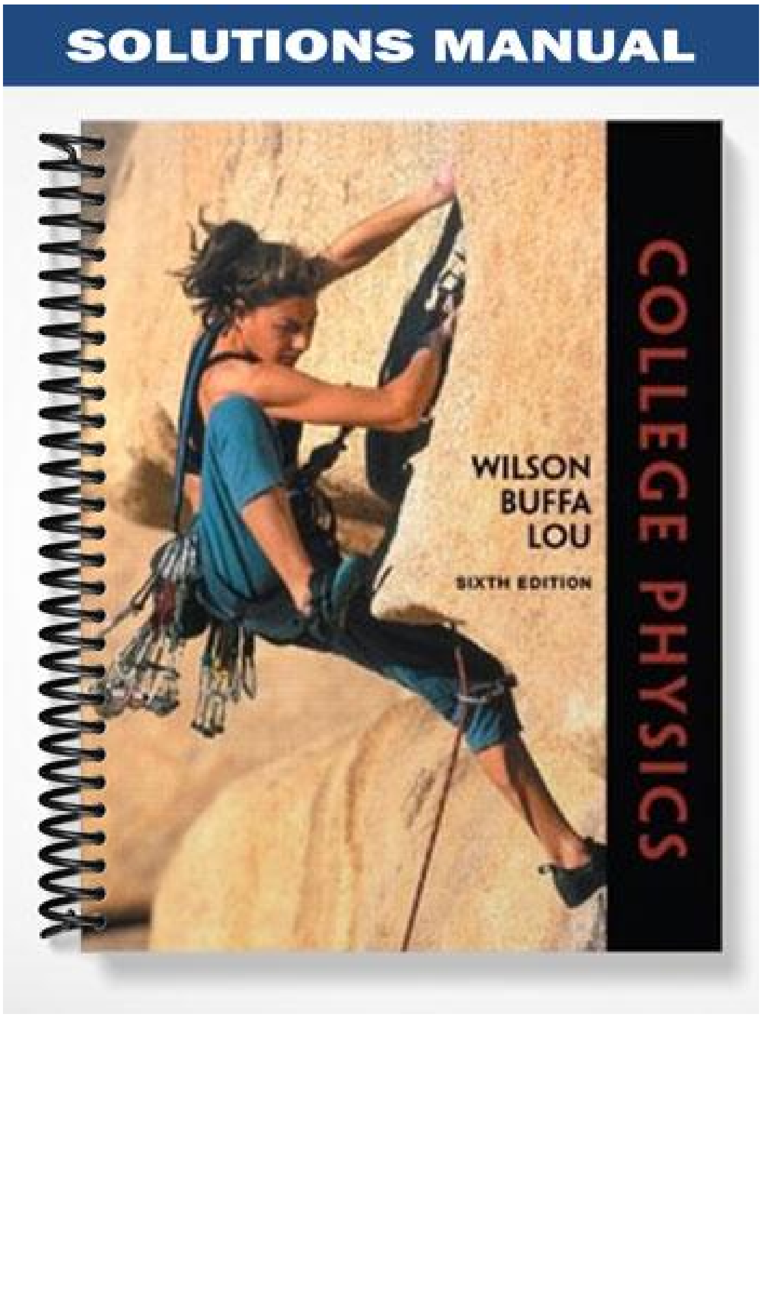
SOLUTIONS MANUAL
COLLEGE PHYSICS
WILSON
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CHAPTER 2

KINEMATICS: DESCRIPTION OF MOTION

1. (a).

2. (c). When it is a straight path, distance is equal to the magnitude of displacement. It is not a straight path; distance is greater than the magnitude of displacement.

3. (c).

4. (c).

5. Yes, for a round-trip. No, distance is always greater than or equal to the magnitude of displacement.

6. [No final position can be given]. The position [may be anywhere from 0 to 750 m from start].

7. [The distance traveled is greater than or equal to 300 m]. The object could travel a variety of ways as long as it ends up at 300 m north. If the object travels straight north, then the minimum distance is 300 m.

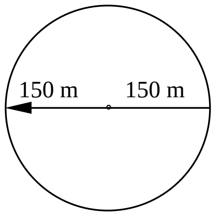
8. [No], this is generally not the case. The average velocity could be zero (for a round trip), while the average speed is never zero.

