3.2

Taking the positive y-aixs to be due north, the change in velocity for the canvasback is $\Delta\vec{v} = (40\,\mathrm{km/h})$-south $-$ $(50\,\mathrm{km/h})$-south $= (-10\,\mathrm{km/h})$-south $= (10\,\mathrm{km/h})$-north $= (10\,\mathrm{km/h})\,\hat{\mathrm{j}}$. The time interval is $\Delta t = 2\!:\!06\,\mathrm{AM} - 2\!:\!02\,\mathrm{AM} = 4\,\mathrm{min}$. Thus the acceleration is given by

$$\bar{a}_{av} = \frac{\Delta\vec{v}}{\Delta t} = \frac{(10\,\mathrm{km/h})\,\hat{\mathrm{j}}}{4\,\mathrm{min}} = \frac{\left[(10\,\mathrm{km/h})(10^3\,\mathrm{m/km})(1\,\mathrm{h}/3600\,\mathrm{s})\right]\hat{\mathrm{j}}}{(4\,\mathrm{min})(60\,\mathrm{s/min})}$$
$$= (0.01\,\mathrm{m/s^2})\,\hat{\mathrm{j}} = (0.01\,\mathrm{m/s^2})\text{-north}.$$

3.5

According to the problem statement the initial speed is $v_i = 1.0\,\mathrm{m/s}$, the final speed is $v_f = 15.0\,\mathrm{m/s}$, and the time interval is given by $\Delta t = 1\,\mathrm{min}\,2\,\mathrm{s} = 60\,\mathrm{s} + 2\,\mathrm{s} = 62\,\mathrm{s}$. Thus from Eq. (3.2) the acceleration is found to be

$$a_{av} = \frac{v_f - v_i}{\Delta t} = \frac{15.0\,\mathrm{m/s} - 1.0\,\mathrm{m/s}}{62\,\mathrm{s}} = 0.23\,\mathrm{m/s^2}.$$

3.15

The change in speed for the train is given by $\Delta v = 0 - 60\,\mathrm{km/h} = -60\,\mathrm{km/h}$, while the time interval is $\Delta t = (1/1000)\,\mathrm{s}$. Thus the deceleration of the train is

$$a = \frac{\Delta v}{\Delta t} = \frac{(-60\,\mathrm{km/h})(1\,\mathrm{h}/3600\,\mathrm{s})}{(1/1000)\,\mathrm{s}} = -17\,\mathrm{km/s^2},$$

where the minus sign indicates that the speed of the train is decreasing.

3.18

From 0 to 0.5 s the velocity of the car remains at $-2.0\,\mathrm{m/s}$ so $\Delta v = 0$, thus $a_{av} = 0$.

From 1.5 s to 2.0 s the velocity of the car remains at zero, so again $a_{av} = 0$.

From 2.0 s to 2.5 s the velocity of the car changes from 0 to 4.0 m/s, so

$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{4.0\,\mathrm{m/s} - 0}{2.5\,\mathrm{s} - 2.0\,\mathrm{s}} = 8.0\,\mathrm{m/s^2}.$$

Since its velocity vs time curve is a straight line for the segment between 2.0 s and 2.5 s, the acceleration of the car for that time duration is a constant. So the instantaneous acceleration at $t = 2.25\,\mathrm{s}$ is the same as the average value for the time interval, which we obtained above to be $8.0\,\mathrm{m/s^2}$.

3.19

In the vicinity of $t = 3.0\,\mathrm{s}$ the velocity of the car is a constant: $v = 40\,\mathrm{m/s}$. Thus the instantaneous acceleration is zero. At $t = 3.7\,\mathrm{s}$ the positive velocity of the car is decreasing, as suggested by the negative slope of the velocity-time curve. So the instantaneous acceleration at that time is negative. Similarly, the acceleration at $t = 1.1\,\mathrm{s}$ is positive, since the slope of the curve is positive at that point. Also, since v remain a constant ($= -20\,\mathrm{m/s}$) between $t = 0$ and $t = 0.50\,\mathrm{s}$, $a = 0$ at $t = 0.25\,\mathrm{s}$.

3.27

The speed of the vehicle as a function of time is the rate at which its path length changes:

$$v(t) = \frac{dl}{dt} = \frac{d}{dt}\left[(10.0\,\mathrm{m/s})t + (5.0\,\mathrm{m/s^2})t^2\right] = 10.0\,\mathrm{m/s} + (5.0\,\mathrm{m/s^2})(2t)\,.$$

The tangential acceleration is then obtained by taking the time derivative of v:

$$a_t = \frac{dv}{dt} = \frac{d}{dt}\left[10.0\,\mathrm{m/s} + (5.0\,\mathrm{m/s^2})(2t)\right] = 10.0\,\mathrm{m/s^2}\,.$$

3.63

The *constant*-$\vec{a}$ equation which relates v_0, v, a and s in a one-dimensional motion is Eq. (3.10): $v^2 = v_0^2 + 2as$. Here $v_0 = 1.5\,\mathrm{m/s}$, $a = 1.0\,\mathrm{m/s^2}$, and $s = 10\,\mathrm{m}$. Thus

$$v = \sqrt{v_0^2 + 2as} = \sqrt{(1.5\,\mathrm{m/s})^2 + 2(1.0\,\mathrm{m/s^2})(10\,\mathrm{m})} = 4.7\,\mathrm{m/s}\,.$$

