5.10. **IDENTIFY:** Apply Newton’s first law to the car.  
**SET UP:** Use $x$ and $y$ coordinates that are parallel and perpendicular to the ramp.  
**EXECUTE:** (a) The free-body diagram for the car is given in Figure 1. The vertical weight $w$ and the tension $T$ in the cable have each been replaced by their $x$ and $y$ components.  
(b) $\sum F_x = 0$ gives $T \cos 31.0^\circ - w \sin 25.0^\circ = 0$ and  
$$T = \frac{w \sin 25.0^\circ}{\cos 31.0^\circ} = \frac{(1130 \text{ kg})(9.80 \text{ m/s}^2) \sin 25.0^\circ}{\cos 31.0^\circ} = 5460 \text{ N}.$$  
(c) $\sum F_y = 0$ gives $n + T \sin 31.0^\circ - w \cos 25.0^\circ = 0$ and  
$$n = w \cos 25.0^\circ - T \sin 31.0^\circ = (1130 \text{ kg})(9.80 \text{ m/s}^2) \cos 25.0^\circ - (5460 \text{ N}) \sin 31.0^\circ = 7220 \text{ N}$$  
**EVALUATE:** We could also use coordinates that are horizontal and vertical and would obtain the same values of $n$ and $T$.

![Free-body diagram of a car](image)

5.18. **IDENTIFY:** Apply Newton’s second law to the three sleds taken together as a composite object and to each individual sled. All three sleds have the same horizontal acceleration $a$.  
**SET UP:** The free-body diagram for the three sleds taken as a composite object is given in Figure 5.18a and for each individual sled in Figure 2b-d. Let $+x$ be to the right, in the direction of the acceleration. $m_{tot} = 60.0 \text{ kg}$.  
**EXECUTE:** (a) $\sum F_x = ma_x$ for the three sleds as a composite object gives $P = m_{tot} a$ and  
$$a = \frac{P}{m_{tot}} = \frac{125 \text{ N}}{60.0 \text{ kg}} = 2.08 \text{ m/s}^2.$$  
(b) $\sum F_x = ma_x$ applied to the 10.0 kg sled gives $P - T_A = m_{10} a$ and  
$$T_A = P - m_{10} a = 125 \text{ N} - (10.0 \text{ kg})(2.08 \text{ m/s}^2) = 104 \text{ N} \cdot \sum F_x = ma_x$ applied to the 30.0 kg sled gives  
$$T_B = m_{30} a = (30.0 \text{ kg})(2.08 \text{ m/s}^2) = 62.4 \text{ N}.$$  
**EVALUATE:** If we apply $\sum F_x = ma_x$ to the 20.0 kg sled and calculate $a$ from $T_A$ and $T_B$ found in part (b), we get  
$$T_A - T_B = m_{20} a \cdot a = \frac{T_A - T_B}{m_{20}} = \frac{104 \text{ N} - 62.4 \text{ N}}{20.0 \text{ kg}} = 2.08 \text{ m/s}^2,$$ which agrees with the value we calculated in part (a).
5.36. **IDENTIFY:** Constant speed means zero acceleration for each block. If the block is moving the friction force the tabletop exerts on it is kinetic friction. Apply \( \sum \vec{F} = m\vec{a} \) to each block.

**SET UP:** The free-body diagrams and choice of coordinates for each block are given by Figure 3. \( m_A = 4.59 \text{ kg} \) and \( m_B = 2.55 \text{ kg} \).

**EXECUTE:** (a) \( \sum F_y = ma_y \) with \( a_y = 0 \) applied to block \( B \) gives \( m_BG - T = 0 \) and \( T = 25.0 \text{ N} \).

\[ \sum F_x = ma_x \] with \( a_x = 0 \) applied to block \( A \) gives \( T - f_k = 0 \) and \( f_k = 25.0 \text{ N} \). \( n_A = m_Ag = 45.0 \text{ N} \) and \( \mu_k = \frac{f_k}{n_A} = \frac{25.0 \text{ N}}{45.0 \text{ N}} = 0.556 \).

(b) Now let \( A \) be block \( A \) plus the cat, so \( m_A = 9.18 \text{ kg} \) : \( n_A = 90.0 \text{ N} \) and \( f_k = \mu_k n = (0.556)(90.0 \text{ N}) = 50.0 \text{ N} \). \( \sum F_x = ma_x \) for \( A \) gives \( T - f_k = m_Aa_x \). \( \sum F_y = ma_y \) for block \( B \) gives \( m_Bg - T = m_Ba_x \). \( a_x \) for \( A \) equals \( a_y \) for \( B \), so adding the two equations gives \( m_Bg - f_k = (m_A + m_B)a_x \) and \( a_x = \frac{m_Bg - f_k}{m_A + m_B} = \frac{25.0 \text{ N} - 50.0 \text{ N}}{9.18 \text{ kg} + 2.55 \text{ kg}} = -2.13 \text{ m/s}^2 \). The acceleration is upward and block \( B \) slows down.