9. [Yes], this is possible. The jogger can jog in the opposite direction during the jog (negative instantaneous velocity) as long as the overall jog is in the forward direction (positive average velocity).

[10]. Displacement is the change in position.

Therefore the magnitude of the displacement for half a lap is [300 m].

For a full lap (the car returns to its starting position), the displacement is [zero].



11. Displacement is the change in position. So it is [1.65 m down].

12. d = 1 mi = 1609 m, Δt = 3 min, 43.13 s = 223.13 s.

So $\bar{s} = \frac{d}{\Delta t} = \frac{1609 \text{ m}}{223.13 \text{ s}} = \boxed{7.2 \text{ m/s}}$.

13. (a) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{(0.30\text{ km})(1000\text{ m/km})}{(10\text{ min})(60\text{ s/min})} = \boxed{0.50\text{ m/s}}$.

(b) $\bar{s}_1 = 1.20\,\bar{s} = 1.20(0.50\text{ m/s}) = 0.60\text{ m/s}$. So $\Delta t = \dfrac{d}{\bar{s}_1} = \dfrac{300\text{ m}}{0.60\text{ m/s}} = 500\text{ s} = \boxed{8.3\text{ min}}$.

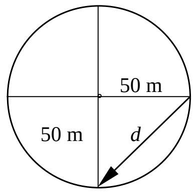
14. 1 cc = 1 mL. This is analogous to average speed.

$\Delta t = \dfrac{d}{\bar{s}} = \dfrac{500\text{ mL}}{4.0\text{ mL/min}} = \boxed{125\text{ min}}$.

15. $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{2(25\text{ m})}{[2(0.50\text{ min}) + 4.0\text{ min}](60\text{ s/min})} = \boxed{0.17\text{ m/s}}$.

16. $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{500\text{ mi} + 380\text{ mi} + 600\text{ mi}}{10\text{ h} + 8.0\text{ h} + 15\text{ h}} = \boxed{45\text{ mi/h}}$.

17. (a) The answer is $\boxed{\text{(2) greater than } R \text{ but less than } 2R}$. For any right triangle, the hypotenuse is always greater than any one of the other two sides (R) and less than the sum of the sum of the other two sides ($R + R = 2R$).

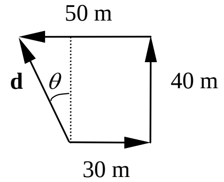


(b) $d = \sqrt{(50\text{ m})^2 + (50\text{ m})^2} = \boxed{71\text{ m}}$.

$\boxed{18}$. (a) The average velocity is $\boxed{\text{(1) zero}}$, because the displacement is zero for a complete lap.

(b) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{2\pi r}{\Delta t} = \dfrac{2\pi(500\text{ m})}{50\text{ s}} = \boxed{63\text{ m/s}}$.

19. (a) The magnitude of the displacement is $\boxed{\text{(3) between 40 m and 60 m}}$, because any side of a triangle cannot be greater than the sum of the other two sides. In this case, looking at the triangle shown, the two sides perpendicular to each other are 20 m and 40 m, respectively. The magnitude of the displacement is the hypotenuse of the right triangle, so it cannot be smaller than the longer of the sides perpendicular to each other.



(b) $d = \sqrt{(40\text{ m})^2 + (50\text{m} - 30\text{ m})^2} = \boxed{45\text{ m}}$. $\theta = \tan^{-1}\left(\dfrac{50\text{ m} - 30\text{ m}}{40\text{ m}}\right) = \boxed{27^\circ\text{ west of north}}$.

$\boxed{20}$. (a) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{2(7.1\text{ m})}{2.4\text{ s}} = \boxed{5.9\text{ m/s}}$.

(b) Average velocity is $\boxed{\text{zero}}$, because the ball is caught at the initial height so $\boxed{\text{displacement is zero}}$.

21. (a) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{27\text{ m} + 21\text{ m}}{(30\text{ min})(60\text{ s/min})} = \boxed{2.7\text{ cm/s}}$.

(b) The displacement is $\Delta x = \sqrt{(27\text{ m})^2 + (21\text{ m})^2} = 34.2\text{ m}$. $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{34.2\text{ m}}{(30\text{ min})(60\text{ s/min})} = \boxed{1.9\text{ cm/s}}$.

