Section 1.6: Acceleration Near Earth's Surface

Tutorial 1 Practice, page 41

1. Given: $\vec{v}_i = 0$ m/s; $\Delta t = 2.6$ s;
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: $\Delta\vec{d}$

Analysis: $\Delta\vec{d} = \vec{v}_i\,\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

Solution:

$$\Delta\vec{d} = \vec{v}_i\,\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$
$$= \left(0\ \frac{\text{m}}{\cancel{\text{s}}}\right)(2.6\ \cancel{\text{s}}) + \frac{1}{2}\left(9.8\ \frac{\text{m}}{\cancel{\text{s}^2}}\ [\text{down}]\right)(2.6\ \cancel{\text{s}})^2$$
$$\Delta\vec{d} = 33\ \text{m [down]}$$

Statement: The displacement of the ball is 33 m [down], so the building is 33 m tall.

2. (a) Given: $\vec{v}_i = 0$ m/s; $\Delta\vec{d} = 52$ m [down];
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δt

Analysis:
$$\Delta\vec{d} = \vec{v}_i\,\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$
$$= (0\ \text{m/s})\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$
$$(\Delta t)^2 = \frac{2\Delta\vec{d}}{\vec{a}}$$
$$\Delta t = \sqrt{\frac{2\Delta\vec{d}}{\vec{a}}}$$

Solution:
$$\Delta t = \sqrt{\frac{2\Delta\vec{d}}{\vec{a}}}$$
$$= \sqrt{\frac{2(52\ \cancel{\text{m}})}{\left(9.8\ \frac{\cancel{\text{m}}}{\text{s}^2}\right)}}$$
$$\Delta t = 3.3\ \text{s}$$

Statement: The penny takes 3.3 s to fall 52 m.

(b) Given: $\vec{v}_i = 0$ m/s; $\Delta\vec{d} = 52$ m [down];
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: $\vec{v}_f$

Analysis:
$$v_f^{\,2} = v_i^{\,2} + 2a\Delta d$$
$$v_f = \sqrt{v_i^{\,2} + 2a\Delta d}$$

Solution:
$$v_f = \sqrt{v_i^{\,2} + 2a\Delta d}$$
$$= \sqrt{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(52\ \text{m})}$$
$$v_f = 32\ \text{m/s}$$

Statement: The final velocity of the penny is 32 m/s.

Tutorial 2 Practice, page 42

1. (a) Given: $\vec{v}_i = 8.3$ m/s [up]; $\vec{v}_f = 0.0$ m/s;
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δd

Analysis:
$$v_f^{\,2} = v_i^{\,2} + 2a\Delta d$$
$$\Delta d = \frac{v_f^{\,2} - v_i^{\,2}}{2a}$$

Solution:
$$\Delta d = \frac{v_f^{\,2} - v_i^{\,2}}{2a}$$
$$= \frac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(8.3\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-9.8\ \frac{\text{m}}{\text{s}^2}\right)}$$
$$= \frac{-68.89\ \frac{\text{m}^{\cancel{2}}}{\cancel{\text{s}^2}}}{-19.6\ \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}}$$
$$\Delta d = 3.5\ \text{m}$$

Statement: The ball will reach a maximum height of 3.5 m.

(b) Given: $\vec{v}_i = 8.3$ m/s [up]; $\vec{v}_f = 0.0$ m/s;
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δt

Analysis:
$$a = \frac{v_f - v_i}{\Delta t}$$
$$\Delta t = \frac{v_f - v_i}{a}$$

Solution:
$$\Delta t = \frac{v_f - v_i}{a}$$
$$= \frac{0\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}} - 8.3\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}{\left(-9.8\ \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\right)}$$
$$\Delta t = 0.85\ \text{s}$$

Statement: It will take the ball 0.85 s to reach its maximum height.

(c) Given: $\vec{v}_i = 0.0$ m/s; $\Delta\vec{d} = 3.5$ m [down]; $\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δt

Analysis:
$$\Delta d = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$$
$$= (0 \text{ m/s})\Delta t + \frac{1}{2}a(\Delta t)^2$$
$$(\Delta t)^2 = \frac{2\Delta d}{a}$$
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$

Solution:
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2(3.5 \cancel{\text{m}})}{\left(9.8 \frac{\cancel{\text{m}}}{\text{s}^2}\right)}}$$
$$\Delta t = 0.85 \text{ s}$$

Statement: It will take the ball 0.85 s to reach its initial height from its maximum height.

2. Given: $\vec{v}_i = 3.0$ m/s [down]; $\Delta\vec{d} = 12$ m [down]; $\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: $\vec{v}_f$

Analysis:
$$v_f^2 = v_i^2 + 2a\Delta d$$
$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$

Solution:
$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$
$$= \sqrt{\left(3.0 \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.8 \frac{\text{m}}{\text{s}^2}\right)(12 \text{ m})}$$
$$v_f = 16 \text{ m/s}$$

Statement: The velocity of the rock when it hits the water is 16 m/s [down].

Section 1.6 Questions, page 43

1. An object that is dropped close to Earth's surface will accelerate toward Earth at 9.8 m/s^2.

2. Answers may vary. Sample answer:
When a basketball player appears to "hang" in mid-air, he is being affected by gravity. Due to gravity, his vertical speed is slowing down from the moment he jumps until he reaches the maximum height of the jump. So, there is a point when the player appears to "hang" in mid-air because he is moving up so slowly, then not moving up, then slowly starting to move down again.

