CHAPTER 5

Quick Quizzes

1. (c), (a), (d), (b). The work in (c) is positive and of the largest possible value because the angle between the force and the displacement is zero. The work done in (a) is zero because the force is perpendicular to the displacement. In (d) and (b), negative work is done by the applied force because in neither case is there a component of the force in the direction of the displacement. Situation (b) is the most negative value because the angle between the force and the displacement is 180°.

2. All three balls have the same speed the moment they hit the ground because all start with the same kinetic energy and undergo the same change in gravitational potential energy.

3. (c).

4. (c). The decrease in mechanical energy of the system is $f_k \Delta x$. This is smaller than the value on the horizontal surface for two reasons: (1) the force of kinetic friction f_k is smaller because the normal force is smaller, and (2) the displacement Δx is smaller because a component of the gravitational force is pulling on the book in the direction opposite to its velocity.

Problem Solutions

5.1 If the weights are to move at constant velocity, the net force on them must be zero. Thus, the force exerted on the weights is upward, parallel to the displacement, with magnitude 350 N. The work done by this force is

$$W = (F\cos\theta)s = [(350\text{ N})\cos 0°](2.00\text{ m}) = \boxed{700\text{ J}}.$$

5.2 To lift the bucket at constant speed, the woman exerts an upward force whose magnitude is $F = mg = (20.0\text{ kg})(9.80\text{ m/s}^2) = 196\text{ N}$. The work done is $W = (F\cos\theta)s$, so the displacement is

$$s = \frac{W}{F\cos\theta} = \frac{6.00\times 10^3\text{ J}}{(196\text{ N})\cos 0°} = \boxed{30.6\text{ m}}.$$

5.3 $W = (F\cos\theta)s = \left[\left(5.00\times 10^3\text{ N}\right)\cos 0°\right]\left(3.00\times 10^3\text{ m}\right) = 1.50\times 10^7\text{ J} = \boxed{15.0\text{ MJ}}$.

5.4 The applied force makes an angle of 25° with the displacement of the cart. Thus, the work done on the cart is

$$W = (F\cos\theta)s = [(35\text{ N})\cos 25°](50\text{ m}) = 1.6\times 10^3\text{ J} = 1.6\text{ kJ}.$$

5.5 (a) The force of gravity is given by $mg = (5.00\text{ kg})(9.80\text{ m/s}^2) = 49.0\text{ N}$ and is directed downwards. The angle between the force of gravity and the direction of motion is θ = 90.0° - 30.0° = 60.0°, and so the work done by gravity is given as

$$W_g = (F\cos\theta)s = [(49.0\text{ N})\cos 60.0°](2.50\text{ m}) = \boxed{61.3\text{ J}}.$$

(b) The normal force exerted on the block by the incline is $n = mg\cos 30.0°$, so the friction force is

$$f_k = \mu_k n = (0.436)(49.0\text{ N})\cos 30.0° = 18.5\text{ N}.$$

This force is directed opposite to the displacement (i.e. θ = 180°), and the work it does is

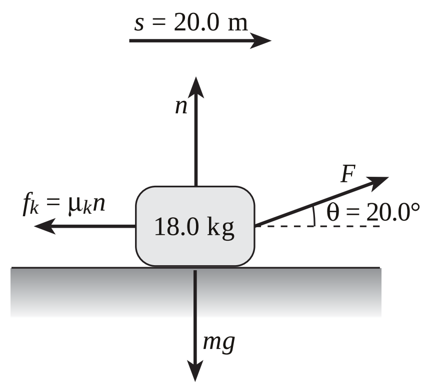
$$W_f = (f_k\cos\theta)s = [(18.5\text{ N})\cos 180°](2.50\text{ m}) = \boxed{-46.3\text{ J}}.$$

(c) Since the normal force is perpendicular to the displacement; $\theta = 90°$, $\cos\theta = 0$, and the work done by the normal force is $\boxed{\text{zero}}$.

5.6 The total distance the scraper is moved over the surface of the tooth is $s = 20(0.75\text{ cm}) = 15\text{ cm} = 0.15\text{ m}$. The friction force has magnitude $f_k = \mu_k n = (0.90)(5.0\text{ N}) = 4.5\text{ N}$. Hence, the force which must be applied in the direction of the motion to overcome friction is $F = 4.5\text{ N}$ and the work done is

$$W = (F\cos\theta)s = [(4.5\text{ N})\cos 0°](0.15\text{ m}) = \boxed{0.68\text{ J}}.$$

5.7 (a) $\Sigma F_y = F\sin\theta + n - mg = 0$



$$n = mg - F\sin\theta$$

$$\Sigma F_x = F\cos\theta - \mu_k n = 0$$

$$n = \frac{F\cos\theta}{\mu_k}$$

$$\therefore \quad mg - F\sin\theta = \frac{F\cos\theta}{\mu_k}$$

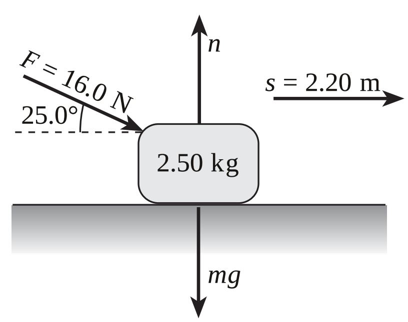
$$F = \frac{\mu_k mg}{\mu_k\sin\theta + \cos\theta} = \frac{(0.500)(18.0\text{ kg})(9.80\text{ m/s}^2)}{(0.500)\sin 20.0° + \cos 20.0°} = \boxed{79.4\text{ N}}$$

(b) $W_F = (F\cos\theta)s = [(79.4\text{ N})\cos 20.0°](20.0\text{ m}) = 1.49\times 10^3\text{ J} = \boxed{1.49\text{ kJ}}$

(c) $f_k = F\cos\theta = 74.6\text{ N}$

$$W_f = (f_k\cos\theta)s = [(74.6\text{ N})\cos 180°](20.0\text{ m}) = -1.49\times 10^3\text{ J} = \boxed{-1.49\text{ kJ}}$$

5.8 (a) $W_F = (F\cos\theta)s = [(16.0\text{ N})\cos 25.0°](2.20\text{ m})$



$W_F = \boxed{31.9\text{ J}}$

(b) $W_n = (n\cos 90°)s = \boxed{0}$

(c) $W_g = (mg\cos 90°)s = \boxed{0}$

(d) $W_{net} = W_F + W_n + W_g = 31.9\text{ J} + 0 + 0 = \boxed{31.9\text{ J}}$

5.9 (a) The work-energy theorem, $W_{net} = KE_f - KE_i$, gives

$$5000\text{ J} = \frac{1}{2}\left(2.50\times10^{3}\text{ kg}\right)v^2 - 0\text{, or}\qquad v = \boxed{2.00\text{ m/s}}.$$

(b) $W = \left(F\cos\theta\right)s = \left(F\cos 0°\right)\left(25.0\text{ m}\right) = 5000\text{ J}$, so $F = \boxed{200\text{ N}}$.

5.10 Requiring that $KE_{ping\ pong} = KE_{bowling}$ with $KE = \frac{1}{2}mv^2$, we have

$$\frac{1}{2}\left(2.45\times10^{-3}\text{ kg}\right)v^2 = \frac{1}{2}\left(7.00\text{ kg}\right)\left(3.00\text{ m/s}\right)^2\text{, giving } v = \boxed{160\text{ m/s}}.$$

5.11 The person's mass is $m = \frac{w}{g} = \frac{700\text{ N}}{9.80\text{ m/s}^2} = 71.4\text{ kg}$. The net upward force acting on the body is $F_{net} = 2\left(355\text{ N}\right) - 700\text{ N} = 10.0\text{ N}$. The final upward velocity can then be calculated from the work-energy theorem as

$$W_{net} = KE_f - KE_i = \frac{1}{2}mv^2 - \frac{1}{2}mv_i^2,$$

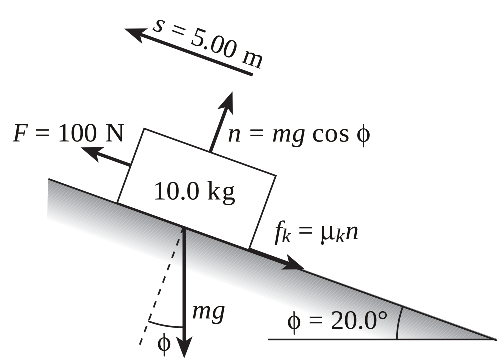
or $$\left(F_{net}\cos\theta\right)s = \left[\left(10.0\text{ N}\right)\cos 0°\right]\left(0.250\text{ m}\right) = \frac{1}{2}\left(71.4\text{ kg}\right)v^2 - 0$$

which gives $v = \boxed{0.265\text{ m/s upward}}$.

5.12 (a) $W_g = \left[mg\cos\theta\right]s = \left[mg\cos\left(90.0° + \phi\right)\right]s$

$$W_g = \left[\left(10.0\text{ kg}\right)\left(9.80\text{ m/s}^2\right)\cos 110°\right]\left(5.00\text{ m}\right)$$

$$= \boxed{-168\text{ J}}$$



(b) $W_f = \left(f_k\cos\theta\right)s = \left[\left(\mu_k n\right)\cos 180°\right]s$

$$= \left[0.400\left(98.0\text{ N }\cos 20.0°\right)\cos 180°\right]\left(5.00\text{ m}\right)$$

$$= \boxed{-184\text{ J}}$$

(c) $W_F = \left(F\cos\theta\right)s = \left[\left(100\text{ N}\right)\cos 0°\right]\left(5.00\text{ m}\right) = \boxed{500\text{ J}}$

(d) $\Delta KE = W_{net} = W_g + W_f + W_F = \boxed{148\text{ J}}$

(e) $\Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mv_i^2$

$$v = \sqrt{\frac{2(\Delta KE)}{m} + v_i^2} = \sqrt{\frac{2(148\text{ J})}{10.0\text{ kg}} + (1.50\text{ m/s})^2} = \boxed{5.64\text{ m/s}}$$

5.13 (a) We use the work-energy theorem to find the work.

$$W = \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mv_i^2 = 0 - \frac{1}{2}(70\text{ kg})(4.0\text{ m/s})^2 = \boxed{-5.6\times 10^2\text{ J}}.$$

(b) $W = (F\cos\theta)s = (f_k \cos 180°)s = (-\mu_k n)s = (-\mu_k mg)s$,

so $$s = -\frac{W}{\mu_k mg} = -\frac{(-5.6\times 10^2\text{ J})}{(0.70)(70\text{ kg})(9.80\text{ m/s}^2)} = \boxed{1.2\text{ m}}.$$

5.14 At the top of the arc, $v_y = 0$, and $v_x = v_{ix} = v_i \cos 30.0° = 34.6\text{ m/s}$.

Therefore $v^2 = v_x^2 + v_y^2 = (34.6\text{ m/s})^2$, and

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(0.150\text{ kg})(34.6\text{ m/s})^2 = \boxed{90.0\text{ J}}.$$

5.15 (a) The final kinetic energy of the bullet is

$$KE_f = \frac{1}{2}mv^2 = \frac{1}{2}(2.0\times 10^{-3}\text{ kg})(300\text{ m/s})^2 = \boxed{90\text{ J}}.$$

(b) We know that $W = \Delta KE$, and also $W = (\overline{F}\cos\theta)s$.