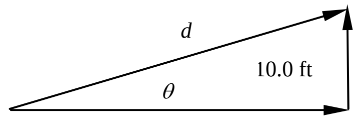
22. (a) The average velocity is $\boxed{\text{zero}}$, because the displacement is zero after one complete day.

(b) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{2\pi r}{\Delta t} = \dfrac{2\pi(6.4\times 10^6\text{ m})}{(24\text{ h})(3600\text{ s/h})} = \boxed{4.7\times 10^3\text{ m/s}}$.

(c) For a person at the North pole, the average velocity and average speed are $\boxed{\text{both zero}}$, because the North pole does not move as the Earth rotates.

23. (a) The magnitude of the displacement is $d = \sqrt{(90.0\text{ ft})^2 + (10.0\text{ ft})^2} = \boxed{90.6\text{ ft}}$.

$\theta = \tan^{-1}\left(\dfrac{10.0}{90.0}\right) = \boxed{6.3^\circ\text{ above horizontal}}$.



(b) $\bar{v} = \dfrac{90.6\text{ ft at }63^\circ}{2.5\text{ s}} = \boxed{36.2\text{ ft/s at }6.3^\circ}$.

(c) Average speed depends on the total path length, which is not given.
The ball might take a curved path.

$\boxed{24}$. (a) $\bar{v} = \dfrac{\Delta x}{\Delta t}$, so

$\bar{v}_{AB} = \dfrac{1.0\text{ m} - 1.0\text{ m}}{1.0\text{ s} - 0} = \boxed{0}$; $\bar{v}_{BC} = \dfrac{7.0\text{ m} - 1.0\text{ m}}{3.0\text{ s} - 1.0\text{ s}} = \boxed{3.0\text{ m/s}}$;

$\bar{v}_{CD} = \dfrac{9.0\text{ m} - 7.0\text{ m}}{4.5\text{ s} - 3.0\text{ s}} = \boxed{1.3\text{ m/s}}$; $\bar{v}_{DE} = \dfrac{7.0\text{ m} - 9.0\text{ m}}{6.0\text{ s} - 4.5\text{ s}} = \boxed{-1.3\text{ m/s}}$;

$\bar{v}_{EF} = \dfrac{2.0\text{ m} - 7.0\text{ m}}{9.0\text{ s} - 6.0\text{ s}} = \boxed{-1.7\text{ m/s}}$; $\bar{v}_{FG} = \dfrac{2.0\text{ m} - 2.0\text{ m}}{11.0\text{ s} - 9.0\text{ s}} = \boxed{0}$;

$\bar{v}_{BG} = \dfrac{2.0\text{ m} - 1.0\text{ m}}{11.0\text{ s} - 1.0\text{ s}} = \boxed{0.10\text{ m/s}}$.

(b) $\boxed{\text{The motion of BC, CD, and DE are not uniform}}$, since they are not straight lines.

(c) The object changes its direction of motion at point D. So it has to stop momentarily, and $v = \boxed{0}$.

25. Use $\bar{s} = \dfrac{d}{\Delta t}$ and $\bar{v} = \dfrac{\Delta x}{\Delta t}$.

(a) $\bar{s}_{0\text{-}2.0\text{ s}} = \dfrac{2.0\text{ m} - 0}{2.0\text{ s} - 0} = \boxed{1.0\text{ m/s}}$; $\bar{s}_{2.0\text{ s-}3.0\text{ s}} = \dfrac{2.0\text{ m} - 2.0\text{ m}}{3.0\text{ s} - 2.0} = \boxed{0}$;

$\bar{s}_{3.0\text{ s-}4.5\text{ s}} = \dfrac{4.0\text{ m} - 2.0\text{ m}}{4.5\text{ s} - 3.0\text{ s}} = \boxed{1.3\text{ m/s}}$; $\bar{s}_{4.5\text{ s-}6.5\text{ s}} = \dfrac{4.0\text{ m} - (-1.5\text{ m})}{6.5\text{ s} - 4.5\text{ s}} = \boxed{2.8\text{ m/s}}$;

$\bar{s}_{6.5\text{ s-}7.5\text{ s}} = \dfrac{-1.5\text{ m} - (-1.5\text{ m})}{7.5\text{ s} - 6.5\text{ s}} = \boxed{0}$; $\bar{s}_{7.5\text{ s-}9.0\text{ s}} = \dfrac{0 - (-1.5\text{ m})}{9.0\text{ s} - 7.5\text{ s}} = \boxed{1.0\text{ m/s}}$;

