Chapter 2

One-Dimensional Kinematics

Answers to Even-numbered Conceptual Questions

2. An odometer measures the distance traveled by a car. You can tell this by the fact that an odometer has a nonzero reading after a round trip.

4. No. After one complete orbit the astronaut's displacement is zero. The distance traveled, however, is roughly 25,000 miles.

6. A speedometer measures speed, not velocity. For example, if you drive with constant speed in a circular path your speedometer maintains the same reading, even though your velocity is constantly changing.

8. Yes. For example, your friends might have backed out of a parking place at some point in the trip, giving a negative velocity for a short time.

10. No. If you throw a ball upward, for example, you might choose the release point to be $y = 0$. This doesn't change the fact that the initial upward speed is nonzero.

12. Bow B gives the greater acceleration. It accelerates the arrow to the same speed as bow A, but in a shorter distance.

14. **(a)** Yes. The object might simply be at rest. **(b)** Yes. An example would be a ball thrown straight upward; at the top of its trajectory its velocity is zero, but it has a nonzero acceleration downward.

16. Yes. A ball thrown straight upward and caught when it returns to its release point has zero average velocity, but it has been accelerating the entire time.

18. When she returns to her original position, her speed is the same as it was initially; that is, 4.5 m/s.

20. **(a)** No. Displacement is the *change* in position, and therefore it is independent of the location chosen for the origin. **(b)** Yes. In order to know whether an object's displacement is positive or negative, we need to know which direction has been chosen to be positive.

22. (ii) The balls have the same speed just before they land because they both have the same downward speed when they are at the level of the roof. Ball B simply starts off with the speed v_0 downward. Ball A travels upward initially, but when it returns to the level of the roof it is moving downward with the speed v_0, just like ball B.

Solutions to Problems

1. (a) $\text{distance} = 0.75\text{ mi} + 0.60\text{ mi} + 0.60\text{ mi} = \boxed{1.95\text{ mi}}$

(b) $\Delta x = x_\text{f} - x_\text{i} = 0.75\text{ mi} - 0 = \boxed{0.75\text{ mi}}$

2. **(a)** distance $= 0.60\text{ mi} + 0.35\text{ mi} + 0.35\text{ mi} + 0.60\text{ mi} + 0.75\text{ mi} = \boxed{2.65\text{ mi}}$

(b) $\Delta x = x_\text{f} - x_\text{i} = -0.75\text{ mi} - 0 = \boxed{-0.75\text{ mi}}$

3. **(a)** distance = 10 m + 2.5 m + 2.5 m = $\boxed{15\text{ m}}$

(b) $\Delta x = x_\text{f} - x_\text{i} = 10\text{ m} - 0 = \boxed{10\text{ m}}$

4. **(a)** $\boxed{\text{distance} = 5\text{ m}}$

$\Delta x = x_\text{f} - x_\text{i} = 5\text{ m} - 0 = \boxed{5\text{ m}}$

(b) $\boxed{\text{distance} = 2\text{ m}}$

$\Delta x = x_\text{f} - x_\text{i} = 5\text{ m} - 7\text{ m} = \boxed{-2\text{ m}}$

5. **(a)** distance $= \dfrac{30}{2}\text{ m} + 100\text{ m} + \dfrac{30}{2}\text{ m} = \boxed{130\text{ m}}$

$\Delta x = x_\text{f} - x_\text{i} = 100\text{ m} - 0 = \boxed{100\text{ m}}$

(b) distance $= 2(130\text{ m}) = \boxed{260\text{ m}}$

$\Delta x = x_\text{f} - x_\text{i} = 0 - 0 = \boxed{0}$

6. **(a)** $C = 2\pi r$

distance $= \dfrac{1}{2}C = \pi r = \pi(5.0\text{ m}) = \boxed{16\text{ m}}$

$\Delta x = 2r = 2(5.0\text{ m}) = \boxed{10\text{ m}}$

(b) $\boxed{\text{The distance increases. The displacement decreases.}}$

(c) $C = 2\pi r = 2\pi(5.0\text{ m}) = \boxed{31\text{ m}}$

The displacement is $\boxed{0}$ since the child and pony have returned to the same place.

7. $s_\text{av} = \dfrac{d}{t} = \dfrac{200\text{ m}}{19.75\text{ s}} = \boxed{10.1\text{ m/s}} = \left(\dfrac{10.13\text{ m}}{\text{s}}\right)\left(\dfrac{3600\text{ s}}{\text{h}}\right)\left(\dfrac{1\text{ mi}}{1609\text{ m}}\right) = \boxed{22.7\text{ mi/h}}$

8. $s_\text{av} = \dfrac{d}{t} = \dfrac{100\text{ m}}{54.64\text{ s}} = \boxed{1.83\text{ m/s}} = \left(\dfrac{1.83\text{ m}}{\text{s}}\right)\left(\dfrac{3600\text{ s}}{\text{h}}\right)\left(\dfrac{1\text{ mi}}{1609\text{ m}}\right) = \boxed{4.09\text{ mi/h}}$

9. $d = s_\text{av}t = \left(\dfrac{65\text{ km}}{\text{h}}\right)(2\text{ min})\left(\dfrac{1\text{ h}}{60\text{ min}}\right) = \boxed{2.2\text{ km}}$

10. average speed $= \frac{d}{t} = \frac{1600\text{ mi}}{10\text{ months}} = 160\ \frac{\text{mi}}{\text{month}}$

hours in one month $= \left(\frac{365\text{ days}}{12\text{ months}}\right)\left(\frac{24\text{ h}}{\text{day}}\right) = 730\ \frac{\text{h}}{\text{month}}$

seconds in one month $= \left(\frac{730\text{ h}}{\text{month}}\right)\left(\frac{60\text{ min}}{\text{h}}\right)\left(\frac{60\text{ s}}{\text{min}}\right) = 2,628,000\ \frac{\text{s}}{\text{month}}$

average speed in $\frac{\text{mi}}{\text{h}} = \left(\frac{160\text{ mi}}{\text{month}}\right)\left(\frac{1\text{ month}}{730\text{ h}}\right) = \boxed{0.22\text{ mi/h}}$

average speed in $\frac{\text{m}}{\text{s}} = \left(\frac{160\text{ mi}}{\text{month}}\right)\left(\frac{1\text{ month}}{2,628,000\text{ s}}\right)\left(\frac{1609\text{ m}}{\text{mi}}\right) = \boxed{0.098\text{ m/s}}$

11. $t = \frac{d}{s_{\text{av}}} = \frac{2(2.39\times10^5\text{ mi})}{1.86\times10^5\ \frac{\text{mi}}{\text{s}}} = \boxed{2.57\text{ s}}$

12. $d = s_{\text{av}}t = \left(\frac{340\text{ m}}{\text{s}}\right)(3.5\text{ s}) = \boxed{1200\text{ m}}$

13. An arm is approximately 1 m in length.

$t = \frac{d}{s_{\text{av}}} = \frac{1\text{ m}}{10^2\ \frac{\text{m}}{\text{s}}} = 10^{-2}\text{ s} = \boxed{10\text{ ms}}$

14. Assume that hair grows 1 ft per year.

$\left(\frac{1\text{ ft}}{\text{y}}\right)\left(\frac{1\text{ mi}}{5280\text{ ft}}\right)\left(\frac{1\text{ y}}{365\text{ d}}\right)\left(\frac{1\text{ d}}{24\text{ h}}\right) = \boxed{2\times10^{-8}\text{ mi/h}}$

15. $d = \left(0.060\ \frac{\text{m}}{\text{s}}\right)(2.0\text{ min})\left(\frac{60\text{ s}}{\text{min}}\right) + \left(12\ \frac{\text{m}}{\text{s}}\right)(2.0\text{ min})\left(\frac{60\text{ s}}{\text{min}}\right) = 1447.2\text{ m}$

$s_{\text{av}} = \frac{d}{t} = \frac{1447.2\text{ m}}{(4\text{ min})\left(\frac{60\text{ s}}{\text{min}}\right)} = \boxed{6.0\text{ m/s}}$

16. Find the total time traveled.

$t = \frac{d}{s_{\text{av}}} = \frac{10.0\text{ mi}}{11\ \frac{\text{mi}}{\text{h}}} = \frac{10}{11}\text{ h}$

Find the time driven.

