

2.1. IDENTIFY: The average velocity is $v_{\text{av-}x} = \frac{\Delta x}{\Delta t}$.

SET UP: Let $+x$ be upward.

EXECUTE: (a) $v_{\text{av-}x} = \frac{1000 \text{ m} - 63 \text{ m}}{4.75 \text{ s}} = 197 \text{ m/s}$

(b) $v_{\text{av-}x} = \frac{1000 \text{ m} - 0}{5.90 \text{ s}} = 169 \text{ m/s}$

EVALUATE: For the first 1.15 s of the flight, $v_{\text{av-}x} = \frac{63 \text{ m} - 0}{1.15 \text{ s}} = 54.8 \text{ m/s}$. When the velocity isn't constant the average velocity depends on the time interval chosen. In this motion the velocity is increasing.

2.8. IDENTIFY: The average velocity is $v_{\text{av-}x} = \frac{\Delta x}{\Delta t}$. Use $x(t)$ to find x for each t .

SET UP: $x(0) = 0$, $x(2.00 \text{ s}) = 5.60 \text{ m}$, and $x(4.00 \text{ s}) = 20.8 \text{ m}$

EXECUTE: (a) $v_{\text{av-}x} = \frac{5.60 \text{ m} - 0}{2.00 \text{ s}} = +2.80 \text{ m/s}$

(b) $v_{\text{av-}x} = \frac{20.8 \text{ m} - 0}{4.00 \text{ s}} = +5.20 \text{ m/s}$

(c) $v_{\text{av-}x} = \frac{20.8 \text{ m} - 5.60 \text{ m}}{2.00 \text{ s}} = +7.60 \text{ m/s}$

EVALUATE: The average velocity depends on the time interval being considered.

2.11. IDENTIFY: The average velocity is given by $v_{\text{av-}x} = \frac{\Delta x}{\Delta t}$. We can find the displacement Δx for each constant

velocity time interval. The average speed is the distance traveled divided by the time.

SET UP: For $t = 0$ to $t = 2.0 \text{ s}$, $v_x = 2.0 \text{ m/s}$. For $t = 2.0 \text{ s}$ to $t = 3.0 \text{ s}$, $v_x = 3.0 \text{ m/s}$. In part (b),

$v_x = -3.0 \text{ m/s}$ for $t = 2.0 \text{ s}$ to $t = 3.0 \text{ s}$. When the velocity is constant, $\Delta x = v_x \Delta t$.

EXECUTE: (a) For $t = 0$ to $t = 2.0 \text{ s}$, $\Delta x = (2.0 \text{ m/s})(2.0 \text{ s}) = 4.0 \text{ m}$. For $t = 2.0 \text{ s}$ to $t = 3.0 \text{ s}$,

$\Delta x = (3.0 \text{ m/s})(1.0 \text{ s}) = 3.0 \text{ m}$. For the first 3.0 s, $\Delta x = 4.0 \text{ m} + 3.0 \text{ m} = 7.0 \text{ m}$. The distance traveled is also 7.0 m.

The average velocity is $v_{\text{av-}x} = \frac{\Delta x}{\Delta t} = \frac{7.0 \text{ m}}{3.0 \text{ s}} = 2.33 \text{ m/s}$. The average speed is also 2.33 m/s.

(b) For $t = 2.0 \text{ s}$ to 3.0 s , $\Delta x = (-3.0 \text{ m/s})(1.0 \text{ s}) = -3.0 \text{ m}$. For the first 3.0 s, $\Delta x = 4.0 \text{ m} + (-3.0 \text{ m}) = +1.0 \text{ m}$.

The dog runs 4.0 m in the $+x$ -direction and then 3.0 m in the $-x$ -direction, so the distance traveled is still 7.0 m.

$v_{\text{av-}x} = \frac{\Delta x}{\Delta t} = \frac{1.0 \text{ m}}{3.0 \text{ s}} = 0.33 \text{ m/s}$. The average speed is $\frac{7.00 \text{ m}}{3.00 \text{ s}} = 2.33 \text{ m/s}$.