(b) $\bar{v}_{0\text{-}2.0\text{ s}} = \dfrac{2.0\text{ m} - 0}{2.0\text{ s} - 0} = \boxed{1.0\text{ m/s}}$; $\bar{v}_{2.0\text{ s-}3.0\text{ s}} = \dfrac{2.0\text{ m} - 2.0\text{ m}}{3.0\text{ s} - 2.0} = \boxed{0}$;

$\bar{v}_{3.0\text{ s-}4.5\text{ s}} = \dfrac{4.0\text{ m} - 2.0}{4.5\text{ s} - 3.0\text{ s}} = \boxed{1.3\text{ m/s}}$; $\bar{v}_{4.5\text{ s-}6.5\text{ s}} = \dfrac{-1.5\text{ m} - 4.0\text{ m}}{6.5\text{ s} - 4.5\text{ s}} = \boxed{-2.8\text{ m/s}}$;

$\bar{v}_{6.5\text{ s-}7.5\text{ s}} = \dfrac{-1.5\text{ m} - (-1.5\text{ m})}{7.5\text{ s} - 6.5\text{ s}} = \boxed{0}$; $\bar{v}_{7.5\text{ s-}9.0\text{ s}} = \dfrac{0 - (-1.5\text{ m})}{9.0\text{ s} - 7.5\text{ s}} = \boxed{1.0\text{ m/s}}$.

(c) $v_{1.0\text{ s}} = \bar{s}_{0\text{-}2.0\text{ s}} = \boxed{1.0\text{ m/s}}$; $v_{2.5\text{ s}} = \bar{s}_{2.0\text{ s-}3.0\text{ s}} = \boxed{0}$;

$v_{4.5\text{ s}} = \boxed{0}$ since the object reverses its direction of motion; $v_{6.0\text{ s}} = \bar{s}_{4.5\text{ s-}6.5\text{ s}} = \boxed{-2.8\text{ m/s}}$.

(d) $v_{4.5\text{ s-}9.0\text{ s}} = \dfrac{0 - 4.0\text{ m}}{9.0\text{ s} - 4.5\text{ s}} = \boxed{-0.89\text{ m/s}}$.

26. (a) $\bar{s} = \dfrac{d}{\Delta t}$, ☞ $\Delta t = \dfrac{1\text{ mi}}{70\text{ mi/h}} = 0.0143\text{ h} = \boxed{51\text{ s}}$.

(b) $\bar{s} = \dfrac{1\text{ mi}}{(65\text{ s})(1\text{ h}/3600\text{ s})} = \boxed{55\text{ mi/h}}$.

27. $d = 3.5\text{ cm} - 1.5\text{ cm} = 2.0\text{ cm}$.

$\bar{s} = \dfrac{d}{\Delta t}$, ☞ $\Delta t = \dfrac{2.0\text{ cm}}{2.0\text{ cm/mo}} = \boxed{1\text{ month}}$.

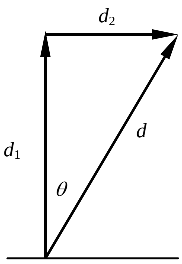
28. The minimum speed is $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{675\text{ km}}{7.00\text{ h}} = 96.4\text{ km/h} = \boxed{59.9\text{ mi/h}}$.

$\boxed{\text{No}}$, she does not have to exceed the 65 mi/h speed limit.

29. (a) See the sketch on the right.

$d = \sqrt{(400\text{ km})^2 + (300\text{ km})^2} = \boxed{500\text{ km}}$.

$\theta = \tan^{-1}\left(\dfrac{300}{400}\right) = \boxed{37°\text{ east of north}}$.



(b) $\Delta t = 45\text{ min} + 30\text{ min} = 75\text{ min} = 1.25\text{ h}$.

$\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{500\text{ km, }37°\text{ east of north}}{1.25\text{ h}} = \boxed{400\text{ km/h, }37°\text{ east of north}}$.

(c) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{400\text{ km} + 300\text{ km}}{1.25\text{ h}} = \boxed{560\text{ km/h}}$.

(d) Since $\boxed{\text{speed involves total distance, which is greater than the magnitude of the displacement}}$, the average speed is not equal to the magnitude of the average velocity.

