

Answer Key

Chapter 6

1. A busy waitress slides a plate of apple pie along a counter to a hungry customer sitting near the end of the counter. The customer is not paying attention, and the plate slides off the counter horizontally at 0.84 m/s. The counter is 1.38 m high.

- a. How long does it take the plate to fall to the floor?

y-direction:

$$v_{yi} = 0, y_i = 0.84 \text{ m}$$

$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2$$

$$0 = y_i + 0 - \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2y_i}{g}} = \sqrt{\frac{2(1.38 \text{ m})}{9.80 \text{ m/s}^2}}$$

$$= 0.53 \text{ s}$$

- b. How far from the base of the counter does the plate hit the floor?

x-direction:

$$v_{xi} = 0.84 \text{ m/s}, x_i = 0.0 \text{ m}$$

$$x_f = x_i + v_{xi}t$$

$$= 0.0 + (0.84 \text{ m/s})(0.53 \text{ s})$$

$$= 0.45 \text{ m}$$

- c. What are the horizontal and vertical components of the plate's velocity just before it hits the floor?

horizontal:

$$v_{xf} = v_{xi} = 0.84 \text{ m/s}$$

vertical:

$$v_{yf} = v_{yi} - gt$$

$$= 0 - (9.80 \text{ m/s}^2)(0.53 \text{ s})$$

$$= -5.2 \text{ m/s}$$

2. DuWayne is on his way out to go grocery shopping when he realizes that he has left his wallet at home, so he calls his wife, Yolanda, who opens a high window and throws DuWayne's wallet down at an angle 23° below the horizontal. Yolanda throws

the wallet at a speed of 4.2 m/s, and the wallet leaves her hand at a height 2.0 m above the ground. How far from the base of the house does the wallet reach the ground?

y-direction:

$$v_{yi} = v_i \sin \theta_i = (4.2 \text{ m/s}) \sin (-23.0^\circ) = -1.6 \text{ m/s}$$

$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2$$

$$0.0 \text{ m} = 2.0 \text{ m} + (-1.6 \text{ m/s})t - \frac{1}{2}(9.80 \text{ m/s}^2)t^2$$

This is a quadratic equation in the form $ax^2 + bx + c = 0$, with

$$a = \frac{1}{2}(9.80 \text{ m/s}^2) = -4.9, b = -1.6, \text{ and } c = 2.0.$$

$$t = \frac{-(-1.6) \pm \sqrt{(-1.6)^2 - 4(-4.9)(2.0)}}{2(-4.9)}$$

The positive solution is $t = 0.50 \text{ s}$

x-direction:

$$v_{xi} = v_i \cos \theta_i$$

$$x_f = x_i + v_{xi}t = x_i + v_i \cos \theta_i t$$

$$= 0.0 \text{ m} + (4.2 \text{ m/s}) \cos(-23.0^\circ)(0.50 \text{ s})$$

$$= 1.9 \text{ m}$$

3. A skateboarder is slowing down at a rate of 0.70 m/s^2 . At the moment he is moving forward at 1.5 m/s, he throws a basketball upward so that it reaches a height of 3.0 m, and then he catches it at the same level it was thrown without changing his position on the skateboard. Determine the vertical and horizontal components of the ball's velocity relative to the skateboard when the ball left his hand.

y-direction:

$$v_{yf}^2 = v_{yi}^2 - 2g(y_f - y_i)$$

$$y_i = 0, \text{ and, at the highest position, } v_{yf} = 0$$

$$0 = v_{yi}^2 - 2gy_f$$

$$v_{yi} = \sqrt{2gy_f} = \sqrt{2(9.80 \text{ m/s}^2)(3.0 \text{ m})} = 7.7 \text{ m/s}$$

Answer Key

Chapter 6 continued

To find the time the ball is in the air:

