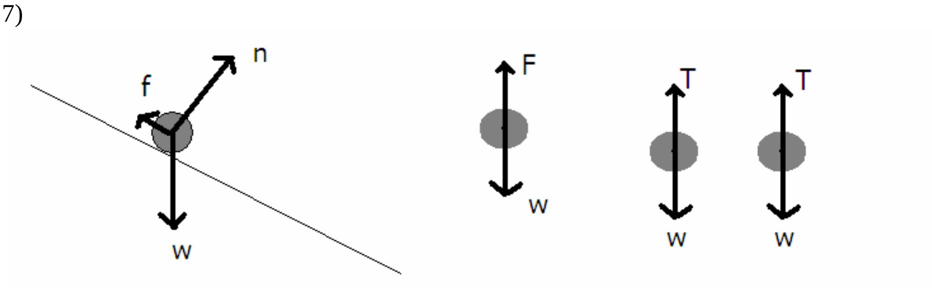
4

NEWTON'S LAWS OF MOTION

1) A force not on a mass hanging (key word) on a rope is the normal force. Tension and Gravity are on the rope.
2) N1 states that inertia keeps an object moving as it was.
3) a = F/m. If F is halved, a is halved from 10 m/s^2 to 5 m/s^2.
4) a = F/m. If m is halved, a is doubled from 10 m/s^2 to 20 m/s^2.
5) a = F/m. If both F and m are halved, a stays the same.
6) a = F/m. If the force is halved and the object's mass is doubled then a is quartered.

7)



8) mass is not weight. w = mg.

9) The normal force is equal on both cars from N3.

4.4. **IDENTIFY:** $F_x = F\cos\theta$, $F_y = F\sin\theta$.

SET UP: Let $+x$ be parallel to the ramp and directed up the ramp. Let $+y$ be perpendicular to the ramp and directed away from it. Then $\theta = 30.0°$.

EXECUTE: **(a)** $F = \dfrac{F_x}{\cos\theta} = \dfrac{60.0\,\text{N}}{\cos 30°} = 69.3$ N.

(b) $F_y = F\sin\theta = F_x \tan\theta = 34.6$ N.

EVALUATE: We can verify that $F_x^2 + F_y^2 = F^2$. The signs of F_x and F_y show their direction.

4.7. **IDENTIFY:** Apply $\sum \vec{F} = m\vec{a}$.

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

EXECUTE: $a_x = F_x / m = (132\text{ N})/(60\text{ kg}) = 2.2\text{ m/s}^2$.

EVALUATE: The acceleration is in the direction of the force.

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

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

(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.

4.12. **IDENTIFY:** Apply $\sum \vec{F} = m\vec{a}$. Then use a constant acceleration equation to relate the kinematic quantities.

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

EXECUTE: **(a)** $a_x = F_x / m = (140\ \text{N})/(32.5\ \text{kg}) = 4.31\ \text{m/s}^2$.

(b) $x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2$. With $v_{0x} = 0,\ x = \frac{1}{2}at^2 = 215\ \text{m}$.

(c) $v_x = v_{0x} + a_x t$. With $v_{0x} = 0,\ v_x = a_x t = 2x/t = 43.0\ \text{m/s}$.

EVALUATE: The acceleration connects the motion to the forces.

4.13. **IDENTIFY:** The force and acceleration are related by Newton's second law.

SET UP: $\sum F_x = ma_x$, where $\sum F_x$ is the net force. $m = 4.50\ \text{kg}$.

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

$\sum F_x = ma_x = (4.50\ \text{kg})(10.0\ \text{m/s}^2) = 45.0\ \text{N}$. This maximum force occurs between 2.0 s and 4.0 s.

(b) The net force is constant when the acceleration is constant. This is between 2.0 s and 4.0 s.

(c) The net force is zero when the acceleration is zero. This is the case at $t = 0$ and $t = 6.0\ \text{s}$.

EVALUATE: A graph of $\sum F_x$ versus *t* would have the same shape as the graph of a_x versus *t*.

4.17. **IDENTIFY** and **SET UP:** $F = ma.$ We must use $w = mg$ to find the mass of the boulder.

EXECUTE: $m = \dfrac{w}{g} = \dfrac{2400\ \text{N}}{9.80\ \text{m/s}^2} = 244.9\ \text{kg}$

Then $F = ma = (244.9\ \text{kg})(12.0\ \text{m/s}^2) = 2940\ \text{N}.$

EVALUATE: We must use mass in Newton's second law. Mass and weight are proportional.

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

On Jupiter's moon, $m = 4.49\ \text{kg},$ 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.

21) Four forces on the reporter are weight, normal, wind, and friction. The N3 pairs are gravitational attraction of the Earth towards the reporter, normal force down on the ground, force on the wind (slowing it down), and friction onto the ground.

4.32. **IDENTIFY:** Identify the forces on the skier and apply $\sum \vec{F} = m\vec{a}$. Constant speed means $a = 0$.

SET UP: Use coordinates that are parallel and perpendicular to the slope.