$\frac{10}{11}\text{ h} - \left(\frac{5\text{ mi}}{6\ \frac{\text{mi}}{\text{h}}}\right) = \frac{10}{11}\text{ h} - \frac{5}{6}\text{ h} = \frac{60}{66}\text{ h} - \frac{55}{66}\text{ h} = \frac{5}{66}\text{ h}$

The average speed driven is

$s_{\text{av}} = \frac{d}{t} = \frac{5\text{ mi}}{\frac{5}{66}\text{ h}} = \boxed{66\text{ mi/h}}$

17. Each owner will travel 5 m in time

$$t = \frac{d}{s_{\text{av}}} = \frac{5.00 \text{ m}}{1.3 \frac{\text{m}}{\text{s}}} = \frac{5.00}{1.3} \text{ s}$$

The dog will travel during this time

$$d = s_{\text{av}}t = \left(3.0 \frac{\text{m}}{\text{s}}\right)\left(\frac{5.00}{1.3}\text{s}\right) = \boxed{12 \text{ m}}$$

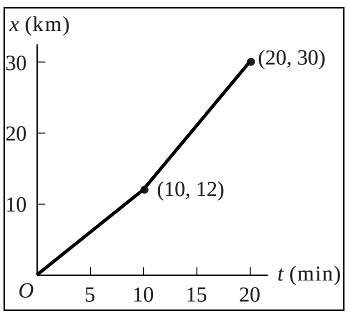
18. (a) Because you drive an equal period of time at each speed, the average speed is the average of the two speeds. Your average speed is $\boxed{25.0 \text{ m/s.}}$

(b) $$d_{20} = \left(20.0 \frac{\text{m}}{\text{s}}\right)(10.0 \text{ min})\left(\frac{60 \text{ s}}{\text{min}}\right) = 12{,}000 \text{ m}$$

$$d_{30} = \left(30.0 \frac{\text{m}}{\text{s}}\right)(10.0 \text{ min})\left(\frac{60 \text{ s}}{\text{min}}\right) = 18{,}000 \text{ m}$$

$$s_{\text{av}} = \frac{d}{\Delta t} = \left(\frac{12{,}000 \text{ m}+18{,}000 \text{ m}}{20.0 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right) = \boxed{25.0 \text{ m/s}}$$

19. (a)



(b) $$s_{\text{av}} = \frac{d}{\Delta t} = \left(\frac{12{,}000 \text{ m} + 9{,}000 \text{ m}}{15 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right) = \boxed{23.3 \text{ m/s}}$$

20. (a) Because you must drive for a longer time at the lower speed to travel the same distance, your average speed is $\boxed{\text{less than } 25.0 \text{ m/s.}}$

(b) $$\Delta t_{20} = \left(\frac{10.0 \text{ mi}}{20.0 \frac{\text{m}}{\text{s}}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1609 \text{ m}}{\text{mi}}\right) = 0.2235 \text{ h}$$

$$\Delta t_{30} = \left(\frac{10.0 \text{ mi}}{30.0 \frac{\text{m}}{\text{s}}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1609 \text{ m}}{\text{mi}}\right) = 0.1490 \text{ h}$$

$$s_{\text{av}} = \frac{d}{\Delta t} = \left(\frac{20 \text{ mi}}{0.2235 \text{ h} + 0.1490 \text{ h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) \times \left(\frac{1609 \text{ m}}{\text{mi}}\right) = \boxed{24.0 \text{ m/s}}$$

21. (a)

A	B	C	D
+	0	+	–

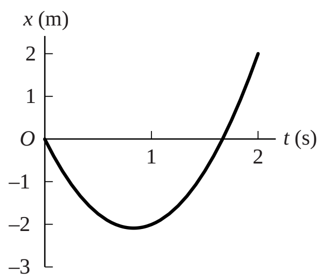
(b) $v_A = \dfrac{2\text{ m} - 0}{1\text{ s} - 0} = \boxed{2\text{ m/s, +}}$

$v_B = \dfrac{2\text{ m} - 2\text{ m}}{2\text{ s} - 1\text{ s}} = \dfrac{0}{1\text{ s}} = \boxed{0}$

$v_C = \dfrac{3\text{ m} - 2\text{ m}}{3\text{ s} - 2\text{ s}} = \dfrac{1\text{ m}}{1\text{ s}} = \boxed{1\text{ m/s, +}}$

$v_D = \dfrac{0\text{ m} - 3\text{ m}}{5\text{ s} - 3\text{ s}} = \dfrac{-3\text{ m}}{2\text{ s}} = \boxed{-1.5\text{ m/s, } -}$

22. (a)



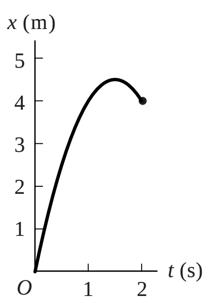
(b) $x(t = 0\text{ s}) = \left(-5.5\ \dfrac{\text{m}}{\text{s}}\right)(0) + \left(3.5\ \dfrac{\text{m}}{\text{s}^2}\right)(0)^2 = 0\text{ m}$

$x(t = 1\text{ s}) = \left(-5.5\ \dfrac{\text{m}}{\text{s}}\right)(1\text{ s}) + \left(3.5\ \dfrac{\text{m}}{\text{s}^2}\right)(1\text{ s})^2 = -5.5\text{ m} + 3.5\text{ m} = -2\text{ m}$

$v_{av} = \dfrac{\Delta x}{\Delta t} = \dfrac{-2\text{ m}-0\text{ m}}{1\text{ s}-0\text{ s}} = \dfrac{-2\text{ m}}{1\text{ s}} = \boxed{-2\text{ m/s}}$

(c) $s_{av} = \dfrac{d}{t} = \dfrac{2\text{ m}}{1\text{ s}} = \boxed{2\text{ m/s}}$

23. (a)



(b) $x(t = 0\text{ s}) = \left(6\ \dfrac{\text{m}}{\text{s}}\right)(0\text{ s}) + \left(-2\ \dfrac{\text{m}}{\text{s}^2}\right)(0\text{ s})^2 = 0\text{ m}$

$x(t = 1\text{ s}) = \left(6\ \dfrac{\text{m}}{\text{s}}\right)(1\text{ s}) + \left(-2\ \dfrac{\text{m}}{\text{s}^2}\right)(1\text{ s})^2 = 6\text{ m} - 2\text{ m} = 4\text{ m}$

$v_{av} = \dfrac{\Delta x}{\Delta t} = \dfrac{4\text{ m}-0\text{ m}}{1\text{ s}-0\text{ s}} = \boxed{4\text{ m/s}}$

(c) $s_{av} = \dfrac{4\text{ m}}{1\text{ s}} = \boxed{4\text{ m/s}}$

24. (a) B

(b) $s_A = \left|\frac{1\text{ m} - 3\text{ m}}{2\text{ s} - 0}\right| = \left|\frac{-2\text{ m}}{2\text{ s}}\right| = \boxed{1\text{ m/s}}$

$s_B = \left|\frac{3\text{ m} - 1\text{ m}}{3\text{ s} - 2\text{ s}}\right| = \left|\frac{2\text{ m}}{1\text{ s}}\right| = \boxed{2\text{ m/s}}$

$s_C = \left|\frac{2\text{ m} - 3\text{ m}}{5\text{ s} - 3\text{ s}}\right| = \left|\frac{-1\text{ m}}{2\text{ s}}\right| = \boxed{0.5\text{ m/s}}$

$s_B > s_A > s_C$

25. The distance traveled for the first 15 min is:

$d = s_{av}t = \left(5\ \frac{\text{mi}}{\text{h}}\right)\left(\frac{1}{4}\text{h}\right) = \frac{5}{4}\text{ mi}$

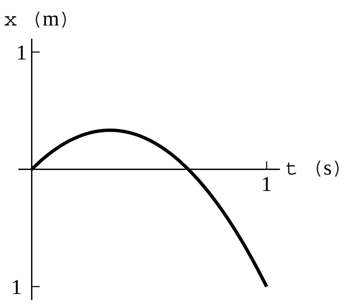
The distance left to travel is

$10\text{ mi} - \frac{5}{4}\text{ mi} = \frac{40}{4}\text{ mi} - \frac{5}{4}\text{ mi} = \frac{35}{4}\text{ mi}$

The average speed needed is

$s_{av} = \frac{d}{t} = \frac{\frac{35}{4}\text{ mi}}{\frac{1}{4}\text{ h}} = \boxed{35\text{ mi/h}}$

26. (a)



(b) $x(t = 0.45\text{ s}) = \left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.45\text{ s}) + \left(-3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.45\text{ s})^2 = 0.2925\text{ m}$

$x(t = 0.55\text{ s}) = \left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.55\text{ s}) + \left(-3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.55\text{ s})^2 = 0.1925\text{ m}$

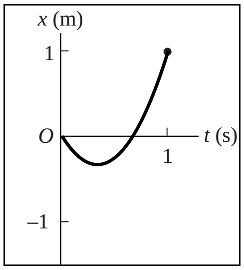
$v_{av} = \frac{\Delta x}{\Delta t} = \frac{0.1925\text{ m}–0.2925\text{ m}}{0.55–0.45\text{ s}} = \frac{-0.10\text{ m}}{0.10\text{ s}} = \boxed{-1.0\text{ m/s}}$

(c) $x(t = 0.49\text{ s}) = \left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.49\text{ s}) + \left(-3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.49\text{ s})^2 = 0.2597\text{ m}$

$x(t = 0.51\text{ s}) = \left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.51\text{ s}) + \left(-3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.51\text{ s})^2 = 0.2397\text{ m}$

$v_{av} = \frac{\Delta x}{\Delta t} = \frac{0.2397\text{ m} - 0.2597\text{ m}}{0.51\text{ s} - 0.49\text{ s}} = \frac{-0.02\text{ m}}{0.02\text{ s}} = \boxed{-1\text{ m/s}}$

27. (a)



(b) $x(t=0.15\text{ s}) = -\left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.15\text{ s}) + \left(3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.15\text{ s})^2 = -0.2325\text{ m}$

$x(t=0.25\text{ s}) = \left(-2.0\ \frac{\text{m}}{\text{s}}\right)(0.25\text{ s}) + \left(3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.25\text{ s})^2 = -0.3125\text{ m}$

$$v_{\text{av}} = \frac{\Delta x}{\Delta t} = \frac{-0.3125\text{ m}-(-0.2325\text{ m})}{0.25\text{ s}-0.15\text{ s}} = \boxed{-0.80\ \text{m/s}}$$

(c) $x(t=0.19\text{ s}) = -\left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.19\text{ s}) + \left(3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.19\text{ s})^2 = -0.2717\text{ m}$