EVALUATE: When the motion is always in the same direction, the displacement and the distance traveled are equal and the average velocity has the same magnitude as the average speed. When the motion changes direction during the time interval, those quantities are different.

2.16. IDENTIFY: Use Eq.(2.4), with $\Delta t = 10 \text{ s}$ in all cases.

SET UP: v_x is negative if the motion is to the right.

EXECUTE: (a) $((5.0 \text{ m/s}) - (15.0 \text{ m/s})) / (10 \text{ s}) = -1.0 \text{ m/s}^2$

(b) $((-15.0 \text{ m/s}) - (-5.0 \text{ m/s})) / (10 \text{ s}) = -1.0 \text{ m/s}^2$

(c) $((-15.0 \text{ m/s}) - (+15.0 \text{ m/s})) / (10 \text{ s}) = -3.0 \text{ m/s}^2$

EVALUATE: In all cases, the negative acceleration indicates an acceleration to the left.

2.22. IDENTIFY: Apply the constant acceleration kinematic equations.

SET UP: Let $+x$ be in the direction of the motion of the plane. $173 \text{ mi/h} = 77.33 \text{ m/s}$. $307 \text{ ft} = 93.57 \text{ m}$.

EXECUTE: (a) $v_{0x} = 0$, $v_x = 77.33 \text{ m/s}$ and $x - x_0 = 93.57 \text{ m}$. $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ gives

$$a_x = \frac{v_x^2 - v_{0x}^2}{2(x - x_0)} = \frac{(77.33 \text{ m/s})^2 - 0}{2(93.57 \text{ m})} = 32.0 \text{ m/s}^2.$$

$$(b) \quad x - x_0 = \left(\frac{v_{0x} + v_x}{2} \right) t \text{ gives } t = \frac{2(x - x_0)}{v_{0x} + v_x} = \frac{2(93.57 \text{ m})}{0 + 77.33 \text{ m/s}} = 2.42 \text{ s}$$

EVALUATE: Either $v_x = v_{0x} + a_x t$ or $x - x_0 = v_{0x} t + \frac{1}{2} a_x t^2$ could also be used to find t and would give the same result as in part (b).

2.23. IDENTIFY: For constant acceleration, Eqs. (2.8), (2.12), (2.13) and (2.14) apply.

SET UP: Assume the ball starts from rest and moves in the $+x$ -direction.

EXECUTE: (a) $x - x_0 = 1.50 \text{ m}$, $v_x = 45.0 \text{ m/s}$ and $v_{0x} = 0$. $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ gives

$$a_x = \frac{v_x^2 - v_{0x}^2}{2(x - x_0)} = \frac{(45.0 \text{ m/s})^2}{2(1.50 \text{ m})} = 675 \text{ m/s}^2.$$

$$(b) \quad x - x_0 = \left(\frac{v_{0x} + v_x}{2} \right) t \text{ gives } t = \frac{2(x - x_0)}{v_{0x} + v_x} = \frac{2(1.50 \text{ m})}{45.0 \text{ m/s}} = 0.0667 \text{ s}$$

EVALUATE: We could also use $v_x = v_{0x} + a_x t$ to find $t = \frac{v_x}{a_x} = \frac{45.0 \text{ m/s}}{675 \text{ m/s}^2} = 0.0667 \text{ s}$ which agrees with our previous result. The acceleration of the ball is very large.

2.37. IDENTIFY: For constant acceleration, Eqs. (2.8), (2.12), (2.13) and (2.14) apply.

SET UP: Take $+y$ to be downward, so the motion is in the $+y$ direction. $19,300 \text{ km/h} = 5361 \text{ m/s}$, $1600 \text{ km/h} = 444.4 \text{ m/s}$, and $321 \text{ km/h} = 89.2 \text{ m/s}$. $4.0 \text{ min} = 240 \text{ s}$.