3. (a) The only acceleration the ball experiences is due to gravity: 9.8 m/s^2 [down].
(b) The only acceleration the ball experiences is due to gravity: 9.8 m/s^2 [down].
(c) The only acceleration the ball experiences is due to gravity: 9.8 m/s^2 [down].

4. (a) Given: $\vec{v}_i = 0.0$ m/s; $\Delta\vec{d} = 1.5$ m [down]; $\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δt

Analysis:
$$\Delta d = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$$
$$= (0 \text{ m/s})\Delta t + \frac{1}{2}a(\Delta t)^2$$
$$(\Delta t)^2 = \frac{2\Delta d}{a}$$
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$

Solution:
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2(1.5 \cancel{\text{m}})}{\left(9.8 \frac{\cancel{\text{m}}}{\text{s}^2}\right)}}$$
$$\Delta t = 0.55 \text{ s}$$

Statement: It will take the ball 0.55 s to hit the ground.

(b) Given: $\vec{v}_i = 0.0$ m/s; $\Delta\vec{d} = 0.75$ m [down]; $\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: $\vec{v}_f$

Analysis:
$$v_f^2 = v_i^2 + 2a\Delta d$$
$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$

Solution:
$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$
$$= \sqrt{\left(0.0 \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.8 \frac{\text{m}}{\text{s}^2}\right)(0.75 \text{ m})}$$
$$v_f = 3.8 \text{ m/s}$$

Statement: The velocity of the ball when it is halfway to the ground is 3.8 m/s [down].

5. (a) Given: $\vec{v}_i$ = 80.0 m/s [up]; $\vec{v}_f$ = 0.0 m/s;
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δd

Analysis: $v_f^2 = v_i^2 + 2a\Delta d$

$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$

Solution:

$$\begin{aligned}\Delta d &= \frac{v_f^2 - v_i^2}{2a} \\ &= \frac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(80.0\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-9.8\ \frac{\text{m}}{\text{s}^2}\right)} \\ &= \frac{-6400\ \frac{\text{m}^{\cancel{2}}}{\cancel{\text{s}^2}}}{-19.6\ \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}} \\ &= 326.5\ \text{m} \\ &= 330\ \text{m}\end{aligned}$$

$\Delta d = 3.3 \times 10^2$ m

Statement: The arrow will reach a maximum height of 3.3×10^2 m or 330 m.

(b) Given: $\vec{v}_i$ = 80.0 m/s [up]; $\vec{v}_f$ = 0.0 m/s;
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δt

Analysis: $a = \dfrac{v_f - v_i}{\Delta t}$

$$\Delta t = \frac{v_f - v_i}{a}$$

Solution: $\Delta t = \dfrac{v_f - v_i}{a}$

$$= \frac{0\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}} - 80.0\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}{\left(-9.8\ \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\right)}$$

$\Delta t = 8.2$ s

Statement: It will take the arrow 8.2 s to reach its maximum height.

(c) Determine the time it will take the arrow to fall from its maximum height and add that amount to 8.2 s.

Given: $\vec{v}_i$ = 0.0 m/s; $\Delta\vec{d} = 3.3 \times 10^2$ m [down];
$\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: Δt

Analysis: $\Delta d = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$

$$\begin{aligned}&= (0\ \text{m/s})\Delta t + \frac{1}{2}a(\Delta t)^2 \\ (\Delta t)^2 &= \frac{2\Delta d}{a} \\ \Delta t &= \sqrt{\frac{2\Delta d}{a}}\end{aligned}$$

Solution:

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(326.5\ \cancel{\text{m}})}{\left(9.8\ \frac{\cancel{\text{m}}}{\text{s}^2}\right)}}\ \text{(two extra digits carried)}\end{aligned}$$

$\Delta t = 8.2$ s

Statement: The total amount of time that the arrow is in the air is double 8.2 s or 16 s.

6. Given: $\vec{v}_i$ = 3.61 m/s [down];
$\Delta\vec{d}$ = 28.4 m [down]; $\vec{a} = \vec{g} = 9.8$ m/s^2 [down]

Required: $\vec{v}_f$

Analysis: $v_f^2 = v_i^2 + 2a\Delta d$

$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$

Solution:

$$\begin{aligned}v_f &= \sqrt{v_i^2 + 2a\Delta d} \\ &= \sqrt{\left(3.61\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(28.4\ \text{m})}\end{aligned}$$

$v_f = 24$ m/s

Statement: The velocity of the rock when it hits the ground is 24 m/s [down].

7. Answers may vary. Sample answer:
The object begins moving at a velocity of 30.0 m/s [up]. It accelerates down due to gravity. After 3 s, the object reaches its maximum height, then it falls for 4 s. An example would be a ball kicked up from a bridge or building because it falls down farther than it travels up.

8. Answers may vary. Sample answer:
A situation where an object experiences acceleration greater than gravity is when a space shuttle takes off. The space shuttle will accelerate upward at around 20 m/s^2, much faster than gravity, in order to get off the planet.