EXECUTE: **(a)** The free-body diagram for the skier is given in Figure 4.32.

(b) $\sum F_x = ma_x$ with $a_x = 0$ gives $T = mg\sin\theta = (65.0\ \text{kg})(9.80\ \text{m/s}^2)\sin 26.0° = 279\ \text{N}$.

EVALUATE: *T* is less than the weight of the skier. It is equal to the component of the weight that is parallel to the incline.

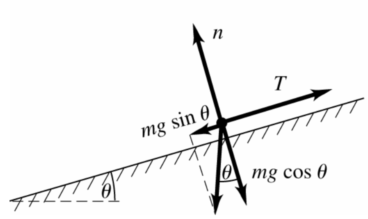

Figure 4.32

4.34. **IDENTIFY:** Use a constant acceleration equation to find the stopping time and acceleration. Then use $\sum \vec{F} = m\vec{a}$ to calculate the force.

SET UP: Let $+x$ be in the direction the bullet is traveling. $\vec{F}$ is the force the wood exerts on the bullet.

EXECUTE: **(a)** $v_{0x} = 350\text{ m/s}$, $v_x = 0$ and $(x - x_0) = 0.130\text{ m}$. $(x - x_0) = \left(\dfrac{v_{0x} + v_x}{2}\right)t$

gives $t = \dfrac{2(x - x_0)}{v_{0x} + v_x} = \dfrac{2(0.130\text{ m})}{350\text{ m/s}} = 7.43\times10^{-4}\text{ s}$.

(b) $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ gives $a_x = \dfrac{v_x^2 - v_{0x}^2}{2(x - x_0)} = \dfrac{0 - (350\text{ m/s})^2}{2(0.130\text{ m})} = -4.71\times10^5\text{ m/s}^2$

$\sum F_x = ma_x$ gives $-F = ma_x$ and $F = -ma_x = -(1.80\times10^{-3}\text{ kg})(-4.71\times10^5\text{ m/s}^2) = 848\text{ N}$.

EVALUATE: The acceleration and net force are opposite to the direction of motion of the bullet.

4.36. **IDENTIFY:** Use the motion of the ball to calculate g, the acceleration of gravity on the planet. Then $w = mg$.

SET UP: Let $+y$ be downward and take $y_0 = 0$. $v_{0y} = 0$ since the ball is released from rest.

EXECUTE: Get g on X: $y = \frac{1}{2}gt^2$ gives $10.0\text{ m} = \frac{1}{2}g(2.2\text{ s})^2$. $g = 4.13\text{ m/s}^2$ and then

$w_X = mg_X = (0.100\text{ kg})(4.03\text{ m/s}^2) = 0.41\text{ N}$.

EVALUATE: g on Planet X is smaller than on earth and the object weighs less than it would on earth.

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.

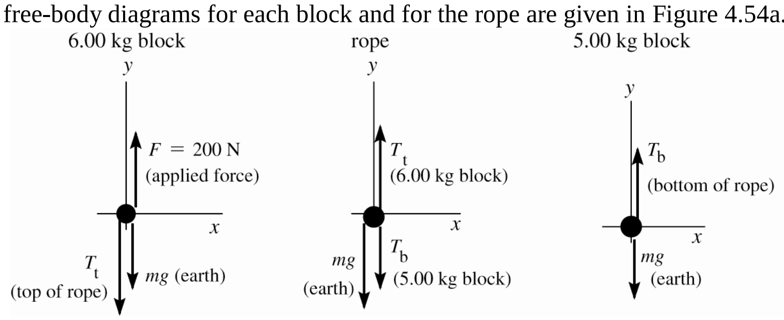

Figure 4.54a

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.

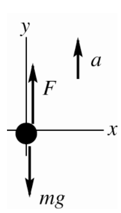

Figure 4.54b

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

(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.

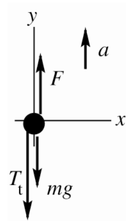

Figure 4.54c

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

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

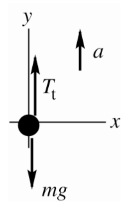

Figure 4.54d

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

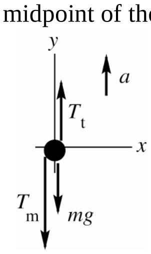

Figure 4.54e

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

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 $(m = 2.00\text{ kg} + 5.00\text{ kg} = 7.00\text{ kg})$:

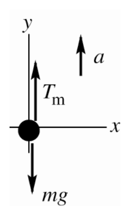

Figure 4.54f

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

4.59. IDENTIFY: $F_x = ma_x$ and $a_x = \dfrac{d^2x}{dt^2}$.

SET UP: $\dfrac{d}{dt}(t^n) = nt^{n-1}$

EXECUTE: The velocity as a function of time is $v_x(t) = A - 3Bt^2$ and the acceleration as a function of time is $a_x(t) = -6Bt$, and so the force as a function of time is $F_x(t) = ma(t) = -6mBt$.

EVALUATE: Since the acceleration is along the *x*-axis, the force is along the *x*-axis.