Thus, $\overline{F} = \frac{\Delta KE}{s\cos\theta} = \frac{90\text{ J} - 0}{(0.50\text{ m})\cos 0°} = \boxed{1.8\times 10^2\text{ N}}$

5.16 (a) $KE_A = \frac{1}{2}mv_A^2 = \frac{1}{2}(0.60\text{ kg})(2.0\text{ m/s})^2 = \boxed{1.2\text{ J}}$

(b) $KE_B = \frac{1}{2}mv_B^2$, so $v_B = \sqrt{\frac{2(KE_B)}{m}} = \sqrt{\frac{2(7.5\text{ J})}{0.60\text{ kg}}} = \boxed{5.0\text{ m/s}}$

(c) $W_{net} = \Delta KE = KE_B - KE_A = (7.5 - 1.2)\ \text{J} = \boxed{6.3\ \text{J}}$

5.17 $W_{net} = (F_{road}\cos\theta_1)s + (F_{resist}\cos\theta_2)s = [(1000\ \text{N})\cos 0°]s + [(950\ \text{N})\cos 180°]s$

$$W_{net} = (1000\ \text{N-950 N})(20\ \text{m}) = 1.0\times 10^3\ \text{J}$$

Also, $W_{net} = KE_f - KE_i = \frac{1}{2}mv^2 - 0$, so

$$v = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{2(1.0\times 10^3\ \text{J})}{2000\ \text{kg}}} = \boxed{1.0\ \text{m/s}}$$

5.18 The initial kinetic energy of the sled is

$$KE_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(10\ \text{kg})(2.0\ \text{m/s})^2 = 20\ \text{J},$$

and the friction force is $f_k = \mu_k n = \mu_k mg = (0.10)(98\ \text{N}) = 9.8\ \text{N}$.

$$W_{net} = (f_k\cos 180°)s = KE_f - KE_i\text{, so } s = \frac{0 - KE_i}{f_k\cos 180°} = \frac{-20\ \text{J}}{-9.8\ \text{N}} = \boxed{2.0\ \text{m}}$$

5.15 (a) The final kinetic energy of the bullet is

$$KE_f = \frac{1}{2}mv^2 = \frac{1}{2}(2.0\times 10^{-3}\ \text{kg})(300\ \text{m/s})^2 = \boxed{90\ \text{J}}.$$

(b) We know that $W = \Delta KE$, and also $W = (\overline{F}\cos\theta)s$.

Thus, $\overline{F} = \frac{\Delta KE}{s\cos\theta} = \frac{90\ \text{J} - 0}{(0.50\ \text{m})\cos 0°} = \boxed{1.8\times 10^2\ \text{N}}$

5.16 (a) $KE_A = \frac{1}{2}mv_A^2 = \frac{1}{2}(0.60\ \text{kg})(2.0\ \text{m/s})^2 = \boxed{1.2\ \text{J}}$

(b) $KE_B = \frac{1}{2}mv_B^2$, so $v_B = \sqrt{\frac{2(KE_B)}{m}} = \sqrt{\frac{2(7.5\ \text{J})}{0.60\ \text{kg}}} = \boxed{5.0\ \text{m/s}}$

(c) $W_{net} = \Delta KE = KE_B - KE_A = (7.5 - 1.2)\ \text{J} = \boxed{6.3\ \text{J}}$

5.17 $W_{net} = \left(F_{road}\cos\theta_1\right)s + \left(F_{resist}\cos\theta_2\right)s = \left[(1000\text{ N})\cos 0°\right]s + \left[(950\text{ N})\cos 180°\right]s$

$W_{net} = (1000\text{ N-}950\text{ N})(20\text{ m}) = 1.0\times 10^3\text{ J}$

Also, $W_{net} = KE_f - KE_i = \frac{1}{2}mv^2 - 0$, so

$$v = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{2\left(1.0\times 10^3\text{ J}\right)}{2000\text{ kg}}} = \boxed{1.0\text{ m/s}}$$

5.18 The initial kinetic energy of the sled is

$$KE_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(10\text{ kg})(2.0\text{ m/s})^2 = 20\text{ J},$$

and the friction force is $f_k = \mu_k n = \mu_k mg = (0.10)(98\text{ N}) = 9.8\text{ N}$.

$$W_{net} = \left(f_k\cos 180°\right)s = KE_f - KE_i\text{, so } s = \frac{0 - KE_i}{f_k\cos 180°} = \frac{-20\text{ J}}{-9.8\text{ N}} = \boxed{2.0\text{ m}}$$

5.19 The weight of the blood is $mg = (0.50\text{ kg})\left(9.80\text{ m/s}^2\right) = 4.9\text{ N}$.

(a) The displacement from the feet to the heart is $y = 1.3\text{ m}$ so the potential energy, using the feet as the reference level, is

$$PE_g = mgy = (4.9\text{ N})(1.3\text{ m}) = \boxed{6.4\text{ J}}.$$

(b) The displacement from the head to the heart is $y = (1.3 - 1.8)\text{ m} = -0.50\text{ m}$. Thus, when the head is used as the reference level, the potential energy is

$$PE_g = mgy = (4.9\text{ N})(-0.50\text{ m}) = \boxed{-2.5\text{ J}}.$$

5.20 (a) Relative to the ceiling, y = -1.00 m.

Thus, $PE_g = mgy = (2.00\text{ kg})\left(9.80\text{ m/s}^2\right)(-1.00\text{ m}) = \boxed{-19.6\text{ J}}$.

(b) Relative to the floor, y = 2.00 m, so

$$PE_g = mgy = (2.00\text{ kg})\left(9.80\text{ m/s}^2\right)(2.00\text{ m}) = \boxed{39.2\text{ J}}.$$

(c) Relative to the height of the ball, y = 0, and $PE_g = \boxed{0}$.

5.21 The work the muscle must do against the force of gravity to raise the arm is

$$W_{muscle} = -W_g = -\left(mgy_i - mgy_f\right) = mg\left(y_f - y_i\right) = mgh = mgL\left(1-\cos 30°\right),$$

or $$W_{muscle} = \left(7.0\text{ kg}\right)\left(9.80\text{ m/s}^2\right)\left(0.21\text{ m}\right)\left(1-\cos 30°\right) = \boxed{1.9\text{ J}}.$$

5.22 When the legs are straightened, the spring will be stretched by

$$x = \left(0.720\text{ m}\right)\left(1-\sin 40.0°\right) + \left(0.740\text{ m}\right)\left(1-\sin 25.0°\right) = 0.684\text{ m}.$$

The work the legs must do to stretch the spring this amount is

$$W = PE_s = \frac{1}{2}kx^2 = \frac{1}{2}\left(250\text{ N/m}\right)\left(0.684\text{ m}\right)^2 = \boxed{58.6\text{ J}}.$$

5.23 The equivalent spring constant for the muscle is

$$k = \frac{F}{x} = \frac{105\text{ N}}{2.00\times 10^{-2}\text{ m}} = 5.25\times 10^3\text{ N/m}.$$

The work done in stretching this by 2.00 cm is

$$W = PE_s = \frac{1}{2}kx^2 = \frac{1}{2}\left(5.25\times 10^3\text{ N/m}\right)\left(2.00\times 10^{-2}\text{ m}\right)^2 = \boxed{1.05\text{ J}}.$$

5.24 Let m be the mass of the ball, R the radius of the circle, and F the 30.0 N force. With y = 0 at the bottom of the circle, $W_{nc} = (KE+PE)_f - (KE+PE)_i$ yields

$$\left(F\cos 0°\right)\pi R = \left(\frac{1}{2}mv_f^2 + 0\right) - \left(\frac{1}{2}mv_i^2 + mg\left(2R\right)\right),$$

or $$v_f = \sqrt{\frac{2F(\pi R)}{m} + v_i^2 + 4gR}.$$

Thus, $$v_f = \sqrt{\frac{2\left(30.0\text{ N}\right)\pi\left(0.600\text{ m}\right)}{0.250\text{ kg}} + \left(15.0\text{ m/s}\right)^2 + 4\left(9.80\text{ m/s}^2\right)\left(0.600\text{ m}\right)}$$

giving $v_f = \boxed{26.5\text{ m/s}}$

5.25 (a) When the rope is horizontal, the swing is 2.0 m above the level of the bottom of the circular arc, and $PE_g = mgy = (40\text{ N})(2.0\text{ m}) = \boxed{80\text{ J}}$.

(b) When the rope makes a 30° angle with the vertical, the vertical distance from the swing to the lowest level in the circular arc is

$y = L - L\cos 30° = L(1-\cos 30°)$ and the potential energy is given by

$$PE_g = mgy = mgL(1-\cos 30°) = (40\text{ N})(2.0\text{ m})(1-\cos 30°) = \boxed{11\text{ J}}.$$

(c) At the bottom of the circular arc, $y = 0$. Hence, $PE_g = \boxed{0}$.

5.26 Using conservation of mechanical energy, we have

$$\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + 0,$$

or $$y_f = \frac{v_i^2 - v_f^2}{2g} = \frac{(10\text{ m/s})^2 - (1.0\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{5.1\text{ m}}.$$

5.27 Since no non-conservative forces do work, we use conservation of mechanical energy, with the zero of potential energy selected at the level of the base of the hill. Then, $\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + mgy_i$ with $y_f = 0$ yields

$$y_i = \frac{v_f^2 - v_i^2}{2g} = \frac{(3.00\text{ m/s})^2 - 0}{2(9.80\text{ m/s}^2)} = \boxed{0.459\text{ m}}.$$

Note that this result is independent of the mass of the child and sled.

