Chapter 4

1. The initial position vector $\vec{r}_o$ satisfies $\vec{r} - \vec{r}_o = \Delta\vec{r}$, which results in

$$\vec{r}_o = \vec{r} - \Delta\vec{r} = (3.0\hat{j} - 4.0\hat{k})\text{m} - (2.0\hat{i} - 3.0\hat{j} + 6.0\hat{k})\text{m} = (-2.0\text{ m})\,\hat{i} + (6.0\text{ m})\,\hat{j} + (-10\text{ m})\,\hat{k}.$$

5. Using Eq. 4-3 and Eq. 4-8, we have

$$\vec{v}_{\text{avg}} = \frac{(-2.0\hat{i} + 8.0\hat{j} - 2.0\hat{k})\text{ m} - (5.0\hat{i} - 6.0\hat{j} + 2.0\hat{k})\text{ m}}{10\text{ s}} = (-0.70\hat{i} + 1.40\hat{j} - 0.40\hat{k})\text{ m/s}.$$

13. In parts (b) and (c), we use Eq. 4-10 and Eq. 4-16. For part (d), we find the direction of the velocity computed in part (b), since that represents the asked-for tangent line.

(a) Plugging into the given expression, we obtain

$$\vec{r}\,\Big|_{t=2.00} = [2.00(8) - 5.00(2)]\,\hat{i} + [6.00 - 7.00(16)]\,\hat{j} = (6.00\,\hat{i} - 106\,\hat{j})\text{ m}$$

(b) Taking the derivative of the given expression produces

$$\vec{v}(t) = (6.00t^2 - 5.00)\,\hat{i} - 28.0t^3\,\hat{j}$$

where we have written $v(t)$ to emphasize its dependence on time. This becomes, at $t = 2.00$ s, $\vec{v} = (19.0\,\hat{i} - 224\,\hat{j})$ m/s.

(c) Differentiating the $\vec{v}(t)$ found above, with respect to t produces $12.0t\,\hat{i} - 84.0t^2\,\hat{j}$, which yields $\vec{a} = (24.0\,\hat{i} - 336\,\hat{j})\text{ m/s}^2$ at $t = 2.00$ s.

(d) The angle of $\vec{v}$, measured from $+x$, is either

$$\tan^{-1}\left(\frac{-224\text{ m/s}}{19.0\text{ m/s}}\right) = -85.2° \text{ or } 94.8°$$

where we settle on the first choice (–85.2°, which is equivalent to 275° measured counterclockwise from the +x axis) since the signs of its components imply that it is in the fourth quadrant.

$$\theta = \cos^{-1}\left(\frac{1}{2}\right) = 60°.$$

21. (a) From Eq. 4-22 (with $\theta_0 = 0$), the time of flight is

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(45.0\text{ m})}{9.80\text{ m/s}^2}} = 3.03\text{ s}.$$

(b) The horizontal distance traveled is given by Eq. 4-21:

$$\Delta x = v_0 t = (250\text{ m/s})(3.03\text{ s}) = 758\text{ m}.$$

(c) And from Eq. 4-23, we find

$$|v_y| = gt = (9.80\text{ m/s}^2)(3.03\text{ s}) = 29.7\text{ m/s}.$$

25. We adopt the positive direction choices used in the textbook so that equations such as Eq. 4-22 are directly applicable. The initial velocity is horizontal so that $v_{0y} = 0$ and $v_{0x} = v_0 = 10\text{ m/s}$.

(a) With the origin at the initial point (where the dart leaves the thrower's hand), the y coordinate of the dart is given by $y = -\frac{1}{2}gt^2$, so that with $y = -PQ$ we have $PQ = \frac{1}{2}(9.8\text{ m/s}^2)(0.19\text{ s})^2 = 0.18\text{ m}$.

(b) From $x = v_0 t$ we obtain $x = (10\text{ m/s})(0.19\text{ s}) = 1.9\text{ m}$.

40. We adopt the positive direction choices used in the textbook so that equations such as Eq. 4-22 are directly applicable. The initial velocity is horizontal so that $v_{0y} = 0$ and $v_{0x} = v_0 = 161\text{ km/h}$. Converting to SI units, this is $v_0 = 44.7$ m/s.

(a) With the origin at the initial point (where the ball leaves the pitcher's hand), the y coordinate of the ball is given by $y = -\frac{1}{2}gt^2$, and the x coordinate is given by $x = v_0 t$. From the latter equation, we have a simple proportionality between horizontal distance and time, which means the time to travel half the total distance is half the total time. Specifically, if $x = 18.3/2$ m, then $t = (18.3/2\text{ m})/(44.7\text{ m/s}) = 0.205$ s.

