Chapter 4 Solutions

P4.2 (a) $\vec{\mathbf{r}} = \boxed{18.0t\hat{\mathbf{i}} + \left(4.00t - 4.90t^2\right)\hat{\mathbf{j}}}$

(b) $\vec{\mathbf{v}} = \boxed{(18.0 \text{ m/s})\hat{\mathbf{i}} + \left[4.00 \text{ m/s} - \left(9.80 \text{ m/s}^2\right)t\right]\hat{\mathbf{j}}}$

(c) $\vec{\mathbf{a}} = \boxed{\left(-9.80 \text{ m/s}^2\right)\hat{\mathbf{j}}}$

(d) by substitution, $\vec{\mathbf{r}}(3.00 \text{ s}) = \boxed{(54.0 \text{ m})\hat{\mathbf{i}} - (32.1 \text{ m})\hat{\mathbf{j}}}$

(e) $\vec{\mathbf{v}}(3.00 \text{ s}) = \boxed{(18.0 \text{ m/s})\hat{\mathbf{i}} - (25.4 \text{ m/s})\hat{\mathbf{j}}}$

(f) $\vec{\mathbf{a}}(3.00 \text{ s}) = \boxed{\left(-9.80 \text{ m/s}^2\right)\hat{\mathbf{j}}}$

P4.6 (a) $\vec{\mathbf{v}} = \frac{d\vec{\mathbf{r}}}{dt} = \left(\frac{d}{dt}\right)\left(3.00\hat{\mathbf{i}} - 6.00t^2\hat{\mathbf{j}}\right) = \boxed{-12.0t\,\hat{\mathbf{j}} \text{ m/s}}$

$\vec{\mathbf{a}} = \frac{d\vec{\mathbf{v}}}{dt} = \left(\frac{d}{dt}\right)\left(-12.0t\,\hat{\mathbf{j}}\right) = \boxed{-12.0\hat{\mathbf{j}} \text{ m/s}^2}$

(b) by substitution, $\boxed{\vec{\mathbf{r}} = \left(3.00\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}}\right) \text{ m; } \vec{\mathbf{v}} = -12.0\hat{\mathbf{j}} \text{ m/s}}$

P4.8 $\vec{\mathbf{a}} = 3.00\hat{\mathbf{j}} \text{ m/s}^2$; $\vec{\mathbf{v}}_i = 5.00\hat{\mathbf{i}} \text{ m/s}$; $\vec{\mathbf{r}}_i = 0\hat{\mathbf{i}} + 0\hat{\mathbf{j}}$

(a) $\vec{\mathbf{r}}_f = \vec{\mathbf{r}}_i + \vec{\mathbf{v}}_i t + \frac{1}{2}\vec{\mathbf{a}}t^2 = \boxed{\left[5.00t\hat{\mathbf{i}} + \frac{1}{2}3.00t^2\hat{\mathbf{j}}\right] \text{ m}}$

$\vec{\mathbf{v}}_f = \vec{\mathbf{v}}_i + \vec{\mathbf{a}}t = \boxed{\left(5.00\hat{\mathbf{i}} + 3.00t\hat{\mathbf{j}}\right) \text{ m/s}}$

(b) $t = 2.00 \text{ s}$, $\vec{\mathbf{r}}_f = 5.00(2.00)\hat{\mathbf{i}} + \frac{1}{2}(3.00)(2.00)^2\hat{\mathbf{j}} = \left(10.0\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}\right) \text{ m}$

so $x_f = \boxed{10.0 \text{ m}}$, $y_f = \boxed{6.00 \text{ m}}$

$$\vec{\mathbf{v}}_f = 5.00\hat{\mathbf{i}} + 3.00(2.00)\hat{\mathbf{j}} = \left(5.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}\right) \text{ m/s}$$

$$v_f = \left|\vec{\mathbf{v}}_f\right| = \sqrt{v_{xf}^2 + v_{yf}^2} = \sqrt{(5.00)^2 + (6.00)^2} = \boxed{7.81 \text{ m/s}}$$