5.28 (a) We take the zero of potential energy at the level of point B, and use conservation of mechanical energy to obtain $\frac{1}{2}mv_B^2 + 0 = \frac{1}{2}mv_A^2 + mgy_A$, or

$$v_B = \sqrt{v_A^2 + 2gy_A} = \sqrt{0 + 2(9.80\text{ m/s}^2)(5.00\text{ m})} = \boxed{9.90\text{ m/s}}.$$

(b) At point C, with the starting point at A, we again use conservation of mechanical energy. This gives $\frac{1}{2}mv_C^2 + mgy_C = \frac{1}{2}mv_A^2 + mgy_A$, and yields

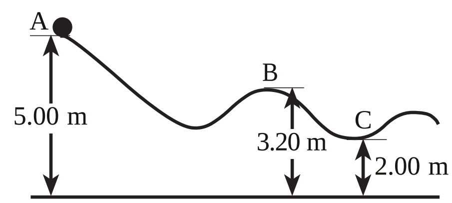
$$v_C = \sqrt{v_A^2 + 2g(y_A - y_C)} = \sqrt{0 + 2(9.80\text{ m/s}^2)(3.00\text{ m})} = \boxed{7.67\text{ m/s}}.$$

5.29 Using conservation of mechanical energy, starting when point A is directly over the bar and ending when it is directly below the bar, gives

$$\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + mgy_i \text{, or}$$

$$v_f = \sqrt{v_i^2 + 2g\left(y_i - y_f\right)} = \sqrt{0 + 2\left(9.80 \text{ m/s}^2\right)\left(2.40 \text{ m}\right)} = \boxed{6.86 \text{ m/s}}$$

5.30 (a) From conservation of mechanical energy,



$$\frac{1}{2}mv_B^2 + mgy_B = \frac{1}{2}mv_A^2 + mgy_A \text{, or}$$

$$v_B = \sqrt{v_A^2 + 2g\left(y_A - y_B\right)}$$

$$= \sqrt{0 + 2\left(9.80 \text{ m/s}^2\right)\left(1.80 \text{ m}\right)} = \boxed{5.94 \text{ m/s}}.$$

Similarly,

$$v_C = \sqrt{v_A^2 + 2g\left(y_A - y_B\right)} = \sqrt{0 + 2g\left(5.00 \text{ m} - 2.00 \text{ m}\right)} = \boxed{7.67 \text{ m/s}}.$$

(b) $W_g\big)_{A \to C} = \left(PE_g\right)_A - \left(PE_g\right)_C = mg\left(y_A - y_C\right) = \left(49.0 \text{ N}\right)\left(3.00 \text{ m}\right) = \boxed{147 \text{ J}}$

5.31 (a) We choose the zero of potential energy at the level of the bottom of the arc. The initial height of Tarzan above this level is

$$y_i = \left(30.0 \text{ m}\right)\left(1 - \cos 37.0°\right) = 6.04 \text{ m}.$$

Then, using conservation of mechanical energy, we find

$$\frac{1}{2}mv_f^2 + 0 = \frac{1}{2}mv_i^2 + mgy_i \text{, or}$$

$$v_f = \sqrt{v_i^2 + 2gy_i} = \sqrt{0 + 2\left(9.80 \text{ m/s}^2\right)\left(6.04 \text{ m}\right)} = \boxed{10.9 \text{ m/s}}.$$

(b) In this case, conservation of mechanical energy yields

$$v_f = \sqrt{v_i^2 + 2gy_i} = \sqrt{\left(4.00 \text{ m/s}\right)^2 + 2\left(9.80 \text{ m/s}^2\right)\left(6.04 \text{ m}\right)} = \boxed{11.6 \text{ m/s}}.$$

5.32 Realize that all three masses have identical *speeds* at each point in the motion and that $v_i = 0$. Then, conservation of mechanical energy gives

$$KE_f = PE_i - PE_f \text{, or}$$

$$\frac{1}{2}(m_1 + m_2 + m_3)v_f^2 = \left[m_1\left(y_{1i} - y_{1f}\right) + m_2\left(y_{2i} - y_{2f}\right) + m_3\left(y_{3i} - y_{3f}\right)\right]g$$

Thus, $\frac{1}{2}(30.0)v_f^2 = \left[(5.00)(-4.00\text{ m}) + (10.0)(0) + (15.0)(+4.00\text{ m})\right]\left(9.80\text{ m/s}^2\right)$

yielding $v_f = \boxed{5.11\text{ m/s}}$.

5.33 (a) Use conservation of mechanical energy from when the projectile is at rest within the gun until it reaches maximum height.

Then, $\left(KE + PE_g + PE_s\right)_f = \left(KE + PE_g + PE_s\right)_i$ becomes

$$0 + mgy_{max} + 0 = 0 + 0 + \frac{1}{2}kx_i^2,$$

or $k = \dfrac{2mgy_{max}}{x_i^2} = \dfrac{2\left(20.0\times10^{-3}\text{ kg}\right)\left(9.80\text{ m/s}^2\right)(20.0\text{ m})}{(0.120\text{ m})^2} = \boxed{544\text{ N/m}}$.

(b) This time, we use conservation of mechanical energy from when the projectile is at rest within the gun until it reaches the equilibrium position of the spring. This gives

$$KE_f = \left(PE_g + PE_s\right)_i - \left(PE_g + PE_s\right)_f = \left(-mgx_i + \frac{1}{2}kx_i^2\right) - (0+0)$$

$$v_f^2 = \left(\frac{k}{m}\right)x_i^2 - 2gx_i$$

$$= \left(\frac{544\text{ N/m}}{20.0\times10^{-3}\text{ kg}}\right)(0.120\text{ m})^2 - 2\left(9.80\text{ m/s}^2\right)(0.120\text{ m})$$

yielding $v_f = \boxed{19.7\text{ m/s}}$

5.34 At maximum height, $v_y = 0$ and $v_x = v_{ix} = (40\ \text{m/s})\cos 60° = 20\ \text{m/s}$.

Thus, $v_f = \sqrt{v_x^2 + v_y^2} = 20\ \text{m/s}$. Choosing $PE_g = 0$ at the level of the launch point, conservation of mechanical energy gives $PE_f = KE_i - KE_f$, and the maximum height reached is

$$y_f = \frac{v_i^2 - v_f^2}{2g} = \frac{(40\ \text{m/s})^2 - (20\ \text{m/s})^2}{2(9.80\ \text{m/s}^2)} = \boxed{61\ \text{m}}.$$

5.35 Choose $PE_g = 0$ at the level of the release point and use conservation of mechanical energy from release until the block reaches maximum height. Then,

$KE_f = KE_i = 0$ and we have $(PE_g + PE_s)_f = (PE_g + PE_s)_i$, or

$mgy_{max} + 0 = 0 + \frac{1}{2}kx_i^2$ which yields

$$y_{max} = \frac{kx_i^2}{2mg} = \frac{(5.00 \times 10^3\ \text{N/m})(0.100\ \text{m})^2}{2(0.250\ \text{kg})(9.80\ \text{m/s}^2)} = \boxed{10.2\ \text{m}}.$$

5.36 (a) Choose $PE_g = 0$ at the level of point B. Between A and B, we can use conservation of mechanical energy, $KE_B + (PE_g)_B = KE_A + (PE_g)_A$, which becomes

$\frac{1}{2}mv_B^2 + 0 = 0 + mgy_A$ or

$$v_B = \sqrt{2gy_A} = \sqrt{2(9.80\ \text{m/s}^2)(5.00\ \text{m})} = \boxed{9.90\ \text{m/s}}.$$

(b) Again, choose $PE_g = 0$ at the level of point B. Between points B and C, we use the work-kinetic energy theorem in the form

$W_{nc} = (KE + PE_g)_C - (KE + PE_g)_B = 0 + mgy_C - \frac{1}{2}mv_B^2 - 0$ to find

$$W_{nc} = (0.400\ \text{kg})(9.80\ \text{m/s}^2)(2.00\ \text{m}) - \frac{1}{2}(0.400\ \text{kg})(9.90\ \text{m/s})^2 = -11.8\ \text{J}.$$

Thus, $\boxed{11.8\ \text{J}}$ of energy is spent overcoming friction between B and C.

5.37 The work done by the non-conservative resistance force is

$$W_{nc} = (f\cos\theta)s = \left[\left(2.7\times10^{-3}\ \text{N}\right)\cos 180°\right](0.20\ \text{m}) = -5.4\times10^{-4}\ \text{J}$$

We use the work-kinetic theorem in the form

$$W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i \text{, or } KE_f = W_{nc} + KE_i + \left(PE_g\right)_i - \left(PE_g\right)_f .$$

Thus, $\frac{1}{2}mv_f^2 = W_{nc} + \frac{1}{2}mv_i^2 + mg\left(y_i - y_f\right)$ or

$$v_f = \sqrt{\frac{2W_{nc}}{m} + v_i^2 + 2g\left(y_i - y_f\right)}$$

$$= \sqrt{\frac{2\left(-5.4\times10^{-4}\ \text{J}\right)}{4.2\times10^{-3}\ \text{kg}} + \left(2.5\times10^{-2}\ \text{m/s}\right)^2 + 2\left(9.80\ \text{m/s}^2\right)(0.20\ \text{m})} = \boxed{1.9\ \text{m/s}}$$

5.38 The friction force does work $W_{friction}$ on the gurney during the 20.7 m horizontal displacement at constant speed. The attendant does 2000 J of work on the gurney during this motion. Applying the work-kinetic energy theorem gives

$$W_{nc} = W_{friction} + 2000\ \text{J} = (KE + PE)_f - (KE + PE)_i = 0\text{, so } W_{friction} = -2000\ \text{J}.$$

Also, $W_{friction} = (f\cos 180°)s = -f\,s$. Therefore, the friction force is given by

$$f = \frac{-W_{friction}}{s} = \frac{-(-2000\ \text{J})}{20.7\ \text{m}} = 96.6\ \text{N}.$$

Now consider the displacement $s' = 0.48\ \text{m}$ that occurs after the gurney is released with an initial speed of $v_i = 0.88\ \text{m/s}$. Applying the work-kinetic energy theorem to this part of the trip gives

$$W_{nc} = (f\cos 180°)s' = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i ,$$

or $-f\,s' = (0+0) - \left(\frac{1}{2}mv_i^2 + 0\right)$ which gives the total mass of the gurney plus patient as $m = 2f\,s'/v_i^2$, and the total weight as

$$w = mg = \left(\frac{2f\,s'}{v_i^2}\right)g = \left[\frac{2(96.6\ \text{N})(0.48\ \text{m})}{(0.88\ \text{m/s})^2}\right]\left(9.80\ \text{m/s}^2\right) = 1.2\times10^3\ \text{N} = \boxed{1.2\ \text{kN}}$$

5.39 We shall take $PE_g = 0$ at the lowest level reached by the diver under the water. The diver falls a total of 15 m, but the non-conservative force due to water resistance acts only during the last 5.0 m of fall. The work-kinetic energy theorem then gives

$$W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i,$$

or $$\left(\bar{F}\cos 180°\right)(5.0 \text{ m}) = (0+0) - \left[0 + (70 \text{ kg})\left(9.80 \text{ m/s}^2\right)(15 \text{ m})\right].$$

This gives the average resistance force as $\bar{F} = 2.1 \times 10^3 \text{ N} = \boxed{2.1 \text{ kN}}$.

