Solution Manual for College Physics 11th Edition by Serway ISBN 1305952308 9781305952300

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QUICK QUIZZES

2.1 **(a)** 200 yd **(b)** 0 **(c)** 0

(a) False. The car may be slowing down, so that the direction of its acceleration is opposite the direction of its velocity.

(b) True. If the velocity is in the direction chosen as negative, a positive acceleration causes a decrease in speed.

(c) True. For an accelerating particle to stop at all, the velocity and acceleration must have opposite signs, so that the speed is decreasing. If this is the case, the particle will eventually come to rest. If the acceleration remains constant, however, the particle must begin to move again, opposite to the direction of its original velocity. If the particle comes to rest and then stays at rest, the acceleration has become zero at the moment the motion stops. This is the case for a braking car—the acceleration is negative and goes to zero as the car comes to rest.

The velocity-vs-time graph (a) has a constant slope, indicating a constant acceleration, which is represented by the acceleration-vs.-time graph (e).

Graph (b) represents an object whose speed always increases, and does so at an ever-increasing rate. Thus, the acceleration must be increasing, and the acceleration-vs-time graph that best indicates this behaviour is (d).

Graph (c) depicts an object which first has a velocity that increases at a constant rate, which means that the object's acceleration is constant. The motion then changes to one at constant speed, indicating that the acceleration of the object becomes zero. Thus, the best match to this situation is graph (f).

Choice (b). According to *graph b*, there are some instants in time when the object is simultaneously at two different *x*-coordinates. This is physically impossible.

(a) The *blue graph* of Figure 2.14b best shows the puck's position as a function of time. As seen in Figure 2.14a, the distance the puck has traveled grows at an increasing rate for approximately three time intervals, grows at a steady rate for about four time intervals, and then grows at a diminishing rate for the last two intervals.

(b) The *red graph* of Figure 2.14c best illustrates the speed (distance traveled per time interval) of the puck as a function of time. It shows the puck gaining speed for approximately three time intervals, moving at constant speed for about four time intervals, then slowing to rest during the last two intervals.

(c) The *green graph* of Figure 2.14d best shows the puck's acceleration as a function of time. The puck gains velocity (positive acceleration) for approximately three time intervals, moves at constant velocity (zero acceleration) for about four time intervals, and then loses velocity (negative acceleration) for roughly the last two time intervals.

Choice (e). The acceleration of the ball remains constant while it is in the air. The magnitude of its acceleration is the free-fall acceleration, $g = 9.80\ \text{m/s}^2$.

Choice (c). As it travels upward, its speed decreases by 9.80 m/s during each second of its motion. When it reaches the peak of its motion, its speed becomes zero. As the ball moves downward, its speed increases by 9.80 m/s each second.

Choices (a) and (f). The first jumper will always be moving with a higher velocity than the second. Thus, in a given time interval, the first jumper covers more distance than the second, and the separation distance between them *increases*. At any given instant of time, the velocities of the jumpers are definitely different, because one had a head start. In a time interval after this instant, however, each jumper increases his or her velocity by the same amount, because they have the same acceleration. Thus, the difference in velocities *stays the same*.

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2.2 Yes. The particle may stop at some instant, but still have an acceleration, as when a ball thrown straight up reaches its maximum height.

2.4 **(a)** No. They can be used only when the acceleration is constant.

(b) Yes. Zero is a constant.

2.6 **(a)** In Figure (c), the images are farther apart for each successive time interval. The object is moving toward the right and speeding up. This means that the acceleration is positive in Figure (c).

(b) In Figure (a), the first four images show an increasing distance traveled each time interval and therefore a positive acceleration. However, after the fourth image, the spacing is decreasing, showing that the object is now slowing down (or has negative acceleration).

(c) In Figure (b), the images are equally spaced, showing that the object moved the same distance in each time interval. Hence, the velocity is constant in Figure (b).

2.8 **(a)** At the maximum height, the ball is momentarily at rest (i.e., has zero velocity). The acceleration remains constant, with magnitude equal to the free-fall acceleration g and directed downward. Thus, even though the velocity is momentarily zero, it continues to change, and the ball will begin to gain speed in the downward direction.

(b) The acceleration of the ball remains constant in magnitude and direction throughout the ball's free flight, from the instant it leaves the hand until the instant just before it strikes the ground. The acceleration is directed downward and has a magnitude equal to the freefall acceleration g.

2.10 Once the ball has left the thrower's hand, it is a freely falling body with a constant, nonzero, acceleration of $a = -g$. Since the acceleration of the ball is not zero at any point on its trajectory, choices (a) through (d) are all false and the correct response is (e).

2.12 The initial velocity of the car is $v_0 = 0$ and the velocity at the time t is v. The constant acceleration is therefore given by

$$a = \frac{\otimes v}{\otimes t} = \frac{v - v_0}{t} = \frac{v - 0}{t} = \frac{v}{t}$$

and the average velocity of the car is

$$\overline{v} = \frac{(v + v_0)}{2} = \frac{(v + 0)}{2} = \frac{v}{2}$$

The distance traveled in time t is $\otimes x = v\overline{t} = vt/2$. In the special case where $a = 0$ (and hence $v = v_0 = 0$), we see that statements (a), (b), (c), and (d) are all correct. However, in the general case ($a \neq 0$, and hence $v \neq 0$) only statements (b) and (c) are true. Statement (e) is not true in either case.

ANSWERS TO EVEN NUMBERED PROBLEMS

2.2 **(a)** 2×10^4 mi **(b)** $\Delta x/2R_E = 2.4$

2.4 **(a)** 8.33 yards/s **(b)** 2.78 yards/s

2.6 **(a)** 5.00 m/s **(b)** 1.25 m/s **(c)** –2.50 m/s

(d) –3.33 m/s **(e)** 0

2.8 **(a)** +4.0 m/s **(b)** –0.50 m/s **(c)** –1.0 m/s

(d)0

2.10 **(a)** 2.3 min **(b)** 64 mi

2.12 **(a)** L/t_1 **(b)** $-L/t_2$ **(c)** 0

(d) $2L/(t_1 + t_2)$

2.14 **(a)** 1.3×10^2 s **(b)** 13 m

2.16 **(a)** 37.1 m/s **(b)** 1.30×10^{-5} m

2.18 **(a)** Some data points that can be used to plot the graph are as given below:

x (m)	5.75	16.0	35.3	68.0	119	192
t (s)	1.00	2.00	3.00	4.00	5.00	6.00

(b) 41.0 m/s, 41.0 m/s, 41.0 m/s

(c) 17.0 m/s, much smaller than the instantaneous velocity at $t = 4.00$ s

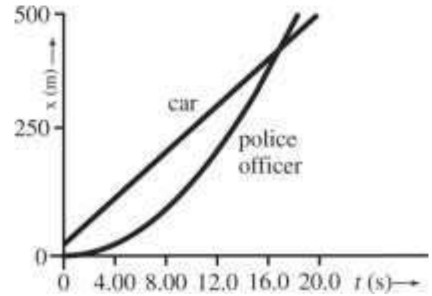
2.20 **(a)** 2.00 m/s, 5.0 m/s **(b)** 263 m

2.22 0.391 s

2.24 **(i)** (a) 0 (b) 1.6 m/s^2 (c) 0.80 m/s^2

(ii) (a) 0 (b) 1.6 m/s^2 (c) 0

2.26 The curves intersect at $t = 16.9$ s.



2.28 $a = 2.74 \times 10^5$ m/s^2 = $(2.79 \times 10^4)g$

2.30 **(a)**

(b) $v_f^2 = v_i^2 + 2a(\otimes x)$ **(c)** $a = (v_f^2 - v_i^2)/(2\otimes x)$ **(d)** 1.25 m/s^2

(e) 8.00 s

2.32 **(a)** 13.5 m **(b)** 13.5 m **(c)** 13.5 m

(d) 22.5 m

2.34 **(a)** 20.0 s

(b) No, it cannot land safely on the 0.800 km runway.

2.36 **(a)** 5.51 km **(b)** 20.8 m/s, 41.5 m/s, 20.8 m/s, 38.7 m/s

2.38 **(a)** 107 m **(b)** 1.49 m/s^2

2.40 **(a)** $v = a_1 t_1$ **(b)** $\otimes x = \frac{1}{2} a_1 t_1^2$

(c) $\otimes x_{\text{total}} = \frac{1}{2} a_1 t_1^2 + a_1 t_1 t_2 + \frac{1}{2} a_2 t_2^2$

2.42 8.9 months

2.44 29.1 s

2.46 1.79 s

2.48 **(a)** Yes. **(b)** $v_{top} = 3.69$ m/s

(c) $|\vec{\mathbf{v}}|_{downward} = 2.39$ m/s

(d) No, $|\vec{\mathbf{v}}|_{upward} = 3.71$ m/s. The two rocks have the same acceleration, but the rock thrown downward has a higher average speed between the two levels, and is accelerated over a smaller time interval.

2.50 **(a)** 21.1 m/s **(b)** 19.6 m **(c)** 1.81 m/s, 19.6 m

2.52 **(a)** $v = |-v_0 - gt| = |v_0 + gt|$ **(b)** $d = \frac{1}{2}gt^2$

(c) $v = |v_0 - gt|$, $d = \frac{1}{2}gt^2$

2.54 **(a)** 29.4 m/s **(b)** 44.1 m

2.56 **(a)** -202 m/s^2 **(b)** 198 m

2.58 **(a)** 4.53 s **(b)** 14.1 m/s

2.60 8.4 m/s

2.62 See Solutions Section for Motion Diagrams.

2.64 **(a)** $v = \sqrt{v_0^2 + 2gh}$ **(b)** $\otimes t = 2v_0/g$

2.66 **(a)** 2.45×10^{-2} m **(b)** 4.67×10^{-2} s

2.68 **(a)** 3.00 s **(b)** $v_{0,2} = -15.2$ m/s

(c) $v_1 = -31.4$ m/s, $v_2 = -34.8$ m/s

2.70 **(a)** 2.2 s **(b)** −21 m/s **(c)** 2.3 s

PROBLEM SOLUTIONS

We assume that you are approximately 2 m tall and that the nerve impulse travels at uniform speed. The elapsed time is then

$$t = \frac{x}{v} = \frac{2\text{ m}}{100\text{ m/s}} = 2 \times 10^{-2}\text{ s} = \boxed{0.02\text{ s}}$$

(a) At constant speed, $c = 3 \times 10^8$ m/s, the distance light travels in 0.1 s is

$$x = c(t) = (3 \times 10^8\text{ m/s})(0.1\text{ s})$$

$$= (\qquad \boxed{2 \times 10^4\text{ mi}}$$

(b) Comparing the result of part (a) to the diameter of the Earth, D_E, we find

$$\frac{x}{D_E} = \frac{x}{2R_E} = \frac{3.0 \times 10^7\text{ m}}{2\,(6.38 \times 10^6\text{ m})} \approx \boxed{2.4} \qquad \text{(with } R_E = \text{Earth's radius)}$$

Distances traveled between pairs of cities are

$$\Delta x_1 = v_1(\Delta t_1) = (80.0 \text{ km/h})(0.500 \text{ h}) = 40.0 \text{ km}$$

$$\Delta x_2 = v_2(\Delta t_2) = (100.0 \text{ km/h})(0.200 \text{ h}) = 20.0 \text{ km}$$

$$\Delta x_3 = v_3(\Delta t_3) = (40.0 \text{ km/h})(0.750 \text{ h}) = 30.0 \text{ km}$$

Thus, the total distance traveled is $\Delta x = (40.0 + 20.0 + 30.0) \text{ km} = 90.0 \text{ km}$, and the elapsed time is $\Delta t = 0.500 \text{ h} + 0.200 \text{ h} + 0.750 \text{ h} + 0.250 \text{ h} = 1.70 \text{ h}$.

