4.5. **IDENTIFY:** Vector addition.

SET UP: Use a coordinate system where the $+x$-axis is in the direction of $\vec{F}_A$, the force applied by dog A. The forces are sketched in Figure 4.5.

EXECUTE:

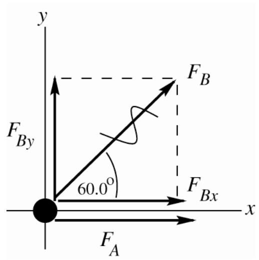

Figure 4.5a

$F_{Ax} = +270\text{ N}, \quad F_{Ay} = 0$

$F_{Bx} = F_B \cos 60.0° = (300\text{ N})\cos 60.0° = +150\text{ N}$

$F_{By} = F_B \sin 60.0° = (300\text{ N})\sin 60.0° = +260\text{ N}$

$\vec{R} = \vec{F}_A + \vec{F}_B$

$R_x = F_{Ax} + F_{Bx} = +270\text{ N} + 150\text{ N} = +420\text{ N}$

$R_y = F_{Ay} + F_{By} = 0 + 260\text{ N} = +260\text{ N}$

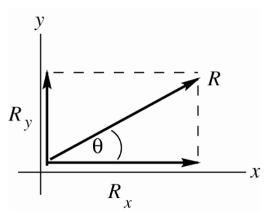

Figure 4.5b

$R = \sqrt{R_x^2 + R_y^2}$

$R = \sqrt{(420\text{ N})^2 + (260\text{ N})^2} = 494\text{ N}$

$\tan\theta = \dfrac{R_y}{R_x} = 0.619$

$\theta = 31.8°$

EVALUATE: The forces must be added as vectors. The magnitude of the resultant force is less than the sum of the magnitudes of the two forces and depends on the angle between the two forces.

4.10. **IDENTIFY:** Use the information about the motion to find the acceleration and then use $\sum F_x = ma_x$ to calculate *m*.

SET UP: Let $+x$ be the direction of the force. $\sum F_x = 80.0\text{ N}$.

EXECUTE: **(a)** $x - x_0 = 11.0\text{ m}$, $t = 5.00\text{ s}$, $v_{0x} = 0$. $x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2$ gives

$a_x = \dfrac{2(x-x_0)}{t^2} = \dfrac{2(11.0\text{ m})}{(5.00\text{ s})^2} = 0.880\text{ m/s}^2$. $m = \dfrac{\sum F_x}{a_x} = \dfrac{80.0\text{ N}}{0.880\text{ m/s}^2} = 90.9\text{ kg}$.

(b) $a_x = 0$ and v_x is constant. After the first 5.0 s, $v_x = v_{0x} + a_x t = (0.880\text{ m/s}^2)(5.00\text{ s}) = 4.40\text{ m/s}$.

$x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2 = (4.40\text{ m/s})(5.00\text{ s}) = 22.0\text{ m}$.

EVALUATE: The mass determines the amount of acceleration produced by a given force. The block moves farther in the second 5.00 s than in the first 5.00 s.

4.14. **IDENTIFY:** The force and acceleration are related by Newton's second law. $a_x = \dfrac{dv_x}{dt}$, so a_x is the slope of the graph of v_x versus *t*.

SET UP: The graph of v_x versus *t* consists of straight-line segments. For $t = 0$ to $t = 2.00\text{ s}$, $a_x = 4.00\text{ m/s}^2$. For $t = 2.00$ s to 6.00 s, $a_x = 0$. For $t = 6.00$ s to 10.0 s, $a_x = 1.00\text{ m/s}^2$.

$\sum F_x = ma_x$, with $m = 2.75\text{ kg}$. $\sum F_x$ is the net force.

EXECUTE: **(a)** The maximum net force occurs when the acceleration has its maximum value.

$\sum F_x = ma_x = (2.75\text{ kg})(4.00\text{ m/s}^2) = 11.0\text{ N}$. This maximum occurs in the interval $t = 0$ to $t = 2.00\text{ s}$.

(b) The net force is zero when the acceleration is zero. This is between 2.00 s and 6.00 s.

(c) Between 6.00 s and 10.0 s, $a_x = 1.00\text{ m/s}^2$, so $\sum F_x = (2.75\text{ kg})(1.00\text{ m/s}^2) = 2.75\text{ N}$.

EVALUATE: The net force is largest when the velocity is changing most rapidly.