3.68

The initial speed of the supertanker before it starts to decelerate is $v_0 = 30\,\mathrm{km/h}$. After decelerating for $t = 20\,\mathrm{min}$, its final speed is $v = 0$. From $v = v_0 + at$ [Eq. (3.6)] we may solve for a:

$$a = \frac{v - v_0}{t} = \frac{0 - (30\,\mathrm{km/h})(10^3\,\mathrm{m/km})(1\,\mathrm{h}/3600\,\mathrm{s})}{(20\,\mathrm{min})(60\,\mathrm{s/min})} = -6.9\times 10^{-3}\,\mathrm{m/s^2}\,,$$

where the minus sign indicates that the supertanker is decelerating. The stopping distance s can now be obtained from $v^2 = v_0^2 + 2as$:

$$s = \frac{v^2 - v_0^2}{2a} = \frac{0 - \left[(30\,\mathrm{km/h})(10^3\,\mathrm{m/km})(1\,\mathrm{h}/3600\,\mathrm{s})\right]^2}{2(-6.9\times 10^{-3}\,\mathrm{m/s^2})} = 5.0\times 10^3\,\mathrm{m} = 5.0\,\mathrm{km}\,.$$

3.78

Since the two cars have the same initial speed ($= 0$) and acceleration ($= a$), they will collide after each covers a distance of $s = 100\,\mathrm{m}/2 = 50.0\,\mathrm{m}$. The time t it takes for either car to traverse that much distance satisfies $s = \frac{1}{2}at^2$. Solve for t:

$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2(50.0\,\mathrm{m})}{2.5\,\mathrm{m/s^2}}} = 6.3\,\mathrm{s}\,.$$

Thus at the moment of the impact the clock will read 12:17:00 + 6.3 s = 12:17:06.

3.90

Since Turtle has only $20\,\mathrm{m} - 19.5\,\mathrm{m} = 0.5\,\mathrm{m}$ left in his journey, he can cross the finish line in $t_T = 0.5\,\mathrm{m}/[(1/4)\,\mathrm{m/s}] = 2.0\,\mathrm{s}$. So for Rabbit to win he must finish the remaining 20 m in $t_R < 2.0\,\mathrm{s}$. Now, the hare must first accelerate to his top speed $v_R = 18\,\mathrm{m/s}$, which takes a time of $t_1 = v_R/a_R = (18\,\mathrm{m/s})/(9\,\mathrm{m/s^2}) = 2.0\,\mathrm{s}$. The distance s_1 he covers during the acceleration stage can be obtained from $v_R^2 = 2a_R s_1$, or

$$s_1 = \frac{v_R^2}{2a_R} = \frac{(18\,\mathrm{m/s})^2}{2(9\,\mathrm{m/s^2})} = 18\,\mathrm{m}\,.$$

With $s_2 = 20\,\mathrm{m} - 18\,\mathrm{m} = 2\,\mathrm{m}$ left, the hare needs another $t_2 = s_2/v_R = 2\,\mathrm{m}/(18\,\mathrm{m/s}) = 0.1\,\mathrm{s}$ before reaching the finish line. Thus Turtle will win the race by 0.1 s.

3.95

Your initial speed v_0, displacement s, final speed v and acceleration g are related by $v^2 - v_0^2 = 2gs$. Since $v_0 = 0$,

$$v = \sqrt{2gs} = \sqrt{2(9.81\,\mathrm{m/s^2})(0.50\,\mathrm{m})} = 3.1\,\mathrm{m/s}.$$

Use $1\,\mathrm{ft} = 0.3048\,\mathrm{m}$ to convert v to ft/s: $v = (3.1\,\mathrm{m/s})(1\,\mathrm{ft}/0.3048\,\mathrm{m}) = 10\,\mathrm{ft/s}$. Use $1\,\mathrm{mi} = 1609\,\mathrm{m}$ and $1\,\mathrm{h} = 3600\,\mathrm{s}$ to convert v to mi/h: $v = (3.13\,\mathrm{m/s})(1\,\mathrm{mi}/1609\,\mathrm{m})(3600\,\mathrm{s/h}) = 7.0\,\mathrm{mi/h}$.

3.99

The final speed v of the hailstone, which has been undergoing an acceleration of g over a distance of s, satisfies $v^2 - v_0^2 = 2gs$, where $v_0 = 0$. Taking the downward direction to be positive, then $g = +9.80665\,\mathrm{m/s^2}$ and $s = +0.9144 \times 10^4\,\mathrm{m}$. Solve for v:

$$v = \sqrt{2gs} = \sqrt{2(9.80665\,\mathrm{m/s^2})(0.9144 \times 10^4\,\mathrm{m})} = 423\,\mathrm{m/s}.$$

You may also use $1\,\mathrm{mi} = 1609\,\mathrm{m}$ and $1\,\mathrm{h} = 3600\,\mathrm{s}$ to convert the unit of v to mi/h: $v = (423.6\,\mathrm{m/s})(1\,\mathrm{mi}/1609\,\mathrm{m})(3600\,\mathrm{s/h}) = 947\,\mathrm{mi/h}$.