(b) And the time to travel the next 18.3/2 m must also be 0.205 s. It can be useful to write the horizontal equation as $\Delta x = v_0 \Delta t$ in order that this result can be seen more clearly.

(c) From $y = -\frac{1}{2}gt^2$, we see that the ball has reached the height of $|-\frac{1}{2}\left(9.80\text{ m/s}^2\right)\left(0.205\text{ s}\right)^2| = 0.205\text{ m}$ at the moment the ball is halfway to the batter.

(d) The ball's height when it reaches the batter is $-\frac{1}{2}\left(9.80\text{ m/s}^2\right)\left(0.409\text{ s}\right)^2 = -0.820\text{m}$, which, when subtracted from the previous result, implies it has fallen another 0.615 m. Since the value of *y* is not simply proportional to *t*, we do not expect equal time-intervals to correspond to equal height-changes; in a physical sense, this is due to the fact that the initial *y*-velocity for the first half of the motion is not the same as the "initial" *y*-velocity for the second half of the motion.

59. We apply Eq. 4-35 to solve for speed *v* and Eq. 4-34 to find centripetal acceleration *a*.

(a) $v = 2\pi r/T = 2\pi(20\text{ km})/1.0\text{ s} = 126\text{ km/s} = 1.3 \times 10^5\text{ m/s}$.

(b) The magnitude of the acceleration is

$$a = \frac{v^2}{r} = \frac{(126\text{ km/s})^2}{20\text{ km}} = 7.9 \times 10^5\text{ m/s}^2.$$

(c) Clearly, both *v* and *a* will increase if *T* is reduced.

62. (a) The circumference is $c = 2\pi r = 2\pi(0.15\text{ m}) = 0.94\text{ m}$.

(b) With $T = (60\text{ s})/1200 = 0.050\text{ s}$, the speed is $v = c/T = (0.94\text{ m})/(0.050\text{ s}) = 19\text{ m/s}$. This is equivalent to using Eq. 4-35.

(c) The magnitude of the acceleration is $a = v^2/r = (19\text{ m/s})^2/(0.15\text{ m}) = 2.4 \times 10^3\text{ m/s}^2$.

(d) The period of revolution is $(1200\text{ rev/min})^{-1} = 8.3 \times 10^{-4}$ min which becomes, in SI units, $T = 0.050\text{ s} = 50\text{ ms}$.

Chapter 5

2. We apply Newton's second law (Eq. 5-1 or, equivalently, Eq. 5-2). The net force applied on the chopping block is $\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2$, where the vector addition is done using unit-vector notation. The acceleration of the block is given by $\vec{a} = \left(\vec{F}_1 + \vec{F}_2\right) / m$.

(a) In the first case

$$\vec{F}_1 + \vec{F}_2 = \left[(3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right] + \left[(-3.0\,\text{N})\hat{\text{i}} + (-4.0\,\text{N})\hat{\text{j}}\right] = 0$$

so $\vec{a} = 0$.

(b) In the second case, the acceleration $\vec{a}$ equals

$$\frac{\vec{F}_1 + \vec{F}_2}{m} = \frac{\left((3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right) + \left((-3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right)}{2.0\,\text{kg}} = (4.0\,\text{m/s}^2)\hat{\text{j}}.$$

(c) In this final situation, $\vec{a}$ is

$$\frac{\vec{F}_1 + \vec{F}_2}{m} = \frac{\left((3.0\,\text{N})\hat{\text{i}} + (4.0\,\text{N})\hat{\text{j}}\right) + \left((3.0\,\text{N})\hat{\text{i}} + (-4.0\,\text{N})\hat{\text{j}}\right)}{2.0\,\text{kg}} = (3.0\,\text{m/s}^2)\hat{\text{i}}.$$

69. (a) We quote our answers to many figures – probably more than are truly "significant." Here (7682 L)("1.77 kg/L") = 13597 kg. The quotation marks around the 1.77 are due to the fact that this was believed (by the flight crew) to be a legitimate conversion factor (it is not).

(b) The amount they felt should be added was 22300 kg – 13597 kg = 87083 kg, which they believed to be equivalent to (87083 kg)/("1.77 kg/L") = 4917 L.

(c) Rounding to 4 figures as instructed, the conversion factor is 1.77 lb/L $\rightarrow$ 0.8034 kg/L, so the amount on board was (7682 L)(0.8034 kg/L) = 6172 kg.

(d) The implication is that what as needed was 22300 kg – 6172 kg = 16128 kg, so the request should have been for (16128 kg)/(0.8034 kg/L) = 20075 L.

(e) The percentage of the required fuel was

$$\frac{7682\text{ L (on board)} + 4917\text{ L (added)}}{(22300\text{ kg required})/(0.8034\text{ kg/L})} = 45\%.$$