4.15. **IDENTIFY:** The net force and the acceleration are related by Newton's second law. When the rocket is near the surface of the earth the forces on it are the upward force $\vec{F}$ exerted on it because of the burning fuel and the downward force $\vec{F}_{\text{grav}}$ of gravity. $F_{\text{grav}} = mg$.

SET UP: Let $+y$ be upward. The weight of the rocket is $F_{\text{grav}} = (8.00\text{ kg})(9.80\text{ m/s}^2) = 78.4\text{ N}$.

EXECUTE: **(a)** At $t = 0$, $F = A = 100.0\text{ N}$. At $t = 2.00\text{ s}$, $F = A + (4.00\text{ s}^2)B = 150.0\text{ N}$ and

$$B = \frac{150.0\text{ N} - 100.0\text{ N}}{4.00\text{ s}^2} = 12.5\text{ N/s}^2 .$$

(b) (i) At $t = 0$, $F = A = 100.0\text{ N}$. The net force is $\sum F_y = F - F_{\text{grav}} = 100.0\text{ N} - 78.4\text{ N} = 21.6\text{ N}$.

$a_y = \dfrac{\sum F_y}{m} = \dfrac{21.6\text{ N}}{8.00\text{ kg}} = 2.70\text{ m/s}^2$. (ii) At $t = 3.00$ s, $F = A + B(3.00\text{ s})^2 = 212.5\text{ N}$.

$\sum F_y = 212.5\text{ N} - 78.4\text{ N} = 134.1\text{ N}$. $a_y = \dfrac{\sum F_y}{m} = \dfrac{134.1\text{ N}}{8.00\text{ kg}} = 16.8\text{ m/s}^2$.

(c) Now $F_{\text{grav}} = 0$ and $\sum F_y = F = 212.5\text{ N}$. $a_y = \dfrac{212.5\text{ N}}{8.00\text{ kg}} = 26.6\text{ m/s}^2$.

EVALUATE: The acceleration increases as F increases.

4.16. **IDENTIFY:** Use constant acceleration equations to calculate a_x and t. Then use $\sum \vec{F} = m\vec{a}$ to calculate the net force.

SET UP: Let $+x$ be in the direction of motion of the electron.

EXECUTE: **(a)** $v_{0x} = 0$, $(x - x_0) = 1.80\times10^{-2}$ m , $v_x = 3.00\times10^6$ m/s . $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ gives

$$a_x = \frac{v_x^2 - v_{0x}^2}{2(x - x_0)} = \frac{(3.00\times10^6\text{ m/s})^2 - 0}{2(1.80\times10^{-2}\text{ m})} = 2.50\times10^{14}\text{ m/s}^2$$

(b) $v_x = v_{0x} + a_x t$ gives $t = \dfrac{v_x - v_{0x}}{a_x} = \dfrac{3.00\times10^6\text{ m/s} - 0}{2.50\times10^{14}\text{ m/s}^2} = 1.2\times10^{-8}$ s

(c) $\sum F_x = ma_x = (9.11\times10^{-31}\text{ kg})(2.50\times10^{14}\text{ m/s}^2) = 2.28\times10^{-16}\text{ N}$.

EVALUATE: The acceleration is in the direction of motion since the speed is increasing, and the net force is in the direction of the acceleration.

4.19. **IDENTIFY** and **SET UP:** $w = mg$. The mass of the watermelon is constant, independent of its location. Its weight differs on earth and Jupiter's moon. Use the information about the watermelon's weight on earth to calculate its mass:

EXECUTE: $w = mg$ gives that $m = \dfrac{w}{g} = \dfrac{44.0\text{ N}}{9.80\text{ m/s}^2} = 4.49$ kg.

On Jupiter's moon, $m = 4.49$ kg, the same as on earth. Thus the weight on Jupiter's moon is

$w = mg = (4.49\text{ kg})(1.81\text{ m/s}^2) = 8.13\text{ N}.$

EVALUATE: The weight of the watermelon is less on Io, since g is smaller there.

4.40. **IDENTIFY:** Use constant acceleration equations to calculate the acceleration a_x that would be required. Then use $\sum F_x = ma_x$ to find the necessary force.

SET UP: Let $+x$ be the direction of the initial motion of the auto.

EXECUTE: $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ with $v_x = 0$ gives $a_x = -\dfrac{v_{0x}^2}{2(x - x_0)}$. The force F is directed opposite to the motion and $a_x = -\dfrac{F}{m}$. Equating these two expressions for a_x gives

$$F = m\frac{v_{0x}^2}{2(x - x_0)} = (850\text{ kg})\frac{(12.5\text{ m/s})^2}{2(1.8\times10^{-2}\text{ m})} = 3.7\times10^6\text{ N}.$$

EVALUATE: A very large force is required to stop such a massive object in such a short distance.