$x(t=0.21\text{ s}) = -\left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.21\text{ s}) + \left(3.0\ \frac{\text{m}}{\text{s}^2}\right)(0.21\text{ s})^2 = -0.2877\text{ m}$

$$v_{\text{av}} = \frac{\Delta x}{\Delta t} = \frac{-0.2717\text{ m}-(-0.2877)\text{ m}}{0.19\text{ s}-0.21\text{ s}} = \boxed{-0.8\ \text{m/s}}$$

28. $$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{v_\text{f}-v_\text{i}}{t_\text{f}-t_\text{i}} = \left(\frac{173\ \frac{\text{mi}}{\text{h}}-0}{35.2\text{ s}-0}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1609\text{ m}}{\text{mi}}\right) = \boxed{2.20\ \text{m/s}^2}$$

29. (a) At $t = 2.0$ s the runner is still accelerating.

$$s(t=2.0\text{ s}) = at = \left(1.9\ \frac{\text{m}}{\text{s}^2}\right)(2.0\text{ s}) = \boxed{3.8\ \text{m/s}}$$

(b) The runner's speed at the end of the race is the same as that at $t = 2.2$ s.

$$s(t=2.2\text{ s}) = at = \left(1.9\ \frac{\text{m}}{\text{s}^2}\right)(2.2\text{ s}) = \boxed{4.2\ \text{m/s}}$$

30. Choose east as the direction of positive acceleration.

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{0\ \frac{\text{m}}{\text{s}}-115\ \frac{\text{m}}{\text{s}}}{13.0\text{ s}-0\text{ s}} = -8.85\ \text{m/s}^2$$

The negative sign indicates acceleration in the western direction, so $\boxed{a_{\text{av}} = 8.85\ \text{m/s}^2,\ \text{due west}}$.

31. Choose north as the positive direction.

(a) $v = 20.7\ \frac{\text{m}}{\text{s}} + \left(1.60\ \frac{\text{m}}{\text{s}^2}\right)(7.50\text{ s}) = 32.7\ \frac{\text{m}}{\text{s}} = \boxed{32.7\ \text{m/s north}}$

(b) $v = 20.7\ \frac{\text{m}}{\text{s}} + \left(-1.95\ \frac{\text{m}}{\text{s}^2}\right)(7.50\ \text{s}) = 6.08\ \frac{\text{m}}{\text{s}} = \boxed{6.08\ \text{m/s north}}$

32. $a_\text{A} = \frac{\Delta v}{\Delta t} = \frac{10\ \frac{\text{m}}{\text{s}} - 0}{5\ \text{s} - 0} = \boxed{2\ \text{m/s}^2}$

$a_\text{B} = \frac{10\ \frac{\text{m}}{\text{s}} - 10\ \frac{\text{m}}{\text{s}}}{15\ \text{s} - 5\ \text{s}} = \frac{0}{10\ \text{s}} = \boxed{0}$

$a_\text{C} = \frac{5\ \frac{\text{m}}{\text{s}} - 10\ \frac{\text{m}}{\text{s}}}{25\ \text{s} - 15\ \text{s}} = \frac{-5\ \frac{\text{m}}{\text{s}}}{10\ \text{s}} = \boxed{-0.5\ \text{m/s}^2}$

33. Segment A:

$a = \frac{\Delta v}{\Delta t} = \frac{2\ \frac{\text{m}}{\text{s}} - 0\ \frac{\text{m}}{\text{s}}}{10\ \text{s}} = 0.2\ \frac{\text{m}}{\text{s}^2}$

$x - x_0 = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}\left(0.2\ \frac{\text{m}}{\text{s}^2}\right)(10\ \text{s})^2 = \boxed{10\ \text{m}}$

Segment B:

$a = \frac{\Delta v}{\Delta t} = \frac{6\ \frac{\text{m}}{\text{s}} - 2\ \frac{\text{m}}{\text{s}}}{5\ \text{s}} = 0.8\ \frac{\text{m}}{\text{s}^2}$

$x - x_0 = v_0 t + \frac{1}{2}at^2 = \left(2\ \frac{\text{m}}{\text{s}}\right)(5\ \text{s}) + \frac{1}{2}\left(0.8\ \frac{\text{m}}{\text{s}^2}\right)(5\ \text{s})^2 = \boxed{20\ \text{m}}$

Segment C:

$a = \frac{\Delta v}{\Delta t} = \frac{2\ \frac{\text{m}}{\text{s}} - 6\ \frac{\text{m}}{\text{s}}}{10\ \text{s}} = -0.4\ \frac{\text{m}}{\text{s}^2}$

$x - x_0 = v_0 t + \frac{1}{2}at^2 = \left(6\ \frac{\text{m}}{\text{s}}\right)(10\ \text{s}) + \frac{1}{2}\left(-0.4\ \frac{\text{m}}{\text{s}^2}\right)(10\ \text{s})^2 = \boxed{40\ \text{m}}$

34. $\Delta t = \frac{\Delta v}{a_\text{av}} = \frac{6.5\ \frac{\text{m}}{\text{s}} - 11\ \frac{\text{m}}{\text{s}}}{-1.81\ \frac{\text{m}}{\text{s}^2}} = \boxed{2.5\ \text{s}}$

35. (a) Because it is assumed that the car decelerates at a constant rate, doubling the driving speed will increase the time to stop by $\boxed{\text{a factor of two}}$.

(b) $\Delta t_{15} = \frac{\Delta v}{a_\text{av}} = \frac{0\ \frac{\text{m}}{\text{s}} - 16\ \frac{\text{m}}{\text{s}}}{-4.2\ \frac{\text{m}}{\text{s}^2}} = \boxed{3.8\ \text{s}}$

$\Delta t_{30} = \frac{\Delta v}{a_\text{av}} = \frac{0\ \frac{\text{m}}{\text{s}} - 32\ \frac{\text{m}}{\text{s}}}{-4.2\ \frac{\text{m}}{\text{s}^2}} = \boxed{7.6\ \text{s}}$

$\frac{\Delta t_{30}}{\Delta t_{15}} = \frac{7.6\ \text{s}}{3.8\ \text{s}} = 2$

The time to stop is doubled.

36. (a) Assuming constant acceleration,

$$v^2 - v_0{}^2 = 2a\Delta x$$
$$0 - v_0{}^2 = 2a\Delta x$$
$$v_0{}^2 = 2a\Delta x$$

It can be seen from this equation that if the speed is doubled, the braking distance $\boxed{\text{increases by a factor of 4}}$.

(b) $$\Delta x_{16} = \frac{v_0{}^2}{2a} = \frac{\left(16\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(4.2\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{30\ \text{m}}$$

$$\Delta x_{32} = \frac{v_0{}^2}{2a} = \frac{\left(32\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(4.2\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{120\ \text{m}}$$

$$\frac{\Delta x_{32}}{\Delta x_{16}} = \frac{120\ \text{m}}{30\ \text{m}} = 4$$

37. $$a_{\text{av}} = \frac{s}{t} = \frac{5.2\ \frac{\text{m}}{\text{s}}}{5.0\ \text{s}} = 1.04\ \frac{\text{m}}{\text{s}^2}$$

$$v_{\text{f}} = v_{\text{i}} + a_{\text{av}}\Delta t = 5.2\ \frac{\text{m}}{\text{s}} + \left(1.04\ \frac{\text{m}}{\text{s}^2}\right)(6.0\ \text{s}) = \boxed{11.4\ \text{m/s}}$$

38. $$v_{\text{i}} = v_{\text{f}} - a_{\text{av}}\Delta t = 9.31\ \frac{\text{m}}{\text{s}} - \left(6.24\ \frac{\text{m}}{\text{s}^2}\right)(0.300\ \text{s}) = 9.31\ \frac{\text{m}}{\text{s}} - 1.87\ \frac{\text{m}}{\text{s}} = \boxed{7.44\ \text{m/s}}$$

39. The velocities and positions are given. To find the acceleration use

$$v^2 = v_0{}^2 + 2a(x - x_0)$$

$$a = \frac{v^2 - v_0{}^2}{2(x - x_0)} = \frac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(81.9\ \frac{\text{m}}{\text{s}}\right)^2}{2(949\ \text{m} - 0\ \text{m})} = -3.53\ \text{m/s}^2$$

The negative sign indicates acceleration in the opposite direction of the velocity. So $\boxed{a = 3.53\ \text{m/s}^2,\ \text{due north}}$.

40. Assuming constant deceleration, the average velocity is simply the average of the initial and final velocities.

$$v_{\text{av}} = \frac{12\ \frac{\text{m}}{\text{s}} + 0\ \frac{\text{m}}{\text{s}}}{2} = \boxed{6.0\ \text{m/s},\ \text{due west}}$$

41. $$v_{\text{av}} = 6.0\ \frac{\text{m}}{\text{s}}$$

$$\Delta t = \frac{\Delta x}{v_{\text{av}}} = \frac{35\ \text{m}}{6\ \frac{\text{m}}{\text{s}}} = \boxed{5.8\ \text{s}}$$

42. (a) $$v_{\text{av}} = \frac{4.12\ \frac{\text{m}}{\text{s}} + 0\ \frac{\text{m}}{\text{s}}}{2} = \boxed{2.06\ \text{m/s}}$$

(b) $$\Delta x = v_{\text{av}}\Delta t = \left(2.06\ \frac{\text{m}}{\text{s}}\right)(4.77\ \text{s}) = \boxed{9.83\ \text{m}}$$

43. **(a)** $x - x_0 = \frac{1}{2}(v_0 + v)t = \frac{1}{2}\left(0\ \frac{\text{m}}{\text{s}} + 25.0\ \frac{\text{m}}{\text{s}}\right)(6.22\text{ s}) = \boxed{77.8\text{ m}}$

(b) Constant acceleration implies equal changes in velocity in equal time intervals. Since 3.11 s is half the 6.22 s time interval, the cheetah's speed increases to one-half its final speed. So its speed is $\boxed{12.5\text{ m/s}}$.