$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2$$

Falling from the highest point, $v_{yi} = 0$,
 $y_f = 0$, and $y_i = 3.0$ m

$$0 = y_i + 0 - \frac{1}{2}gt_{\text{down}}^2$$

$$t_{\text{down}} = \sqrt{\frac{2y_i}{g}} = \sqrt{\frac{2(3.0 \text{ m})}{9.80 \text{ m/s}^2}}$$

$$= 0.782 \text{ s}$$

$$t = 2t_{\text{down}} = 2(0.782 \text{ s})$$

$$= 1.565 \text{ s}$$

x-direction:

Distance the skateboarder moves:

$$x_s = x_{si} + v_{xsi}t + \frac{1}{2}at^2$$

$$= 0 + (1.5 \text{ m/s})(1.565 \text{ s}) + \frac{1}{2}(-0.70 \text{ m/s}^2)(1.565 \text{ s})^2$$

$$= 1.490 \text{ m}$$

Horizontal distance the ball moves:

$$x_b = x_{bi} + v_{xbi}t$$

$$= 0 + (1.5 \text{ m/s})(1.565 \text{ s})$$

$$= 2.348 \text{ m}$$

$$x_b + \Delta x = x_s$$

Distance skateboard lags behind ball:

$$\Delta x = x_s - x_b = 1.490 \text{ m} - 2.348 \text{ m}$$

$$= -0.848 \text{ m}$$

Horizontal velocity skateboarder must throw ball relative to skateboard:

$$v_{xi} = \frac{\Delta x}{t} = \frac{-0.848 \text{ m}}{1.565 \text{ s}}$$

$$= -0.548 \text{ m/s}$$

$v_{xi} = 0.55$ m/s opposite the direction of motion of the skateboarder

4. A tennis ball is thrown toward a vertical wall with a speed of 21.0 m/s at an angle of 40.0° above the horizontal. The horizontal distance between the wall and the point where the tennis ball is released is 23.0 m.

- a. At what height above the point of release does the tennis ball hit the wall?

x-direction:

$$v_{xi} = v_i \cos \theta_i =$$

$$x_f = x_i + v_{xi}t$$

$$x_f - x_i = v_{xi}t$$

$$t = \frac{x_f - x_i}{v_{xi}} = \frac{x_f - x_i}{v_i \cos \theta_i} = \frac{23.0 \text{ m} - 0.0 \text{ m}}{(21.0 \text{ m/s}) \cos 40.0^\circ}$$

$$t_{\text{wall}} = 1.43 \text{ s}$$

y-direction:

$$v_{yi} = v_i \sin \theta_i$$

$$y_f = y_i + v_{yi}t - \frac{1}{2}gt^2$$

$$y_f - y_i = v_{yi}t - \frac{1}{2}gt^2 = v_i \sin \theta_i(t) - \frac{1}{2}gt^2$$

$$= (21.0 \text{ m/s}) \sin 40.0^\circ(1.43 \text{ s}) -$$

$$\frac{1}{2}(9.80 \text{ m/s}^2)(1.43 \text{ s})^2$$

$$= 9.28 \text{ m}$$

- b. Has the tennis ball already passed the highest point on its trajectory when it hits the wall? Justify your answer.

Method One: Find the time to maximum height.

$$v_{yf} = v_{yi} - gt$$

At maximum height, $v_{yf} = 0$

$$0 = v_{yi} - gt$$

$$t = \frac{v_{yi}}{g} = \frac{v_i \sin \theta_i}{g} = \frac{(21.0 \text{ m/s}) \sin 40.0^\circ}{9.80 \text{ m/s}^2}$$

$$t_{\text{highest}} = 1.38 \text{ s}$$

From part a, $t_{\text{wall}} = 1.43$ s

Since $t_{\text{wall}} > t_{\text{highest}}$, the ball has already passed the highest point when it hits the wall.

Answer Key

Chapter 6 continued

Method Two: Find v_{yf} component just before the ball hits the wall.

$$\begin{aligned} v_{yf, \text{ wall}} &= v_{yi} - gt_{\text{wall}} = v_i \sin \theta_i - gt_{\text{wall}} \\ &= (21.0 \text{ m/s}) \sin 40.0^\circ - \\ &\quad (9.80 \text{ m/s}^2)(1.43 \text{ s}) \\ &= -0.515 \text{ m/s} \end{aligned}$$

Since $v_{yf, \text{ wall}} < 0$, the ball is on its way down and has already passed the highest point.

