2 + \frac{1}{6}Bt^3$

P10.72 (a) (i) –794 N·m, (ii) –2 510 N·m, (iii) 0 N·m, (iv) –1 160 N·m, (v) 2 940 N·m; (b) See P10.72(b) for full description.

P10.74 -0.322 rad/s^2

P10.76 (a) 2.57×10^{29} J; (b) -1.63×10^{17} J/day

P10.78 (a) $Mg/3$; (b) $2g/3$; (c) $\sqrt{4gh/3}$; (d) The answer is the same.

P10.80 (a) $\theta \leq 35.5°$; (b) 0.184 m from the moving end

P10.82 (a) $a_{\text{CM}} = \frac{4F}{3M}$; (b) $\frac{1}{3}F$; (c) $\sqrt{\frac{8Fd}{3M}}$

P10.84 (a) 35.0 m/s^2; (b) $7.35\hat{\mathbf{i}}$ N; (c) 17.5 m/s^2; (d) $-3.68\hat{\mathbf{i}}$ N; (e) 0.827 m (from the top)

P10.86 54.0°

P10.88 See P10.88 for full design and specifications of flywheel.

P10.90 (a) See P10.90(a) for full solution; (b) See P10.90(g) for full solution;

(c) $\frac{2\pi r_i}{h}\left(\sqrt{1 + \frac{vh}{\pi r_i^2}t} - 1\right)$; (d) $\alpha = -\frac{hv^2}{2\pi r_i^2\left(1 + \frac{vh}{\pi r_i^2}t\right)^{3/2}}$

P10.92 (a) See P10.92(a) for full explanation; (b) $\frac{2Mg(\sin\theta - \mu\cos\theta)}{2M + m}$

P10.94 $R\left[m\left(g - \frac{2y}{t^2}\right) - \frac{5}{4}\frac{My}{t^2}\right]$

ANSWERS TO EVEN-NUMBERED PROBLEMS

P11.2 (a) 740 cm^2; (b) 59.5 cm

P11.4 See full solution in P11.4.

P11.6 (a) 168°; (b) 11.9°; (c) the first method

P11.8 (a) $(-10.0\text{ N}\cdot\text{m})\hat{\mathbf{k}}$; (b) Yes; (c) Yes; (d) Yes; (e) No; (f) $5.00\hat{\mathbf{j}}$ m

P11.10 (a) No; (b) No, the cross product could not work out that way.

P11.12 $\left(-22.0\text{ kg}\cdot\text{m}^2/\text{s}\right)\hat{\mathbf{k}}$

P11.14 (a) $\left(-9.03\times10^9\text{kg}\cdot\text{m}^2/\text{s}\right)\hat{\mathbf{j}}$; (b) No; (c) Zero

P11.16 $\sqrt{m^2 g \ell^3 \dfrac{\sin^4\theta}{\cos\theta}}$

P11.18 (a) 3.14 N · m; (b) (0.480 kg · m)v; (c) 6.53 m/s^2

P11.20 (a) $2t^3\hat{\mathbf{i}}+t^2\hat{\mathbf{j}}$; (b) The particle starts from rest at the origin, starts moving into the first quadrant, and gains speed faster while turning to move more nearly parallel to the x axis; (c) $\left(12t\hat{\mathbf{i}}+2\hat{\mathbf{j}}\right)$ m/s^2;
(d) $\left(60t\hat{\mathbf{i}}+10\hat{\mathbf{j}}\right)$ N; (e) $-40t^3\hat{\mathbf{k}}$ N·m;; (f) $-10t^4\hat{\mathbf{k}}$ kg·m^2/s;
(g) $(90t^4 + 10t^2)$ J; (h) $(360t^3 + 20t)$ W

P11.22 $\vec{\mathbf{L}}=\left(4.50\text{ kg}\cdot\text{m}^2/\text{s}\right)\hat{\mathbf{k}}$

P11.24 $K=\dfrac{1}{2}I\omega^2=\dfrac{1}{2}\dfrac{I^2\omega^2}{I}=\dfrac{L^2}{2I}$

P11.26 (a) $7.06\times10^{33}\text{kg}\cdot\text{m}^2/\text{s}$, toward the north celestial pole;
(b) $2.66\times10^{40}\text{kg}\cdot\text{m}^2/\text{s}$, toward the north ecliptic pole; (c) See P11.26(c) for full explanation.