3.103

The displacement s of the baseball in free fall as a function of time t is given by $s = v_0 t + \frac{1}{2}gt^2$. Since the ball returns to the boy's hand, its net displacement is $s = 0$, so $v_0 t + \frac{1}{2}gt^2 = 0$. Take the upward direction to be positive and solve for the initial speed v_0:

$$v_0 = -\frac{1}{2}gt = -\frac{1}{2}(-9.8\,\mathrm{m/s^2})(1.0\,\mathrm{s}) = 4.9\,\mathrm{m/s}.$$

3.104

The speed v of the arrow in free fall as a function of time t is given by $v = v_0 + gt$. Taking the upward direction to be positive, we have $g = -9.81\,\mathrm{m/s^2}$ and $v_0 = +98.1\,\mathrm{m/s}$. Thus at $t = 10\,\mathrm{s}$

$$v = v_0 + gt = 98.1\,\mathrm{m/s} + (-9.81\,\mathrm{m/s^2})(10\,\mathrm{s}) = 0.$$

Since the acceleration of the arrow is a constant, $v_{av} = \frac{1}{2}(v_0 + v) = \frac{1}{2}(0 + 98.1\,\mathrm{m/s}) = 49.1\,\mathrm{m/s}$. The distance s it has risen is then $s = v_{av}t = (49.1\,\mathrm{m/s})(10\,\mathrm{s}) = 4.9 \times 10^2\,\mathrm{m}$. The acceleration of the arrow at any time during its free fall is always equal to g [=$(9.81\,\mathrm{m/s^2})$-downward].

3.105

Use Eq. (3.9) for the displacement of the firecracker: $s = v_0 t + \frac{1}{2}at^2$. Choosing the upward direction to be positive, we have $a = g = -9.800\,\mathrm{m/s^2}$ and $v_0 = +50.00\,\mathrm{m/s}$. Thus at $t = 5.000\,\mathrm{s}$

$$s = v_0 t + \frac{1}{2}gt^2 = (50.00\,\mathrm{m/s})(5.000\,\mathrm{s}) + \frac{1}{2}(-9.800\,\mathrm{m/s^2})(5.000\,\mathrm{s})^2 = 127.5\,\mathrm{m}.$$

The speed v when it blows up is given by

$$v = v_0 + gt = +50.00\,\mathrm{m/s} + (-9.800\,\mathrm{m/s^2})(5.000\,\mathrm{s}) = +1.000\,\mathrm{m/s}.$$

Here the positive sign indicates that the firecracker is still moving upward, so it has not yet made it to its maximum height when it exploded.

3.111

Take the downward direction as positive. Let the initial speed of the bag as it passes the top of his head be v_0, then a time t (= 0.20 s) later as it hit the ground its speed becomes $v = v_0 + gt$. The average speed of the bag during time t is then $v_{av} = (v_0 + v)/2 = v_0 + \frac{1}{2}gt = v - \frac{1}{2}gt$. Let $s = +2\,\text{m} = v_{av}t$ and solve for v:

$$v = \frac{s}{t} + \frac{1}{2}gt = \frac{2\,\text{m}}{0.20\,\text{s}} + \frac{1}{2}(9.81\,\text{m/s}^2)(0.20\,\text{s}) = 10.98\,\text{m/s}.$$

To reach this final speed, the bag must have fallen freely from a height s_B, where $v^2 = 2gs_B$. Thus the height of the building is

$$s_B = \frac{v^2}{2g} = \frac{(10.98\,\text{m/s})^2}{2(9.81\,\text{m/s}^2)} = 6.14\,\text{m} \approx 6\,\text{m}.$$

(Note that the final answer has only one significant figure, since the height of the gangster is given by $s = 2\,\text{m}$.)

3.115

Take the downward direction to be positive. Since the egg falls vertically for $t = 2.0\,\text{s}$, its vertical displacement, which is equal in magnitude to the height of its launch point, is given by

$$s_y = \frac{1}{2}gt^2 = \frac{1}{2}(9.81\,\text{m/s}^2)(2.0\,\text{s})^2 = 20\,\text{m}.$$

Here we noted that, since the egg is projected out of the window horizontally, the vertical component of its initial velocity is zero.

3.120

Take the upward direction as positive. The range s_R of the flea [= (8.0 in.)(0.0254 m/in.) = 0.2032 m] is related with v_0, its initial speed, via Eq. (3.19): $s_R = -(2v_0^2/g)\sin\theta\cos\theta = -(v_0^2/g)\sin 2\theta$, which we solve for v_0:

$$v_0 = \sqrt{-\frac{gs_R}{\sin 2\theta}} = \sqrt{-\frac{(-9.81\,\text{m/s}^2)(0.2032\,\text{m})}{\sin(2\times 45^\circ)}} = 1.4\,\text{m/s}.$$