5. The Moon revolves around Earth in a circular orbit with a radius of 3.84×10^8 m. It takes 27.3 days for the Moon to complete one orbit around Earth. What is the centripetal acceleration of the Moon?

$$a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$\begin{aligned} T &= (27.3 \text{ days}) \left(\frac{24 \text{ h}}{1 \text{ day}} \right) \left(\frac{3600 \text{ s}}{1 \text{ h}} \right) \\ &= 2.3587 \times 10^6 \text{ s} \end{aligned}$$

$$\begin{aligned} a_c &= \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 (3.84 \times 10^8 \text{ m})}{(2.3587 \times 10^6 \text{ s})^2} \\ &= 2.72 \times 10^{-3} \text{ m/s}^2 \end{aligned}$$

6. A clown rides a small car at a speed of 15 km/h along a circular path with a radius of 3.5 m.

- a. What is the magnitude of the centripetal force on a 0.18-kg ball held by the clown?

$$\begin{aligned} v &= \left(\frac{15 \text{ km}}{1 \text{ h}} \right) \left(\frac{1000 \text{ m}}{1 \text{ km}} \right) \left(\frac{1 \text{ h}}{3600 \text{ s}} \right) \\ &= 4.17 \text{ m/s} \end{aligned}$$

$$\begin{aligned} F_c &= ma_c = m \frac{v^2}{r} \\ &= (0.18 \text{ kg}) \frac{(4.17 \text{ m/s})^2}{3.5 \text{ m}} \\ &= 0.89 \text{ N} \end{aligned}$$

- b. At the point where the car is headed due north, the clown throws the ball vertically upward with a speed of 5.0 m/s relative to the moving car. To where must a second clown run to catch the ball the same distance above the ground as it was thrown?

y-direction:

$$v_{yf} = v_{yi} - gt$$

At the highest point, $v_{yf} = 0$

$$t_{\text{highest}} = \frac{v_{yi}}{g}$$

$$t_{\text{total}} = 2t_{\text{highest}} = \frac{2v_{yi}}{g}$$

x-direction:

$$\begin{aligned} R &= v_{xi} t = \frac{v_{xi}^2 v_{yi}}{g} \\ &= \frac{(4.17 \text{ m/s})(2)(5.0 \text{ m/s})}{9.80 \text{ m/s}^2} \end{aligned}$$

= 4.3 m north of the point where the clown threw the ball

7. A 0.45-kg ball is attached to the end of a cord of length 1.4 m. The ball is whirled in a circular path in a horizontal plane. The cord can withstand a maximum tension of 57.0 N before it breaks. What is the maximum speed the ball can have without the cord breaking?

$$F_{\text{net}} = ma_c$$

$$F_T = m \frac{v^2}{r}$$

$$v = \sqrt{\frac{F_T r}{m}}$$

$$\begin{aligned} v_{\text{max}} &= \sqrt{\frac{F_{T, \text{max}} r}{m}} = \sqrt{\frac{(57.0 \text{ N})(1.4 \text{ m})}{(0.45 \text{ kg})}} \\ &= 13 \text{ m/s} \end{aligned}$$

8. The moving sidewalk at an airport has a speed of 0.9 m/s toward the departure gate.

- a. A man is walking toward the departure gate on the moving sidewalk at a speed of 1.0 m/s relative to the sidewalk. What is the velocity of the man relative to a woman who is standing off the moving sidewalk?

$$v_{m/w} = v_{m/s} + v_{s/gr} + v_{gr/w}$$

$$v_{gr/w} = 0.0 \text{ m/s, since the woman is standing still}$$

Answer Key

Chapter 6 continued

$$v_{m/w} = 1.0 \text{ m/s} + 0.9 \text{ m/s} + 0.0 \text{ m/s}$$

$$= 1.9 \text{ m/s toward the departure gate}$$

- b. On a similar moving sidewalk that is going in the opposite direction, a child walks toward the terminal at a speed of 0.4 m/s relative to the sidewalk. What is the velocity of the man relative to the child?