**EVALUATE:** The equation \( m_Bg - f_k = (m_A + m_B)a_x \) has a simple interpretation. If both blocks are considered together then there are two external forces: \( m_Bg \) that acts to move the system one way and \( f_k \) that acts oppositely. The net force of \( m_Bg - f_k \) must accelerate a total mass of \( m_A + m_B \).

5.55. **IDENTIFY:** The acceleration due to circular motion is \( a_{cm} = \frac{4\pi^2R}{T^2} \).

**SET UP:** \( R = 800 \text{ m} \). \( 1/T \) is the number of revolutions per second.

**EXECUTE:** (a) Setting \( a_{cm} = g \) and solving for the period \( T \) gives

\[ T = 2\pi \sqrt{\frac{R}{g}} = 2\pi \sqrt{\frac{400 \text{ m}}{9.80 \text{ m/s}^2}} = 40.1 \text{ s}, \]
so the number of revolutions per minute is \((60 \text{ s/min})/(40.1 \text{ s}) = 1.5 \text{ rev/min}\).

(b) The lower acceleration corresponds to a longer period, and hence a lower rotation rate, by a factor of the square root of the ratio of the accelerations, \(T' = (1.5 \text{ rev/min}) \times \sqrt{3.70/9.8} = 0.92 \text{ rev/min}\).

**Evaluate:** In part (a) the tangential speed of a point at the rim is given by \(a_{\text{tan}} = \frac{v^2}{R}\), so \(v = \sqrt{Ra_{\text{tan}}} = \sqrt{Rg} = 62.6 \text{ m/s}\); the space station is rotating rapidly.
6.2. **IDENTIFY:** In each case the forces are constant and the displacement is along a straight line, so $W = Fs \cos \phi$.

**SET UP:** In part (a), when the cable pulls horizontally $\phi = 0^\circ$ and when it pulls at $35.0^\circ$ above the horizontal $\phi = 35.0^\circ$. In part (b), if the cable pulls horizontally $\phi = 180^\circ$. If the cable pulls on the car at $35.0^\circ$ above the horizontal it pulls on the truck at $35.0^\circ$ below the horizontal and $\phi = 145.0^\circ$. For the gravity force $\phi = 90^\circ$, since the force is vertical and the displacement is horizontal.

**EXECUTE:** (a) When the cable is horizontal, $W = 850 \text{ N}(5.00 \times 10^1 \text{ m}) \cos 0^\circ = 4.25 \times 10^6 \text{ J}$. When the cable is $35.0^\circ$ above the horizontal, $W = 850 \text{ N}(5.00 \times 10^1 \text{ m}) \cos 35.0^\circ = 3.48 \times 10^6 \text{ J}$.

(b) $\cos 180^\circ = -\cos 0^\circ$ and $\cos 145.0^\circ = -\cos 35.0^\circ$, so the answers are $-4.26 \times 10^6 \text{ J}$ and $-3.48 \times 10^6 \text{ J}$.

(c) Since $\cos \phi = \cos 90^\circ = 0$, $W = 0$ in both cases.

**EVALUATE:** If the car and truck are taken together as the system, the tension in the cable does no net work.

6.8. **IDENTIFY:** Apply Eq.(6.5).

**SET UP:** $\hat{i} \cdot \hat{j} = 1$ and $\hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{i} = 0$

**EXECUTE:** The work you do is $\vec{F} \cdot \vec{s} = ((30 \text{ N})\hat{i} - (40 \text{ N})\hat{j}) \cdot ((-9.0 \text{ m})\hat{i} - (3.0 \text{ m})\hat{j})$

$\vec{F} \cdot \vec{s} = (30 \text{ N})(-9.0 \text{ m}) + (-40 \text{ N})(-3.0 \text{ m}) = -270 \text{ N} \cdot \text{m} + 120 \text{ N} \cdot \text{m} = -150 \text{ J}$

**EVALUATE:** The $x$-component of $\vec{F}$ does negative work and the $y$-component of $\vec{F}$ does positive work. The total

6.22. **IDENTIFY** and **SET UP:** Use Eq.(6.6) to calculate the work done by the foot on the ball. Then use Eq.(6.2) to find the distance over which this force acts.