5.40 Since the plane is in level flight, $\left(PE_g\right)_f = \left(PE_g\right)_i$ and the work-kinetic energy theorem reduces to $W_{nc} = W_{thrust} + W_{resistance} = KE_f - KE_i$, or

$$\left(F\cos 0°\right)s + \left(f\cos 180\right)s = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2.$$

This gives

$$v_f = \sqrt{v_i^2 + \frac{2(F-f)s}{m}} = \sqrt{(60 \text{ m/s})^2 + \frac{2\left[(7.5-4.0)\times 10^4 \text{ N}\right](500 \text{ m})}{1.5\times 10^4 \text{ kg}}} = \boxed{77 \text{ m/s}}$$

5.41 Choose $PE_g = 0$ at the level of the bottom of the driveway.

Then $W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i$ becomes

$$\left(f\cos 180°\right)s = \left[\frac{1}{2}mv_f^2 + 0\right] - \left[0 + mg\left(s\sin 20°\right)\right].$$

Solving for the final speed gives $v_f = \sqrt{(2gs)\sin 20° - \frac{2fs}{m}}$, or

or $$v_f = \sqrt{2\left(9.80 \text{ m/s}^2\right)(5.0 \text{ m})\sin 20° - \frac{2\left(4.0\times 10^3 \text{ N}\right)(5.0 \text{ m})}{2.10\times 10^3 \text{ kg}}} = \boxed{3.8 \text{ m/s}}.$$

5.42 (a) Choose $PE_g = 0$ at the level of the bottom of the arc. The child's initial vertical displacement from this level is

$$y_i = (2.00\text{ m})(1 - \cos 30.0°) = 0.268\text{ m}\ .$$

In the absence of friction, we use conservation of mechanical energy as

$(KE + PE_g)_f = (KE + PE_g)_i$, or $\frac{1}{2}mv_f^2 + 0 = 0 + mgy_i$, which gives

$$v_f = \sqrt{2gy_i} = \sqrt{2(9.80\text{ m/s}^2)(0.268\text{ m})} = \boxed{2.29\text{ m/s}}.$$

(b) With a non-conservative force present, we use

$W_{nc} = (KE + PE_g)_f - (KE + PE_g)_i = \left(\frac{1}{2}mv_f^2 + 0\right) - (0 + mgy_i)$, or

$$W_{nc} = m\left(\frac{v_f^2}{2} - gy_i\right)$$

$$= (25.0\text{ kg})\left[\frac{(2.00\text{ m/s})^2}{2} - (9.80\text{ m/s}^2)(0.268\text{ m})\right] = -15.6\text{ J}$$

Thus, $\boxed{15.6\text{ J}}$ of energy is spent overcoming friction.

5.43 (a) We use conservation of mechanical energy, $(KE + PE_g)_f = (KE + PE_g)_i$, for the trip down the frictionless ramp. With $v_i = 0$, this reduces to

$$v_f = \sqrt{2g(y_i - y_f)} = \sqrt{2(9.80\text{ m/s}^2)[(3.00\text{ m})\sin 30.0°]} = \boxed{5.42\text{ m/s}}.$$

(b) Using the work-kinetic energy theorem,

$$W_{nc} = (KE + PE_g)_f - (KE + PE_g)_i,$$

for the trip across the rough floor gives

$(f_k \cos 180°)s = (0 + 0) - \left(\frac{1}{2}mv_i^2 + 0\right)$, or $f_k\, s = \mu_k (mg)s = \frac{1}{2}mv_i^2$.

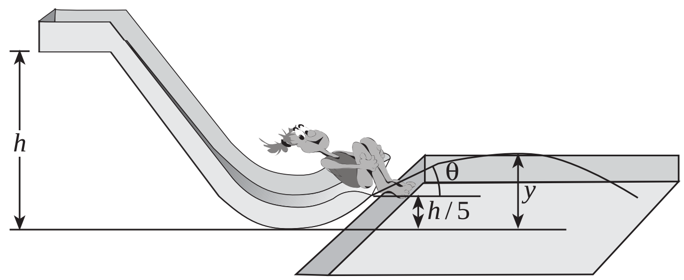
Thus, the coefficient of kinetic friction is

$$\mu_k = \frac{v_i^2}{2gs} = \frac{(5.42\ \text{m/s})^2}{2(9.80\ \text{m/s}^2)(5.00\ \text{m})} = \boxed{0.300}.$$

(c) All of the initial mechanical energy, $(KE + PE_g)_i = 0 + mgy_i$, is spent overcoming friction on the rough floor. Therefore, the energy "lost" is

$$mgy_i = (10.0\ \text{m})(9.80\ \text{m/s}^2)\left[(3.00\ \text{m})\sin 30.0°\right] = \boxed{147\ \text{J}}.$$

5.44 Choose $PE_g = 0$ at water level and use $(KE + PE_g)_f = (KE + PE_g)_i$ for the trip down the curved slide. This gives



$\frac{1}{2}mv^2 + mg\left(\frac{h}{5}\right) = 0 + mgh$, so the speed of the child as she leaves the end of the slide is $v = \sqrt{2g(4h/5)}$.

The vertical component of this launch velocity is

$$v_{iy} = v\sin\theta = \sin\theta\sqrt{2g\left(\frac{4h}{5}\right)}.$$

At the top of the arc, $v_y = 0$. Thus, $v_y^2 = v_{iy}^2 + 2a_y(\Delta y)$ gives the maximum height the child reaches during the airborne trip as

$$0 = \sin^2\theta\left[2g\left(\frac{4h}{5}\right)\right] + 2(-g)\left(y_{max} - \frac{h}{5}\right)$$

This may be solved for y_{max} to yield $y_{max} = \boxed{\frac{h}{5}(4\sin^2\theta + 1)}$.

5.45 Choose $PE_g = 0$ at the level of the base of the hill and let x represent the distance the skier moves along the horizontal portion before coming to rest. The normal force exerted on the skier by the snow while on the hill is $n_1 = mg\cos 10.5°$ and, while on the horizontal portion, $n_2 = mg$.

Consider the entire trip, starting from rest at the top of the hill until the skier comes to rest on the horizontal portion. The work done by friction forces is

$$W_{nc} = \left[\left(f_k\right)_1 \cos 180°\right](200\text{ m}) + \left[\left(f_k\right)_2 \cos 180°\right]x$$

$$= -\mu_k\left(mg\cos 10.5°\right)(200\text{ m}) - \mu_k\left(mg\right)x$$

Applying $W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i$ to this complete trip gives

$$-\mu_k\left(mg\cos 10.5°\right)(200\text{ m}) - \mu_k\left(mg\right)x = \left[0+0\right] - \left[0 + mg(200\text{ m})\sin 10.5°\right],$$

or $x = \left(\dfrac{\sin 10.5°}{\mu_k} - \cos 10.5°\right)(200\text{ m})$. If $\mu_k = 0.0750$, then $x = \boxed{289\text{ m}}$.

5.46 The normal force exerted on the sled by the track is $n = mg\cos\theta$ and the friction force is $f_k = \mu_k n = \mu_k\, mg\cos\theta$.

If s is the distance measured along the incline that the sled travels, applying $W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i$ to the entire trip gives

$$\left[\left(\mu_k\, mg\cos\theta\right)\cos 180°\right]s = \left[0 + mg\,s\left(\sin\theta\right)\right] - \left[\frac{1}{2}mv_i^2 + 0\right],$$

or $s = \dfrac{v_i^2}{2g\left(\sin\theta + \mu_k\cos\theta\right)} = \dfrac{\left(4.0\text{ m/s}\right)^2}{2\left(9.80\text{ m/s}^2\right)\left(\sin 20° + 0.20\cos 20°\right)} = \boxed{1.5\text{ m}}$.

5.47 (a) Consider the entire trip and apply $W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i$ to obtain

$$\left(f_1 \cos 180°\right) d_1 + \left(f_2 \cos 180°\right) d_2 = \left(\frac{1}{2} m v_f^2 + 0\right) - \left(0 + m g y_i\right), \text{ or}$$

$$v_f = \sqrt{2\left(g y_i - \frac{f_1 d_1 + f_2 d_2}{m}\right)}$$

$$= \sqrt{2\left(\left(9.80 \text{ m/s}^2\right)(1000 \text{ m}) - \frac{(50.0 \text{ N})(800 \text{ m}) + (3600 \text{ N})(200 \text{ m})}{80.0 \text{ kg}}\right)}$$

which yields $v_f = \boxed{24.5 \text{ m/s}}$.

(b) $\boxed{\text{Yes}}$, this is too fast for safety.

(c) Again, apply $W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i$, now with d_2 considered to be a variable, $d_1 = 1000 \text{ m} - d_2$, and $v_f = 5.00 \text{ m/s}$. This gives

$$\left(f_1 \cos 180°\right)\left(1000 \text{ m} - d_2\right) + \left(f_2 \cos 180°\right) d_2 = \left(\frac{1}{2} m v_f^2 + 0\right) - \left(0 + m g y_i\right),$$

which reduces to $-(1000 \text{ m}) f_1 + f_1 d_2 - f_2 d_2 = \frac{1}{2} m v_f^2 - m g y_i$. Therefore,

$$d_2 = \frac{(mg) y_i - (1000 \text{ m}) f_1 - \frac{1}{2} m v_f^2}{f_2 - f_1}$$

$$= \frac{(784 \text{ N})(1000 \text{ m}) - (1000 \text{ m})(50.0 \text{ N}) - \frac{1}{2}(80.0 \text{ kg})(5.00 \text{ m/s})^2}{3600 \text{ N} - 50.0 \text{ N}} = \boxed{206 \text{ m}}$$

(d) In reality. the air drag will depend on the skydiver's speed. It will be larger than her 784 N weight only after the chute is opened. It will be nearly equal to 784 N before she opens the chute and again before she touches down, whenever she moves near terminal speed.