(c) first 3.11 s: $s_{\text{av}} = \frac{0 + 12.5\text{ m/s}}{2} = \boxed{6.25\text{ m/s}}$ assuming constant acceleration

second 3.11 s: $s_{\text{av}} = \frac{12.5\text{ m/s} + 25.0\text{ m/s}}{2} = 18.75\text{ m/s} = \boxed{18.8\text{ m/s}}$

(d) $d = s_{\text{av}}t$

first 3.11 s: $d = (6.25\text{ m/s})(3.11\text{ s}) = \boxed{19.4\text{ m}}$

second 3.11 s: $d = (18.75\text{ m/s})(3.11\text{ s}) = \boxed{58.3\text{ m}}$

44. $x - x_0 = v_0 t + \frac{1}{2}at^2$

(a) $x - x_0 = \left(0\ \frac{\text{m}}{\text{s}}\right)(1.0\text{ s}) + \frac{1}{2}\left(1.5\ \frac{\text{m}}{\text{s}^2}\right)(1.0\text{ s})^2 = \boxed{0.75\text{ m}}$

(b) $x - x_0 = \left(0\ \frac{\text{m}}{\text{s}}\right)(2.0\text{ s}) + \frac{1}{2}\left(1.5\ \frac{\text{m}}{\text{s}^2}\right)(2.0\text{ s})^2 = \boxed{3.00\text{ m}}$

(c) $x - x_0 = \left(0\ \frac{\text{m}}{\text{s}}\right)(3.0\text{ s}) + \frac{1}{2}\left(1.5\ \frac{\text{m}}{\text{s}^2}\right)(3.0\text{ s})^2 = \boxed{6.75\text{ m}}$

45. $v = \left(\frac{45\text{ mi}}{\text{h}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1609\text{ m}}{1\text{ mi}}\right) = 20.1\ \frac{\text{m}}{\text{s}}$

$a_{\text{av}} = \frac{\Delta v}{\Delta t} = \frac{20.1\ \frac{\text{m}}{\text{s}} - 0\ \frac{\text{m}}{\text{s}}}{2.2\text{ s} - 0\text{ s}} = \boxed{9.1\ \text{m/s}^2}$

46. Assume that the surface of the bag moves 0.3 m in 10 ms with constant acceleration.

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$0.3\text{ m} = 0 + (0)(0.01\text{ s}) + \frac{1}{2}a(0.01\text{ s})^2$

$a = \frac{2(0.3\text{ m})}{(0.01\text{ s})^2} = 6000\ \frac{\text{m}}{\text{s}^2} = \boxed{612g}$

47. Choose east as the positive direction.

$\boxed{x_1 = \left(20.0\ \frac{\text{m}}{\text{s}}\right)t + \left(1.25\ \frac{\text{m}}{\text{s}^2}\right)t^2}$

$\boxed{x_2 = 1000\text{ m} + \left(-30.0\ \frac{\text{m}}{\text{s}}\right)t + \left(1.60\ \frac{\text{m}}{\text{s}^2}\right)t^2}$

48. $|a| = \left|\dfrac{v^2 - v_0{}^2}{2(x - x_0)}\right| = \left|\dfrac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(550\ \frac{\text{m}}{\text{s}}\right)^2}{2(0.22\ \text{m} - 0\ \text{m})}\right| = \boxed{6.9\times10^5\ \text{m/s}^2}$

49. **(a)** $a = \dfrac{2(x - x_0)}{t^2} = \dfrac{2(80.0\ \text{m} - 0\ \text{m})}{(3.0\ \text{s})^2} = \boxed{18\ \text{m/s}^2}$

(b) $v = v_0 + at = 0\ \dfrac{\text{m}}{\text{s}} + \left(17.8\ \dfrac{\text{m}}{\text{s}^2}\right)(3.0\ \text{s}) = \boxed{53\ \text{m/s}}$

50. **(a)** $x - x_0 = \dfrac{v^2 - v_0{}^2}{2a} = \dfrac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(12.0\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-3.5\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{21\ \text{m}}$

(b) Your speed is greater than 6.0 m/s.

$$v^2 = v_0{}^2 + 2a(x - x_0)$$
$$= \left(12.0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(-3.5\ \frac{\text{m}}{\text{s}^2}\right)(10.3\ \text{m})$$
$$= 71.9\ \frac{\text{m}^2}{\text{s}^2}$$
$$v = \sqrt{71.9\ \frac{\text{m}^2}{\text{s}^2}} = \boxed{8.5\ \text{m/s}}$$

51. **(a)** $t = \dfrac{v - v_0}{a} = \dfrac{0\ \frac{\text{m}}{\text{s}} - 12.0\ \frac{\text{m}}{\text{s}}}{-3.5\ \frac{\text{m}}{\text{s}^2}} = \boxed{3.4\ \text{s}}$

(b) Your speed is 6.0 m/s.

$$v = v_0 + at = 12.0\ \frac{\text{m}}{\text{s}} + \left(-3.5\ \frac{\text{m}}{\text{s}^2}\right)(1.715\ \text{s}) = \boxed{6.0\ \text{m/s}}$$

52. **(a)** $a = \dfrac{2(x - x_0)}{t^2} = \dfrac{2(0.16\ \text{m}-0\ \text{m})}{(0.10\ \text{s})^2} = \boxed{32\ \text{m/s}^2}$

(b) The tongue extends $\boxed{\text{less}}$.

$$x - x_0 = \frac{1}{2}\left(32\ \frac{\text{m}}{\text{s}^2}\right)(0.050\ \text{s})^2 = 4.0\ \text{cm}$$

53. Choose west as the positive direction.

$$a = \frac{v^2 - v_0{}^2}{2(x - x_0)} = \frac{\left(6.5\ \frac{\text{m}}{\text{s}}\right)^2 - \left(8.0\ \frac{\text{m}}{\text{s}}\right)^2}{2(7.2\ \text{m} - 0\ \text{m})} = -1.5\ \frac{\text{m}}{\text{s}^2}$$

$$\vec{\mathbf{a}} = \boxed{1.5\ \text{m/s}^2,\ \text{due east}}$$

54. Your speed decreases by $\boxed{\text{more than 1.5 m/s}}$.

$$v^2 = v_0{}^2 + 2a(x - x_0)$$
$$= \left(7.0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(-1.51\ \frac{\text{m}}{\text{s}^2}\right)(7.2\ \text{m} - 0\ \text{m})$$
$$= 27.26\ \frac{\text{m}^2}{\text{s}^2}$$
$$v = \sqrt{27.26\ \frac{\text{m}^2}{\text{s}^2}} = 5.2\ \frac{\text{m}}{\text{s}}$$
$$7.0\ \frac{\text{m}}{\text{s}} - 5.2\ \frac{\text{m}}{\text{s}} = 1.8\ \frac{\text{m}}{\text{s}} > 1.5\ \frac{\text{m}}{\text{s}}$$

55. $$t = \frac{2(x - x_0)}{v_0 + v} = \frac{2(10.0\ \text{m} - 0\ \text{m})}{2.2\ \frac{\text{m}}{\text{s}} + 1.6\ \frac{\text{m}}{\text{s}}} = \boxed{5.3\ \text{s}}$$

56. (a) $$t = \frac{2(x - x_0)}{v_0 + v} = \frac{2(3.2\ \text{m} - 0\ \text{m})}{0\ \frac{\text{m}}{\text{s}} + 26.0\ \frac{\text{m}}{\text{s}}} = \boxed{0.25\ \text{s}}$$

(b) $$a = \frac{v - v_0}{t} = \frac{26.0\ \frac{\text{m}}{\text{s}} - 0\ \frac{\text{m}}{\text{s}}}{0.246\ \text{s}} = \boxed{110\ \text{m/s}^2}$$

(c) $$y = y_0 + v_0 t + \frac{1}{2}at^2 = 0\ \text{m} + \left(0\ \frac{\text{m}}{\text{s}}\right)(0.10\ \text{s}) + \frac{1}{2}\left(105.6\ \frac{\text{m}}{\text{s}^2}\right)(0.10\ \text{s})^2 = \boxed{0.53\ \text{m}}$$
$$v = at = \left(105.6\ \frac{\text{m}}{\text{s}^2}\right)(0.10\ \text{s}) = \boxed{11\ \text{m/s}}$$

57. (a) $$a = \frac{v - v_0}{t} = \frac{0\ \frac{\text{m}}{\text{s}} - 6.0\ \frac{\text{m}}{\text{s}}}{1.2\ \text{s}} = -5.0\ \frac{\text{m}}{\text{s}^2}$$
$$\vec{\mathbf{a}} = \boxed{5.0\ \text{m/s}^2\text{, toward third base}}$$

(b) $$x - x_0 = \frac{1}{2}(v_0 + v)t = \frac{1}{2}\left(6.0\ \frac{\text{m}}{\text{s}} + 0\ \frac{\text{m}}{\text{s}}\right)(1.2\ \text{s}) = \boxed{3.6\ \text{m}}$$

58. (a) Let x_1 be the position of the bicyclist with the flat tire and x_2 be the position of his friend.