**EXECUTE:** $W_{\text{net}} = K_2 - K_1$

$K_1 = \frac{1}{2} mv_1^2 = \frac{1}{2}(0.420 \text{ kg})(2.00 \text{ m/s})^2 = 0.84 \text{ J}$

$K_2 = \frac{1}{2} mv_2^2 = \frac{1}{2}(0.420 \text{ kg})(6.00 \text{ m/s})^2 = 7.56 \text{ J}$

$W_{\text{net}} = K_2 - K_1 = 7.56 \text{ J} - 0.84 \text{ J} = 6.72 \text{ J}$

The 40.0 N force is the only force doing work on the ball, so it must do 6.72 J of work. $W_{K} = (F \cos \phi)s$ gives that $s = \frac{W}{F \cos \phi} = \frac{6.72 \text{ J}}{40.0 \text{ N}\cos 0^\circ} = 0.168 \text{ m}$

**EVALUATE:** The force is in the direction of the motion so positive work is done and this is consistent with an increase in kinetic energy.

6.28. **IDENTIFY:** The work that must be done to move the end of a spring from $x_i$ to $x_f$ is $W = \frac{1}{2} k x_f^2 - \frac{1}{2} k x_i^2$.

The force required to hold the end of the spring at displacement $x$ is $F_x = kx$.

**SET UP:** When the spring is at its unstretched length, $x = 0$. When the spring is stretched, $x > 0$, and when the spring is compressed, $x < 0$.

**EXECUTE:** (a) $x_i = 0$ and $W = \frac{1}{2} k x_f^2$. $k = \frac{W}{x_f^2} = \frac{2(12.0 \text{ J})}{(0.0300 \text{ m})^2} = 2.67 \times 10^4 \text{ N/m}$

(b) $F_x = kx = (2.67 \times 10^4 \text{ N/m})(0.0300 \text{ m}) = 801 \text{ N}$

(c) $x_i = 0$, $x_f = -0.0400 \text{ m}$. $W = \frac{1}{2}(2.67 \times 10^4 \text{ N/m})(-0.0400 \text{ m})^2 = 21.4 \text{ J}$

$F = kx = (2.67 \times 10^4 \text{ N/m})(0.0400 \text{ m}) = 1070 \text{ N}$

**EVALUATE:** When a spring, initially unstretched, is either compressed or stretched, positive work is done by the force that moves the end of the spring.
IDENTIFY: The thermal energy is produced as a result of the force of friction, $F = \mu mg$. The average thermal power is thus the average rate of work done by friction or $P = Fv_{av}$.

SET UP: \[ v_{av} = \frac{v_f + v_i}{2} = \frac{8.00 \text{ m/s} + 0}{2} = 4.00 \text{ m/s} \]

EXECUTE: \[ P = Fv_{av} = \left[ (0.200)(20.0 \text{ kg})(9.80 \text{ m/s}^2) \right] (4.00 \text{ m/s}) = 157 \text{ W} \]

EVALUATE: The power could also be determined as the rate of change of kinetic energy, $\Delta K/t$, where the time is calculated from $v_f = v_i + at$ and $a$ is calculated from a force balance, $\sum F = ma = \mu mg$. 
Note: Referred equations are from your textbook.

7.4. **IDENTIFY:** Only gravity does work on him from the point where he has just left the board until just before he enters the water, so Eq (7.4) applies.

**SET UP:** Let point 1 be just after he leaves the board and point 2 be just before he enters the water. +y is upward and y = 0 at the water.

**EXECUTE:**

(a) \( K_1 = 0 \), \( y_2 = 0 \), \( y_1 = 3.25 \, \text{m} \). \( K_1 + U_{\text{grav,1}} = K_2 + U_{\text{grav,2}} \) gives \( U_{\text{grav,1}} = K_2 \) and

\[ mgy_1 = \frac{1}{2}m v_1^2. \quad v_2 = \sqrt{2gy_1} = \sqrt{2(9.80 \, \text{m/s}^2)(3.25 \, \text{m})} = 7.98 \, \text{m/s}. \]

(b) \( v_1 = 2.50 \, \text{m/s}, \quad y_2 = 0, \quad y_1 = 3.25 \, \text{m} \). \( K_1 + U_{\text{grav,1}} = K_2 \) and \( \frac{1}{2}mv_1^2 + mgy_1 = \frac{1}{2}mv_2^2. \)

\[ v_2 = \sqrt{v_1^2 + 2gy_1} = \sqrt{(2.50 \, \text{m/s})^2 + 2(9.80 \, \text{m/s}^2)(3.25 \, \text{m})} = 8.36 \, \text{m/s}. \]

(c) \( v_1 = 2.5 \, \text{m/s} \) and \( v_2 = 8.36 \, \text{m/s} \), the same as in part (b).

**EVALUATE:** Kinetic energy depends only on the speed, not on the direction of the velocity.