EXECUTE: (a) Stage A: $t = 240 \text{ s}$, $v_{0y} = 5361 \text{ m/s}$, $v_y = 444.4 \text{ m/s}$. $v_y = v_{0y} + a_y t$ gives

$$a_y = \frac{v_y - v_{0y}}{t} = \frac{444.4 \text{ m/s} - 5361 \text{ m/s}}{240 \text{ s}} = -20.5 \text{ m/s}^2.$$

Stage B: $t = 94 \text{ s}$, $v_{0y} = 444.4 \text{ m/s}$, $v_y = 89.2 \text{ m/s}$. $v_y = v_{0y} + a_y t$ gives

$$a_y = \frac{v_y - v_{0y}}{t} = \frac{89.2 \text{ m/s} - 444.4 \text{ m/s}}{94 \text{ s}} = -3.8 \text{ m/s}^2.$$

Stage C: $y - y_0 = 75 \text{ m}$, $v_{0y} = 89.2 \text{ m/s}$, $v_y = 0$. $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ gives

$$a_y = \frac{v_y^2 - v_{0y}^2}{2(y - y_0)} = \frac{0 - (89.2 \text{ m/s})^2}{2(75 \text{ m})} = -53.0 \text{ m/s}^2. \text{ In each case the negative sign means that the acceleration is upward.}$$

$$(b) \text{ Stage A: } y - y_0 = \left(\frac{v_{0y} + v_y}{2} \right) t = \left(\frac{5361 \text{ m/s} + 444.4 \text{ m/s}}{2} \right) (240 \text{ s}) = 697 \text{ km}.$$

$$\text{Stage B: } y - y_0 = \left(\frac{444.4 \text{ m/s} + 89.2 \text{ m/s}}{2} \right) (94 \text{ s}) = 25 \text{ km}.$$

Stage C: The problem states that $y - y_0 = 75 \text{ m} = 0.075 \text{ km}$.

The total distance traveled during all three stages is $697 \text{ km} + 25 \text{ km} + 0.075 \text{ km} = 722 \text{ km}$.

EVALUATE: The upward acceleration produced by friction in stage A is calculated to be greater than the upward acceleration due to the parachute in stage B. The effects of air resistance increase with increasing speed and in reality the acceleration was probably not constant during stages A and B.

2.40. IDENTIFY: Apply constant acceleration equations to the motion of the lander.

SET UP: Let $+y$ be positive. Since the lander is in free-fall, $a_y = +1.6 \text{ m/s}^2$.

EXECUTE: $v_{0y} = 0.8 \text{ m/s}$, $y - y_0 = 5.0 \text{ m}$, $a_y = +1.6 \text{ m/s}^2$ in $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ gives

$$v_y = \sqrt{v_{0y}^2 + 2a_y(y - y_0)} = \sqrt{(0.8 \text{ m/s})^2 + 2(1.6 \text{ m/s}^2)(5.0 \text{ m})} = 4.1 \text{ m/s}.$$

EVALUATE: The same descent on earth would result in a final speed of 9.9 m/s , since the acceleration due to gravity on earth is much larger than on the moon.

2.44. IDENTIFY: Apply constant acceleration equations to the vertical motion of the sandbag.

SET UP: Take $+y$ upward. $a_y = -9.80 \text{ m/s}^2$. The initial velocity of the sandbag equals the velocity of the balloon, so $v_{0y} = +5.00 \text{ m/s}$. When the balloon reaches the ground, $y - y_0 = -40.0 \text{ m}$. At its maximum height the sandbag has $v_y = 0$.

EXECUTE: (a) $t = 0.250 \text{ s}$: $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2 = (5.00 \text{ m/s})(0.250 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(0.250 \text{ s})^2 = 0.94 \text{ m}$. The sandbag is 40.9 m above the ground. $v_y = v_{0y} + a_y t = +5.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(0.250 \text{ s}) = 2.55 \text{ m/s}$.