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$
$$x_1 = \frac{1}{2}\left(2.4\ \frac{\text{m}}{\text{s}^2}\right)t^2 = \left(1.2\ \frac{\text{m}}{\text{s}^2}\right)t^2$$
$$x_2 = (7\ \text{m}) + \left(3.5\ \frac{\text{m}}{\text{s}}\right)t$$

Set $x_1 = x_2$.

$$\left(1.2\ \frac{\text{m}}{\text{s}^2}\right)t^2 = \left(3.5\ \frac{\text{m}}{\text{s}}\right)t + (7\ \text{m})$$

$$0 = \left(1.2\ \frac{\text{m}}{\text{s}^2}\right)t^2 - \left(3.5\ \frac{\text{m}}{\text{s}}\right)t - (7\ \text{m})$$

Use the quadratic formula to solve.

$$t = \frac{\left(3.5\ \frac{\text{m}}{\text{s}}\right) \pm \sqrt{\left(-3.5\ \frac{\text{m}}{\text{s}}\right)^2 - 4\left(1.2\ \frac{\text{m}}{\text{s}^2}\right)(-7\ \text{m})}}{(2)\left(1.2\ \frac{\text{m}}{\text{s}^2}\right)} = \frac{\left(3.5\ \frac{\text{m}}{\text{s}}\right) \pm \left(6.77\ \frac{\text{m}}{\text{s}}\right)}{\left(2.4\ \frac{\text{m}}{\text{s}^2}\right)} = 1.46\ \frac{\text{m}}{\text{s}} \pm 2.82\ \frac{\text{m}}{\text{s}}$$

Time must be positive, so $t = \boxed{4.3\ \text{s}}$.

(b) $x - x_0 = \frac{1}{2}at^2 = \frac{1}{2}\left(2.4\ \frac{\text{m}}{\text{s}^2}\right)(4.28\ \text{s})^2 = \boxed{22\ \text{m}}$

(c) $v = at = \left(2.4\ \frac{\text{m}}{\text{s}^2}\right)(4.28\ \text{s}) = \boxed{10\ \text{m/s}}$

59. Assume that the cart starts from rest.

(a) $a = \frac{2(x - x_0)}{t^2}$

$$a_{10} = \frac{2(1.00\ \text{m}–0\ \text{m})}{(1.08\ \text{s})^2} = \boxed{1.71\ \text{m/s}^2}$$

$$a_{20} = \frac{2.00\ \text{m}}{(0.770\ \text{s})^2} = \boxed{3.37\ \text{m/s}^2}$$

$$a_{30} = \frac{2.00\ \text{m}}{(0.640\ \text{s})^2} = \boxed{4.88\ \text{m/s}^2}$$

(b) $a_{10} = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 10.0° = \boxed{1.70\ \text{m/s}^2}$

$$a_{20} = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 20.0° = \boxed{3.36\ \text{m/s}^2}$$

$$a_{30} = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\sin 30.0° = \boxed{4.91\ \text{m/s}^2}$$

60. Assume the apple falls 2 m.

$$v^2 = v_0{}^2 - 2g(x - x_0)$$

$$v^2 = \left(0\ \frac{\text{m}}{\text{s}}\right)^2 - 2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0\ \text{m} - 2\ \text{m})$$

$$= 39.24\ \frac{\text{m}^2}{\text{s}^2}$$

$$v = \sqrt{39.24\ \frac{\text{m}^2}{\text{s}^2}} \cong \boxed{6\ \text{m/s}}$$

61. $\left(\frac{60 \text{ mi}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1609 \text{ m}}{\text{mi}}\right) = 26.8 \ \frac{\text{m}}{\text{s}}$

$$\Delta t = \frac{\Delta v}{g} = \frac{26.8 \ \frac{\text{m}}{\text{s}} - 0 \ \frac{\text{m}}{\text{s}}}{9.81 \ \frac{\text{m}}{\text{s}^2}} = 2.7 \text{ s}$$

A falling car will achieve 60 mi/h in about 2.7 s. The statement is accurate.

62. $30 \ \frac{\text{mi}}{\text{h}} = 13.4 \ \frac{\text{m}}{\text{s}}$

$$\Delta t = \frac{\Delta v}{g} = \frac{13.4 \ \frac{\text{m}}{\text{s}} - 0 \ \frac{\text{m}}{\text{s}}}{9.81 \ \frac{\text{m}}{\text{s}^2}} = \boxed{1.4 \text{ s}}$$

63. $v_0^2 = v^2 + 2g(x - x_0)$

$$= \left(0 \ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(48 \text{ in.} - 0 \text{ in.})\left(\frac{1 \text{ m}}{39.37 \text{ in.}}\right)$$

$$= 23.9 \ \frac{\text{m}^2}{\text{s}^2}$$

$$v_0 = \sqrt{23.9 \ \frac{\text{m}^2}{s^2}} = \boxed{4.9 \ \text{m/s}}$$

64. $v^2 = 2g\Delta x$

$$v = \sqrt{2g\Delta x}$$

$$= \sqrt{2\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(14 \text{ m})}$$

$$= \boxed{17 \ \text{m/s}}$$

65. (a) $v = v_0 - gt$

$$v = \left(23 \ \frac{\text{m}}{\text{s}}\right) - \left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(2.0 \text{ s}) = 3.4 \ \frac{\text{m}}{\text{s}}$$

3.4 m/s, 3.4 m/s

(b) $v = \left(23 \ \frac{\text{m}}{\text{s}}\right) - \left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(3.0 \text{ s}) = -6.4 \ \frac{\text{m}}{\text{s}}$

6.4 m/s, –6.4 m/s

66. $0 = v_0{}^2 - 2a(x - x_0)$

$$v_0 = \sqrt{2a(x - x_0)}$$

$$= \sqrt{2\left(1.80 \ \frac{\text{m}}{\text{s}^2}\right)(2.00 \times 10^5 \ \text{m})}$$

$$= \boxed{849 \ \text{m/s}}$$

67. $t^2 = \dfrac{2(x - x_0)}{g}$

$t = \sqrt{\dfrac{2(0.052\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}} = \boxed{0.10\text{ s}}$

68. $\boxed{x_\text{B} = (3.0\text{ m}) - \frac{1}{2}gt^2}$

$\boxed{x_\text{T} = (1.0\text{ m}) + \left(4.2\ \frac{\text{m}}{\text{s}}\right)t - \frac{1}{2}gt^2}$

69. $\boxed{x_\text{B} = \frac{1}{2}gt^2}$

$\boxed{x_\text{T} = (2.0\text{ m}) + \left(-4.2\ \frac{\text{m}}{\text{s}}\right)t + \frac{1}{2}gt^2}$

70. (a) $\text{height} = \frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.5\text{ s})^2 = \boxed{11\text{ m}}$

(b) Down is positive.

$v = v_0 + gt = \left(0\ \frac{\text{m}}{\text{s}}\right) + \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.5\text{ s}) = \boxed{15\text{ m/s}}$

71. (a) The shell is moving more than half as fast.

(b) $v_\text{sg} = 17\text{ m/s}$

$v_\text{sc} = \sqrt{2g\Delta x} = \sqrt{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(7.0\text{ m})} = 12\text{ m/s}$

72. (a) The time the ball takes to go up is the same as it takes to come down.

$v_0 = gt = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.25\text{ s}) = \boxed{22.1\text{ m/s}}$

(b) $\boxed{\text{2.25 s after it was hit}}$
Assuming no air resistance, the time it takes to go up is the same as it takes to come down.

(c) $h = \frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.25\text{ s})^2 = \boxed{24.8\text{ m}}$

73. (a) $(560\text{ ft})\left(\dfrac{1\text{ m}}{3.281\text{ ft}}\right) = 170.7\text{ m}$

$v_0 = \sqrt{2g\Delta x} = \sqrt{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(170.7\text{ m})} = \boxed{58\text{ m/s}}$

(b) $t = \frac{v_0}{g} = \frac{57.9\ \frac{\text{m}}{\text{s}}}{9.81\ \frac{\text{m}}{\text{s}^2}} = \boxed{5.9\ \text{s}}$

74. The time to drop from the greatest height to the floor is

$\frac{2.5\ \text{s}}{2} = 1.25\ \text{s}$

$\text{height} = \frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.25\ \text{s})^2 = \boxed{7.7\ \text{m}}$

75. (a) It takes the same amount of time for the glove to go up as down, so

$t = \frac{2v_0}{g} = \frac{2\left(6.0\ \frac{\text{m}}{\text{s}}\right)}{9.81\ \frac{\text{m}}{\text{s}^2}} = \boxed{1.2\ \text{s}}$

(b) $v = v_0 - gt$

$v = 0$ at the maximum height, so

$t = \frac{v_0}{g} = \frac{6.0\ \frac{\text{m}}{\text{s}}}{9.81\ \frac{\text{m}}{\text{s}^2}} = \boxed{0.61\ \text{s}}$

76. (a) $\boxed{\text{The first ball}}$ has a greater increase in speed because it is acted upon longer by the force of gravity.