4.41. **IDENTIFY:** Apply Newton's second law to calculate a.

(a) SET UP: The free-body diagram for the bucket is sketched in Figure 4.41.

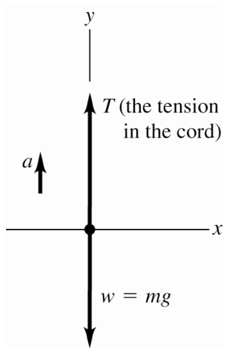

Figure 4.41

The net force on the bucket is $T - mg$, upward.

(b) EXECUTE: $\sum F_y = ma_y$ gives $T - mg = ma$

$$a = \frac{T - mg}{m} = \frac{75.0 \text{ N} - (4.80 \text{ kg})(9.80 \text{ m/s}^2)}{4.80 \text{ kg}} = \frac{75.0 \text{ N} - 47.04 \text{ N}}{4.80 \text{ kg}} = 5.82 \text{ m/s}^2.$$

EVALUATE: The weight of the bucket is 47.0 N. The upward force exerted by the cord is larger than this, so the bucket accelerates upward.

4.44. IDENTIFY: Apply Newton's second and third laws.
SET UP: Action-reaction forces act between a pair of objects. In the second law all the forces act on the same object.
EXECUTE: **(a)** The force the astronaut exerts on the cable and the force that the cable exerts on the astronaut are an action-reaction pair, so the cable exerts a force of 80.0 N on the astronaut.
(b) The cable is under tension.

(c) $a = \dfrac{F}{m} = \dfrac{80.0 \text{ N}}{105.0 \text{ kg}} = 0.762 \text{ m/s}^2$.

(d) There is no net force on the massless cable, so the force that the shuttle exerts on the cable must be 80.0 N (this is *not* an action-reaction pair). Thus, the force that the cable exerts on the shuttle must be 80.0 N.

(e) $a = \dfrac{F}{m} = \dfrac{80.0 \text{ N}}{9.05 \times 10^4 \text{ kg}} = 8.84 \times 10^{-4} \text{ m/s}^2$.

EVALUATE: Since the cable is massless the net force on it is zero and the tension is the same at each end.

4.54. IDENTIFY: Note that in this problem the mass of the rope is given, and that it is not negligible compared to the other masses. Apply $\sum \vec{F} = m\vec{a}$ to each object to relate the forces to the acceleration.
(a) SET UP: The free-body diagrams for each block and for the rope are given in Figure 4.54a.

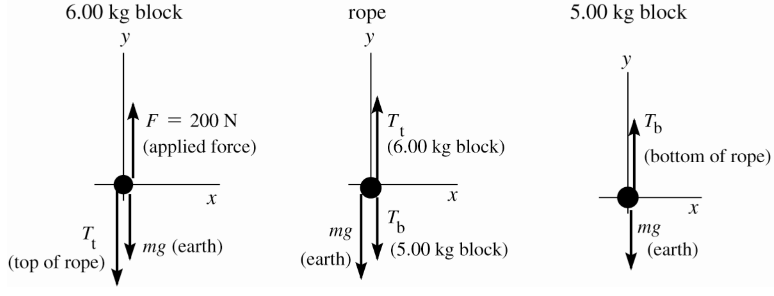

Figure 4.54a

T_t is the tension at the top of the rope and T_b is the tension at the bottom of the rope.

EXECUTE: **(b)** Treat the rope and the two blocks together as a single object, with mass $m = 6.00 \text{ kg} + 4.00 \text{ kg} + 5.00 \text{ kg} = 15.0 \text{ kg}$. Take $+y$ upward, since the acceleration is upward. The free-body diagram is given in Figure 4.54b.

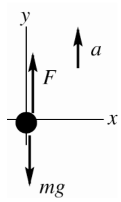

Figure 4.54b

$$\sum F_y = ma_y$$
$$F - mg = ma$$
$$a = \frac{F - mg}{m}$$
$$a = \frac{200\text{ N} - (15.0\text{ kg})(9.80\text{ m/s}^2)}{15.0\text{ kg}} = 3.53\text{ m/s}^2$$

(c) Consider the forces on the top block $(m = 6.00\text{ kg})$, since the tension at the top of the rope (T_t) will be one of these forces.