(a) $\bar{v} = \frac{x}{t} = \frac{90.0 \text{ km}}{1.70 \text{ h}} = \boxed{52.9 \text{ km/h}}$

(b) $\Delta x = \boxed{90.0 \text{ km}}$ (see above)

(a) The player runs 100 yards from his own goal line to the opposing team's goal line. Then he runs an additional 50 yards back to the fifty- yard line, all in 18.0 s. Substitute values into the definition of average speed to find

$$\text{Average speed} = \frac{\text{path length}}{\text{elapsed time}} = \frac{100 \text{ yards} + 50 \text{ yards}}{18.0 \text{ s}}$$

$$= \boxed{8.33 \text{ yards/s}}$$

(b) After returning to the fifty-yard line, the player's displacement is ⊗x = $x_f - x_i = 50.0 \text{ yards} - 0 \text{ yards} = 50.0 \text{ yards}$. Substitute values into the definition of average velocity to find

$$\bar{v} = \frac{x}{t} = \frac{50.0 \text{ yards}}{18.0 \text{ s}} = \boxed{2.78 \text{ yards/s}}$$

(a) Boat A requires 1.0 h to cross the lake and 1.0 h to return, total time 2.0 h. Boat B requires 2.0 h to cross the lake at which time the race is over. Boat A wins, being 60 km ahead of B when the race ends.

(b) Average velocity is the net displacement of the boat divided by the total elapsed time. The winning boat is back where it started, its displacement thus being zero, yielding an average velocity of zero.

The average velocity over any time interval is

$$\bar{v} = \frac{x}{t} = \frac{x_f - x_i}{t_f - t_i}$$

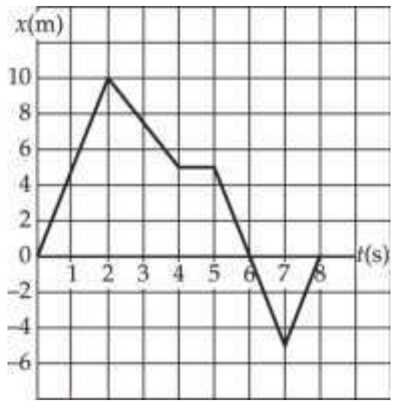
(a) $\bar{v} = \frac{x}{t} = \frac{10.0 \text{ m} - 0}{2.00 \text{ s} - 0} = \boxed{5.00 \text{ m/s}}$

(b) $\bar{v} = \frac{x}{t} = \frac{5.00 \text{ m} - 0}{4.00 \text{ s} - 0} = \boxed{1.25 \text{ m/s}}$

(c) $\bar{v} = \frac{x}{t} = \frac{5.00 \text{ m} - 10.0 \text{ m}}{4.00 \text{ s} - 2.00 \text{ s}} = \boxed{-2.50 \text{ m/s}}$

(d) $\bar{v} = \frac{x}{t} = \frac{-5.00 \text{ m} - 5.00 \text{ m}}{7.00 \text{ s} - 4.00 \text{ s}} = \boxed{-3.33 \text{ m/s}}$

(e) $\overline{v} = \frac{x}{t} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{0 - 0}{8.00\,\text{s} - 0} = \boxed{0}$



2.7 **(a)**

$$\text{Displacement} = x = (8.50\ \text{km/h})(35.0\ \text{min})\left(\frac{1\ \text{h}}{60.0\ \text{min}}\right) + 130\ \text{km} = \boxed{180\ \text{km}}$$

(b) The total elapsed time is

$$t = (35.0\ \text{min} + 15.0\ \text{min})\left(\frac{1\ \text{h}}{60.0\ \text{min}}\right) + 2.00\ \text{h} = 2.83\,\text{h}$$

so, $\overline{v} = \frac{x}{t} = \frac{180\ \text{km}}{2.84\ \text{h}} = \boxed{63.6\ \text{km}}$

The average velocity over any time interval is

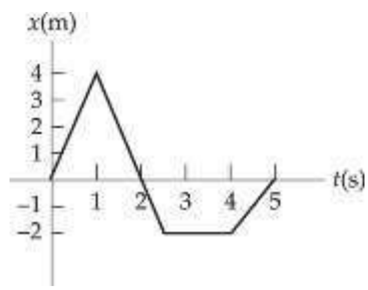
$$\overline{v} = \frac{x}{t} = \frac{x_f - x_i}{t_f - t_i}$$

(a) $\overline{v} = \frac{x}{t} = \frac{4.0\ \text{m} - 0}{1.0\ \text{s} - 0} = \boxed{+4.0\ \text{m/s}}$

(b) $\bar{v} = \frac{x}{t} = \frac{-2.0\text{ m} - 0}{4.0\text{ s} - 0} = \boxed{-0.50\text{ m/s}}$

(c) $\bar{v} = \frac{x}{t} = \frac{0 - 4.0\text{ m}}{5.0\text{ s} - 1.0\text{ s}} = \boxed{-1.0\text{ m/s}}$

(d) $\bar{v} = \frac{x}{t} = \frac{0 - 0}{5.0\text{ s} - 0} = \boxed{0}$



The plane starts from rest ($v_0 = 0$) and maintains a constant acceleration of $a =$ +1.3 m/s². Thus, we find the distance it will travel before reaching the required takeoff speed ($v = 75$ m/s), from $v^2 = v_0^2 + 2a(\otimes x)$, as

$$\otimes x = \frac{v^2 - v_0^2}{2a} = \frac{(75\text{ m/s})^2}{2(1.3\text{ m/s}^2)} = 2.2 \times 10^3\text{ m} = 2.2\text{ km}$$

Since this distance is less than the length of the runway, $\boxed{\text{the plane takes off safely.}}$

(a) The time for a car to make the trip is $t = \frac{\otimes x}{v}$. Thus, the difference in the times for the two cars to complete the same 10 mile trip is

$$\Delta t = t_1 - t_2 = \frac{x}{v_1} - \frac{x}{v_2} = \left(\frac{10\text{ mi}}{55\text{ mi/h}} - \frac{10\text{ mi}}{70\text{ mi/h}}\right)\left(\frac{60\text{ min}}{1\text{ h}}\right) = \boxed{2.3\text{ min}}$$

(b) When the faster car has a 15.0 min lead, it is ahead by a distance equal to that traveled by the slower car in a time of 15.0 min. This distance is given by $\Delta x_1 = v_1(\Delta t) = (55\text{ mi/h})(15\text{ min})$.

The faster car pulls ahead of the slower car at a rate of

$$v_{\text{relative}} = 70\text{ mi/h} - 55\text{ mi/h} = 15\text{ mi/h}$$

Thus, the time required for it to get distance Δx_1 ahead is

$$t = \frac{x_1}{v_{\text{relative}}} = \frac{(55\text{ mi/h})(15\text{ min})}{15.0\text{ mi/h}} = 15\text{ min}$$

Finally, the distance the faster car has traveled during this time is

$$x_2 = v_2(t) = (70\text{ mi/h})(55\text{ min})\left(\frac{1\text{ h}}{60\text{ min}}\right) = \boxed{64\text{ mi}}$$

(a) From $v_f^2 + v_i^2 + 2a(x)$, with $v_i = 0$, $v_f = 72$ km/h, and $\Delta x = 45$ m, the acceleration of the cheetah is found to be

(b) The cheetah's displacement 3.5 s after starting from rest is

$$x = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(4.4\ \text{m/s}^2)(3.5\ \text{s}) = \boxed{27\ \text{m}}$$

(a) $$\bar{v}_1 = \frac{(\Delta x)_1}{(\Delta t)_1} = \frac{+L}{t_1} = \boxed{+L/t_1}$$

(b) $$\bar{v}_2 = \frac{(\Delta x)_2}{(\Delta t)_2} = \frac{-L}{t_2} = \boxed{-L/t_2}$$

(c) $$\bar{v}_{\text{total}} = \frac{(\Delta x)_{\text{total}}}{(\Delta t)_{\text{total}}} = \frac{(\Delta x)_1 + (\Delta x)_2}{t_1 + t_2} = \frac{+L - L}{t_1 + t_2} = \frac{0}{t_1 + t_2} = \boxed{0}$$

(d)

$$(\text{ave speed})_{\text{trip}} = \frac{\text{total distance traveled}}{(\Delta t)_{\text{total}}} = \frac{|(\Delta x)_1| + |(\Delta x)_2|}{t_1 + t_2} = \frac{|+L| + |-L|}{t_1 + t_2} = \boxed{\frac{2L}{t_1 + t_2}}$$

(a) The total time for the trip is $t_{\text{total}} = t_1 + 22.0\ \text{min} = t_1 + 0.367\ \text{h}$, where t_1 is the time spent traveling at $v_1 = 89.5$ km/h. Thus, the distance traveled is $\Delta x = v_1 t_1 = \bar{v} t_{\text{total}}$, which gives

$$(89.5\ \text{km/h})t_1 = (77.8\ \text{km/h})(t_1 + 0.367\ \text{h}) = (77.8\ \text{km/h})t_1 + 28.5\ \text{km}$$

or, $(89.5\ \text{km/h} - 77.8\ \text{km/h})t_1 = 28.5\ \text{km}$

From which, $t_1 = 2.44$ h for a total time of $t_{\text{total}} = t_1 + 0.367\ \text{h} = \boxed{2.81\ \text{h}}$