(b)
$$
\begin{aligned}
v_1^2 &= v_{01}^2 + 2g(x - x_0) \\
&= \left(0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(32.5\ \text{m}) \\
&= 637.7\ \frac{\text{m}^2}{\text{s}^2}
\end{aligned}
$$

$v_1 = \sqrt{637.7\ \frac{\text{m}^2}{\text{s}^2}} = 25.3\ \text{m/s}$

$\boxed{\text{The speed of the first ball increased by 25.3 m/s.}}$

$$
\begin{aligned}
v_2^2 &= v_{02}^2 + 2g(x - x_0) \\
&= \left(11.0\ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(32.5\ \text{m}) \\
&= 758.7\ \frac{\text{m}^2}{\text{s}^2}
\end{aligned}
$$

$v_2 = \sqrt{758.7\ \frac{\text{m}^2}{\text{s}^2}} = 27.5\ \text{m/s}$

$\boxed{\text{The speed of the second ball increased by 16.5 m/s.}}$

77. $x - x_0 = v_0 t - \frac{1}{2}gt^2$

$$v_0 = \frac{x - x_0}{t} + \frac{1}{2}gt$$
$$= \left(\frac{30.0\text{ m}}{2\text{ s}}\right) + \left(\frac{1}{2}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2\text{ s})$$
$$= \boxed{24.8\ \text{m/s}}$$

78. Both the elevator and the book move initially with the same constant speed, therefore it can be ignored in part (a).

(a) $x - x_0 = v_0 t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$

$$t^2 = \frac{2(x_0 - x)}{g}$$
$$t = \sqrt{\frac{2(x_0 - x)}{g}}$$
$$= \sqrt{\frac{2(1.2\text{ m} - 0\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}}$$
$$= \boxed{0.49\text{ s}}$$

(b) $v = v_0 + gt = 3.0\ \frac{\text{m}}{\text{s}} + \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.4946\text{ s}) = \boxed{7.9\ \text{m/s}}$

79. **(a)** $x - x_0 = v_0 t - \frac{1}{2}gt^2$

$$0 = \frac{1}{2}gt^2 - v_0 t + (x - x_0)$$
$$= \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)t^2 - \left(-2.0\ \frac{\text{m}}{\text{s}}\right)t + (0\text{ m} - 45\text{ m})$$
$$= \left(4.905\ \frac{\text{m}}{\text{s}^2}\right)t^2 + \left(2.0\ \frac{\text{m}}{\text{s}}\right)t - (45\text{ m})$$

Solve for t using the quadratic formula.

$$t = \frac{\left(-2\ \frac{\text{m}}{\text{s}}\right) \pm \sqrt{\left(2\ \frac{\text{m}}{\text{s}}\right) - (4)\left(4.905\ \frac{\text{m}}{\text{s}^2}\right)(-45\text{ m})}}{2\left(4.905\ \frac{\text{m}}{\text{s}^2}\right)} = -0.204\text{ s} + 3.036\text{ s} = \boxed{2.8\text{ s}}$$

The positive sign was chosen because time cannot be negative.

(b) $v = v_0 - gt = \left(-2.0\ \frac{\text{m}}{\text{s}}\right) - \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.83\text{ s}) = \boxed{-30\ \text{m/s}}$

80. (a) The separation is more than 2 m.

(b) Determine how long it takes for your friend to fall 2 m.

$$x - x_0 = v_0 t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$$

$$t^2 = \frac{2(x_0 - x)}{g}$$

$$t = \sqrt{\frac{2(x_0 - x)}{g}} = \sqrt{\frac{2(2.0\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}} = 0.639\text{ s}$$

You fall for 1.6 s – 0.639 s = 0.961 s before your friend hits the water. In this time, you fall

$$\frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.961\text{ s})^2 = 4.53\text{ m}.$$

The distance to the water is

$$\frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.6\text{ s})^2 = 12.6\text{ m}.$$

$\boxed{\text{The separation is } 12.6\text{ m} - 4.53\text{ m} \approx 8\text{ m} > 2\text{ m.}}$

81. The time it takes for the first chestnut to reach the ground is

$$x - x_0 = v_0 t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$$

$$t^2 = \frac{2(x_0 - x)}{g} = \frac{2(10.0\text{ m}–0\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}} = 2.039\text{ s}^2$$

$$t = \sqrt{2.039\text{ s}^2} = 1.428\text{ s}$$

The time for it to fall 2.5 m is

$$t = \sqrt{\frac{2(x_0 - x)}{g}} = \sqrt{\frac{2(10.0\text{ m}–7.5\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}} = 0.714\text{ s}$$

The time to fall from 7.5 m to the ground is
1.428 s – 0.714 s = 0.714 s.

The second chestnut must reach the ground in 0.714 s. The initial velocity needed is

$$x - x_0 = v_0 t - \frac{1}{2}gt^2$$

$$v_0 = \frac{x - x_0}{t} + \frac{1}{2}gt$$

$$= \left(\frac{0\text{ m}–10.0\text{ m}}{0.714\text{ s}}\right) + \left(\frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\right)(0.714\text{ s})$$

$$= -11\ \frac{\text{m}}{\text{s}}$$

The initial speed needed is $\boxed{11\text{ m/s}}$.

82. The circumference of the earth is approximately 4×10^7 m.

$$v = \frac{\Delta x}{\Delta t} = \left(\frac{4 \times 10^7\text{ m}}{80\text{ days}}\right)\left(\frac{1\text{ day}}{24\text{ h}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right) = \boxed{5.8\text{ m/s}}$$

83. $v^2 = {v_0}^2 + 2a(x - x_0)$

$$= \left(0\ \frac{\text{m}}{\text{s}}\right) + 2\left(-1.62\ \frac{\text{m}}{\text{s}^2}\right)(0\ \text{m} - 0.95\ \text{m})$$

$$= 3.078\ \frac{\text{m}^2}{\text{s}^2}$$

$$v = \sqrt{3.078\ \frac{\text{m}^2}{\text{s}^2}} = \boxed{1.8\ \text{m/s}}$$

84. Just before you reach the ground, your speed will be $\sqrt{2gh}$. To estimate your deceleration, use $v^2 = v_0^2 + 2a\Delta x$, where $v = 0$, $v_0 = \sqrt{2gh}$, and $\Delta x = 0.5$ m, which is an estimate of the distance your legs will bend to soften your landing.

$$0 = 2gh + 2a\Delta x$$

$$a = -\frac{2gh}{2\Delta x}$$

$$= -\frac{gh}{\Delta x}$$

$$= -g\left(\frac{2.0\ \text{m}}{0.5\ \text{m}}\right)$$

$$= -4g$$

$\boxed{\text{Your deceleration will be about } 4g.}$

85. **(a)** The youngster's time in the air doubles.

(b) The youngster's maximum height quadruples.

(c) $v = v_0 - gt = 0$

$$2t_2 = \frac{2v_0}{g} = \frac{2\left(2.0\ \frac{\text{m}}{\text{s}}\right)}{9.81\ \frac{\text{m}}{\text{s}}} = 0.41\ \text{s}$$

$$2t_4 = \frac{2v_0}{g} = \frac{2\left(4.0\ \frac{\text{m}}{\text{s}}\right)}{9.81\ \frac{\text{m}}{\text{s}}} = 0.82\ \text{s}$$

$$\boxed{t_4 = 2t_2}$$

$$v^2 = {v_0}^2 - 2g(x - x_0) = 0$$

$$(x - x_0)_2 = \frac{{v_0}^2}{2g} = \frac{\left(2.0\ \frac{\text{m}}{\text{s}}\right)^2}{2g} = \frac{\left(4.0\ \frac{\text{m}^2}{\text{s}^2}\right)}{2g}$$

$$(x - x_0)_4 = \frac{{v_0}^2}{2g} = \frac{\left(4.0\ \frac{\text{m}}{\text{s}}\right)^2}{2g} = \frac{\left(16\ \frac{\text{m}^2}{\text{s}^2}\right)}{2g}$$

$$\boxed{(x - x_0)_4 = 4(x - x_0)_2}$$

86. (a) Determine the acceleration.

$$v^2 = v_0^2 + 2a(x - x_0) = 0$$

$$a = \frac{-v_0^2}{2(x - x_0)} = \frac{-\left(1.57 \ \frac{\text{m}}{\text{s}}\right)^2}{2(14.0 \text{ ft} - 0 \text{ ft})\left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right)} = -0.289 \ \frac{\text{m}}{\text{s}^2}$$

Find the initial speed.

$$v_0^2 = 2a(x_0 - x)$$

$$v_0 = \sqrt{2a(x_0 - x)}$$

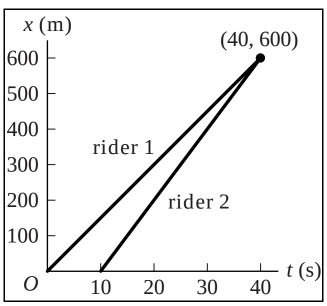
$$= \sqrt{2\left(-0.289 \ \frac{\text{m}}{\text{s}^2}\right)(0 \text{ ft} - 20.0 \text{ ft})\left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right)}$$

$$= \boxed{1.88 \text{ m/s}}$$

(b) $$v_0 = \sqrt{2\left(-0.289 \ \frac{\text{m}}{\text{s}^2}\right)(0 \text{ ft} - 6.00 \text{ ft})\left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right)}$$

$$= \boxed{1.03 \text{ m/s}}$$

87. (a)



(b) $$x_1 = v_1 t = \left(15.0 \ \frac{\text{m}}{\text{s}}\right)t$$

$$x_2 = v_2 t + b$$

$$x_2 = \left(20.0 \ \frac{\text{m}}{\text{s}}\right)t + b$$

$$x_2(t = 10) = \left(20.0 \ \frac{\text{m}}{\text{s}}\right)(10 \text{ s}) + b = 0$$

$$b = -200 \text{ m}$$

$$x_2 = \left(20.0 \ \frac{\text{m}}{\text{s}}\right)t - 200 \text{ m}$$

Set $x_1 = x_2$.

$$\left(15.0 \ \frac{\text{m}}{\text{s}}\right)t = \left(20.0 \ \frac{\text{m}}{\text{s}}\right)t - 200 \text{ m}$$

$$\left(5.0 \ \frac{\text{m}}{\text{s}}\right)t = 200 \text{ m}$$

$$\boxed{t = 40 \text{ s}}$$

(c) $x_1 = \left(15.0\ \frac{\text{m}}{\text{s}}\right)(40\ \text{s}) = \boxed{600\ \text{m}}$

88. $x_1 = 565\ \text{m} = \left(15.0\ \frac{\text{m}}{\text{s}}\right)t$

$t = \frac{565\ \text{m}}{15.0\ \frac{\text{m}}{\text{s}}} = \frac{113}{3}\ \text{s}$

$x_2 = vt - 200\,\text{m}$

Substitute for t and x_2.