30. To the runner on the right, the runner on the left is running at a velocity of

+4.50 m/s – (–3.50 m/s) = +8.00 m/s. So it takes $\Delta t = \dfrac{\Delta x}{\bar{v}} = \dfrac{100\text{ m}}{8.00\text{ m/s}} = \boxed{12.5\text{ s}}$.

They meet at (4.50 m/s)(12.5 s) = $\boxed{\text{56.3 m (relative to runner on left)}}$.

31. (d).

32. (d).

33. (c). A negative acceleration only means it is pointing in a particular direction, for example, the –*x*-axis. If an object is moving in the positive *x*-axis, the velocity of the object decreases. However, if an object is moving in the – *x*-axis, then its velocity can actually increase (speed up).

34. (d). Any change in either magnitude or direction results in a change in velocity. The brakes and gearshift change the magnitude, and the steering wheel changes the direction.

35. $\boxed{\text{Yes}}$, although the speed of the car is constant, its velocity is not, because of the change in direction. A change in velocity signifies an acceleration.

36. $\boxed{\text{Not necessarily}}$. The change in velocity is the key. If a fast-moving object does not change its velocity, its acceleration is zero. However, if a slow-moving object changes its velocity, it will have some acceleration.

37. $\boxed{\text{Not necessarily}}$. A negative acceleration can also speed up objects if the velocity is also negative (that is, in the same direction as the acceleration).

38. In Fig. 2.21(a), the object accelerates uniformly first, maintains constant velocity for a while, and then accelerates uniformly at the same rate again as in the first segment.
In Fig. 2.21(b), the object accelerates uniformly.

39. $\boxed{v_o}$. Since an equal amount of time is spent on acceleration and deceleration of the same magnitude.

40. 15.0 km/h = $(15.0\text{ km/h}) \times \dfrac{1000\text{ m}}{1\text{ km}} \times \dfrac{1\text{ h}}{3600\text{ s}} = 4.167\text{ m/s}$, 65.0 km/h = 18.06 m/s.

So $\bar{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{18.06\text{ m/s} - 4.167\text{ m/s}}{6.00\text{ s}} = \boxed{2.32\text{ m/s}^2}$.

41. $60 \text{ mi/h} = (60 \text{ mi/h}) \times \frac{1609 \text{ m}}{1 \text{ mi}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 26.8 \text{ m/s}.$ $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{26.8 \text{ m/s} - 0}{3.9 \text{ s}} = \boxed{6.9 \text{ m/s}^2}.$

42. $\Delta t = \frac{26.8 \text{ m/s} - 0}{7.2 \text{ m/s}^2} = \boxed{3.7 \text{ s}}.$

43. (a) The direction of the acceleration vector is $\boxed{\text{(2) opposite to velocity}}$ as the object slows down.

(b) $40.0 \text{ km/h} = (40 \text{ km/h}) \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 11.1 \text{ m/s}.$

So $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{0 - 11.1 \text{ m/s}}{5.0 \text{ s}} = -2.2 \text{ m/s}^2$ or $\boxed{-2.2 \text{ m/s each second}}$.

The negative sign indicates that the acceleration vector is in $\boxed{\text{opposite direction of velocity}}$.

$\boxed{44}$. $75 \text{ km/h} = (75 \text{ km/h}) \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 20.8 \text{ m/s},$ $30 \text{ km/h} = 8.33 \text{ m/s}.$

So $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{8.33 \text{ m/s} - 20.8 \text{ m/s}}{6.0 \text{ s}} = \boxed{-2.1 \text{ m/s}^2}.$

The negative sign indicates that the acceleration vector is in opposite direction of velocity.

45. $50 \text{ mi/h} = (50 \text{ mi/h}) \times \frac{1609 \text{ m}}{1 \text{ mi}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 22.3 \text{ m/s},$ $400 \text{ ft} = (400 \text{ ft}) \times \frac{1 \text{ m}}{3.281 \text{ ft}} = 122 \text{ m}.$

Average velocity is $\bar{v} = \frac{22.3 \text{ m/s} + 0}{2} = 11.2 \text{ m/s}.$

Time to travel 122 m is $t = \frac{122 \text{ m}}{11.2 \text{ m/s}} = 10.9 \text{ s}.$

So $a = \frac{v - v_o}{t} = \frac{0 - 22.3 \text{ m/s}}{10.9 \text{ s}} = \boxed{-2.0 \text{ m/s}^2}.$

The negative sign indicates that the acceleration vector is in the opposite direction of velocity.