P11.28 8.63 m/s^2

P11.30 (a) $\dfrac{I_1}{I_1+I_2}\omega_i$; (b) $\dfrac{I_1}{I_1+I_2}$

P11.32 (a) 2.91 s; (b) Yes because there is no net external torque acting on the puck-rod-putty system; (c) No because the pivot pin is always pulling on the rod to change the direction of the momentum; (d) No. Some mechanical energy is converted into internal energy. The collision is perfectly inelastic.

P11.34 (a) 1.91 rad/s; (b) 2.53 J, 6.44 J

P11.36 (a) $7.20 \times 10^{-3} \text{kg} \cdot \text{m}^2/\text{s}$; (b) 9.47 rad/s

P11.38 (a) 2.35 rad/s; (b) 0.498 rad/s; (c) 5.58°

P11.40 When the people move to the center, the angular speed of the station increases. This increases the effective gravity by 26%. Therefore, the ball will not take the same amount of time to drop.

P11.42 131 s

P11.44 (a) 0; (b) monkey and bananas move upward with the same speed; (c) The monkey will not reach the bananas.

P11.46 (a) $0.250\hat{\mathbf{i}}$ m/s; (b) 0.000 716; (c) $0.250\hat{\mathbf{i}}$ m/s; (d) 15.8 rad/s; (e) 1.00; (f) See P11.46(f) for full explanation.

P11.48 (a) 11.1 m/s; (b) $5.32 \times 10^3 \text{kg} \cdot \text{m}^2/\text{s}$; (c) See P11.48(c) for full explanation; (d) 12.0 m/s; (e) 1.08 kJ

P11.50 (a) $2.11\hat{\mathbf{j}}$ rad/s; (b) See P11.50(b) for full problem statement; (c) Yes, with the left-hand side representing the final situation and the right-hand side representing the original situation, the equation describes the throwing process.

P11.52 (a) 4.50 m/s; (b) 10.1 N; (c) 0.450 J

P11.54 An asteroid that would cause a 0.500-s change in the rotation period of the Earth has a mass of 1.38×10^{19} kg and is an order of magnitude larger in diameter than the one that caused the extinction of the dinosaurs.

P11.56 (a) Mvd; (b) Mv^2; (c) Mvd; (d) $2v$; (e) $4Mv^2$; (f) $3Mv^2$

P11.58 (a) $\omega_f = \dfrac{36.0(1+3.20m)}{1+20.0m}$ rad/s; (b) ω_f decreases smoothly from a maximum value of 36.0 rad/s for $m = 0$ toward a minimum value of $(36 \times 3.2/20) = 5.76$ rad/s as $m \to \infty$

P11.60 5.99×10^{-2} J

P11.62 (a) 2.0 m/s; (b) 1.0 rad/s

P11.64 $\dfrac{M}{m}\sqrt{3ga\left(\sqrt{2}-1\right)}$

ANSWERS TO EVEN-NUMBERED PROBLEMS

P15.2 1.59 k N/m

P15.4 (a) 4.33 cm; (b) –5.00 cm/s; (c) –17.3 cm/s^2; (d) 3.14 s; (e) 5.00 cm

P15.6 (a) 18.8 m/s; (b) 7.11 km/s^2

P15.8 (a) 2.40 s; (b) 0.417 Hz; (c) 2.62 rad/s

P15.10 39.2 N

P15.12 (a) 15.8 cm; (b) 51.1 m; (c) –15.9 cm; (d) 50.8 m; (e) The patterns of oscillation diverge from each other, starting out in phase but becoming completely out of phase. To calculate the future, we would need *exact* knowledge of the present; an impossibility.

P15.14 (a) motion is periodic; (b) 1.81 s; (c) The motion is not simple harmonic. The net force acting on the ball is a constant given by $F = -mg$ (except when it is in contact with the ground), which is not in the form of Hooke's law.

P15.16 (a) See P15.16(a) for complete solution; (b) See P15.16(b) for complete solution

P15.18 (a) 1.26 s; (b) 0.150 m/s, 0.750 m/s^2; (c) $x = 3.00\cos(5.00t + \pi)$, $-15.0\sin(5.00t + \pi)$, and $-75.0\cos(5.00t + \pi)$

P15.20 (a) yes; (b) We see that finding the period does not depend on knowing the mass: $T = 0.859$ s.

P15.22 (a) 126 N/m; (b) 0.178 m

P15.24 (a) 0.153 J; (b) 0.784 m/s; (c) 17.5 m/s^2

P15.26 (a) E increases by a factor of 4; (b) v_{max} is doubled; (c) a_{max} also doubles; (d) the period is unchanged.