$565\ \text{m} = v\left(\frac{113}{3}\ \text{s}\right) - 200\ \text{m}$

$$v = \frac{565\ \text{m} + 200\ \text{m}}{\frac{113}{3}\ \text{s}} = \boxed{20.3\ \text{m/s}}$$

89. (a) Find the time to fall 28.0 ft, starting from rest. Let down be positive.

$\Delta x = v_0 t + \frac{1}{2}gt^2$

$t^2 = \frac{2\Delta x}{g}$

$t = \sqrt{\frac{2\Delta x}{g}}$

$$t = \sqrt{\frac{2(28.0\ \text{ft})(1\ \text{m}/3.28\ \text{ft})}{9.81\ \text{m/s}^2}} = \sqrt{1.740\ \text{s}^2} = 1.319\ \text{s}$$

total time in air = $2t$ = $\boxed{2.64\ \text{s}}$

(b) Time spent above 14.0 ft is $\boxed{\text{more}}$ than time spent below 14.0 ft.

(c) Find the time to fall 14.0 ft, starting from rest.

$$t = \sqrt{\frac{2(14.0\ \text{ft})(1\ \text{m}/3.28\ \text{ft})}{9.81\ \frac{\text{m}}{\text{s}^2}}} = \sqrt{0.8702\ \text{s}^2} = 0.933\ \text{s}$$

total time in air while above 14.0 ft = $2t$ = 1.87 s

total time in air while below 14.0 ft = 2.64 s − 1.87 s = 0.77 s

$\boxed{1.87\ \text{s} > 0.77\ \text{s}}$

90. Assume the second rock is dropped at $t = 0$. Down is the positive direction.

x_1 = position of first rock

x_2 = position of second rock

At $t = 0$, $x_1 = 4$ m and $x_2 = 0$.

The speed of the first rock at $t = 0$ is

$$v_{10} = \sqrt{2gx_{10}} = \sqrt{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(4\text{ m})} = 8.86\ \frac{\text{m}}{\text{s}}$$

At $t = 1.0$ s,

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$x_1 = 4\text{ m} + \left(8.86\ \frac{\text{m}}{\text{s}}\right)(1.0\text{ s}) + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.0\text{ s})^2 = 17.77\text{ m}$$

$$x_2 = 0\text{ m} + \left(0\ \frac{\text{m}}{\text{s}}\right)(1.0\text{ s}) + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.0\text{ s})^2 = 4.91\text{ m}$$

$$x_2 - x_1 = 17.77\text{ m} - 4.91\text{ m} = \boxed{13\text{ m}}$$

At $t = 2.0$ s,

$$x_1 = 4\text{ m} + \left(8.86\ \frac{\text{m}}{\text{s}}\right)(2.0\text{ s}) + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.0\text{ s})^2 = 41.34\text{ m}$$

$$x_2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.0\text{ s})^2 = 19.62\text{ m}$$

$$x_1 - x_2 = 41.34\text{ m} - 19.62\text{ m} = \boxed{22\text{ m}}$$

At $t = 3.0$ s,

$$x_1 = 4\text{ m} + \left(8.86\ \frac{\text{m}}{\text{s}}\right)(3.0\text{ s}) + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(3.0\text{ s})^2 = 74.73\text{ m}$$

$$x_2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(3.0\text{ s})^2 = 44.15\text{ m}$$

$$x_1 - x_2 = 74.73\text{ m} - 44.15\text{ m} = \boxed{31\text{ m}}$$

The separation increases linearly with time according to (approximately) $\boxed{x_1 - x_2 = \left(8.9\ \frac{\text{m}}{\text{s}}\right)t + 4\text{ m.}}$

91. (a) Just after release, the only acceleration is due to gravity.

$\boxed{9.81\text{ m/s}^2,\ \text{downward}}$

(b) At the maximum height, $v = 0$.

$$v^2 = v_0^2 - 2g(x - x_0) = 0$$

$$x = x_0 + \frac{v_0^2}{2g} = 12.5\text{ m} + \frac{\left(5.20\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{13.9\text{ m}}$$

(c) $x = x_0 - \frac{1}{2}gt^2$

$$t^2 = \frac{2(x_0 - x)}{g}$$

$$t = \sqrt{\frac{2(x_0 - x)}{g}}$$

$$= \sqrt{\frac{2(13.9\text{ m} - 12.5\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}}$$

$$= 0.53\text{ s}$$

The shell goes up and down.

$2t = 2(0.53\text{ s}) = \boxed{1.1\text{ s}}$

(d) The speed is $\boxed{5.20\text{ m/s}}$.

92. (a) It will take the liquid equal times to go up and down.

$v = v_0 - gt = 0$

$$t = \frac{v_0}{g} = \frac{1.5\ \frac{\text{m}}{\text{s}}}{9.81\ \frac{\text{m}}{\text{s}^2}} = 0.153\text{ s}$$

$2t = 2(0.153\text{ s}) = \boxed{0.31\text{ s}}$

(b) The velocity is zero at maximum height.

$0 = v_0{}^2 - 2g(x - x_0)$

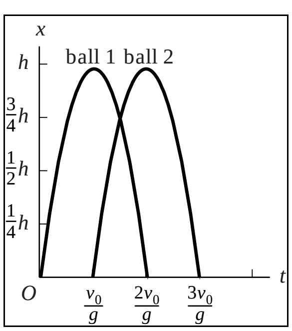
$$x - x_0 = \frac{v_0{}^2}{2g} = \frac{\left(1.5\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{11\text{ cm}}$$

93. (a) Set the origin at the maximum height of the water and let $t = 0$ when the water reaches this height.

$$x = x_0 + v_0 t + \frac{1}{2}at^2 = 0 + (0)t + \frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.65\text{ s})^2 = \boxed{13.4\text{ m}}$$

(b) $v_0 = gt = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.65\text{ s}) = \boxed{16.2\text{ m/s}}$

94. (a)



(b) The balls cross paths $\boxed{\text{above } h/2}$.

(c) $x_1 =$ position of first ball

$x_2 =$ position of second ball

$$x_1 = h - \frac{1}{2}gt^2$$

$$x_2 = v_0 t - \frac{1}{2}gt^2$$

Set $x_1 = x_2$.

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

$$h = v_0 t,\ t = \frac{h}{v_0}$$

Find v_0 in terms of g and h.

$v^2 = v_0^2 - 2gh = 0$ at maximum height

$$v_0 = \sqrt{2gh}$$

Find the height at which the balls meet.

$$\begin{aligned}\text{height} &= v_0 t - \frac{1}{2}gt^2 \\ &= v_0\left(\frac{h}{v_0}\right) - \frac{1}{2}g\left(\frac{h}{v_0}\right)^2 \\ &= h - \frac{gh^2}{2v_0^2} \\ &= h - \frac{gh^2}{2\left(\sqrt{2gh}\right)^2} \\ &= h - \frac{gh^2}{2(2gh)} \\ &= h - \frac{h}{4} \\ &= \boxed{\frac{3}{4}h}\end{aligned}$$

95. $x_p =$ height of the passenger

$x_c =$ height of the camera

$$x_p = x_0 + vt = 2.5\text{ m} + \left(2.0\ \frac{\text{m}}{\text{s}}\right)t$$

$$x_c = v_0 t - \frac{1}{2}gt^2 = \left(10.0\ \frac{\text{m}}{\text{s}}\right)t - \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)t^2 = \left(10.0\ \frac{\text{m}}{\text{s}}\right)t - \left(4.905\ \frac{\text{m}}{\text{s}^2}\right)t^2$$

Set $x_p = x_c$ and solve for t using the quadratic equation.

$$\begin{aligned}2.5\text{ m} + \left(2.0\ \frac{\text{m}}{\text{s}}\right)t &= \left(10.0\ \frac{\text{m}}{\text{s}}\right)t - \left(4.905\ \frac{\text{m}}{\text{s}^2}\right)t^2 \\ 0 &= \left(4.905\ \frac{\text{m}}{\text{s}^2}\right)t^2 - \left(8.0\ \frac{\text{m}}{\text{s}}\right)t + 2.5\text{ m}\end{aligned}$$

$$t=\frac{\left(8.0\ \frac{\text{m}}{\text{s}}\right)\pm\sqrt{\left(-8.0\ \frac{\text{m}}{\text{s}}\right)^2-4\left(4.905\ \frac{\text{m}}{\text{s}^2}\right)(2.5\text{ m})}}{2\left(4.905\ \frac{\text{m}}{\text{s}^2}\right)}=0.816\text{ s}\pm 0.394\text{ s}=0.421\text{ s}$$