5.48 (a) $W_{nc} = \Delta KE + \Delta PE$, but $\Delta KE = 0$ because the speed is constant. The skier rises a vertical distance of $\Delta y = (60 \text{ m}) \sin 30° = 30 \text{ m}$. Thus,

$$W_{nc} = (70 \text{ kg})\left(9.80 \text{ m/s}^2\right)(30 \text{ m}) = 2.06 \times 10^4 \text{ J} = \boxed{21 \text{ kJ}}.$$

(b) The time to travel 60 m at a constant speed of 2.0 m/s is 30 s. Thus, the required power input is

$$\wp = \frac{W_{nc}}{\Delta t} = \frac{2.06 \times 10^4 \text{ J}}{30 \text{ s}} = (686 \text{ W})\left(\frac{1 \text{ hp}}{746 \text{ W}}\right) = \boxed{0.92 \text{ hp}}.$$

5.49 (a) The work done by the student is

$$W = \Delta PE_g = mg(\Delta y) = (50.0 \text{ kg})(9.80 \text{ m/s}^2)(5.00 \text{ m}) = 2.45 \times 10^3 \text{ J}.$$

The time to do this work if she is to match the power output of a 200 W light bulb is $t = \frac{W}{\wp} = \frac{2.45 \times 10^3 \text{ J}}{200 \text{ W}} = 12.3 \text{ s}$, so the required average speed is

$$\bar{v} = \frac{\Delta y}{t} = \frac{5.00 \text{ m}}{12.3 \text{ s}} = \boxed{0.408 \text{ m/s}}.$$

(b) The work done was found in part (a) as $W = 2.45 \times 10^3 \text{ J} = \boxed{2.45 \text{ kJ}}$.

5.50 Let ΔN be the number of steps taken in time Δt. We determine the number of steps per unit time by

$$\text{Power} = \frac{\text{work done}}{\Delta t} = \frac{(\text{work per step per unit mass})(\text{mass})(\text{\# steps})}{\Delta t},$$

or $$70 \text{ W} = \left(0.60 \frac{\text{J/step}}{\text{kg}}\right)(60 \text{ kg})\left(\frac{\Delta N}{\Delta t}\right), \text{ giving } \frac{\Delta N}{\Delta t} = 1.9 \text{ steps/s}.$$

The running speed is then

$$\bar{v} = \frac{\Delta x}{\Delta t} = \left(\frac{\Delta N}{\Delta t}\right)(\text{distance traveled per step}) = \left(1.9 \frac{\text{step}}{\text{s}}\right)\left(1.5 \frac{\text{m}}{\text{step}}\right) = \boxed{2.9 \text{ m/s}}$$

5.51 The power output is given by

$$\wp = \frac{\textit{energy spent}}{\Delta t} = \frac{(\Delta m) g h}{\Delta t} = (1.2 \times 10^6 \text{ kg/s})(9.80 \text{ m/s}^2)(50 \text{ m}),$$

or $$\wp = 5.9 \times 10^8 \text{ W} = \boxed{5.9 \times 10^2 \text{ MW}}.$$

5.52 (a) We use the work-kinetic energy theorem with $KE_i = 0$ and $\Delta PE = 0$ to find

$$W = \Delta KE + \Delta PE = \left(\frac{1}{2}mv^2 - 0\right) + (0) = \frac{1}{2}(1500\text{ kg})(10.0\text{ m/s})^2$$

$$W = 7.50 \times 10^4\text{ J} = \boxed{75.0\text{ kJ}}.$$

(b) The average power input is given by

$$\bar{\wp} = \frac{W}{\Delta t} = \frac{7.50 \times 10^4\text{ J}}{3.00\text{ s}}\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \boxed{33.5\text{ hp}}.$$

(c) The acceleration of the car is

$$a = \frac{\Delta v}{\Delta t} = \frac{10.0\text{ m/s} - 0}{3.00\text{ s}} = 3.33\text{ m/s}^2 .$$

Thus, the net force acting on the car is

$$F = ma = (1.50 \times 10^3\text{ kg})(3.33\text{ m/s}^2) = 5.00 \times 10^3\text{ N} .$$

At t = 2.00 s, the instantaneous velocity is

$$v = v_i + at = 0 + (3.33\text{ m/s}^2)(2.00\text{ s}) = 6.66\text{ m/s}$$

and the instantaneous power input is

$$\wp = Fv = (5.00 \times 10^3\text{ N})(6.66\text{ m/s})\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \boxed{44.7\text{ hp}}.$$

5.53 (a) The acceleration of the car is $a = \frac{v_f - v_i}{t} = \frac{18.0\text{ m/s} - 0}{12.0\text{ s}} = 1.50\text{ m/s}^2$. Thus, the constant forward force due to the engine is found from $\Sigma F = F_{engine} - F_{air} = ma$ as

$$F_{engine} = F_{air} + ma = 400\text{ N} + (1.50 \times 10^3\text{ kg})(1.50\text{ m/s}^2) = 2.65 \times 10^3\text{ N}$$

The average velocity of the car during this interval is $\bar{v} = \frac{v_f + v_i}{2} = 9.00\text{ m/s}$, so the average power input from the engine during this time is

$$\bar{\wp} = F_{engine}\,\bar{v} = (2.65 \times 10^3\text{ N})(9.00\text{ m/s})\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \boxed{32.0\text{ hp}}.$$

(b) At $t = 12.0\text{ s}$, the instantaneous velocity of the car is $v = 18.0\text{ m/s}$ and the instantaneous power input from the engine is

$$\wp = F_{engine}\,v = \left(2.65\times10^{3}\text{ N}\right)\left(18.0\text{ m/s}\right)\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \boxed{63.9\text{ hp}}.$$

5.54 (a) The acceleration of the elevator during the first 3.00 s is

$$a = \frac{v_f - v_i}{t} = \frac{1.75\text{ m/s} - 0}{3.00\text{ s}} = 0.583\text{ m/s}^2,$$

so $F_{net} = F_{motor} - mg = ma$ gives the force exerted by the motor as

$$F_{motor} = m\left(a+g\right) = \left(650\text{ kg}\right)\left[\left(0.583+9.80\right)\text{ m/s}^2\right] = 6.75\times10^{3}\text{ N}.$$

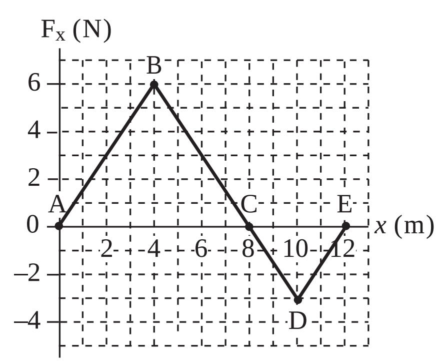
The average velocity of the elevator during this interval is $\bar{v} = \dfrac{v_f + v_i}{2} = 0.875\text{ m/s}$, so the average power input from the motor during this time is

$$\bar{\wp} = F_{motor}\,\bar{v} = \left(6.75\times10^{3}\text{ N}\right)\left(0.875\text{ m/s}\right)\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \boxed{7.92\text{ hp}}.$$

(b) When the elevator moves upward with a constant speed of $v = 1.75\text{ m/s}$, the upward force exerted by the motor is $F_{motor} = mg$ and the instantaneous power input from the motor is

$$\wp = \left(mg\right)v = \left(650\text{ kg}\right)\left(9.80\text{ m/s}^2\right)\left(1.75\text{ m/s}\right)\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \boxed{14.9\text{ hp}}.$$

5.55 The work done on the particle by the force F as the particle moves from $x = x_i$ to $x = x_f$ is the area under the curve from x_i to x_f.



(a) For $x = 0$ to $x = 8.00\text{ m}$,

$$W = \text{area of triangle } ABC = \frac{1}{2}\overline{AC}\times\text{altitude}$$

$$W_{0\to8} = \frac{1}{2}\left(8.00\text{ m}\right)\left(6.00\text{ N}\right) = \boxed{24.0\text{ J}}$$

(b) For $x = 8.00\text{ m}$ to $x = 10.0\text{ m}$,

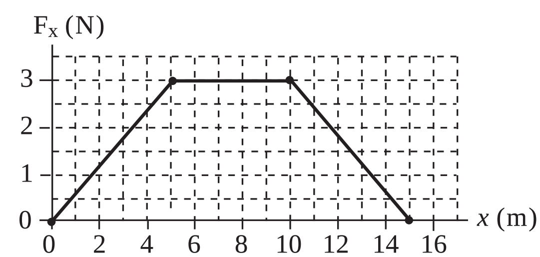
$$W_{8\to 10} = \text{area of triangle } CDE = \frac{1}{2}\overline{CE} \times \text{altitude}$$

$$= \frac{1}{2}(2.00\text{ m})(-3.00\text{ N}) = \boxed{-3.00\text{ J}}$$

(c) $W_{0\to 10} = W_{0\to 8} + W_{8\to 10} = 24.0\text{ J} + (-3.00\text{ J}) = \boxed{21.0\text{ J}}$

5.56 W equals the area under the Force-Displacement Curve

(a) For the region $0 \le x \le 5.00\text{ m}$,



$$W = \frac{(3.00\text{ N})(5.00\text{ m})}{2} = \boxed{7.50\text{ J}}$$

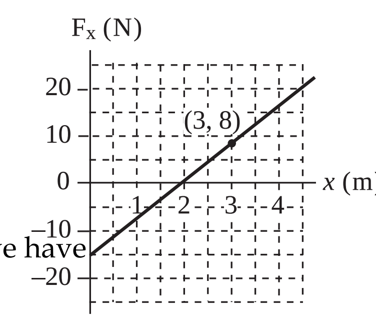
(b) For the region $5.00\text{ m} \le x \le 10.0\text{ m}$,

$$W = (3.00\text{ N})(5.00\text{ m}) = \boxed{15.0\text{ J}}$$

(c) For the region $10.0\text{ m} \le x \le 15.0\text{ m}$, $W = \dfrac{(3.00\text{ N})(5.00\text{ m})}{2} = \boxed{7.50\text{ J}}$

(d) For the region $0 \le x \le 15.0\text{ m}$, $W = (7.50 + 15.0 + 7.50)\text{ J} = \boxed{30.0\text{ J}}$

5.57 (a) $F_x = (8x - 16)\text{ N}$



(b) $W_{net} = \dfrac{-(2.00\text{ m})(16.0\text{ N})}{2} + \dfrac{(1.00\text{ m})(8.00\text{ N})}{2} = \boxed{-12.0\text{ J}}$

5.58 From the work-kinetic energy theorem, $W_{net} = KE_f - KE_i$, we have

$$(F_{applied}\cos 0°)s = \frac{1}{2}mv_f^2 - 0.$$

The mass of the cart is $m = \dfrac{w}{g} = 10.0\text{ kg}$, and the final speed of the cart is

$$v_f = \sqrt{\frac{2F_{applied}\,s}{m}} = \sqrt{\frac{2(40.0\text{ N})(12.0\text{ m})}{10.0\text{ kg}}} = \boxed{9.80\text{ m/s}}.$$

5.59 (a) The equivalent spring constant of the bow is given by $F = kx$ as

$$k = \frac{F_f}{x_f} = \frac{230\ \text{N}}{0.400\ \text{m}} = \boxed{575\ \text{N/m}}.$$