(b) The distance traveled during the trip is $\Delta x = v_1 t_1 = \bar{v} t_{\text{total}}$, giving

$$\Delta x = \bar{v} t_{\text{total}} = (77.8\ \text{km/h})(2.81\ \text{h}) = \boxed{219\ \text{km}}$$

(a) At the end of the race, the tortoise has been moving for time t and the hare for a time $t - 2.0\text{ min} = t - 120\text{ s}$. The speed of the tortoise is $v_i = 0.100\text{ m/s}$, and the speed of the hare is $v_h = 20\ v_t = 2.0\text{ m/s}$. The tortoise travels distance x_t, which is 0.20 m larger than the distance x_h traveled by the hare. Hence,

$$x_t = x_h + 0.20\text{ m}$$

which becomes $v_t t = v_h(t - 120\text{ s}) + 0.20\text{ m}$

or $(0.100\text{ m/s})t = (2.0\text{ m/s})(t - 120\text{ s}) + 0.20\text{ m}$

This gives the time of the race as $t = \boxed{1.30 \times 10^2\text{ s}}$

(b) $x_t = v_t t = (0.100\text{ m/s})(1.3 \times 10^2\text{ s}) = \boxed{13\text{ m}}$

The maximum allowed time to complete the trip is

$$t_{\text{total}} = \frac{\text{total distance}}{\text{required average speed}} = \frac{1600\text{ m}}{250\text{ km/h}}\left(\frac{1\text{ km/h}}{0.278\text{ m/s}}\right) = 23.0\text{ s}$$

The time spent in the first half of the trip is

$$t_1 = \frac{\text{half distance}}{\bar{v}_1} = \frac{800\text{ m}}{230\text{ km/h}}\left(\frac{1\text{ km/h}}{0.278\text{ m/s}}\right) = 12.5\text{ s}$$

Thus, the maximum time that can be spent on the second half of the trip is

$t_2 = t_{total} - t_1 = 23.0\text{ s} - 12.5\text{ s} = 10.5\text{ s}$

and the required average speed on the second half is

$$\bar{v}_2 = \frac{\text{half distance}}{t_2} = \frac{800\text{ m}}{10.5\text{ s}} = 76.2\text{ m/s}\left(\frac{1\text{ km/h}}{0.278\text{ m/s}}\right) = \boxed{274\text{ km/h}}$$

(a) From the first kinematic equation with $v_0 = 0$, $t = 7.00 \times 10^{-7}$ s, and $a = 5.30 \times 10^7\text{ m/s}^2$, the maximum speed is

$$v = v_0 + at = (5.30 \times 10^7\text{ m/s}^2)(7.00 \times 10^{-7}\text{ s})$$

$$v = \boxed{37.1\text{ m/s}}$$

(b) Use $x = v_0 t + \frac{1}{2}at^2$ with $v_0 = 0$ to find the distance travelled during the acceleration:

$$x = \frac{1}{2}at^2 = \frac{1}{2}\left(5.30 \times 10^7\text{ m/s}^2\right)\left(7.00 \times 10^{-7}\text{ s}\right)^2$$

$$x = \boxed{1.30 \times 10^{-5}\text{ m}}$$

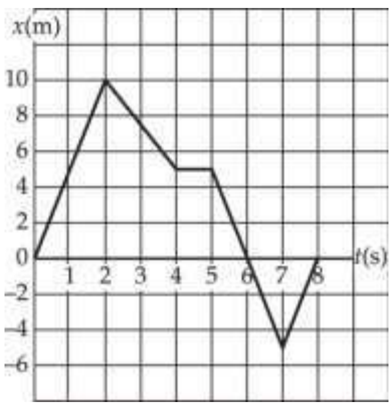
The instantaneous velocity at any time is the slope of the x vs. t graph at that time. We compute this slope by using two points on a straight segment of the curve, one point on each side of the point of interest.

(a) $$v_{t=1.00\text{ s}} = \frac{10.0\text{ m} - 0}{2.00\text{ s} - 0} = \boxed{5.00\text{ m/s}}$$

(b) $v_{t=3.00\text{ s}} = \dfrac{(5.00 - 10.0)\text{ m}}{(4.00 - 2.00)\text{ s}} = \boxed{-2.50\text{ m/s}}$

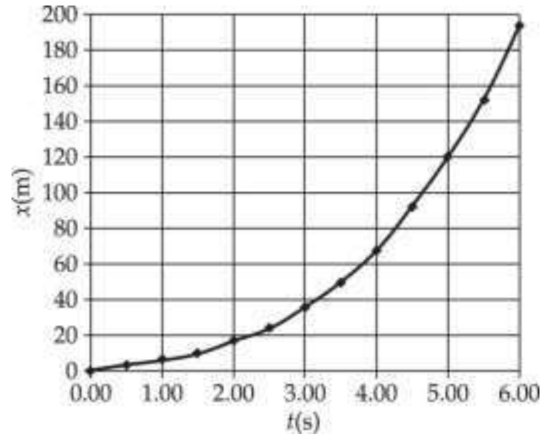
(c) $v_{t=4.50\text{ s}} = \dfrac{(5.00 - 5.00)\text{ m}}{(5.00 - 4.00)\text{ s}} = \boxed{0}$

(d) $v_{t=7.50\text{ s}} = \dfrac{0 - (-5.00)\text{ m}}{(8.00 - 7.00)\text{ s}} = \boxed{5.00\text{ m/s}}$



(a) A few typical values are

t (s)	x (m)
1.00	5.75
2.00	16.0
3.00	35.3
4.00	68.0
5.00	119
6.00	192



(b) We will use a 0.400 s interval centered at $t = 400$ s. We find at $t =$ 3.80 s, $x = 60.2$ m and at $t = 4.20$ s, $x = 76.6$ m. Therefore,

$$v = \frac{\otimes x}{\otimes t} = \frac{16.4 \text{ m}}{0.400 \text{ s}} = \boxed{41.0 \text{ m/s}}$$

Using a time interval of 0.200 s, we find the corresponding values to be: at $t = 3.90$ s, $x = 64.0$ m and at $t = 4.10$ s, $x = 72.2$ m. Thus,

$$v = \frac{\otimes x}{\otimes t} = \frac{8.20 \text{ m}}{0.200 \text{ s}} = \boxed{41.0 \text{ m/s}}$$

For a time interval of 0.100 s, the values are: at $t = 3.95$ s, $x = 66.0$ m, and at $t = 4.05$ s, $x = 70.1$ m. Therefore,

$$v = \frac{x}{t} = \frac{4.10 \text{ m}}{0.100 \text{ s}} = \boxed{41.0 \text{ m/s}}$$

(c) At $t = 4.00$ s, $x = 68.0$ m. Thus, for the first 4.00 s,

$$\overline{v} = \frac{x}{t} = \frac{68.0 \text{ m} - 0}{4.00 \text{ s} - 0} = \boxed{17.0 \text{ m/s}}$$

This value is **much less** than the instantaneous velocity at $t = 4.00$ s.

Choose a coordinate axis with the origin at the flagpole and east as the positive direction. Then, using $x = x_0 + v_0 t + \frac{1}{2}at^2$ with $a = 0$ for each runner, the x-coordinate of each runner at time t is

$x_A = -4.0\text{ mi} + (6.0\text{ mi/h})t$ and $x_B = 3.0\text{ mi} + (-5.0\text{ mi/h})t$

When the runners meet, $x_A = x_B$ giving

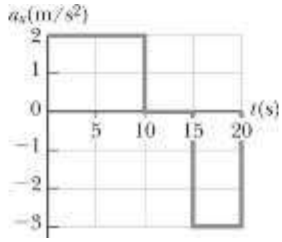
$-4.0\text{ mi} + (60\text{ mi/h})t = 3.0\text{ mi} + (-5.0\text{ mi/h})t$

or $(6.0\text{ mi/h} + 5.0\text{ mi/h})t = 3.0\text{ mi} + 4.0\text{ mi}$. This gives the elapsed time when they meet as $t = (7.0\text{ mi})/(11.0\text{ mi/h}) = 0.64$ h. At this time, $x_A = x_B = -0.18$ mi. Thus, they meet **0.18 mi west of the flagpole**.

From the figure below, observe that the motion of this particle can be broken into three distinct time intervals, during each of which the particle has a constant acceleration. These intervals and the associated accelerations are

$0 \le t \le 10.0\text{ s},\ a = a_1 = +2.00\text{ m/s}^2$

$10 \le t \le 15.0\text{ s},\ a = a_2 = 0$



and $\quad 15.0 \le t \le 20.0$ s, $a = a_3 = -3.00$ m/s^2

(a) Applying $v_f = v_i + a(\otimes t)$ to each of the three time intervals gives

for $0 \le t \le 10.0$ s,

$$v_{10} + v_0 + a_1(t_1) = 0 + (2.00 \text{ m/s}^2)(10.0 \text{ s}) = \boxed{20.0 \text{ m/s}}$$

for $10.0 \text{ s} \le t \le 15.0$ s,

$$v_{15} + v_{10} + a_2(t_2) = 20.0 \text{ m/s} + 0 = 20.0 \text{ m/s}$$for

$15.0 \text{ s} \le t \le 20.0$ s,

$$v_{20} + v_{15} + a_3(t_3) = 20.0 \text{ m/s} + (-3.00 \text{ m/s}^2)(5.00 \text{ s}) = \boxed{5.00 \text{ m/s}}$$

(b) Applying $x = v_i(t) + \frac{1}{2}a(t)^2$ to each of the time intervals gives

for $0 \le t \le 10.0$ s,

$$x_1 = v_0 t_1 + \frac{1}{2} a_1 (t_1)^2 = 0 + \frac{1}{2}(2.00 \text{ m/s}^2)(10.0 \text{ s})^2 = 1.00 \times 10^2 \text{ m}$$

for $10.0 \text{ s} \le t \le 15.0$ s,

$$x_2 = v_{10} t_2 + \frac{1}{2} a_2 (\quad_2)^2 = (20.0 \text{ m/s})(5.00 \text{ s}) + 0 = 1.00 \times 10^2 \text{ m}$$

for 15.0 s ≤ t ≤ 20.0 s,

$$x_3 = v_{15} t_3 + \frac{1}{2} a_3 (t_3)^2$$

$$= (20.0 \text{ m/s})(5.00 \text{ s}) + \frac{1}{2}(-3.00 \text{ m/s}^2)(5.00 \text{ s})^2 = 62.5 \text{ m}$$

Thus, the total distance traveled in the first 20.0 s is

$$x_{\text{total}} = x_1 + x_2 + x_3 = 100 \text{ m} + 100 \text{ m} + 62.5 \text{ m} = \boxed{263 \text{ m}}$$