P15.28 (a) 100 N/m; (b) 1.13 Hz; (c) 1.41 m/s; (d) $x = 0$; (e) 10.0 m/s^2; (f) ±0.200 m; (g) 2.00 J; (h) 1.33 m/s; (i) 3.33 m/s^2

P15.30 (a) Particle under constant acceleration; (b) 1.50 s; (c) isolated; (d) 73.4 N/m; (e) 19.7 m below the bridge; (f) 1.06 rad/s; (g) +2.01 s; (h) 3.50 s

P15.32 (a) 5.98 m/s; (b) 206 N/m; (c) 0.238 m

P15.34 1.001 5

P15.36 $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{R}}$

P15.38 $I = \frac{mgd}{4\pi^2 f^2}$

P15.40 (a) $2\pi\sqrt{\frac{(I_{CM} + md^2)}{mgd}}$; (b) $I_{CM} = md^2$

P15.42 (a) 2.09 s; (b) 4.08%

P15.44 For Length, L (m): 1.000, 0.750, 0.500 and Period, T (s): 2.00, 1.73, 1.42; (b) For Period T(s): 2.00, 1.73, 1.42 and g (m/s^2): 9.87, 9.89, 9.79. This agrees with the accepted value of $g = 9.80$ m/s^2 within 0.5%; (c) 9.94 m/s^2

P15.46 1.00×10^{-3} s^{-1}

P15.48 $\frac{dE}{dt} = -bv^2 < 0$

P15.50 (a) 1.19 Hz; (b) 17.5 cm

P15.52 318 N

P15.54 See P15.54 for complete solution.

P15.56 0.919×10^{14} Hz

P15.58 (a) 0.368 m/s; (b) 3.51 cm; (c) 40.6 mJ; (d) 27.7 mJ

P15.60 (a) 4.31 cm; (b) When the rock is on the point of lifting off, the surrounding water is also barely in free fall. No pressure gradient exists in the water, so no buoyant force acts on the rock. The effect of the surrounding water disappears at that instant.

P15.62 (a) See P15.62(a) for complete solution; (b) 1.04 m/s; (c) 3.40 m

P15.64 (a) $A = 2.00$ cm; (b) $T = 4.00$ s; (c) $\frac{\pi}{2}$ rad/s; (d) π cm/s; (e) 4.93 cm/s^2; (f) $x = 2.00\sin\left(\frac{\pi}{2}t\right)$, where x is in centimeters and t is in seconds

P15.66 $\frac{\mu_s g}{4\pi^2 f^2}$

P15.68 (a) $2\pi\sqrt{\frac{m(k_1 + k_2)}{k_1 k_2}}$; (b) $2\pi\sqrt{\frac{m}{(k_1 + k_2)}}$

P15.70 $\omega = \sqrt{\frac{3k}{m}}$

P15.72 (a) $\sum \vec{\mathbf{F}} = \frac{-2Ty}{L}\hat{\mathbf{j}}$; (b) $\omega = \sqrt{\frac{2T}{mL}}$

P15.74 If he encounters washboard bumps at the same frequency as the free vibration, resonance will make the motorcycle bounce a lot. It may bounce so much as to interfere with the rider's control of the machine; $\sim 10^1$ m.

P15.76 (a) See ANS. FIG. P15.76(a); (b) 1.74 N/m ± 6%; (c) See table in P15.76(c); (d) See table in P15.76(d); (e) See ANS. FIG. P15.64(e); (f) 1.82 N/m ± 3%; (g) they agree; (h) 8 grams ± 12% in agreement

P15.78 (a) 5.20 s; (b) 2.60 s; (c) $\frac{dA/dt}{A} = \frac{1}{2}\frac{dE/dt}{E}$

P15.80 See P15.80 for complete solution.

P15.82 If the damping constant is doubled, $b/2m = 120\ \text{s}^{-1}$. In this case, however, $b/2m > \omega_0$ and the system is overdamped. Your design objective is not met because the system does not oscillate.

P15.84 (a) $v = 2\left[\frac{Rg(1-\cos\theta)}{M/m + r^2/R^2 + 2}\right]^{1/2}$; (b) $2\pi\left[\frac{(M+2m)R^2 + mr^2}{2mgR}\right]^{1/2}$

P15.86 This is exactly the same time interval as for your competitor, so you have no advantage! In fact, you have the disadvantage of the initial capital outlay to bore through the entire Earth!