$$v_{m/c} = v_{m/s1} + v_{s1/gr} + v_{gr/s2} + v_{s2/c}$$

$$v_{gr/s2} = v_{s2/gr}$$

$$v_{s2/c} = -v_{c/s2}$$

$$\begin{aligned} v_{m/c} &= v_{m/s1} + v_{s1/gr} - v_{s2/gr} - v_{c/s2} \\ &= 1.0 \text{ m/s} + 0.9 \text{ m/s} - (-0.9 \text{ m/s}) - (-0.4 \text{ m/s}) \\ &= 3.2 \text{ m/s toward the departure gate} \end{aligned}$$

9. On a sightseeing trip in Europe, Soraya is riding in a tour bus moving north along a straight section of road at 8.0 m/s. While Soraya looks out at a forest, she hears some passengers on the other side of the bus say they can see a famous castle from their side. Soraya hurries straight across the bus, going east at 4.0 m/s relative to the bus, so that she also can see the castle. What is Soraya's velocity relative to the castle?

$$v_{S/c} = v_{S/b} + v_{b/c}$$

$$v_{S/c} = v_{S/b} + v_{b/c}$$

$$v_{S/b} = 4.0 \text{ m/s}, v_{b/c} = 8.0 \text{ m/s}, v_{S/c} = ?$$

Because the two velocities are at right angles, use the Pythagorean theorem:

$$v_{S/c}^2 = v_{b/c}^2 + v_{S/b}^2$$

$$v_{S/c} = \sqrt{v_{b/c}^2 + v_{S/b}^2}$$

$$= \sqrt{(8.0 \text{ m/s})^2 + (4.0 \text{ m/s})^2}$$

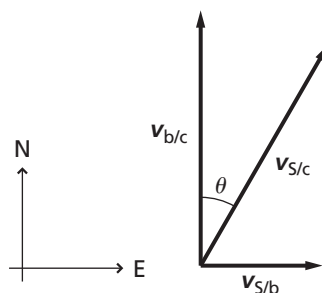
$$= 8.9 \text{ m/s}$$

$$\theta = \tan^{-1}\left(\frac{v_{S/b}}{v_{b/c}}\right)$$

$$= \tan^{-1}\left(\frac{4.0 \text{ m/s}}{8.0 \text{ m/s}}\right)$$

$$= 27^\circ$$

$$v_{S/c} = 8.9 \text{ m/s at } 27^\circ \text{ east of north}$$



Answer Key

Chapter 6 continued

10. A kite is tethered to a stake on a beach. The wind has a constant velocity of 16 km/h at an angle of 15° from the horizontal relative to the beach. Find the components of the kite's velocity relative to the wind.

$$v_{x, w} = v_w \cos \theta$$

$$v_{y, w} = v_w \sin \theta$$

$$v_{k/w} = v_{k/b} + v_{b/w}$$

$$v_{b/w} = -v_{w/b} = -v_w$$

$$v_{k/w} = v_{k/b} - v_w$$

$$\begin{aligned} v_{x, k/w} &= v_{x, k/b} - v_{x, w} = v_{x, k/b} - v_w \cos \theta \\ &= 0.0 \text{ km/h} - (16 \text{ km/h})(\cos 15^\circ) \\ &= -15 \text{ km/h} \end{aligned}$$

$$\begin{aligned} v_{y, k/w} &= v_{y, k/b} - v_{y, w} = v_{y, k/b} - v_w \sin \theta \\ &= 0.0 \text{ km/h} - (16 \text{ km/h})(\sin 15^\circ) = -4.1 \text{ km/h} \end{aligned}$$

11. A marble rolls off the edge of a table that is 0.734 m high. The marble is moving at a speed of 0.122 m/s at the moment that it leaves the edge of the table. How far from the table does the marble land?