P4.14 The horizontal component of displacement is $x_f = v_{xi}t = (v_i\cos\theta_i)t$. Therefore, the time required to reach the building a distance d away is $t = \frac{d}{v_i\cos\theta_i}$. At this time, the altitude of the water is

$$y_f = v_{yi}t + \frac{1}{2}a_y t^2 = v_i \sin\theta_i \left(\frac{d}{v_i \cos\theta_i}\right) - \frac{g}{2}\left(\frac{d}{v_i \cos\theta_i}\right)^2$$

Therefore the water strikes the building at a height h above ground level of

$$h = y_f = \boxed{d \tan\theta_i - \frac{gd^2}{2v_i^2 \cos^2\theta_i}}$$

P4.15 (a) $x_f = v_{xi}\, t = 8.00 \cos 20.0° (3.00) = \boxed{22.6 \text{ m}}$

(b) Taking y positive downwards,

$$y_f = v_{yi}t + \frac{1}{2}g t^2$$

$$y_f = 8.00 \sin 20.0° (3.00) + \frac{1}{2}(9.80)(3.00)^2 = \boxed{52.3 \text{ m}}$$

(c) $10.0 = 8.00(\sin 20.0°)t + \frac{1}{2}(9.80)t^2$

$$4.90t^2 + 2.74t - 10.0 = 0$$

$$t = \frac{-2.74 \pm \sqrt{(2.74)^2 + 196}}{9.80} = \boxed{1.18 \text{ s}}$$

P4.19 (a) For the horizontal motion, we have

$$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$$

$$24 \text{ m} = 0 + v_i(\cos 53°)(2.2 \text{ s}) + 0$$

$$v_i = \boxed{18.1 \text{ m/s}}$$

(b) As it passes over the wall, the ball is above the street by $y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$

$$y_f = 0 + (18.1 \text{ m/s})(\sin 53°)(2.2 \text{ s}) + \frac{1}{2}(-9.8 \text{ m/s}^2)(2.2 \text{ s})^2 = 8.13 \text{ m}$$

So it clears the parapet by $8.13 \text{ m} - 7 \text{ m} = \boxed{1.13 \text{ m}}$.

(c) Note that the highest point of the ball's trajectory is not directly above the wall. For the whole flight, we have from the trajectory equation

$$y_f = (\tan\theta_i)x_f - \left(\frac{g}{2v_i^2 \cos^2\theta_i}\right)x_f^2$$

or

$$6 \text{ m} = (\tan 53°)x_f - \left(\frac{9.8 \text{ m/s}^2}{2(18.1 \text{ m/s})^2 \cos^2 53°}\right)x_f^2$$

Solving,

$$\left(0.041\,2 \text{ m}^{-1}\right)x_f^2 - 1.33x_f + 6 \text{ m} = 0$$

and

$$x_f = \frac{1.33 \pm \sqrt{1.33^2 - 4(0.0412)(6)}}{2\left(0.0412 \text{ m}^{-1}\right)}.$$

This yields two results:

$$x_f = 26.8 \text{ m or } 5.44 \text{ m}$$

The ball passes twice through the level of the roof.

It hits the roof at distance from the wall

$$26.8\text{ m} - 24\text{ m} = \boxed{2.79\text{ m}}$$

P4.21 The horizontal kick gives zero vertical velocity to the rock. Then its time of flight follows from

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

$$-40.0\text{ m} = 0 + 0 + \frac{1}{2}\left(-9.80\text{ m/s}^2\right)t^2$$

$$t = 2.86\text{ s}$$

The extra time $3.00\text{ s} - 2.86\text{ s} = 0.143\text{ s}$ is the time required for the sound she hears to travel straight back to the player. It covers distance

$$(343\text{ m/s})0.143\text{ s} = 49.0\text{ m} = \sqrt{x^2 + (40.0\text{ m})^2}$$

where x represents the horizontal distance the rock travels.