We choose the positive direction to point away from the wall. Then, the initial velocity of the ball is $v_i = -25.0$ m/s and the final velocity is $v_f =$ +22.0 m/s. If this change in velocity occurs over a time interval of ⊗t = 3.50 ms (i.e., the interval during which the ball is in contact with the wall), the average acceleration is

$$\bar{a} = \frac{v}{t} = \frac{v_f - v_i}{t} = \frac{+22.0 \text{ m/s} - (-25.0 \text{ m/s})}{3.50 \times 10^{-3} \text{ s}} = \boxed{1.34 \times 10^4 \text{ m/s}^2}$$

From $a = v/t$, the required time is

(i) **(a)** From $t = 0$ to $t = 5.0$ s,

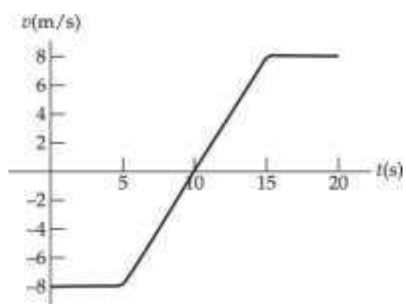
$$\bar{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{-8.0 \text{ m/s} - (-8.0 \text{ m/s})}{5.0 \text{ s} - 0} = \boxed{0}$$

(b) From $t = 5.0$ s to $t = 15$ s,

$$\bar{a} = \frac{8.0 \text{ m/s} - (-8.0 \text{ m/s})}{15 \text{ s} - 5.0 \text{ s}} = \boxed{1.6 \text{ m/s}^2}$$

(c) From $t = 0$ to $t = 20$ s,

$$\bar{a} = \frac{8.0 \text{ m/s} - (-8.0 \text{ m/s})}{20 \text{ s} - 0} = \boxed{0.80 \text{ m/s}^2}$$



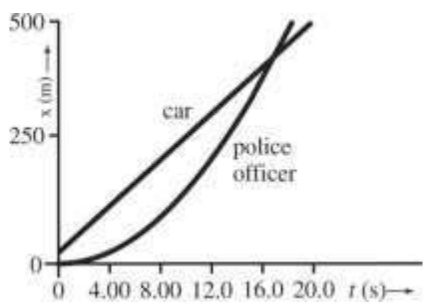
(ii) At any instant, the instantaneous acceleration equals the slope of the line tangent to the v vs. t graph at that point in time.

(a) At $t = 2.0$ s, the slope of the tangent line to the curve is $\boxed{0}$.

(b) At $t = 10$ s, the slope of the tangent line is $\boxed{1.6 \text{ m/s}^2}$.

(c) At $t = 18$ s, the slope of the tangent line is $\boxed{0}$.

As in the algebraic solution to Example 2.5, we let t represent the time the trooper has been moving.



We graph

$$x_{\text{car}} = 24.0\text{ m} + (24.0\text{ m/s})t$$

and

$$x_{\text{trooper}} = (1.50\text{ m/s}^2)t^2$$

The curves intersect at $t = \boxed{16.9\text{ s}}$

Apply $\Delta x = v_0 t + \frac{1}{2}at^2$ to the 2.00-second time interval during which the object moves from $x_i = 3.00$ cm to $x_f = -5.00$ cm. With $v_0 = 12.0$ cm/s, this yields an acceleration of

$$a = \frac{2\left[(x_f - x_i) - v_0 t\right]}{t^2} = \frac{2[(-5.00 - 3.00)\text{ cm} - (12.0\text{ cm/s})(2.00\text{ s})]}{(2.00\text{ s})^2}$$

or $a = \boxed{-16.0\text{ cm/s}^2}$

2.28

0

2.30 **(a)**

(b) The known quantities are initial velocity, final velocity, and displacement. The kinematics equation that relates these quantities to acceleration is $\boxed{v_f^2 = v_i^2 + 2a(x)}$

(c) $a = \boxed{\dfrac{v_f^2 - v_i^2}{2(x)}}$

(d) $a = \dfrac{v_f^2 - v_i^2}{2(x)} = \dfrac{(30.0\text{ m/s})^2 - (20.0\text{ m/s})^2}{2(2.00 \times 10^2\text{ m})} = \boxed{1.25\text{ m/s}^2}$

(e) Using $a = v/t$, we find that

$$t = \frac{v}{a} = \frac{v_f - v_i}{a} = \frac{30.0\text{ m/s} - 20.0\text{ m/s}}{1.25\text{ m/s}^2} = \boxed{8.00\text{ s}}$$

(a) With $v = 120$ km/h, $v^2 = v^2 + 2a_0(x)$ yields $\boxed{2.32\text{ m/s}^2}$

(b) The required time is

$\boxed{14.4\text{ s}}$

(a) From $v_f^2 = v_i^2 + 2a(x)$, with $v_i = 6.00$ m/s and $v_f = 12.0$ m/s, we find

$$x = \frac{v_f^2 - v_i^2}{2a} = \frac{(120 \text{ m/s})^2 - (6.00 \text{ m/s})^2}{2(4.00 \text{ m/s}^2)} = \boxed{13.5 \text{ m}}$$

(b) In this case, the object moves in the same direction for the entire time interval and the total distance traveled is simply the magnitude or absolute value of the displacement. That is,

$$d = |x| = \boxed{13.5 \text{ m}}$$

(c) Here, $v_i = -6.00$ m/s and $v_f = 12.0$ m/s, and we find

$$x = \frac{v_f^2 - v_i^2}{2a} = \boxed{13.5\text{m}} \qquad \text{[the same as in part (a)]}$$

(d) In this case, the object initially slows down as it travels in the negative x-direction, stops momentarily, and then gains speed as it begins traveling in the positive x-direction. We find the total distance traveled by first finding the displacement during each phase of this motion.

While coming to rest ($v_i = -6.00$ m/s, $v_f = 0$),

$$x_1 = \frac{v_f^2 - v_i^2}{2a} = \frac{(0)^2 - (-6.00 \text{ m/s})^2}{2(4.00 \text{ m/s}^2)} = -4.50 \text{ m}$$

After reversing direction ($v_i = 0$ m/s, $v_f = 12.0$ m/s),

$$v_f^2 - v_i^2 \qquad x_2 = \qquad 2a$$

$$\frac{(12.0\ \text{m/s})^2 - (0)^2}{2(4.00\ \text{m/s}^2)} = 18.0\ \text{m}$$

Note that the net displacement is $x = x_1 + x_2 = -4.50\text{ m} + 18.0\text{ m} =$ 13.5 m, as found in part (c) above. However, the total distance traveled in this case is

$$d = |x_1| + |x_2| = |-4.50\text{ m}| + |18.0\text{ m}| = \boxed{22.5\text{ m}}$$

2.33 **(a)** $a = \dfrac{v - v_0}{t} = \dfrac{24.0\text{ m/s}^2 - 0}{2.95\text{ s}} = \boxed{8.14\text{ m / s}^2}$

(b) From $a = v/t$, the required time is

$$\otimes = \frac{v_f - v_i}{a} = \frac{20.0\text{ m/s} - 10.0\text{ m/s}}{8.15\text{ m/s}^2} = \boxed{1.23\text{ s}}$$

(c) $\boxed{\text{Yes.}}$ For uniform acceleration, the change in velocity $\otimes v$ generated in time t is given by $v = a(t)$. From this, it is seen that doubling thelength of the time interval t will always double the change in velocity $\otimes v$. A more precise way of stating this is: "When acceleration is constant, velocity is a linear function of time."

(a) The time required to stop the plane is

$$t = \frac{v - v_0}{a} = \frac{0 - 100\text{ m/s}}{-5.00\text{ m/s}^2} = \boxed{20.0\text{ s}}$$

(b) The minimum distance needed to stop is

–

Thus, the plane requires a minimum runway length of 1.00 km.

It cannot land safely on a 0.800 km runway.

We choose $x = 0$ and $t = 0$ at the location of Sue's car when she first spots the van and applies the brakes. Then, the initial conditions for Sue's car are $x_{0S} = 0$ and $v_{0S} = 30.0$ m/s. Her constant acceleration for $a_S = -2.00 \text{m/s}^2$.

The initial conditions for the van are $x_{0V} = 155$ m, $v_{0V} = 5.00$ m/s, and its constant acceleration is $a_V = 0$. We then use $x = x - x_0 = v_0 t + \frac{1}{2}at^2$ to write an equation for the x-coordinate of each vehicle for $t \geq 0$. This gives

Sue's Car:

$$x_S - 0 = (30.0 \text{ m/s})t + \frac{1}{2}(-2.00 \text{ m/s}^2)t^2 \text{ or } x_S = (30.0 \text{ m/s})t - (-1.00 \text{ m/s}^2)t^2$$

Van:

$$x_V - 155 \text{ m} = (5.00 \text{ m/s})t + \frac{1}{2}(0)t^2 \text{ or } x_V = 155 \text{ m} + (5.00 \text{ m/s})t$$

In order for a collision to occur, the two vehicles must be at the same location (i.e., $x_S = x_V$). Thus, we test for a collision by equating the two equations for the x-coordinates and see if the resulting equation has any real solutions.

$$x_S = x_V \quad \Rightarrow \quad (30.0 \text{ m/s})t - (1.00 \text{ m/s}^2)t^2 = 155 \text{ m} + (5.00 \text{ m/s})t$$

$$\text{or} \quad (1.00 \text{ m/s}^2)t^2 - (25.00 \text{ m/s}) + 155 \text{ m} = 0$$

Using the quadratic formula yields

$$t = \frac{-(-25.00\text{ m/s}) \pm \sqrt{(-25.00\text{ m/s}^2) - 4(1.00\text{ m/s}^2)(155\text{ m})}}{2(1.00\text{ m/s}^2)} = 13.6\text{ s or } \boxed{11.4\text{ s}}$$

The solutions are real, not imaginary, so $\boxed{\text{a collision will occur}}$. The smaller of the two solutions is the collision time. (The larger solution tells when the van would pull ahead of the car again if the vehicles could pass harmlessly through each other.) The x-coordinate where the collision occurs is given by

$$x_{\text{collision}} = x_S|_{t=11.4\text{ s}} = x_V|_{t=11.4\text{ s}} = 155\text{ m} + (5.00\text{ m/s})(11.4\text{ s}) = \boxed{212\text{ m}}$$

The velocity at the end of the first interval is

$$v = v_0 + at = 0 + (2.77\text{ m/s}^2)(15.0\text{ s}) = 41.6\text{ m/s}$$

This is also the constant velocity during the second interval and the initial velocity for the third interval. Also, note that the duration of the second interval is $t_2 = (2.05\text{ min})(60.0\text{ s/1 min}) = 123\text{ s}$.