$t = 1.00 \text{ s}$: $y - y_0 = (5.00 \text{ m/s})(1.00 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(1.00 \text{ s})^2 = 0.10 \text{ m}$. The sandbag is 40.1 m above the ground. $v_y = v_{0y} + a_y t = +5.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(1.00 \text{ s}) = -4.80 \text{ m/s}$.

(b) $y - y_0 = -40.0 \text{ m}$, $v_{0y} = 5.00 \text{ m/s}$, $a_y = -9.80 \text{ m/s}^2$. $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2$ gives $-40.0 \text{ m} = (5.00 \text{ m/s})t - (4.90 \text{ m/s}^2)t^2$. $(4.90 \text{ m/s}^2)t^2 - (5.00 \text{ m/s})t - 40.0 \text{ m} = 0$ and

$$t = \frac{1}{9.80} \left(5.00 \pm \sqrt{(-5.00)^2 - 4(4.90)(-40.0)} \right) \text{ s} = (0.51 \pm 2.90) \text{ s}. \text{ } t \text{ must be positive, so } t = 3.41 \text{ s}.$$

(c) $v_y = v_{0y} + a_y t = +5.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(3.41 \text{ s}) = -28.4 \text{ m/s}$

(d) $v_{0y} = 5.00 \text{ m/s}$, $a_y = -9.80 \text{ m/s}^2$, $v_y = 0$. $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ gives

$$y - y_0 = \frac{v_y^2 - v_{0y}^2}{2a_y} = \frac{0 - (5.00 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 1.28 \text{ m}. \text{ The maximum height is } 41.3 \text{ m above the ground}.$$

(e) The graphs of a_y , v_y , and y versus t are given in Fig. 2.44. Take $y = 0$ at the ground.

EVALUATE: The sandbag initially travels upward with decreasing velocity and then moves downward with increasing speed.

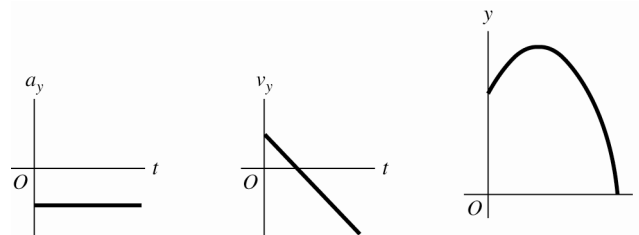


Figure 2.44

2.45. IDENTIFY: The balloon has constant acceleration $a_y = g$, downward.

(a) **SET UP:** Take the $+y$ direction to be upward.

$$t = 2.00 \text{ s}, \quad v_{0y} = -6.00 \text{ m/s}, \quad a_y = -9.80 \text{ m/s}^2, \quad v_y = ?$$

EXECUTE: $v_y = v_{0y} + a_y t = -6.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(2.00 \text{ s}) = -25.5 \text{ m/s}$

(b) **SET UP:** $y - y_0 = ?$

EXECUTE: $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2 = (-6.00 \text{ m/s})(2.00 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(2.00 \text{ s})^2 = -31.6 \text{ m}$

(c) **SET UP:** $y - y_0 = -10.0 \text{ m}$, $v_{0y} = -6.00 \text{ m/s}$, $a_y = -9.80 \text{ m/s}^2$, $v_y = ?$

$$v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$$

EXECUTE: $v_y = -\sqrt{v_{0y}^2 + 2a_y(y - y_0)} = -\sqrt{(-6.00 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(-10.0 \text{ m})} = -15.2 \text{ m/s}$

(d) The graphs are sketched in Figure 2.45.