$$x = 28.3\text{ m} = v_{xi}t + 0t^2$$

$$\therefore v_{xi} = \frac{28.3\text{ m}}{2.86\text{ s}} = \boxed{9.91\text{ m/s}}$$

P4.24 $a = \frac{v^2}{R}$, $T = 24\text{ h}(3\,600\text{ s/h}) = 86\,400\text{ s}$

$$v = \frac{2\pi R}{T} = \frac{2\pi(6.37\times10^6\text{ m})}{86\,400\text{ s}} = 463\text{ m/s}$$

$$a = \frac{(463\text{ m/s})^2}{6.37\times10^6\text{ m}} = \boxed{0.033\,7\text{ m/s}^2\text{ directed toward the center of Earth}}$$

P4.26 $a_c = \frac{v^2}{r}$

$$v = \sqrt{a_c r} = \sqrt{3\left(9.8\text{ m/s}^2\right)(9.45\text{ m})} = 16.7\text{ m/s}$$

Each revolution carries the astronaut over a distance of $2\pi r = 2\pi(9.45\text{ m}) = 59.4\text{ m}$. Then the rotation rate is

$$16.7\text{ m/s}\left(\frac{1\text{ rev}}{59.4\text{ m}}\right) = \boxed{0.281\text{ rev/s}}$$

P4.30 (a) See figure to the right.

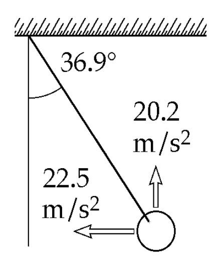

FIG. P4.30

(b) The components of the 20.2 and the 22.5 m/s^2 along the rope together constitute the centripetal acceleration:

$$a_c = \left(22.5\text{ m/s}^2\right)\cos(90.0° - 36.9°) + \left(20.2\text{ m/s}^2\right)\cos 36.9° = \boxed{29.7\text{ m/s}^2}$$

(c) $a_c = \frac{v^2}{r}$ so $v = \sqrt{a_c r} = \sqrt{29.7\text{ m/s}^2(1.50\text{ m})} = 6.67\text{ m/s}$ tangent to circle

$$\vec{\mathbf{v}} = \boxed{6.67\text{ m/s at }36.9°\text{ above the horizontal}}$$

P4.34 (a)

$$\vec{\mathbf{v}}_H = 0 + \vec{\mathbf{a}}_H t = \left(3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}}\right) \text{ m/s}^2 (5.00 \text{ s})$$

$$\vec{\mathbf{v}}_H = \left(15.0\hat{\mathbf{i}} - 10.0\hat{\mathbf{j}}\right) \text{ m/s}$$

$$\vec{\mathbf{v}}_J = 0 + \vec{\mathbf{a}}_j t = \left(1.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}}\right) \text{ m/s}^2 (5.00 \text{ s})$$

$$\vec{\mathbf{v}}_J = \left(5.00\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}}\right) \text{ m/s}$$

$$\vec{\mathbf{v}}_{HJ} = v_H - v_J = \left(15.0\hat{\mathbf{i}} - 10.0\hat{\mathbf{j}} - 5.00\hat{\mathbf{i}} - 15.0\hat{\mathbf{j}}\right) \text{ m/s}$$

$$\vec{\mathbf{v}}_{HJ} = \left(10.0\hat{\mathbf{i}} - 25.0\hat{\mathbf{j}}\right) \text{ m/s}$$

$$\left|\vec{\mathbf{v}}_{HJ}\right| = \sqrt{(10.0)^2 + (25.0)^2} \text{ m/s} = \boxed{26.9 \text{ m/s}}$$