The choice of the shorter time is arbitrary and corresponds to the camera reaching the passenger on its way up.
Find the height of the passenger.

$$x_\text{p}=2.5\text{ m}+\left(2.0\ \frac{\text{m}}{\text{s}}\right)(0.421\text{ s})=\boxed{3.3\text{ m}}$$

96. x_p = height of passenger

x_c = height of camera

$$x_\text{p}=x_0+vt$$

$$x_\text{c}=v_0t-\frac{1}{2}gt^2$$

Set $x_\text{c}=x_\text{p}$.

$$v_0t-\frac{1}{2}gt^2=x_0+vt$$

$$0=\frac{1}{2}gt^2-v_0t+vt+x_0$$

$$0=t^2-\frac{2(v_0-v)t}{g}+\frac{2x_0}{g}$$

Solve for t using the quadratic equation.

$$t=\frac{\frac{2(v_0-v)}{g}-\sqrt{\left[-\frac{2(v_0-v)}{g}\right]^2-4(1)\left(\frac{2x_0}{g}\right)}}{2(1)}$$

The term inside the square root must be greater than or equal to zero for this solution to be valid.

$$\frac{4(v_0-v)^2}{g^2}-\frac{8x_0}{g}\ge 0$$

$$4(v_0-v)^2-8gx_0\ge 0$$

$$(v_0-v)^2-2gx_0\ge 0$$

$$(v_0-v)^2\ge 2gx_0$$

$$v_0-v\ge\sqrt{2gx_0}$$

$$v_0\ge\sqrt{2gx_0}+v$$

$$v_0\ge\sqrt{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.5\text{ m})}+2.0\ \frac{\text{m}}{\text{s}}$$

$$=\boxed{9.0\text{ m/s}}$$

97. Determine the speed at impact for each weight.

$$v^2=v_0{}^2-2g(x-x_0)=2g(x_0-x)$$

$$v=\sqrt{2g(x_0-x)}$$

$$v_1=\sqrt{2gh},\ v_2=\sqrt{2g(h+20.0\text{ cm})}$$

Find the times.

$v_1 = gt_1 = \sqrt{2gh}$

$t_1 = \sqrt{\frac{2h}{g}}$, and similarly $t_2 = \sqrt{\frac{2(h+20.0\text{ cm})}{g}}$

Now, $t_2 = 2t_1$, so

$$2\sqrt{\frac{2h}{g}} = \sqrt{\frac{2(h+20.0\text{ cm})}{g}}$$

$$\sqrt{\frac{2h}{g}} = \sqrt{\frac{h+20.0\text{ cm}}{2g}}$$

$$\frac{2h}{g} = \frac{h+20.0\text{ cm}}{2g}$$

$$2h = \frac{1}{2}h + 10.0\text{ cm}$$

$$\frac{3}{2}h = 10.0\text{ cm}$$

$$h = \frac{2}{3}(10.0\text{ cm})$$

$$= \boxed{6.67\text{ cm}}$$

98. $x = x_0 + v_0 t - \frac{1}{2}gt^2$

h = total height

t_h = time to fall h

t_1 = time to fall the first $\frac{1}{4}h$

t_2 = time to fall the final $\frac{3}{4}h = 1\text{ s}$

$v_0 = 0$, so $x_0 - x = \frac{1}{2}gt^2$ gives $h = \frac{1}{2}gt_h^2$

$$\frac{1}{4}h = \frac{1}{2}gt_1{}^2$$

$$h = 2gt_1{}^2 = \frac{1}{2}gt_h{}^2$$

$$4t_1{}^2 = t_h{}^2$$

$$2t_1 = t_h$$

$t_h = t_1 + t_2 = 2t_1$, so $t_1 = 1\text{ s}$, $t_h = 2\text{ s}$

(a) $h = \frac{1}{2}gt_h{}^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2\text{ s})^2 = \boxed{19.6\text{ m}}$

(b) $t_h = 2(1\text{ s}) = \boxed{2\text{ s}}$

99. Find the time it takes for the first drop to reach the pool.

$$x = x_0 + v_0 t - \frac{1}{2}gt^2$$

$$x_0 - x = \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2(x_0 - x)}{g}} = \sqrt{\frac{2(4.0\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}} = 0.903\text{ s}$$

So, a drop falls every $\frac{0.903\text{ s}}{2} = 0.4515\text{ s}.$

(a) $x - x_0 = -\frac{1}{2}gt^2$

$$x_0 - x = \frac{1}{2}gt^2 = \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.4515\text{ s})^2 = \boxed{1.0\text{ m}}$$

$$v = gt = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.4515\text{ s}) = \boxed{4.4\ \text{m/s}}$$

(b) $\left(\frac{1\text{ drop}}{0.4515\text{ s}}\right)\left(\frac{60\text{ s}}{\text{min}}\right) = \boxed{130\text{ drops/min}}$

100. (a) $v^2 = v_0{}^2 - 2g(x - x_0)$

$$v = \sqrt{v_0{}^2 + 2g(x_0 - x)}$$

$$= \sqrt{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 + 2gh}$$

$$= \boxed{\sqrt{2gh}}$$

(b) Let down be positive.

$v_0 = \sqrt{2gh},\ v = 0,\ x_0 = 0,\ x = d$

$v^2 = v_0^2 + 2a(x - x_0)$

$$a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - \left(\sqrt{2gh}\right)^2}{2(d - 0\text{ m})} = -\frac{2gh}{2d} = -\frac{gh}{d}$$

$\boxed{\text{magnitude of } a = \frac{gh}{d};\text{ the negative sign shows that the direction is upward.}}$

101. The time it takes for the ball to reach its maximum height is $0.75\text{ s} + \frac{(1.5\text{ s} - 0.75\text{ s})}{2} = 1.125\text{ s}.$

The final speed is $v = v_0 - gt = 0$ at maximum height.

$$v_0 = gt = \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.125\text{ s}) = \boxed{11\ \text{m/s}}$$

Find the height of the power line.

$$\text{height} = v_0 t - \frac{1}{2}gt^2 = \left(11\ \frac{\text{m}}{\text{s}}\right)(0.75\text{ s}) - \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.75\text{ s})^2 = \boxed{5.5\text{ m}}$$

102. The positive direction is down.

x_1 = position of first rock

x_2 = position of second rock

The speed of the first rock at height h and $t = 0$ is

$$v_1^2 = v_0{}^2 + 2g(x - x_0) = 2gh$$

$$v_{10} = \sqrt{2gh}$$

$$x_1 = h + v_{10}t + \frac{1}{2}gt^2$$

$$x_2 = \frac{1}{2}gt^2$$

$$S = x_1 - x_2 = h + v_{10}t = h + t\sqrt{2gh}$$

103. (a) Relative to the block, the arrow's acceleration is $a = -1550\ \frac{\text{m}}{\text{s}^2} - 450\ \frac{\text{m}}{\text{s}^2} = -2000\ \frac{\text{m}}{\text{s}^2}$.

$$v = v_0 + at = 0$$

$$t = \frac{-v_0}{a} = \frac{-20.0\ \frac{\text{m}}{\text{s}}}{-2000\ \frac{\text{m}}{\text{s}}} = \boxed{10\text{ ms}}$$

(b) $v = at = \left(450\ \frac{\text{m}}{\text{s}^2}\right)(10\times10^{-3}\text{ s}) = \boxed{4.5\text{ m/s}}$

(c) $v^2 = v_0{}^2 + 2a(x - x_0)$

$$x - x_0 = \frac{v^2 - v_0{}^2}{2a} = \frac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(20.0\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-2000\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{0.10\text{ m}}$$

104. (a) The ball must travel 0.45 m to its maximum height and return the same distance before it reappears.

$$x - x_0 = v_0t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$$

$$t^2 = \frac{2(x_0 - x)}{g}$$

$$t = \sqrt{\frac{2(x_0 - x)}{g}} = \sqrt{\frac{2(0.451\text{ m})}{9.81\ \frac{\text{m}}{\text{s}^2}}} = 0.303\text{ s}$$

The time is twice this or $2t = 2(0.303\text{ s}) = \boxed{0.61\text{ s}}$.

(b) Find the initial velocity.

$$x = x_0 + v_0t - \frac{1}{2}gt^2$$

$$v_0 = \frac{x - x_0}{t} + \frac{1}{2}gt = \frac{1.05\text{ m}}{0.25\text{ s}} + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.25\text{ s}) = 5.426\ \frac{\text{m}}{\text{s}}$$

Find the greatest height above the bottom of the window.

$v^2 = v_0^2 - 2g(x - x_0) = 0$ at maximum height.

$$x - x_0 = \frac{v_0{}^2}{2g} = \frac{\left(5.426\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)} = 1.501\text{ m}$$

The greatest height of the ball above the top of the window is 1.501 m – 1.05 m = $\boxed{0.45\text{ m}}$.

105. (a) $v^2 = v_0^2 + 2a(x - x_0) = v_0^2 - 2ax_0$ when $x = 0$

$$v = \pm\sqrt{v_0^2 - 2ax_0}$$

(b) $v = v_0 + at$

$$t = \frac{v - v_0}{a} = -\frac{v_0 + v}{2}$$

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 2ax_0}}{a}$$

(c) $x = x_0 + v_0 t + \frac{1}{2}at^2 = 0$

$$\frac{1}{2}at^2 + v_0 t + x_0 = 0$$

Using the quadratic formula:

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 4\left(\frac{1}{2}a\right)(x_0)}}{2\left(\frac{1}{2}a\right)}$$

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 2ax_0}}{a}$$