

Physics 16 – Spring 2010 – Problem Set 3

- 3.82. IDENTIFY:** Both the bolt and the elevator move vertically with constant acceleration.
- SET UP:** Let $+y$ be upward and let $y = 0$ at the initial position of the floor of the elevator, so y_0 for the bolt is 3.00 m.
- EXECUTE:** (a) The position of the bolt is $3.00 \text{ m} + (2.50 \text{ m/s})t - (1/2)(9.80 \text{ m/s}^2)t^2$ and the position of the floor is $(2.50 \text{ m/s})t$. Equating the two, $3.00 \text{ m} = (4.90 \text{ m/s}^2)t^2$. Therefore, $t = 0.782 \text{ s}$.
- (b) The velocity of the bolt is $2.50 \text{ m/s} - (9.80 \text{ m/s}^2)(0.782 \text{ s}) = -5.17 \text{ m/s}$ relative to Earth, therefore, relative to an observer in the elevator $v = -5.17 \text{ m/s} - 2.50 \text{ m/s} = -7.67 \text{ m/s}$.
- (c) As calculated in part (b), the speed relative to Earth is 5.17 m/s.
- (d) Relative to Earth, the distance the bolt traveled is $(2.50 \text{ m/s})t - (1/2)(9.80 \text{ m/s}^2)t^2 = (2.50 \text{ m/s})(0.782 \text{ s}) - (4.90 \text{ m/s}^2)(0.782 \text{ s})^2 = -1.04 \text{ m}$.
- EVALUATE:** As viewed by an observer in the elevator, the bolt has $v_{0y} = 0$ and $a_y = -9.80 \text{ m/s}^2$, so in 0.782 s it falls $-\frac{1}{2}(9.80 \text{ m/s}^2)(0.782 \text{ s})^2 = -3.00 \text{ m}$.

- 4.24. IDENTIFY:** The reaction forces in Newton's third law are always between a pair of objects. In Newton's second law all the forces act on a single object.
- SET UP:** Let $+y$ be downward. $m = w/g$.
- EXECUTE:** The reaction to the upward normal force on the passenger is the downward normal force, also of magnitude 620 N, that the passenger exerts on the floor. The reaction to the passenger's weight is the gravitational force that the passenger exerts on the earth, upward and also of magnitude 650 N.
- $$\frac{\sum F_y}{m} = a_y \text{ gives } a_y = \frac{650 \text{ N} - 620 \text{ N}}{(650 \text{ N})/(9.80 \text{ m/s}^2)} = 0.452 \text{ m/s}^2.$$
- The passenger's acceleration is 0.452 m/s^2 , downward.
- EVALUATE:** There is a net downward force on the passenger and the passenger has a downward acceleration.

- 4.27. IDENTIFY:** Identify the forces on each object.
- SET UP:** In each case the forces are the noncontact force of gravity (the weight) and the forces applied by objects that are in contact with each crate. Each crate touches the floor and the other crate, and some object applies \vec{F} to crate A.
- EXECUTE:** (a) The free-body diagrams for each crate are given in Figure 4.27.
- F_{AB} (the force on m_A due to m_B) and F_{BA} (the force on m_B due to m_A) form an action-reaction pair.
- (b) Since there is no horizontal force opposing F , any value of F , no matter how small, will cause the crates to accelerate to the right. The weight of the two crates acts at a right angle to the horizontal, and is in any case balanced by the upward force of the surface on them.
- EVALUATE:** Crate B is accelerated by F_{BA} and crate A is accelerated by the net force $F - F_{AB}$. The greater the total weight of the two crates, the greater their total mass and the smaller will be their acceleration.

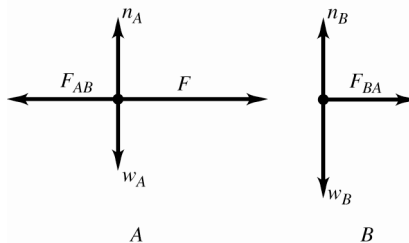


Figure 4.27

- 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 $T = mg \sin \theta = (65.0 \text{ kg})(9.80 \text{ m/s}^2) \sin 26.0^\circ = 279 \text{ N}$.
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.