(b)

$$\vec{\mathbf{r}}_H = 0 + 0 + \frac{1}{2}\vec{\mathbf{a}}_H t^2 = \frac{1}{2}\left(3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}}\right) \text{ m/s}^2 (5.00 \text{ s})^2$$

$$\vec{\mathbf{r}}_H = \left(37.5\hat{\mathbf{i}} - 25.0\hat{\mathbf{j}}\right) \text{ m}$$

$$\vec{\mathbf{r}}_J = \frac{1}{2}\left(1.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}}\right) \text{ m/s}^2 (5.00\text{s})^2 = \left(12.5\hat{\mathbf{i}} + 37.5\hat{\mathbf{j}}\right) \text{ m}$$

$$\vec{\mathbf{r}}_{HJ} = \vec{\mathbf{r}}_H - \vec{\mathbf{r}}_J = \left(37.5\hat{\mathbf{i}} - 25.0\hat{\mathbf{j}} - 12.5\hat{\mathbf{i}} - 37.5\hat{\mathbf{j}}\right) \text{ m}$$

$$\vec{\mathbf{r}}_{HJ} = \left(25.0\hat{\mathbf{i}} - 62.5\hat{\mathbf{j}}\right) \text{ m}$$

$$\left|\vec{\mathbf{r}}_{HJ}\right| = \sqrt{(25.0)^2 + (62.5)^2} \text{ m} = \boxed{67.3 \text{ m}}$$

(c)

$$\vec{\mathbf{a}}_{HJ} = \vec{\mathbf{a}}_H - \vec{\mathbf{a}}_J = \left(3.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}} - 1.00\hat{\mathbf{i}} - 3.00\hat{\mathbf{j}}\right) \text{ m/s}^2$$

$$\vec{\mathbf{a}}_{HJ} = \boxed{\left(2.00\hat{\mathbf{i}} - 5.00\hat{\mathbf{j}}\right) \text{ m/s}^2}$$

P4.36 The bumpers are initially $100 \text{ m} = 0.100 \text{ km}$ apart. After time t the bumper of the leading car travels $40.0\, t$, while the bumper of the chasing car travels $60.0t$. Since the cars are side by side at time t, we have

$$0.100 + 40.0t = 60.0t$$

yielding

$$t = 5.00 \times 10^{-3} \text{ h} = \boxed{18.0 \text{ s}}$$

***P4.38** We can find the time of flight of the can by considering its horizontal motion:
16 m = (9.5 m/s) t + 0 $\qquad t$ = 1.68 s

(a) For the boy to catch the can at the same location on the truck bed, he must throw it $\boxed{\text{straight up, at 0° to the vertical}}$.

(b) For the free fall of the can, $y_f = y_i + v_{yi}t + (1/2)a_y t^2$:
$0 = 0 + v_{yi}(1.68 \text{ s}) - (1/2)(9.8 \text{ m/s}^2)(1.68 \text{ s})^2 \qquad v_{yi} = \boxed{8.25 \text{ m/s}}$

(c) The boy sees the can always over his head, traversing $\boxed{\text{a straight line segment upward and then downward}}$.

(d) The ground observer sees the can move as a projectile on a symmetric section of a parabola opening downward. Its initial velocity is $(9.5^2 + 8.25^2)^{1/2}$ m/s = 12.6 m/s north at $\tan^{-1}(8.25/9.5) = 41.0°$ above the horizontal

***P4.40** (a) To an observer at rest in the train car, the bolt accelerates downward and toward the rear of the train.

$$a = \sqrt{(2.50 \text{ m/s})^2 + (9.80 \text{ m/s})^2} = \boxed{10.1 \text{ m/s}^2}$$

$$\tan\theta = \frac{2.50 \text{ m/s}^2}{9.80 \text{ m/s}^2} = 0.255$$

$$\theta = \boxed{14.3° \text{ to the south from the vertical}}$$

To this observer, the bolt moves as if it were in a gravitational field of 9.80 m/s^2 down + 2.50 m/s^2 south.

(b) $a = \boxed{9.80 \text{ m/s}^2 \text{ vertically downward}}$

(c) If it is rest relative to the ceiling at release, the bolt moves on a straight line download and southward at 14.3 degrees from the vertical.

(d) The bolt moves on a parabola with a vertical axis.