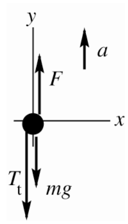

Figure 4.54c

$$\sum F_y = ma_y$$
$$F - mg - T_\text{t} = ma$$
$$T_\text{t} = F - m(g + a)$$
$$T = 200\text{ N} - (6.00\text{ kg})(9.80\text{ m/s}^2 + 3.53\text{ m/s}^2) = 120\text{ N}$$

Alternatively, can consider the forces on the combined object rope plus bottom block $(m = 9.00\text{ kg})$:

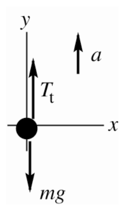

Figure 4.54d

$$\sum F_y = ma_y$$
$$T_\text{t} - mg = ma$$
$$T_\text{t} = m(g + a) = 9.00\text{ kg}(9.80\text{ m/s}^2 + 3.53\text{ m/s}^2) = 120\text{ N},$$
which checks

(d) One way to do this is to consider the forces on the top half of the rope $(m = 2.00\text{ kg})$. Let T_m be the tension at the midpoint of the rope.

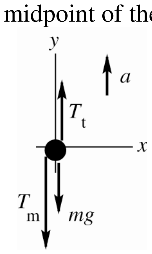

Figure 4.54e

$$\sum F_y = ma_y$$
$$T_\text{t} - T_\text{m} - mg = ma$$
$$T_\text{m} = T_\text{t} - m(g + a) = 120\text{ N} - 2.00\text{ kg}(9.80\text{ m/s}^2 + 3.53\text{ m/s}^2) = 93.3\text{ N}$$

To check this answer we can alternatively consider the forces on the bottom half of the rope plus the lower block taken together as a combined object $(m = 2.00\text{ kg} + 5.00\text{ kg} = 7.00\text{ kg})$:

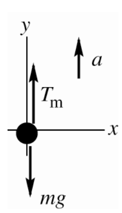

Figure 4.54f

$$\sum F_y = ma_y$$
$$T_\text{m} - mg = ma$$
$$T_\text{m} = m(g + a) = 7.00\text{ kg}(9.80\text{ m/s}^2 + 3.53\text{ m/s}^2) = 93.3\text{ N},$$
which checks

EVALUATE: The tension in the rope is not constant but increases from the bottom of the rope to the top. The tension at the top of the rope must accelerate the rope as well the 5.00-kg block. The tension at the top of the rope is less than *F*; there must be a net upward force on the 6.00-kg block.

4.55. **IDENTIFY:** Apply $\sum \vec{F} = m\vec{a}$ to the barbell and to the athlete. Use the motion of the barbell to calculate its acceleration.

SET UP: Let $+y$ be upward.

EXECUTE: **(a)** The free-body diagrams for the baseball and for the athlete are sketched in Figure 4.55.

(b) The athlete's weight is $mg = (90.0 \text{ kg})(9.80 \text{ m/s}^2) = 882 \text{ N}$. The upward acceleration of the barbell is found from $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2$. $a_y = \dfrac{2(y - y_0)}{t^2} = \dfrac{2(0.600 \text{ m})}{(1.6 \text{ s})^2} = 0.469 \text{ m/s}^2$. The force needed to lift the barbell is given by $F_{\text{lift}} - w_{\text{barbell}} = ma_y$. The barbell's mass is $(490 \text{ N})/(9.80 \text{ m/s}^2) = 50.0 \text{ kg}$, so

$F_{\text{lift}} = w_{\text{barbell}} + ma = 490 \text{ N} + (50.0 \text{ kg})(0.469 \text{ m/s}^2) = 490 \text{ N} + 23 \text{ N} = 513 \text{ N}$.

The athlete is not accelerating, so $F_{\text{floor}} - F_{\text{lift}} - w_{\text{athlete}} = 0$. $F_{\text{floor}} = F_{\text{lift}} + w_{\text{athlete}} = 513 \text{ N} + 882 \text{ N} = 1395 \text{ N}$.

EVALUATE: Since the athlete pushes upward on the barbell with a force greater than its weight the barbell pushes down on him and the normal force on the athlete is greater than the total weight, 1362 N, of the athlete plus barbell.

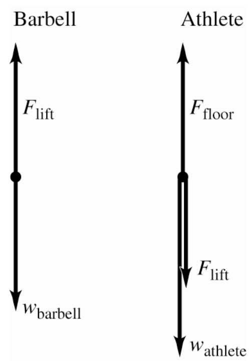

Figure 4.55