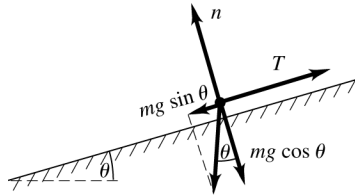
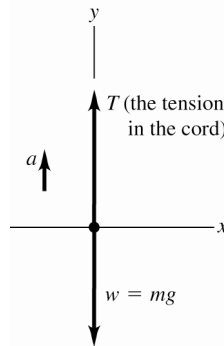


Figure 4.32

- 4.41. **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.



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

Figure 4.41

- (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.

- 4.54. **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.

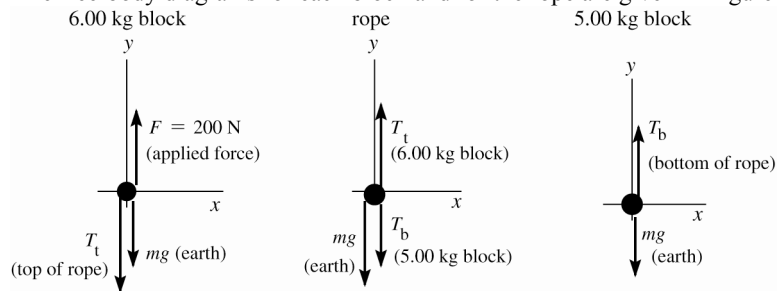


Figure 4.54a

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.

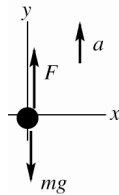


Figure 4.54b

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

(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.

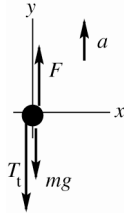


Figure 4.54c

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

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

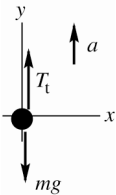


Figure 4.54d

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

(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.

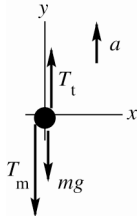


Figure 4.54e

$$\begin{aligned}\sum F_y &= ma_y \\ T_t - T_m - mg &= ma \\ T_m &= T_t - m(g + a) = 120 \text{ N} - 2.00 \text{ kg}(9.80 \text{ m/s}^2 + 3.53 \text{ m/s}^2) = 93.3 \text{ N}\end{aligned}$$

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

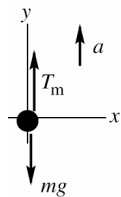


Figure 4.54f

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

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.

4.56. IDENTIFY: Apply $\sum \vec{F} = m\vec{a}$ to the balloon and its passengers and cargo, both before and after objects are dropped overboard.

SET UP: When the acceleration is downward take $+y$ to be downward and when the acceleration is upward take $+y$ to be upward.

EXECUTE: (a) The free-body diagram for the descending balloon is given in Figure 4.56. L is the lift force.

(b) $\sum F_y = ma_y$ gives $Mg - L = M(g/3)$ and $L = 2Mg/3$.

(c) Now $+y$ is upward, so $L - mg = m(g/2)$, where m is the mass remaining.

$L = 2Mg/3$, so $m = 4M/9$. Mass $5M/9$ must be dropped overboard.

EVALUATE: In part (b) the lift force is greater than the total weight and in part (c) the lift force is less than the total weight.

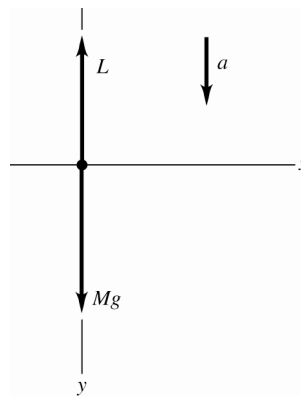


Figure 4.56