P15.88 (a) $y_f = -0.110$ m; (b) its period will be longer

ANSWERS TO EVEN-NUMBERED PROBLEMS

P16.2 (a) See ANS. FIG. P16.2(a); (b) See ANS. FIG. P16.2(b); (c) The graph in ANS. FIG. P16.2(b) has the same amplitude and wavelength as the graph in ANS. FIG. P16.2(a). It differs just by being shifted toward larger x by 2.40 m; (d) The wave has traveled $d = vt = 2.40$ m to the right.

P16.4 (a) longitudinal P wave; (b) 666 s

P16.6 (a) See ANS. FIG. P16.6(a); (b) See ANS. FIG. P16.6(b); (c) See ANS. FIG. P16.6(c); (d) See ANS. FIG. P16.6(d); (e) See ANS. FIG. P16.6(e)

P16.8 0.800 m/s

P16.10 2.40 m/s

P16.12 ±6.67 cm

P16.14 (a) See ANS FIG P16.14; (b) 0.125 s; (c) This agrees with the period found in the example in the text.

P16.16 (a) 0.100 sin (1.002–20.0t); (b) 3.18 Hz

P16.18 (a) See ANS FIG P13.12(a); (b) 18.0 rad/m; (c) 0.083 3 s; (d) 75.4 rad/s; (e) 4.20 m/s; (f) $y = (0.200 \text{ m}) \sin(18.0x/\text{m} + 75.4t/\text{s} + \phi)$; (g) $y(x, t) = 0.200 \sin(18.0x + 75.4t - 0.151)$, where x and y are in meters and t is in seconds.

P16.20 (a) 0.021 5 m; (b) 1.95 rad; (c) 5.41 m/s; (d) $y(x,t) = (0.021\,5) \sin(8.38x + 80.0\pi t + 1.95)$

P16.22 520 m/s

P16.24 (a) units are seconds and newtons; (b) The first T is period of time; the second is force of tension.

P16.26 (a) $y = (2.00 \times 10^{-4}) \sin(16.0x - 3\,140t)$, where y and x are in meters and t is in seconds; (b) 158 N

P16.28 The calculated gravitational acceleration of the Moon is almost twice that of the accepted value.

P16.30 (a) $v = (30.4)\sqrt{m}$ where v is in meters per second and m is in kilograms; (b) $m = 3.89$ kg

P16.32 (a) As for a string wave, the rate of energy transfer is proportional to the square of the amplitude to the speed. The rate of energy transfer stays constant because each wavefront carries constant energy, and the frequency stays constant. As the speed drops, the amplitude must increase; (b) The amplitude increases by 5.00 times

P16.34 55.1 Hz

P16.36 1.07 kW

P16.38 $\sqrt{2}P_0$

P16.40 See P16.40 for the full explanation.

P16.42 (a) $A = 40.0$; (b) $A = 7.00$, $B = 0$, and $C = 3.00$; (c) In order for two vectors to be equal, they must have the same magnitude and the same direction in three-directional space. All of their components must be equal, so all coefficients of the unit vectors must be equal; (d) $A = 0$, $B = 7.00$, $C = 3.00$, $D = 4.00$, $E = 2.00$; (e) Identify corresponding parts. In order for two functions to be identically equal, corresponding parts must be identical. The argument of the sine function must have no units or be equal to units of radians.

P16.44 (a) See P16.44(a) for full explanation; (b) $f(x+vt) = \frac{1}{2}(x+vt)^2$ and $g(x-vt) = \frac{1}{2}(x-vt)^2$; (c) $f(x+vt) = \frac{1}{2}\sin(x+vt)$ and $g(x-vt) = \frac{1}{2}\sin(x-vt)$

P16.46 ~1 min

P16.48 6.01 km

P16.50 (a) 2 Mg; (b) $L_0 + \frac{2\,Mg}{k}$; (c) $\sqrt{\frac{2\,Mg}{k}\left(L_0 + \frac{2\,Mg}{k}\right)}$

P16.52 (a) 375 m/s^2; (b) 0.045 0 N; (c) 46.9 N. The maximum transverse force is very small compared to the tension, more than a thousand times smaller.

P16.54 (a) The energy a wave crest carries is constant in the absence of absorption. Then the rate at which energy passes a stationary point, which is the power of the wave, is constant; (b) The power is proportional to the square of the amplitude and to the wave speed. The speed decreases as the wave moves into shallower water near shore, so the amplitude must increase; (c) 8.31 m; (d) As the water depth goes to zero, our model would predict zero speed and infinite amplitude. In fact, the amplitude must be finite as the wave comes ashore. As the speed decreases, the wavelength also decreases. When it becomes comparable to the water depth, or smaller, our formula $\sqrt{gd}$ for wave speed no longer applies.

P16.56 8.43×10^{-3} s