$$d_f - d_i = v_i t + \frac{1}{2} a t^2$$

$$v_i = 0 \text{ and } a = -g$$

$$\Delta d = -\frac{1}{2} g t^2$$

$$t = \sqrt{\frac{-2\Delta d}{g}}$$

R is the range which is equal to $v_{xi} t$

$$R = v_{xi}$$

$$= v_{xi} \sqrt{\frac{-2\Delta d}{g}}$$

$$= v_{xi} \sqrt{\frac{-2(d_f - d_i)}{g}}$$

$$= (0.122 \text{ m/s}) \left(\sqrt{\frac{-2(0.0 \text{ m} - 0.734 \text{ m})}{9.80 \text{ m/s}^2}} \right)$$

$$= 0.0472 \text{ m}$$

Answer Key

Chapter 6 continued

12. Frank and Carmen are playing catch with a flying disk when it gets stuck in a tree. The disk is lodged between two branches 8.8 m above the ground. If a rock is thrown straight up to hit the disk, what is the minimum speed with which the disk must be thrown?

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

$$v_f = 0 \text{ and } a = -g$$

$$0 = v_i^2 - 2g\Delta d$$

$$\begin{aligned} v_i &= \sqrt{2g\Delta d} \\ &= \sqrt{2(9.80 \text{ m/s}^2)(8.8 \text{ m})} \\ &= 13 \text{ m/s} \end{aligned}$$

13. A baseball player is playing catch with his friend. When the ball leaves his hand it is moving at 29.1 m/s. He throws the ball at an angle of 30.0° above the horizontal. His friend catches the ball at the same height from which it was thrown. How far is the baseball player from his friend?

$$v_{fy} = v_{iy} + at$$

$$v_{fy} = 0 \text{ m/s and } a = -g$$

$$0 = v_{iy} - gt$$

$$\begin{aligned} t &= \frac{v_{iy}}{g} = \frac{v_i \sin \theta}{g} \\ &= \frac{(29.1 \text{ m/s}) \sin 30.0^\circ}{9.80 \text{ m/s}^2} \\ &= 1.48 \text{ s} \end{aligned}$$

$$t_{\text{total}} = 2t = 2(1.48 \text{ s}) = 2.96 \text{ s}$$

$$\Delta d = v_{xi}\Delta t$$

$$\Delta t = t_{\text{total}}$$

$$\begin{aligned} \Delta d &= (v_i \cos \theta) t_{\text{total}} \\ &= (29.1 \text{ m/s})(\cos 30.0^\circ)(2.96 \text{ s}) \\ &= 74.6 \text{ m} \end{aligned}$$

14. A car moving at 12.67 m/s rounds a bend in the road. The bend is semicircular and has a radius of 60.0 m. What is the centripetal acceleration of the car?

$$\begin{aligned} a_c &= \frac{v^2}{r} \\ &= \frac{(12.67 \text{ m/s})^2}{60.0 \text{ m}} \\ &= 2.68 \text{ m/s}^2 \end{aligned}$$

15. A town has a large clock on the hall in the town square. The clock has hands that show the hours, minutes, and seconds. A fly is sitting on the tip of the hand that shows the seconds. If the length of the hand is 1.20 m, what is the fly's centripetal acceleration?

$$\begin{aligned} a_c &= \frac{4\pi^2 r}{T^2} \\ &= \frac{4\pi^2(1.20 \text{ m})}{(60.0 \text{ s})^2} \\ &= 0.0132 \text{ m/s}^2 \end{aligned}$$

16. A rock is tied to a string and spun in a horizontal circle. The string is 1.8 m long and the rock has an acceleration of 3.4 m/s². What is the tangential velocity of the rock?

$$\begin{aligned} a_c &= \frac{v^2}{r} \\ v &= \sqrt{a_c r} \\ &= \sqrt{(3.4 \text{ m/s}^2)(1.8 \text{ m})} \\ &= 2.5 \text{ m/s} \end{aligned}$$

17. An airplane flies north at 300.0 km/h relative to the air and the wind is blowing south at 15.0 km/h. What is the airplane's velocity relative to the ground?

$$\begin{aligned} v_{p/g} &= v_{p/a} + v_{a/g} \\ &= 300.0 \text{ km/h} + (-15.0 \text{ km/h}) \\ &= 285.0 \text{ km/h northward} \end{aligned}$$