(a) From $x = v_0 t + \frac{1}{2}at^2$, the total displacement is

$$\begin{aligned}(x)_{\text{total}} &= (x)_1 + (x)_2 + (x)_3 \\ &= \left[0 + \frac{1}{2}(2.77\text{ m/s}^2)(15.0\text{ s})^2\right] + [(2.77\text{ m/s}^2)(15.0\text{ s})(123\text{ s}) + 0] \\ &\quad + \left[(2.77\text{ m/s}^2)(15.0\text{ s})(4.39\text{ s}) + \frac{1}{2}(-9.47\text{ m/s}^2)(4.39\text{ s})^2\right]\end{aligned}$$

or $(x)_{total} = 312\text{ m} + 5.11 \times 10^3\text{ m} + 91.2\text{ m} = 5.51 \times 10^3\text{ m} = \boxed{5.51\text{ km}}$

(b) $\bar{v}_1 = \frac{(x)_1}{t_1} = \frac{312\text{ m}}{15.0\text{ s}} = \boxed{20.8\text{ m/s}}$

$\bar{v}_2 = \frac{(x)_2}{t_2} = \frac{5.11 \times 10^3\text{ m}}{123\text{ s}} = \boxed{41.5\text{ m/s}}$

$\bar{v}_3 = \frac{(x)_3}{t_3} = \frac{91.2\text{ m}}{4.39\text{ s}} = \boxed{20.8\text{ m/s}}$, and the average velocity for the

total trip is $\bar{v}_{total} = \frac{(x)_{total}}{t_{total}} = \frac{5.51 \times 10^3\text{ m}}{(15.0 + 123 + 4.39)\text{ s}} = \boxed{38.7\text{ m/s}}$

Using the uniformly accelerated motion equation $x + v_0 t + \frac{1}{2}at^2$ forthe

full 40 s interval yields $x = (20\text{ m/s})(40\text{ s}) + \frac{1}{2}(-1.0\text{ m/s}^2)(40\text{ s})^2 = 0$, which

is obviously wrong. The source of the error is found by computing the

time required for the train to come to rest. This time is

$$t = \frac{v - v_0}{a} = \frac{0 - 20\text{ m/s}}{-1.0\text{ m/s}^2} = 20\text{ s}.$$

Thus, the train is slowing down for the first 20 s and is at rest for the last

20 s of the 40 s interval.

The acceleration is not constant during the full 40 s. It is, however,

constant during the first 20 s as the train slows to rest. Application of

$x = v_0 t + \frac{1}{2} at^2$ to this interval gives the stopping distance as

$$x = (20\text{ m/s})(20\text{ s}) + \frac{1}{2}(-1.0\text{ m/s}^2)(20\text{ s})^2 = \boxed{200\text{ m}}$$

v

(a) To find the distance traveled, we use

(b) The constant acceleration is $a = \frac{v_f - v_0}{t} = \frac{17.9\text{ m/s} - 0}{12.0\text{ s}} = \boxed{1.49\text{ m/s}^2}$

At the end of the acceleration period, the velocity is

$$v = v_0 + at_{accel} = 0 + (1.5\text{ m/s}^2)(5.0\text{ s}) = 7.5\text{ m/s}$$

This is also the initial velocity for the braking period.

(a) After braking, $v_f = v + at_{brake} = 7.5\text{ m/s} + (-2.0\text{ m/s}^2)(3.0\text{ s}) = \boxed{1.5\text{ m/s}}$

(b) The total distance traveled is

For the acceleration period, the parameters for the car are: initial velocity $= v_{ia} = 0$, acceleration $= a_a = a_1$, elapsed time $= (\otimes t)_a = t_1$, and final velocity $= v_{fa}$. For the braking period, the parameters are: initial velocity $= v_{ib} =$ final velocity of acceleration period $= v_{fa}$, acceleration $= a_b = a_2$, and elapsed time $= (t)_b = t_2$.

(a) To determine the velocity of the car just before the brakes are engaged, we apply $v_f = v_i + a(t)$ to the acceleration period and find

$$v_{ib} = v_{fa} = v_{ia} + a_a(t)_a = 0 + a_1 t_1 \qquad \text{or} \qquad v_{ib} = \boxed{a_1 t_1}$$

(b) We may use $\otimes x = v_i(\otimes t) + \frac{1}{2}a(\otimes t)^2$ to determine the distance traveled during the acceleration period (i.e., before the driver begins to brake). This gives

$$(\otimes x)_a = v_{ia}(\otimes t)_a + \frac{1}{2}a_a(\otimes t)_a^2 = 0 + \frac{1}{2}a_1 t_1^2 \qquad \text{or} \qquad (\otimes x)_a = \boxed{\frac{1}{2}a_1 t_1^2}$$

(c) The displacement occurring during the braking period is

$$(\otimes x)_b = v_{ib}(\otimes t)_b + \frac{1}{2}a_b(\otimes t)_b^2 = (a_1 t_1)t_2 + \frac{1}{2}a_2 t_2^2$$

Thus, the total displacement of the car during the two intervals combined is

$$(\otimes x)_{\text{total}} = (\otimes x)_a + (\otimes x)_b = \boxed{\frac{1}{2}a_1t_1^2 + a_1t_1t_2 + \frac{1}{2}a_2t_2^2}$$

The time the Thunderbird spends slowing down is

$$\otimes t_1 = \frac{\otimes x_1}{\bar{v}_1} = \frac{2(\otimes x_1)}{v + v_0} = \frac{2(250\ \text{m})}{0 + 71.5\ \text{m/s}} = 6.99\ \text{s}$$

The time required to regain speed after the pit stop is

$$\otimes t_2 = \frac{\otimes x_2}{\bar{v}_2} = \frac{2(\otimes x_2)}{v + v_0} = \frac{2(350\ \text{m})}{71.5\ \text{m/s} + 0} = 9.79\ \text{s.}$$

Thus, the total elapsed time before the Thunderbird is back up to speed is

$$\otimes t = \otimes t_1 + 5.00\ \text{s} + \otimes t_2 = 6.99\ \text{s} + 5.00\ \text{s} + 9.79\ \text{s} = 2.18\ \text{s}$$

During this time, the Mercedes has traveled (at constant speed) a distance

$$\otimes x_M = v_0(\otimes t) = (71.5\ \text{m/s})(21.8\ \text{s}) = 1\,559\ \text{m}$$

and the Thunderbird has fallen behind a distance

$$d = \otimes x_M - \otimes x_1 - \otimes x_2 = 1\,559\ \text{m} - 250\ \text{m} - 350\ \text{m} = \boxed{959\ \text{m}}$$

The initial bank account balance is $x_i = \$1.0 \times 10^4$ (to two significant figures) and the bank account is empty when $x_f = 0$ with a change of $\otimes x = x_f - x_i = \$(-1.0 \times 10^4)$. Use

$$\otimes x = v_0 t + \tfrac{1}{2}at^2$$

with $v_0 = 0$ and $a = -2.5 \times 10^2$ \$/month to find the time, t:

$$\otimes x = \tfrac{1}{2} a t^2 \rightarrow t = \sqrt{\frac{2\otimes x}{}}$$

$$t = \sqrt{\frac{2\left(\$(-1.0 \times 10^4)\right)}{\left(-2.5 \times 10^2\ \$/\text{month}^2\right)}} = \boxed{8.9\ \text{months}}$$

(a) Take $t = 0$ at the time when the player starts to chase his opponent. At this time, the opponent is distance $d = (12\text{ m/s})(30\text{ s}) = 36\text{ m}$ in front of the player. At time $t > 0$, the displacements of the players from their initial positions are

$$\otimes x_{\text{player}} = (v_0)_{\text{player}} t + \frac{1}{2} a_{\text{player}} t^2 = 0 + \frac{1}{2}(4.0\text{ m/s}^2)t^2 \qquad \textbf{[1]}$$

and $$\otimes x_{\text{opponent}} = (v_0)_{\text{opponent}} t + \frac{1}{2} a_{\text{opponent}} t^2 = (12\text{ m/s})t + 0 \qquad \textbf{[2]}$$

When the players are side-by-side, $\otimes x_{\text{player}} = \otimes x_{\text{opponent}} + 36\text{ m}$ **[3]**

Substituting Equations [1] and [2] into Equation [3] gives

$$\frac{1}{2}(4.0\text{ m/s}^2)t^2 = (12\text{ m/s})t + 36\text{ m} \qquad \text{or} \qquad t^2 + (-6.0\text{ s})t + (-18\text{ s}^2) = 0$$

Applying the quadratic formula to this result gives

$$t = \frac{-(-6.0\text{ s}) \pm \sqrt{(-6.0\text{ s})^2 - 4(1)(-18\text{ s}^2)}}{2(1)}$$

which has solutions of $t = -2.2$ s and $t = +8.2$ s. Since the time must be greater than zero, we must choose $\boxed{t = 8.2\ \text{s}}$ as the proper answer.

(b) $\otimes x_{player} = (v_{0\,player})t + \frac{1}{2}a_{player}t^2 = 0 + \frac{1}{2}(4.0\ \text{m/s}^2)(8.2\ \text{s})^2 = \boxed{1.3\times 10^2\ \text{m}}$

The initial velocity of the train is $v_0 = 82.4$ and the final velocity is $v = 16.4$ km/h.