(b) From the work-kinetic energy theorem applied to this situation,

$$W_{nc} = \left(KE + PE_g + PE_s\right)_f - \left(KE + PE_g + PE_s\right)_f = \left(0 + 0 + \frac{1}{2}kx_f^2\right) - (0 + 0 + 0).$$

The work done pulling the bow is then

$$W_{nc} = \frac{1}{2}kx_f^2 = \frac{1}{2}(575\ \text{N/m})(0.400\ \text{m})^2 = \boxed{46.0\ \text{J}}.$$

5.60 Choose $PE_g = 0$ at the level where the block comes to rest against the spring. Then, in the absence of work done by non-conservative forces, the conservation of mechanical energy gives

$$\left(KE + PE_g + PE_s\right)_f = \left(KE + PE_g + PE_s\right)_i,$$

or $$0 + 0 + \frac{1}{2}kx_f^2 = 0 + mgL\sin\theta + 0.$$ Thus,

$$x_f = \sqrt{\frac{2mgL\sin\theta}{k}} = \sqrt{\frac{2(12.0\ \text{kg})(9.80\ \text{m/s}^2)(3.00\ \text{m})\sin 35.0^\circ}{3.00\times10^4\ \text{N/m}}} = \boxed{0.116\ \text{m}}.$$

5.61 (a) From $v^2 = v_i^2 + 2a_y(\Delta y)$, we find the speed just before touching the ground as

$$v = \sqrt{0 + 2(9.80\ \text{m/s}^2)(1.0\ \text{m})} = \boxed{4.4\ \text{m/s}}.$$

(b) Choose $PE_g = 0$ at the level where the feet come to rest. Then
$W_{nc} = \left(KE + PE_g\right)_f - \left(KE + PE_g\right)_i$ becomes

$$\left(\bar{F}\cos 180^\circ\right)s = (0 + 0) - \left(\frac{1}{2}mv_i^2 + mgs\right)$$

or $$\bar{F} = \frac{mv_i^2}{2s} + mg = \frac{(75\ \text{kg})(4.4\ \text{m/s})^2}{2(5.0\times10^{-3}\ \text{m})} + (75\ \text{kg})(9.80\ \text{m/s}^2) = \boxed{1.5\times10^5\ \text{N}}$$

5.62 From the work-kinetic energy theorem,

$$W_{nc} = \left(KE + PE_g + PE_s\right)_f - \left(KE + PE_g + PE_s\right)_i,$$

we have $\left(f_k \cos 180°\right)s = \left(\frac{1}{2}mv_f^2 + 0 + 0\right) - \left(0 + 0 + \frac{1}{2}kx_i^2\right)$, or

$$v_f = \sqrt{\frac{kx_i^2 - 2\,f_k\,s}{m}} = \sqrt{\frac{(8.0\ \text{N/m})\left(5.0\times 10^{-2}\ \text{m}\right)^2 - 2(0.032\ \text{N})(0.15\ \text{m})}{5.3\times 10^{-3}\ \text{kg}}} = \boxed{1.4\ \text{m/s}}$$

5.63 (a) The two masses will pass when both are at $y_f = 2.00\ \text{m}$ above the floor. From conservation of energy, $\left(KE + PE_g + PE_s\right)_f = \left(KE + PE_g + PE_s\right)_i$,

$$\frac{1}{2}(m_1 + m_2)v_f^2 + (m_1 + m_2)gy_f + 0 = 0 + m_1 g y_{1i} + 0, \text{ or}$$

$$v_f = \sqrt{\frac{2m_1\,g\,y_{1i}}{m_1 + m_2} - 2\,g\,y_f}$$

$$= \sqrt{\frac{2(5.00\ \text{kg})(9.80\ \text{m/s}^2)(4.00\ \text{m})}{8.00\ \text{kg}} - 2(9.80\ \text{m/s}^2)(2.00\ \text{m})}\ .$$

This yields the passing speed as $v_f = \boxed{3.13\ \text{m/s}}$.

(b) When $m_1 = 5.00\ \text{kg}$ reaches the floor, $m_2 = 3.00\ \text{kg}$ is $y_{2f} = 4.00\ \text{m}$ above the floor. Thus, $\left(KE + PE_g + PE_s\right)_f = \left(KE + PE_g + PE_s\right)_i$ becomes

$$\frac{1}{2}(m_1 + m_2)v_f^2 + m_2 g\,y_{2f} + 0 = 0 + m_1 g y_{1i} + 0, \text{ or } v_f = \sqrt{\frac{2\,g\left(m_1 y_{1i} - m_2 y_{2f}\right)}{m_1 + m_2}}$$

Thus,

$$v_f = \sqrt{\frac{2(9.80\ \text{m/s}^2)\left[(5.00\ \text{kg})(4.00\ \text{m}) - (3.00\ \text{kg})(4.00\ \text{m})\right]}{8.00\ \text{kg}}} = \boxed{4.43\ \text{m/s}}$$

(c) When the 5.00-kg hits the floor, the string goes slack and the 3.00-kg becomes a projectile launched straight upward with initial speed $v_{iy} = 4.43\ \text{m/s}$. At the top of its arc, $v_y^2 = v_{iy}^2 + 2a_y(\Delta y)$ gives

$$\Delta y = \frac{v_y^2 - v_{iy}^2}{2a_y} = \frac{0 - (4.43\ \text{m/s})^2}{2(-9.80\ \text{m/s}^2)} = \boxed{1.00\ \text{m}}.$$

5.64 The normal force the incline exerts on block A is $n_A = (m_A g)\cos 37°$, and the friction force is $f_k = \mu_k n_A = \mu_k m_A g \cos 37°$. The vertical distance block A rises is $\Delta y_A = (20\ \text{m})\sin 37° = 12\ \text{m}$, while the vertical displacement of block B is $\Delta y_B = -20\ \text{m}$.

We find the common final speed of the two blocks by use of

$$W_{nc} = (KE + PE_g)_f - (KE + PE_g)_i = \Delta KE + \Delta PE_g.$$

This gives $-(\mu_k m_A g \cos 37°)s = \left[\frac{1}{2}(m_A + m_B)v_f^2 - 0\right] + \left[m_A g(\Delta y_A) + m_B g(\Delta y_B)\right]$

or $$v_f^2 = \frac{2g\left[-m_B(\Delta y_B) - m_A(\Delta y_A) - (\mu_k m_A \cos 37°)s\right]}{m_A + m_B}$$

$$= \frac{2(9.80\ \text{m/s}^2)\left[-(100\ \text{kg})(-20\ \text{m}) - (50\ \text{kg})(12\ \text{m}) - 0.25(50\ \text{kg})(20\ \text{m})\cos 37°\right]}{150\ \text{kg}}$$

which yields $v_f^2 = 157\ \text{m}^2/\text{s}^2$.

The change in the kinetic energy of block A is then

$$\Delta KE_A = \frac{1}{2}m_A v_f^2 - 0 = \frac{1}{2}(50\ \text{kg})(157\ \text{m}^2/\text{s}^2) = 3.9 \times 10^3\ \text{J} = \boxed{3.9\ \text{kJ}}.$$

5.65 Since the Marine moves at constant speed, the upward force the rope exerts on him must equal his weight, or $F = 700\ \text{N}$. The constant speed at which he moves up the rope is $v = \frac{\Delta y}{\Delta t} = \frac{10.0\ \text{m}}{8.00\ \text{s}} = 1.25\ \text{m/s}$, so the constant power output is

$$\wp = Fv = (700\ \text{N})(1.25\ \text{m/s}) = \boxed{875\ \text{W}}.$$

5.66 When 1 pound (454 grams) of fat is metabolized, the energy released is $E = (454\ \text{g})(9.00\ \text{kcal/g}) = 4.09\times10^{3}\ \text{kcal}$. Of this, 20.0% goes into mechanical energy (climbing stairs in this case). Thus, the mechanical energy generated by metabolizing 1 pound of fat is

$$E_m = (0.200)(4.09\times10^{3}\ \text{kcal}) = 817\ \text{kcal}.$$

Each time the student climbs the stairs, she raises her body a vertical distance of $\Delta y = (80\ \text{steps})(0.150\ \text{m/step}) = 12.0\ \text{m}$. The mechanical energy required to do this is $\Delta PE_g = mg(\Delta y)$, or

$$\Delta PE_g = (50.0\ \text{kg})(9.80\ \text{m/s}^2)(12.0\ \text{m}) = (5.88\times10^{3}\ \text{J})\left(\frac{1\ \text{kcal}}{4186\ \text{J}}\right) = 1.40\ \text{kcal}.$$

(a) The number of times the student must climb the stairs to metabolize 1 pound of fat is $N = \dfrac{E_m}{\Delta PE_g} = \dfrac{817\ \text{kcal}}{1.40\ \text{kcal/trip}} = \boxed{582\ \text{trips}}$.

It would be more practical for her to reduce food intake.

(b) The useful work done each time the student climbs the stairs is $W = \Delta PE_g = 5.88\times10^{3}\ \text{J}$. Since this is accomplished in 65.0 s, the average power output is

$$\overline{\wp} = \frac{W}{t} = \frac{5.88\times10^{3}\ \text{J}}{65.0\ \text{s}} = \boxed{90.5\ \text{W}} = (90.5\ \text{W})\left(\frac{1\ \text{hp}}{746\ \text{W}}\right) = \boxed{0.121\ \text{hp}}.$$

5.67 (a) The person walking uses $E_w = (220\ \text{kcal})\left(\dfrac{4186\ \text{J}}{1\ \text{kcal}}\right) = 9.21\times10^{5}\ \text{J}$ of energy while going 3.00 miles. The quantity of gasoline which could furnish this much energy is $V_1 = \dfrac{9.21\times10^{5}\ \text{J}}{1.30\times10^{8}\ \text{J/gal}} = 7.08\times10^{-3}\ \text{gal}$. This means that the walker's fuel economy in equivalent miles per gallon is

$$\textit{fuel economy} = \frac{3.00\ \text{mi}}{7.08\times10^{-3}\ \text{gal}} = \boxed{423\ \text{mi/gal}}.$$

(b) In 1 hour, the bicyclist travels 10.0 miles and uses

$$E_B = (400\text{ kcal})\left(\frac{4186\text{ J}}{1\text{ kcal}}\right) = 1.67\times10^{6}\text{ J},$$

which is equal to the energy available in

$V_2 = \dfrac{1.67\times10^{6}\text{ J}}{1.30\times10^{8}\text{ J/gal}} = 1.29\times10^{-2}\text{ gal}$ of gasoline. Thus, the equivalent fuel economy for the bicyclist is $\dfrac{10.0\text{ mi}}{1.29\times10^{-2}\text{ gal}} = \boxed{776\text{ mi/gal}}$.