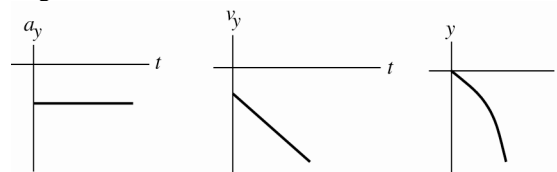


Figure 2.45

EVALUATE: The speed of the balloon increases steadily since the acceleration and velocity are in the same direction. $|v_y| = 25.5 \text{ m/s}$ when $|y - y_0| = 31.6 \text{ m}$, so $|v_y|$ is less than this (15.2 m/s) when $|y - y_0|$ is less (10.0 m).

2.49. IDENTIFY: We can avoid solving for the common height by considering the relation between height, time of fall and acceleration due to gravity and setting up a ratio involving time of fall and acceleration due to gravity.

SET UP: Let g_{En} be the acceleration due to gravity on Enceladus and let g be this quantity on earth. Let h be the common height from which the object is dropped. Let $+y$ be downward, so $y - y_0 = h$. $v_{0y} = 0$

EXECUTE: $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2$ gives $h = \frac{1}{2}gt_E^2$ and $h = \frac{1}{2}g_{En}t_{En}^2$. Combining these two equations gives

$$gt_E^2 = g_{En}t_{En}^2 \text{ and } g_{En} = g \left(\frac{t_E}{t_{En}} \right)^2 = (9.80 \text{ m/s}^2) \left(\frac{1.75 \text{ s}}{18.6 \text{ s}} \right)^2 = 0.0868 \text{ m/s}^2.$$

EVALUATE: The acceleration due to gravity is inversely proportional to the square of the time of fall.

2.52. IDENTIFY: $a(t)$ is the slope of the v versus t graph and the distance traveled is the area under the v versus t graph.

SET UP: The v versus t graph can be approximated by the graph sketched in Figure 2.52.

EXECUTE: (a) Slope = $a = 0$ for $t \geq 1.3 \text{ ms}$.

(b)

$$h_{\max} = \text{Area under } v\text{-}t \text{ graph} \approx A_{\text{Triangle}} + A_{\text{Rectangle}} \approx \frac{1}{2}(1.3 \text{ ms})(133 \text{ cm/s}) + (2.5 \text{ ms} - 1.3 \text{ ms})(133 \text{ cm/s}) \approx 0.25 \text{ cm}$$

(c) $a = \text{slope of } v\text{-}t \text{ graph. } a(0.5 \text{ ms}) \approx a(1.0 \text{ ms}) \approx \frac{133 \text{ cm/s}}{1.3 \text{ ms}} = 1.0 \times 10^5 \text{ cm/s}^2.$

$a(1.5 \text{ ms}) = 0$ because the slope is zero.

(d) $h = \text{area under } v\text{-}t \text{ graph. } h(0.5 \text{ ms}) \approx A_{\text{Triangle}} = \frac{1}{2}(0.5 \text{ ms})(33 \text{ cm/s}) = 8.3 \times 10^{-3} \text{ cm}.$

$$h(1.0 \text{ ms}) \approx A_{\text{Triangle}} = \frac{1}{2}(1.0 \text{ ms})(100 \text{ cm/s}) = 5.0 \times 10^{-2} \text{ cm}.$$

$$h(1.5 \text{ ms}) \approx A_{\text{Triangle}} + A_{\text{Rectangle}} = \frac{1}{2}(1.3 \text{ ms})(133 \text{ cm/s}) + (0.2 \text{ ms})(133) = 0.11 \text{ cm}$$

EVALUATE: The acceleration is constant until $t = 1.3 \text{ ms}$, and then it is zero. $g = 980 \text{ cm/s}^2$. The acceleration during the first 1.3 ms is much larger than this and gravity can be neglected for the portion of the jump that we are considering.

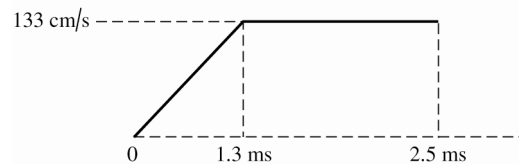


Figure 2.52