The time required for the 400 m train to pass the crossing is found from $\otimes x = \bar{v}t = [(v + v_0)/2]t$ as

$$t = \frac{2(\otimes x)}{v + v_0} = \frac{2(0.400\ \text{km})}{(82.4 + 16.4)\ \text{km/h}} = (8.10\times 10^{-3}\ \text{h})\left(\frac{3600\ \text{s}}{1\ \text{h}}\right) = \boxed{29.1\ \text{s}}$$

(a) From $v^2 = v_0^2 + 2a_0(\otimes y)$ with $v = 0$, we have

$$(\otimes y)_{max} = \frac{v^2 - v_0^2}{2a} = \frac{0 - (25.0\ \text{m/s})^2}{2(-9.80\ \text{m/s}^2)} = \boxed{31.9\ \text{m}}$$

(b) The time to reach the highest point is

$$t_{up} = \frac{v^2 - v_0^2}{a} = \frac{0 - 25.0\ \text{m/s}}{-9.80\ \text{m/s}^2} = \boxed{2.55\ \text{s}}$$

(c) The time required for the ball to fall 31.9 m, starting from rest, is found from

$$\otimes y = (0)t + \frac{1}{2}at^2 \text{ as } t = \sqrt{\frac{2(\otimes y)}{a}} = \sqrt{\frac{2(-31.9\ \text{m})}{-9.80\ \text{m/s}^2}} = \boxed{2.55\ \text{s}}$$

(d) The velocity of the ball when it returns to the original level (2.55 s after it starts to fall from rest) is

$$v = v_0 + at = 0 + (-9.80\ \text{m/s}^2)(2.55\ \text{s}) = \boxed{-25.0\ \text{m/s}}$$

We take upward as the positive y-direction and $y = 0$ at the point where the ball is released. Then, $v_{0y} = -8.00$ m/s, $a_y = -g = -9.80$ m/s², and $\Delta y = -30.0$ m when the ball reaches the ground. From $v_y^2 = v_{0y}^2 + 2a_y(\Delta y)$, the velocity of the ball just before it hits the ground is

$$v_y = \sqrt{v_{0y}^2 + 2a_y(\Delta y)} = -\sqrt{(8.00\ \text{m/s})^2 + 2(-9.80\ \text{m/s}^2)(-30.0\text{m})} = -25.5\ \text{m/s}$$

Then, $v_y = v_{0y} + a_y t$ gives the elapsed time as

$$t = \frac{v_y - v_{0y}}{a_y} = \frac{-25.5\ \text{m/s} - (-8.00\ \text{m/s})}{-9.80\ \text{m/s}^2} = \boxed{1.79\ \text{s}}$$

(a) The velocity of the object when it was 30.0 m above the ground can be determined by applying $\Delta y = v_0 t + \frac{1}{2}at^2$ to the last 1.50 s of the fall. This gives

$$-30.0\ \text{m} = v_0(1.50\ \text{s}) + \frac{1}{2}\left(-9.80\ \frac{\text{m}}{\text{s}^2}\right)(1.50\ \text{s})^2 \qquad \text{or} \qquad v_0 = \boxed{-12.7\ \text{m/s}}$$

(b) The displacement the object must have undergone, starting from rest, to achieve this velocity at a point 30.0 m above the ground is given by $v^2 = v_0^2 + 2a(\Delta y)$ as

$$(\otimes y)_1 = \frac{v^2 - v_0^2}{2a} = \frac{(-12.7\text{ m/s})^2 - 0}{2(-9.80\text{ m/s}^2)} = -8.23\text{ m}$$

The total distance the object drops during the fall is then

$$|(\otimes y)_{\text{total}}| = |(-8.23\text{ m}) + (-30.0\text{ m})| = \boxed{38.2\text{ m}}$$

(a) Consider the rock's entire upward flight, for which $v_0 = +7.40$ m/s,

$v_f = 0$, $a = -g = -9.80\text{ m/s}^2$, $y_i = 1.55$ m, (taking $y = 0$ at ground level),

and $y_f = h_{\max}$ = maximum altitude reached. Then applying

$v_f^2 = v_i^2 + 2a(\otimes y)$ to this upward flight gives

$$0 = (7.40\text{ m/s})^2 + 2(-9.80\text{ m/s}^2)(h_{\max} - 1.55\text{ m})$$

Solving for the maximum altitude of the rock gives

$$h_{\max} = 1.55\text{ m} + \frac{(7.40\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = 4.34\text{ m}$$

Since $h_{\max} > 3.65$ m (height of the wall), $\boxed{\text{the rock does reach the top of the wall}}$.

(b) To find the velocity of the rock when it reaches the top of the wall, we use $v_f^2 = v_i^2 + 2a(\otimes y)$ and solve for v_f when $y_f = 3.65$ m (starting with v_i = +7.40 m/s at $y_i = 1.55$ m). This yields

$$v_f = \sqrt{v_i^2 + 2a(y_f - y_i)} = \sqrt{(7.40\text{ m/s})^2 + 2(-9.80\text{ m/s}^2)(3.65\text{ m} - 1.55\text{ m})} = \boxed{3.69\text{ m/s}}$$

(c) A rock thrown *downward* at a speed of 7.40 m/s ($v_i = -7.40$ m/s) from the top of the wall undergoes a displacement of $(\otimes y) = y_f - y_i =$ 1.55 m − 3.65 m = −2.10 m before reaching the level of the attacker. Its velocity when it reaches the attacker is

$$v_f = -\sqrt{v_i^2 + 2a(\otimes y)} = -\sqrt{(-7.40\ \text{m/s})^2 + 2(-9.80\ \text{m/s}^2)(-2.10\ \text{m})} = -9.79\ \text{m/s}$$

so the change in speed of this rock as it goes between the 2 points located at the top of the wall and the attacker is given by

$$\otimes(\text{speed})_{\text{down}} = \big||v_f| - |v_i|\big| = \big||-9.79\ \text{m/s}| - |-7.40\ \text{m/s}|\big| = \boxed{2.39\ \text{m/s}}.$$

(d) Observe that the change in speed of the ball thrown upward as it went from the attacker to the top of the wall was

$$\otimes(\text{speed})_{\text{up}} = \big||v_f| - |v_i|\big| = |3.69\ \text{m/s} - 7.40\ \text{m/s}| = 3.71\ \text{m/s}$$

The two rocks do not undergo the same magnitude speed change.

The rocks have the same acceleration, but the rock thrown downward has a higher average speed between the two levels, and is accelerated over a smaller time interval.

The velocity of the child’s head just before impact (after falling a distance of 0.40 m, starting from rest) is given by $v^2 = v^2{}_0 + 2a(\otimes y)$ as

$$v_I = \sqrt{v_0^2 + 2a(\otimes y)} = -\sqrt{0 + 2(-9.8\ \text{m/s}^2)(-0.40\ \text{m})} = -2.8\ \text{m/s}$$

If, upon impact, the child's head undergoes an additional displacement $\otimes y = -h$ before coming to rest, the acceleration during the impact can be found from $v^2 = v_0^2 + 2a(\otimes y)$ to be $a = (0 - v_I^2)/2(-h) = v_I^2/2h$. The duration of the impact is found from $v = v_0 + at$ as

$t = \otimes v/a = -v_I/(v_I^2/2h)$, or $t = -2h/v_I$.

Applying these results to the two cases yields

Hardwood Floor

$$(h = 2.0 \times 10^{-3}\text{ m}) : a = \frac{v_I^2}{2h} = \frac{(-2.8\text{ m/s})^2}{2(2.0 \times 10^{-3}\text{ m})} = \boxed{2.0 \times 10^3\text{ m/s}^2}$$

and $$t = \frac{-2h}{v_I} = \frac{-2(2.0 \times 10^{-3}\text{ m})}{-2.8\text{ m/s}} = 1.4 \times 10^{-3}\text{ s} = \boxed{1.4\text{ ms}}$$

Carpeted Floor $$(h = 1.0 \times 10^{-2}\text{ m}) : a = \frac{v_I^2}{2h} = \frac{(-2.8\text{ m/s})^2}{2(1.0 \times 10^{-2}\text{ m})} = \boxed{3.9 \times 10^2\text{ m/s}^2}$$

and $$t = \frac{-2h}{v_I} = \frac{-2(1.0 \times 10^{-2}\text{ m})}{-2.8\text{ m/s}} = 7.1 \times 10^{-3}\text{ s} = \boxed{7.1\text{ ms}}$$

(a) After 2.00 s, the velocity of the mailbag is

$$v_{\text{bag}} = v_0 + at = -1.50\text{ m/s} + (-9.80\text{ m/s}^2)(2.00\text{ s}) = -21.1\text{ m/s}$$

The negative sign tells us that the bag is moving downward and the magnitude of the velocity gives the speed as $\boxed{21.1\text{ m/s}}$.

(b) The displacement of the mailbag after 2.00 s is

During this time, the helicopter, moving downward with constant velocity, undergoes a displacement of

$$(y)_{copter} = v_0 t + \frac{1}{2} at^2 = (-1.5\ \text{m/s})(2.00\ \text{s}) + 0 = -3.00\ \text{m}$$

The distance separating the package and the helicopter at this time is then

$$d = |(y)_P - (y)_h| = |-22.6\ \text{m} - (-3.00\ \text{m})| = |-19.6\ \text{m}| = \boxed{19.6\ \text{m}}$$

(c) Here, $(v_0)_{bag} = (v_0)_{copter} = +1.50$ m/s and $a_{bag} = -9.80$ m/s^2 while $a_{copter} = 0$.

After 2.00 s, the velocity of the mailbag is

$$v_{bag} = 1.50\ \frac{\text{m}}{}.00\ \text{s}) = -18.1\ \frac{\text{m}}{}\ \text{and its speed is}\ v_{bag}\ |\ \ | = \boxed{18.1\ \frac{\text{m}}{\text{s}}}$$

In this case, the displacement of the helicopter during the 2.00 s interval is

$$\otimes y_{copier} = (+1.50\ \text{m/s})(2.00\ \text{s}) + 0 = +3.00\ \text{m}$$

Meanwhile, the mailbag has a displacement of

The distance separating the package and the helicopter at this time is then

$$d = |(\otimes y)_p - (\otimes y)_h| = |-16.6\text{ m} - (+3.00\text{ m})| = |-19.6\text{ m}| = \boxed{19.6\text{ m}}$$

(a) From the instant the ball leaves the player's hand until it is caught, the ball is a freely falling body with an acceleration of

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

(b) At its maximum height, the ball comes to rest momentarily and then begins to fall back downward. Thus, $v_{\substack{\text{max}\\\text{height}}} = \boxed{0}$.

(c) Consider the relation $\otimes y = v_0 t + \frac{1}{2}at^2$ with $a = -g$. When the ball is at the thrower's hand, the displacement is $\otimes y = 0$, giving

$$0 = v_0 t - \frac{1}{2}gt^2$$

This equation has two solutions, $t = 0$, which corresponds to when the ball was thrown, and $t = 2v_0/g$ corresponding to when the ball is caught. Therefore, if the ball is caught at $t = 2.00$ s, the initial velocity must have been

$$v_0 = \frac{gt}{2} = \frac{(9.80\text{ m/s}^2)(2.00\text{ s})}{2} = \boxed{9.80\text{ m/s}}$$

(d) From $v^2 = v_0^2 + 2a(\otimes y)$, with $v = 0$ at the maximum height,

$$(\otimes y)_{\text{max}} = \frac{v^2 - v_0^2}{2a} = \frac{0 - (9.80 \text{ m/s}^2)}{2(-9.80 \text{ m/s}^2)} = \boxed{4.90 \text{ m}}$$

(a) Let $t = 0$ be the instant the package leaves the helicopter, so the package and the helicopter have a common initial velocity of $v_i = -v_0$ (choosing upward as positive).