5.68 We use $W_{net} = KE_f - KE_i$ to find the average force the hand exerts on the baseball.

$$W_{net} = \left(\overline{F}\cos 180°\right)s = 0 - \frac{1}{2}m_{ball}v_i^2,\text{ so }\overline{F} = \frac{m_{ball}v_i^2}{2s}.$$

The force the ball exerts on the hand is in the opposite direction but has the same magnitude.

(a) If $s = 2.0\text{ cm} = 2.0\times10^{-2}\text{ m}$,

$$\overline{F} = \frac{(0.15\text{ kg})(25\text{ m/s})^2}{2\left(2.0\times10^{-2}\text{ m}\right)} = 2.3\times10^{3}\text{ N} = \boxed{2.3\text{ kN}}.$$

(b) Similarly, if $s = 10\text{ cm} = 0.10\text{ m}$, we find $\overline{F} = \boxed{4.7\times10^{2}\text{ N}}$.

5.69 (a) Use conservation of mechanical energy, $\left(KE + PE_g\right)_f = \left(KE + PE_g\right)_i$, from the start to the end of the track to find the speed of the skier as he leaves the track. This gives $\frac{1}{2}mv^2 + mgy_f = 0 + mgy_i$, or

$$v = \sqrt{2g\left(y_i - y_f\right)} = \sqrt{2\left(9.80\text{ m/s}^2\right)(40.0\text{ m})} = \boxed{28.0\text{ m/s}}.$$

(b) At the top of the parabolic arc the skier follows after leaving the track, $v_y = 0$ and $v_x = (28.0\ \text{m/s})\cos 45.0° = 19.8\ \text{m/s}$. Thus, $v_{top} = \sqrt{v_x^2 + v_y^2} = 19.8\ \text{m/s}$. Applying conservation of mechanical energy from the end of the track to the top of the arc gives $\frac{1}{2}m(19.8\ \text{m/s})^2 + mgy_{max} = \frac{1}{2}m(28.0\ \text{m/s})^2 + mg(10.0\ \text{m})$, or

$$y_{max} = 10.0\ \text{m} + \frac{(28.0\ \text{m/s})^2 - (19.8\ \text{m/s})^2}{2(9.80\ \text{m/s}^2)} = \boxed{30.0\ \text{m}}.$$

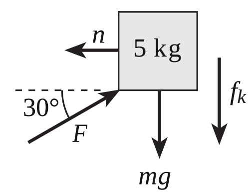
(c) Using $\Delta y = v_{iy}t + \frac{1}{2}a_y t^2$ for the flight from the end of the track to the ground gives

$$-10.0\ \text{m} = \left[(28.0\ \text{m/s})\sin 45.0°\right]t + \frac{1}{2}(-9.80\ \text{m/s}^2)t^2$$

The positive solution of this equation gives the total time of flight as $t = 4.49\ \text{s}$. During this time, the skier has a horizontal displacement of

$$\Delta x = v_{ix}t = \left[(28.0\ \text{m/s})\cos 45.0°\right](4.49\ \text{s}) = \boxed{89.0\ \text{m}}.$$

5.70 First, determine the magnitude of the applied force by considering a free-body diagram of the block. Since the block moves with constant velocity, $\Sigma F_x = \Sigma F_y = 0$.



From $\Sigma F_x = 0$, we see that $n = F\cos 30°$.

Thus, $f_k = \mu_k n = \mu_k F\cos 30°$, and $\Sigma F_y = 0$ becomes

$$F\sin 30° = mg + \mu_k F\cos 30°, \text{ or}$$

$$F = \frac{mg}{\sin 30° - \mu_k \cos 30°} = \frac{(5.0\ \text{kg})(9.80\ \text{m/s}^2)}{\sin 30° - (0.30)\cos 30°} = 2.0 \times 10^2\ \text{N}.$$

(a) The applied force makes a 60° angle with the displacement up the wall. Therefore,

$$W_F = (F\cos 60°)s = \left[(2.0\times 10^2\ \text{N})\cos 60°\right](3.0\ \text{m}) = \boxed{3.1\times 10^2\ \text{J}}.$$

(b) $W_g = (mg\cos 180°)s = (49\ \text{N})(-1.0)(3.0\ \text{m}) = \boxed{-1.5\times 10^2\ \text{J}}$.

(c) $W_n = (n\cos 90°)s = \boxed{0}$.

(d) $PE_g = mg(\Delta y) = (49\text{ N})(3.0\text{ m}) = \boxed{1.5 \times 10^2\text{ J}}$.

5.71 The force constant of the spring is $k = 1.20\text{ N/cm} = 120\text{ N/m}$. If the spring is initially compressed a distance x_i, the vertical distance the ball rises as the spring returns to the equilibrium position is

$$y_f = x_i \sin 10.0°$$

In the absence of friction, we apply $(KE + PE_g + PE_s)_f = (KE + PE_g + PE_s)_i$ from the release of the plunger to when the spring has returned to the equilibrium position and obtain $\frac{1}{2}mv_f^2 + mg(x_i \sin 10.0°) + 0 = 0 + 0 + \frac{1}{2}kx_i^2$, or

$$v_f = \sqrt{\frac{kx_i^2}{m} - 2gx_i \sin 10.0°}$$

$$= \sqrt{\frac{(120\text{ N/m})(5.00 \times 10^{-2}\text{ m})^2}{0.100\text{ kg}} - 2(9.80\text{ m/s}^2)(5.00 \times 10^{-2}\text{ m})\sin 10.0°}$$

This yields $v_f = \boxed{1.68\text{ m/s}}$.

5.72 If a projectile is launched, in the absence of air resistance, with speed v_i at angle θ above the horizontal, the time required to return to the original level is found from $\Delta y = v_{iy}t + \frac{1}{2}a_y t^2$ as $0 = (v_i \sin\theta)t - \frac{g}{2}t^2$, which gives $t = \frac{2v_i \sin\theta}{g}$. The range is the horizontal displacement occurring in this time.

Thus, $R = v_{ix}\,t = (v_i \cos\theta)\left(\frac{2v_i \sin\theta}{g}\right) = \frac{v_i^2(2\sin\theta\cos\theta)}{g} = \frac{v_i^2 \sin(2\theta)}{g}$.

Maximum range occurs when $\theta = 45°$, giving $v_i^2 = gR_{\max}$. The minimum kinetic energy required to reach a given maximum range is

$$KE = \frac{1}{2}mv_i^2 = \frac{1}{2}mgR_{max}$$

(a) The minimum kinetic energy needed in the record throw of each object is

Javelin: $$KE = \frac{1}{2}(0.80\ \text{kg})(9.80\ \text{m/s}^2)(89\ \text{m}) = \boxed{3.5 \times 10^2\ \text{J}}$$

Discus: $$KE = \frac{1}{2}(2.0\ \text{kg})(9.80\ \text{m/s}^2)(69\ \text{m}) = \boxed{6.8 \times 10^2\ \text{J}}$$

Shot: $$KE = \frac{1}{2}(7.2\ \text{kg})(9.80\ \text{m/s}^2)(21\ \text{m}) = \boxed{7.4 \times 10^2\ \text{J}}$$

(b) The average force exerted on an object during launch, when it starts from rest and is given the kinetic energy found above, is computed from $W_{net} = \bar{F}s = \Delta KE$ as $\bar{F} = \frac{KE - 0}{s}$. Thus, the required force for each object is

Javelin: $$\bar{F} = \frac{3.5 \times 10^2\ \text{J}}{2.00\ \text{m}} = \boxed{1.7 \times 10^2\ \text{N}}$$

Discus: $$\bar{F} = \frac{6.8 \times 10^2\ \text{J}}{2.00\ \text{m}} = \boxed{3.4 \times 10^2\ \text{N}}$$

Shot: $$\bar{F} = \frac{7.4 \times 10^2\ \text{J}}{2.00\ \text{m}} = \boxed{3.7 \times 10^2\ \text{N}}$$

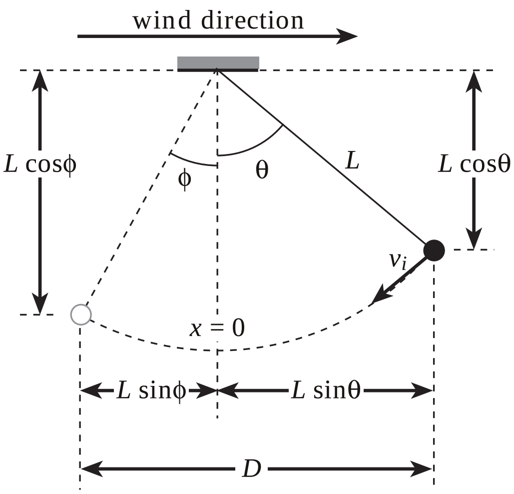
(c) $\boxed{\text{Yes}}$. If the muscles are capable of exerting $3.7 \times 10^2\ \text{N}$ on an object and giving that object a kinetic energy of $7.4 \times 10^2\ \text{J}$, as in the case of the shot, those same muscles should be able to give the javelin a launch speed of

$$v_i = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2\left(7.4 \times 10^2\ \text{J}\right)}{0.80\ \text{kg}}} = 43\ \text{m/s},$$

with a resulting range of $R_{max} = \frac{v_i^2}{g} = \frac{(43\ \text{m/s})^2}{9.80\ \text{m/s}^2} = 1.9 \times 10^2\ \text{m}$.

Since this far exceeds the record range for the javelin, one must conclude that air resistance plays a very significant role in these events.

5.73 The potential energy associated with the wind is $PE_w = Fx$, where x is measured horizontally from directly below the pivot of the swing and positive when moving into the wind, negative when moving with the wind. We choose $PE_g = 0$ at the level of the pivot as shown in the figure. Also, note that $D = L\sin\phi + L\sin\theta$



so $\phi = \sin^{-1}\left(\frac{D}{L} - \sin\theta\right)$, or

$$\phi = \sin^{-1}\left(\frac{50.0\text{ m}}{40.0\text{ m}} - \sin 50.0°\right) = 28.94°.$$

(a) Use conservation of mechanical energy, including the potential energy associated with the wind. The final kinetic energy is zero if Jane barely makes it to the other side, and $\left(KE + PE_g + PE_w\right)_f = \left(KE + PE_g + PE_w\right)_i$ becomes

$$0 + mg\left(-L\cos\phi\right) + F\left(+L\sin\phi\right) = \frac{1}{2}mv_i^2 + mg\left(-L\cos\theta\right) + F\left(-L\sin\theta\right),$$

or $v_i = \sqrt{2gL\left(\cos\theta - \cos\phi\right) + \frac{2FL}{m}\left(\sin\theta + \sin\phi\right)}$

where m is the mass of Jane alone. This yields $v_i = \boxed{6.15\text{ m/s}}$.