At times $t > 0$, the velocity of the package (in free-fall with constant acceleration $a_p = -g$) is given by $v = v_i + at$ as $v_p = -v_0 - gt = -(v_0 + gt)$ and $speed = |v_p| = v_0 + gt$.

(b) After an elapsed time t, the downward displacement of the package from its point of release will be

$$(\otimes y)_P = v_i t + \frac{1}{2} a_P t^2 = -v_0 t - \frac{1}{2} g t^2 = -\left(v_0 t + \frac{1}{2} g t^2\right)$$

and the downward displacement of the helicopter (moving with constant velocity, or acceleration $a_h = 0$) from the release point at this time is

$$(\otimes y)_h = v_i t + \frac{1}{2} a_h t^2 = -v_0 t + 0 = -v_0 t$$

The distance separating the package and the helicopter at this time is then

(c) If the helicopter and package are moving upward at the instant of release, then the common initial velocity is $v_i = +v_0$. The accelerations of the helicopter (moving with constant velocity) and the package (a freely falling object) remain unchanged from the previous case ($a_p = -g$ and $a_h = 0$).

In this case, the package speed at time $t > 0$ is $|v_P| = |v_i + a_p t| = \boxed{|v_0 - gt|}$.

At this time, the displacements from the release point of the package and the helicopter are given by

$$(\Delta y)_p = v_i t + \frac{1}{2} a_p t^2 = v_0 t - \frac{1}{2} g t^2 \quad \text{and}$$

$$(\Delta y)_h = v_i t + \frac{1}{2} a_h t^2 = v_0 t + 0 = +v_0 t$$

The distance separating the package and helicopter at time t is now given by

$$d = \left|(\Delta y)_p - (\Delta y)_h\right| = \left|v_0 t - \frac{1}{2} g t^2 - v_0 t\right| = \boxed{\frac{1}{2} g t^2} \quad \text{(the same as earlier!)}$$

(a) After its engines stop, the rocket is a freely falling body. It continues upward, slowing under the influence of gravity until it comes to rest momentarily at its maximum altitude. Then it falls back to Earth, gaining speed as it falls.

(b) When it reaches a height of 150 m, the speed of the rocket is

$$v = \sqrt{v_0^2 + 2a(\otimes y)} = \sqrt{(50.0\text{ m/s})^2 + 2(2.00\text{ m/s}^2)(150\text{ m})} = 55.7\text{ m/s}$$

After the engines stop, the rocket continues moving upward with an initial velocity of $v_0 = 55.7$ m/s and acceleration $a = -g = -9.80\text{ m/s}^2$.

When the rocket reaches maximum height, $v = 0$. The displacement of the rocket above the point where the engines stopped (that is, above the 150 m level) is

$$\otimes y = \frac{v^2 - v_0^2}{2a} = \frac{0 - (55.7\text{ m/s})^2}{2(-9.80\text{ m/s}^2)} = 158\text{ m}$$

The maximum height above ground that the rocket reaches is then given by $h_{max} = 150\text{ m} + 158\text{ m} = \boxed{308\text{ m}}$

(c) The total time of the upward motion of the rocket is the sum of two intervals. The first is the time for the rocket to go from $v_0 = 50.0$ m/s at the ground to a velocity of $v = 55.7$ m/s at an altitude of 150 m. This time is given by

$$t_1 = \frac{(\Delta y)_1}{\bar{v}_1} = \frac{(\Delta y)_1}{(v + v_0)/2} = \frac{2(150 \text{ m})}{(55.7 + 50.0)\text{ m/s}} = 2.84 \text{ s}$$

The second interval is the time to rise 158 m starting with $v_0 = 55.7$ m/s and ending with $v = 0$. This time is

$$t_2 = \frac{(\Delta y)_2}{\bar{v}_2} = \frac{(\Delta y)_2}{(v + v_0)/2} = \frac{2(158 \text{ m})}{0 + 55.7 \text{ m/s}} = 5.67 \text{ s}$$

The total time of the upward flight is then $t_{ap} = t_1 + t_2 =$ (2.84 + 5.67) s = $\boxed{8.51 \text{ s}}$

(d) The time for the rocket to fall 308 m back to the ground, with $v_0 = 0$ and acceleration $a = -g = -9.80 \text{ m/s}^2$, is found from $\Delta y = v_0 t + \frac{1}{2}at^2$ as

$$t_{\text{down}} = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-308 \text{ m})}{-9.80 \text{ m/s}^2}} = 7.93 \text{ s}$$

so the total time of the flight is $t_{\text{flight}} = t_{\text{up}} + t_{\text{down}} = (8.51 + 7.93)$ s = $\boxed{16.4 \text{ s}}$.

(a) For the upward flight of the ball, we have $v_i = v_0$, $v_f = 0$, $a = -g$, and Δt = 3.00 s. Thus, $v_f = v_i + a(\Delta t)$ gives the initial velocity as

$$v_i = v_f - a(\Delta t) = v_f + g(\Delta t) \text{ or } v_0 = 0 + (9.80 \text{ m/s}^2)(3.00 \text{ s}) = \boxed{+29.4 \text{ m/s}}$$

(b) The vertical displacement of the ball during this 3.00-s upward flight is

During the 0.600 s required for the rig to pass completely onto the bridge, the f r o m t b u p er of the tractor moves a distance equal to the length of the rig at constant velocity of v = 100n km/h. Therefore the length of the rig is

While some part of the rig is on the bridge, the front bumper moves a distance $\otimes x = L_{\text{bridge}} + L_{\text{rig}} = 100\text{ m} + 16.7\text{ m}$. With a constant velocity of v = 100 km/h, the time for this to occur is

(a) The acceleration **(b)** The distance traveled while stopping is found from

(a) The acceleration of the bullet is

$$a = \frac{v^2 - v_0^2}{2(\otimes x)} = \frac{(300\text{ m/s})^2 - (400\text{ m/s})^2}{2(0.100\text{ m})} = \boxed{-3.50 \times 10^5\text{ m/s}^2}$$

(b) The time of contact with the board is

$$t = \frac{v - v_0}{a} = \frac{(300 - 400)\text{ m/s}}{-3.50 \times 10^5\text{ m/s}^2} = \boxed{2.86 \times 10^{-4}\text{ s}}$$

(a) From $\otimes x = v_0 t + \frac{1}{2}at^2$, we have

$$100\ \text{m} = (30.0\ \text{m/s})t + \frac{1}{2}(-3.50\ \text{m/s}^2)t^2$$

This reduces to $3.50t^2 + (-60.0\text{ s})t + (200\text{ s}^2) = 0$, and the quadratic formula gives

$$t = \frac{-(-60.0\text{ s}) \pm \sqrt{(-60.0\text{ s})^2 - 4(3.50)(200\text{ s}^2)}}{2(3.50)}$$

The desired time is the smaller solution of $t = \boxed{4.53\text{ s}}$. The larger solution of $t = 12.6$ s is the time when the boat would pass the buoy moving backwards, assuming it maintained a constant acceleration.

(b) The velocity of the boat when it first reaches the buoy is

$v = v_0 + at = 30.0\text{ m/s} + (-350\text{ m/s}^2)(4.53\text{ s}) = \boxed{14.1\text{ m/s}}$

(a) The keys have acceleration $a = -g = -9.80\text{ m/s}^2$ from the release point until they are caught 1.50 s later. Thus, $\otimes y = v_0 t + \frac{1}{2}at^2$ gives

$$v_0 = \frac{\otimes y - at^2/2}{t} = \frac{(+4.00\text{ m}) - (-9.80\text{ m/s}^2)(1.50\text{ s})^2/2}{1.50\text{ s}} = +10.0\text{ m/s}$$

or $v_0 = \boxed{10.0\text{ m/s upward}}$

(b) The velocity of the keys just before the catch was

$$v = v_0 + at = 10.0\text{ m/s} + (-9.80\text{ m/s}^2)(1.50\text{ s}) = -4.70\text{ m/s}$$

or $v = \boxed{4.70\text{ m/s downward}}$

(a) While in the air after launching itself from the water, the salmon's vertical acceleration is $a_y = -g = -9.80\text{ m/s}^2$. Assume it comes to rest at the top of its vertical leap, a distance $\otimes y = 3.60$ m above the bottom ofthe waterfall. From the time-independent kinematic equation, with the final velocity $v = 0$, the initial speed v_0 is

$$v^2 = v_0^2 - 2g(\otimes y)$$

$$v_0 = \sqrt{2g(\otimes y} = \sqrt{2(9.80\text{ m/s}^2)(3.6\text{ m})}$$

$$v_0 = \boxed{8.4\text{ m/s}}$$

(a) From $v^2 = v_0^2 + 2a(\otimes y)$, the insect's velocity after straightening its legs is

$$v = \sqrt{v_0^2 + 2a(\otimes y)} = \sqrt{0 + 2(4\,000\ \text{m/s}^2)(2.0 \times 10^{-3}\ \text{m})} = \boxed{4.0\ \text{m/s}}$$

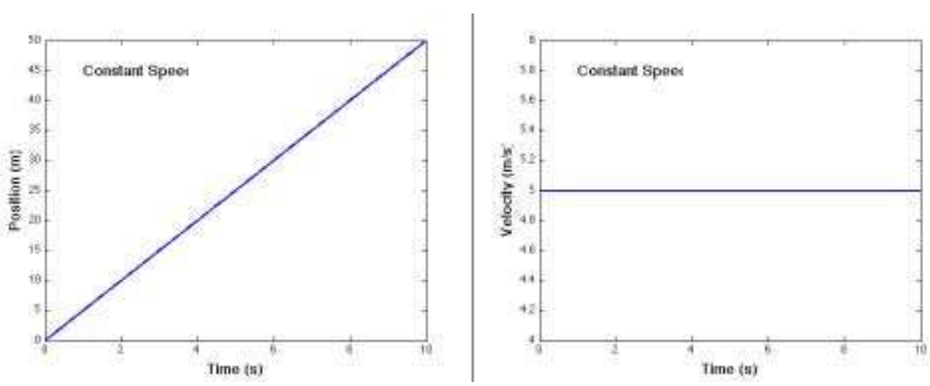
(b) The time to reach this velocity is

$$t = \frac{v - v_0}{a} = \frac{4.0\ \text{m/s} - 0}{4\ 000\ \text{m/s}^2} = 1.0 \times 10^{-3}\ \text{s} = \boxed{1.0\ \text{ms}}$$