(b) Again, using conservation of mechanical energy with $KE_f = 0$,

$\left(KE + PE_g + PE_w\right)_f = \left(KE + PE_g + PE_w\right)_i$ gives

$$0 + Mg\left(-L\cos\theta\right) + F\left(-L\sin\theta\right) = \frac{1}{2}Mv_i^2 + Mg\left(-L\cos\phi\right) + F\left(+L\sin\phi\right)$$

where $M = 130\text{ kg}$ is the combined mass of Tarzan and Jane. Thus,

$v_i = \sqrt{2gL\left(\cos\phi - \cos\theta\right) - \frac{2FL}{M}\left(\sin\theta + \sin\phi\right)}$ which gives $v_i = \boxed{9.87\text{ m/s}}$

5.74 The power loss is the rate at which work is done moving air, or

$$\wp_{loss} = \frac{W}{\Delta t} = \frac{\Delta KE}{\Delta t} = \frac{\frac{1}{2}(\Delta m)v^2}{\Delta t}$$. But the mass of air moved in time Δt is

$$\Delta m = (density \cdot volume) = \rho(area \cdot length) = \rho A\,\Delta x = \rho A v(\Delta t).$$

Thus, $$\wp_{loss} = \frac{(\Delta m)v^2}{2(\Delta t)} = \frac{[\rho A v(\Delta t)]v^2}{2(\Delta t)} = \boxed{\frac{1}{2}\rho A v^3}.$$

When an object is moved at constant speed, the power expenditure is $\wp_{loss} = f_{resistance}\,v$, so the resistance force is given by

$$f_{resistance} = \frac{\wp_{loss}}{v} = \frac{(1/2)\rho A v^3}{v} = \boxed{\frac{1}{2}\rho A v^2}.$$

5.75 We choose $PE_g = 0$ at the level where the spring is relaxed (x = 0), or at the level of position B.

(a) At position A, $KE = 0$ and the total energy of the system is given by

$$E = (0 + PE_g + PE_s)_A = mg\,x_1 + \frac{1}{2}k\,x_1^2, \text{ or}$$

$$E = (25.0\text{ kg})(9.80\text{ m/s}^2)(-0.100\text{ m}) + \frac{1}{2}(2.50\times 10^4\text{ N/m})(-0.100\text{ m})^2 = \boxed{101\text{ J}}$$

(b) In position C, $KE = 0$ and the spring is uncompressed so $PE_s = 0$.

Hence, $E = (0 + PE_g + 0)_C = mg\,x_2$

or $$x_2 = \frac{E}{mg} = \frac{101\text{ J}}{(25.0\text{ kg})(9.80\text{ m/s}^2)} = \boxed{0.410\text{ m}}.$$

(c) At Position B, $PE_g = PE_s = 0$ and $E = (KE + 0 + 0)_B = \frac{1}{2}mv_B^2$.

Therefore, $$v_B = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2(101\text{ J})}{25.0\text{ kg}}} = \boxed{2.84\text{ m/s}}.$$

(d) Where the velocity (and hence the kinetic energy) is a maximum, the acceleration is $a_y = \frac{\Sigma F_y}{m} = 0$ (at this point, an upward force due to the spring exactly balances the downward force of gravity). Thus, taking upward as positive, $\Sigma F_y = -kx - mg = 0$ or

$$x = -\frac{mg}{k} = -\frac{245 \text{ kg}}{2.50\times 10^4 \text{ N/m}} = -9.80\times 10^{-3} \text{ m} = \boxed{-9.80 \text{ mm}}.$$

(e) From the total energy, $E = KE + PE_g + PE_s = \frac{1}{2}mv^2 + mgx + \frac{1}{2}kx^2$, we find

$$v = \sqrt{\frac{2E}{m} - 2gx - \frac{k}{m}x^2}$$

Where the speed, and hence kinetic energy is a maximum (i.e., at $x = -9.80 \text{ mm}$), this gives $v_{\max} = \boxed{2.85 \text{ m/s}}$

5.76 When the block moves distance x down the incline, the work done by the friction force is $W_f = (f_k \cos 180°)x = -\mu_k nx = -\mu_k (mg\cos\theta)x$. From the work-kinetic energy theorem, $W_{nc} = (KE + PE_g + PE_s)_f - (KE + PE_g + PE_s)_i$, we find

$$W_{nc} = W_f = -\mu_k (mg\cos\theta)x = \Delta KE + \Delta PE_g + \Delta PE_s .$$

Since the block is at rest at both the start and the end, this gives

$$-\mu_k (19.6 \text{ N} \ \cos 37.0°)(0.200 \text{ m})$$
$$= 0 + (19.6 \text{ N})(-0.200 \text{ m} \ \sin 37.0°) + \frac{1}{2}(100 \text{ N/m})(0.200 \text{ m})^2$$

or $\mu_k = \boxed{0.115}$.

5.77 Choose $PE_g = 0$ at the level of the river. Then $y_i = 36.0 \text{ m}$, $y_f = 4.00 \text{ m}$, the jumper falls 32.0 m, and the cord stretches 7.00 m. Between the balloon and the level where the diver stops momentarily, $(KE + PE_g + PE_s)_f = (KE + PE_g + PE_s)_i$ gives

$$0 + (700 \text{ N})(4.00 \text{ m}) + \frac{1}{2}k(7.00 \text{ m})^2 = 0 + (700 \text{ N})(36.0 \text{ m}) + 0,$$

or $k = \boxed{914 \text{ N/m}}$.

5.78 (a) Since the tension in the string is always perpendicular to the motion of the object, the string does no work on the object. Then, mechanical energy is conserved: $\left(KE+PE_g\right)_f=\left(KE+PE_g\right)_i$.

Choosing $PE_g=0$ at the level where the string attaches to the cart, this gives

$$0+mg\left(-L\cos\theta\right)=\frac{1}{2}mv_o^2+mg\left(-L\right)\text{, or }\boxed{v_0=\sqrt{2gL\left(1-\cos\theta\right)}}$$

(b) If L = 1.20 m and $\theta=35.0°$, the result of part (a) gives

$$v_0=\sqrt{2\left(9.80\text{ m/s}^2\right)\left(1.20\text{ m}\right)\left(1-\cos 35.0°\right)}=\boxed{2.06\text{ m/s}}.$$

Answers to Even Numbered Conceptual Questions

2. (a) The chicken does positive work on the ground. (b) No work is done. (c) The crane does positive work on the bucket. (d) The force of gravity does negative work on the bucket. (e) The leg muscles do negative work on the individual.

4. (a) Kinetic energy is always positive. Mass and speed squared are both positive.
(b) Gravitational potential energy can be negative when the object is below (i.e., closer to the Earth) the chosen zero level.

6. (a) Kinetic energy is proportional to the speed squared. Doubling the speed makes the object's kinetic energy four times larger. (b) If the total work done on an object in some process is zero, its speed must be the same at the final point as it was at the initial point.

8. The total energy of the bowling ball is conserved. Because the ball initially has gravitational potential energy mgh and no kinetic energy, it will again have zero kinetic energy when it returns to its original position. Air resistance and friction at the support will cause the ball to come back to a point slightly below its initial position. On the other hand, if anyone gives a forward push to the ball anywhere along its path, the demonstrator will have to duck.

10. The effects are the same except for such features as having to overcome air resistance outside. The person must lift his body slightly with each step on the tilted treadmill. Thus, the effect is that of running uphill.

12. Both the force of kinetic friction exerted on the sled by the snow and the resistance force exerted on the moving sled by the air will do negative work on the sled. Since the sled is maintaining constant velocity, some towing agent must do an equal amount of positive work, so the net work done on the sled is zero.

14. The kinetic energy is converted to internal energy within the brake pads of the car, the roadway, and the tires.

16. The kinetic energy is a maximum at the instant the ball is released. The gravitational potential energy is a maximum at the top of the flight path.

18. The normal force is always perpendicular to the surface and the motion is generally parallel to the surface. Thus, in most circumstances, the normal force is perpendicular to the displacement and does no work. The force of static friction does no work because there is no displacement of the object relative to the surface in a static situation.

Answers to Even Numbered Problems

2. 30.6 m

4. 1.6 kJ

6. 0.68 J

8. (a) 31.9 J (b) 0 (c) 0 (d) 31.9 J

10. 160 m/s

12. (a) –168 J (b) –184 J (c) 500 J (d) 148 J (e) 5.64 m/s

14. 90.0 J

16. (a) 1.2 J (b) 5.0 m/s (c) 6.3 J

18. 2.0 m

20. (a) -19.6 J (b) 39.2 J (c) 0

22. 58.6 J

24. 26.5 m/s

26. 5.1 m

28. (a) 9.90 m/s (b) 7.67 m/s

30. (a) $v_B = 5.94\ \text{m/s}$, $v_C = 7.67\ \text{m/s}$ (b) 147 J

32. 5.11 m/s

34. 61 m

36. (a) 9.90 m/s (b) 11.8 J

38. 1.2 kN

40. 77 m/s

42. (a) 2.29 m/s (b) 15.6 J

44. $\frac{h}{5}\left(4\sin^2\theta+1\right)$

46. 1.5 m (measured along the incline)

48. (a) 21 kJ (b) 0.92 hp

50. $2.9\ \text{m/s}$

52. (a) 75.0 kJ (b) 33.5 hp (c) 44.7 hp

54. (a) 7.92 hp (b) 14.9 hp

56. (a) 7.50 J (b) 15.0 J (c) 7.50 J (d) 30.0 J

58. $9.80\ \text{m/s}$

60. 0.116 m

62. $1.4\ \text{m/s}$

64. 3.9 kJ

66. (a) 582 trips (b) 90.5 W (0.121 hp)

68. (a) 2.3 kN (b) $4.7 \times 10^2\ \text{N}$

70. (a) $3.1 \times 10^2\ \text{J}$ (b) $-1.5 \times 10^2\ \text{J}$ (c) 0 (d) $1.5 \times 10^2\ \text{J}$

72. (a) $3.5 \times 10^2\ \text{J}$ for javelin, $6.8 \times 10^2\ \text{J}$ for discus, $7.4 \times 10^2\ \text{J}$ for shot
(b) $1.7 \times 10^2\ \text{N}$ on javelin, $3.4 \times 10^2\ \text{N}$ on discus, $3.7 \times 10^2\ \text{N}$ on shot
(c) Yes

76. 0.115

78. (b) $2.06\ \text{m/s}$