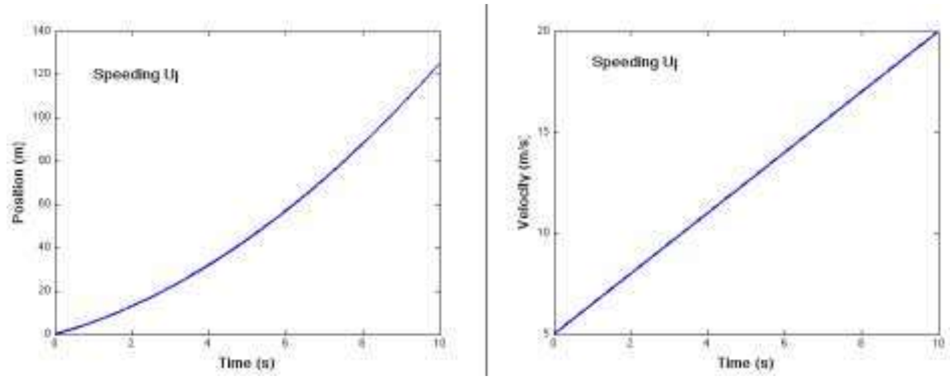
(c) The upward displacement of the insect between when its feet leave the ground and it comes to rest momentarily at maximum altitude is

$$\otimes y = \frac{v^2 - v_0^2}{2a} = \frac{0 - v_0^2}{2(-g)} = \frac{-(4.0\ \text{m/s})^2}{2(-9.8\ \text{m/s}^2)} = \boxed{0.82\ \text{m}}$$

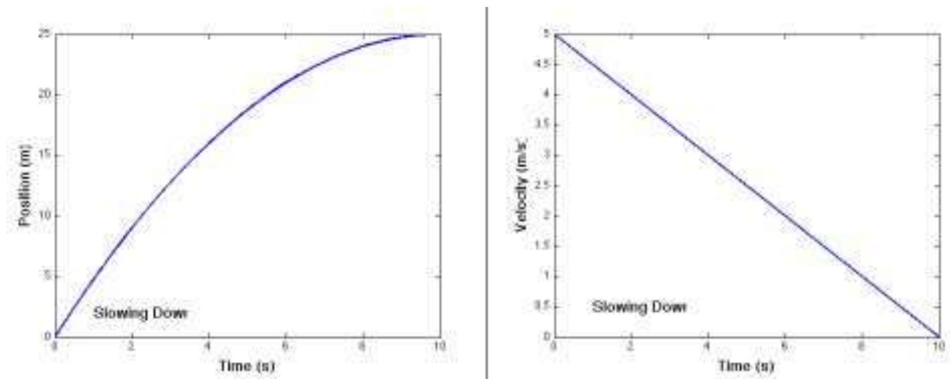
(a) For constant speed:



(b) When speeding up at a constant rate:



(c) When slowing down at a constant rate:



The falling ball moves a distance of (15 m – *h*) before they meet, where *h* is the height above the ground where they meet. Apply $\otimes y = v_0 t + \frac{1}{2}at^2$, with $a = -g$, to obtain

$$-(15\text{ m} - h) = 0 - \frac{1}{2}gt^2 \qquad \text{or} \qquad h = 15\text{ m} - \frac{1}{2}gt^2 \quad [1]$$

Applying $\otimes y = v_0 t + \frac{1}{2}at^2$ to the rising ball gives

$$h = (25\text{ m/s})t - \frac{1}{2}gt^2 \qquad [2]$$

Combining Equations [1] and [2] gives

$$(25\text{ m/s})t - \cancel{\frac{1}{2}gt^2} = 15\text{ m} - \cancel{\frac{1}{2}gt^2}$$

or $$t = \frac{15\text{ m}}{25\text{ m/s}} = \boxed{0.60\text{ s}}$$

(a) When the ball hits the ground, its change in height will be $\otimes y = -h$.

Solve for the final speed of each ball using the time-independent kinematic equation:

$$v^2 = v_0^2 - 2g(\otimes y)$$

$$v = \sqrt{(\pm v_0)^2 - 2g(-h)} = \boxed{\sqrt{v_0^2 + 2gh}}$$

(b) We're asked to find an expression for the time difference $\otimes t$ between the times of flight for the upward- and downward-thrown balls.

For the upward-thrown ball, the path to the ground can be separated into two parts. In the first part the ball rises with initial velocity $+v_0$ and falls back to its original height where its velocity is $-v_0$. In the second part it moves from height h to the ground in exactly the same time it takes the downward-thrown ball to reach the ground. The difference between the two ball's times of flight is therefore equal to the time for the first part of the upward-thrown ball's path. That time is found using the first kinematic equation with $v_0 = +v_0$ and $v = -v_0$:

$$v = v_0 - g \otimes t$$

$$\otimes t = \frac{v - v_0}{-g} = \frac{-v_0 - v_0}{-g} = \boxed{\frac{2v_0}{g}}$$

From the time-independent kinematic equation with $v_0 > 0$, $\otimes y = 2.00$ m, and $v = \pm 1.50$ m/s:

$$v^2 = v_0^2 - 2g(\otimes y)$$

$$v_0 = \sqrt{v^2 + 2g(\otimes y)} = \sqrt{(\pm 1.50 \text{ m/s})^2 + 2g(2.00 \text{ m})} = \boxed{6.44 \text{ m/s}}$$

(a) To find the distance $\otimes x$ traveled by the blood during the acceleration, apply the time-independent kinematic equation with $v_0 = 0$, $v = 1.05$ m/s, and $a = 22.5$ m/s^2:

$$v^2 = v_0^2 + 2a\otimes x$$

$$\otimes x = \frac{v^2 - v_0^2}{2a} = \frac{(1.05 \text{ m/s})^2 - 0}{2(22.5 \text{ m/s}^2)} = \boxed{2.45 \times 10^{-2} \text{ m}} = 2.45 \text{ cm}$$

(b) Solve for the time t required for the blood to reach its peak speed using the first kinematic equation:

$$v = v_0 + at$$

$$t = \frac{v - v_0}{a} = \frac{(1.05\ \text{m/s}) - 0}{22.5\ \text{m/s}^2} = \boxed{4.67 \times 10^{-2}\ \text{s}}$$

When released from rest ($v_0 = 0$), the bill falls freely with a downward

acceleration due to gravity ($a = -g = -9.80\ \text{m/s}^2$). Thus, the magnitude of its downward displacement during David's 0.2 s reaction time will be

$$|\otimes y| = \left|v_0 t + \frac{1}{2}at^2\right| = \left|0 + \frac{1}{2}(-9.80\ \text{m/s}^2)(0.2\ \text{s})^2\right| = 0.2\ \text{m} = 20\ \text{cm}$$

This is over twice the distance from the center of the bill to its top edge (≈8 cm), so $\boxed{\text{David will be unsuccessful}}$.

(a) The velocity with which the first stone hits the water is

$$v_1 = -\sqrt{v_{01}^2 + 2a(\otimes\ y)} = - \qquad = -31.4\ \frac{\text{m}}{\text{s}}$$

The time for this stone to hit the water is

$$t_1 = \frac{v_1 - v_{01}}{a} = \frac{[-31.4\ \text{m/s} - (-2.00\ \text{m/s})]}{-9.80\ \text{m/s}^2} = \boxed{3.00\ \text{s}}$$

(b) Since they hit simultaneously, the second stone, which is released 1.00 s later, will hit the water after an flight time of 2.00 s. Thus,

$$v_{02} = \frac{\otimes y - at_2^2/2}{t_2} = \frac{-50.0\ \text{m} - (-9.80\ \text{m/s}^2)(2.00\ \text{s})^2/2}{2.00\ \text{s}} = \boxed{-15.2\ \text{m/s}}$$

(c) From part (a), the final velocity of the first stone is $v_1 = -31.4$ m/s.

The final velocity of the second stone is

$$v_2 = v_{02} + at_2 = -15.2\text{ m/s} + (-9.80\text{ m/s}^2)(2.00\text{ s}) = \boxed{-34.8\text{ m/s}}$$

When the hare wakes up, the tortoise is a distance $L > 0$ from the finish line whereas the hare is a distance $L + d$ from the finish line. The hare, running with constant speed v_1, reaches the finish line in a time given by

$$t_{\text{hare}} = \frac{L + d}{v_1}$$

The tortoise, crawling with constant speed $v_2 < v_1$, reaches the finish line in a time given by

$$t_{\text{tortoise}} = \frac{L}{v_2}$$

The tortoise wins the race if $t_{\text{tortoise}} < t_{\text{hare}}$, so it follows that

$$\frac{L}{v_2} < \frac{L + d}{v_1}$$

Rearrange this expression to find a condition on the length L:

$$Lv_1 < Lv_2 + v_2 d \;\rightarrow\; L < \frac{v_2 d}{v_1 - v_2}$$

The tortoise wins the race if the length to the finish line, L, satisfies that inequality.

(a) From $\Delta y = v_0 t + \frac{1}{2}at^2$ with $v_0 = 0$, we have

$$t = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-23\ \text{m})}{-9.80\ \text{m/s}^2}} = \boxed{2.2\ \text{s}}$$

(b) From the time-independent velocity equation, the final speed is:

$$v^2 = v_0^2 - 2g\,\Delta y$$
$$v = \sqrt{2g\Delta} = \sqrt{2(-9.80\ \text{m/s}^2)(-23\ \text{m})}$$
$$= 21\ \text{m/s}$$

Because the man is falling, his final velocity is $v = \boxed{-21\ \text{m/s}}$.

(c) The time it takes for the sound of the impact to reach the spectator is

$$t_{\text{sound}} = \frac{\Delta y}{v_{\text{sound}}} = \frac{23\ \text{m}}{340\ \text{m/s}} = 6.8 \times 10^{-2}\ \text{s}$$

so the total elapsed time is $t_{\text{total}} = 2.2\ \text{s} + 6.8 \times 10^{-2}\ \text{s} \approx \boxed{2.3\ \text{s}}$.

The time required for the stuntman to fall 3.00 m, starting from rest, is

found from $\Delta y = v_0 t + \frac{1}{2}at^2$ as

$$-3.00\ \text{m} = 0 + \frac{1}{2}(-9.80\ \text{m/s}^2)t^2 \qquad \text{so} \qquad t = \sqrt{\frac{2(3.00\ \text{m})}{9.80\ \text{m/s}^2}} = 0.782\ \text{s}$$

(a) With the horse moving with constant velocity of 10.0 m/s, the

horizontal distance is

$$\Delta x = v_{\text{horse}}t = (10.0\ \text{m/s})(0.782\ \text{s}) = \boxed{7.82\ \text{m}}$$

(b) The required time is $\boxed{t = 0.782\ \text{s}}$ as calculated above.