46. (a) Take the upward direction as positive. $a = \frac{\Delta v}{\Delta t} = \frac{(-9.8 \text{ m/s}) - (+9.8 \text{ m/s})}{2.0 \text{ s}} = \boxed{-9.8 \text{ m/s}^2}.$

The negative sign indicates that the acceleration vector is downward.

(b) The average velocity is $\boxed{0}$, because the displacement is zero.

47. $\bar{v} = \frac{v + v_o}{2} = \frac{v_o + 0}{2},$ ☞ $v_o = 2\bar{v} = \boxed{-70.0 \text{ km/h}} = \boxed{-19.4 \text{ m/s}}.$

$a = \frac{v - v_o}{t} = \frac{0 - (-19.4 \text{ m/s})}{7.00 \text{ s}} = \boxed{+2.78 \text{ m/s}^2}.$

In this case, the positive 2.78 m/s^2 indicates deceleration because the velocity is negative.

48. (a) Given: $v_o = 35.0$ km/h = 9.72 m/s, $a = 1.50$ m/s^2, $x = 200$ m (take $x_o = 0$). Find: v.

$v^2 = v_o^2 + 2a(x - x_o) = (9.72 \text{ m/s})^2 + 2(1.5 \text{ m/s}^2)(200 \text{ m}) = 694 \text{ m}^2/\text{s}^2$, ☞ $v = \boxed{26.3 \text{ m/s}}$.

(b) $v = v_o + at$, ☞ $t = \dfrac{v - v_o}{a} = \dfrac{26.3 \text{ m/s} - 9.72 \text{ m/s}}{1.50 \text{ m/s}^2} = \boxed{11.1 \text{ s}}$.

49. Use the direction to the right as the positive direction.

$\bar{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{11 \text{ m/s} - (-35 \text{ m/s})}{0.095 \text{ s}} = \boxed{4.8 \times 10^2 \text{ m/s}^2}$.

This is a very large acceleration due to the change in direction of the velocity and the short contact time.

50. $\bar{a}_{0\text{-}4.0} = \dfrac{\Delta v}{\Delta t} = \dfrac{8.0 \text{ m/s} - 0}{4.0 \text{ s} - 0} = \boxed{2.0 \text{ m/s}^2}$; $\bar{a}_{4.0\text{-}10.0} = \dfrac{8.0 \text{ m/s} - 8.0 \text{ m/s}}{10.0 \text{ s} - 4.0 \text{ s}} = \boxed{0}$;

$\bar{a}_{10.0\text{-}18.0} = \dfrac{0 - 8.0 \text{ m/s}}{18.0 \text{ s} - 10.0 \text{ s}} = \boxed{-1.0 \text{ m/s}^2}$.

The object accelerates at 2.0 m/s^2 first, moves with constant velocity, then decelerates at 1.0 m/s^2.

51. (a) $\bar{a}_{0\text{-}1.0 \text{ s}} = \dfrac{\Delta v}{\Delta t} = \dfrac{0 - 0}{1.0 \text{ s} - 0} = \boxed{0}$; $\bar{a}_{1.0 \text{ s-}3.0 \text{ s}} = \dfrac{8.0 \text{ m/s} - 0}{3.0 \text{ s} - 1.0 \text{ s}} = \boxed{4.0 \text{ m/s}^2}$;

$\bar{a}_{3.0 \text{ s-}8.0 \text{ s}} = \dfrac{-12 \text{ m/s} - 8.0 \text{ m/s}}{8.0 \text{ s} - 3.0 \text{ s}} = \boxed{-4.0 \text{ m/s}^2}$; $\bar{a}_{8.0 \text{ s-}9.0 \text{ s}} = \dfrac{-4 \text{ m/s} - (-12.0 \text{ m/s})}{9.0 \text{ s} - 8.0 \text{ s}} = \boxed{8.0 \text{ m/s}^2}$;

$\bar{a}_{9.0 \text{ s-}13.0 \text{ s}} = \dfrac{-4.0 \text{ m/s} - 4.0 \text{ m/s}}{13.0 \text{ s} - 9.0 \text{ s}} = \boxed{0}$.

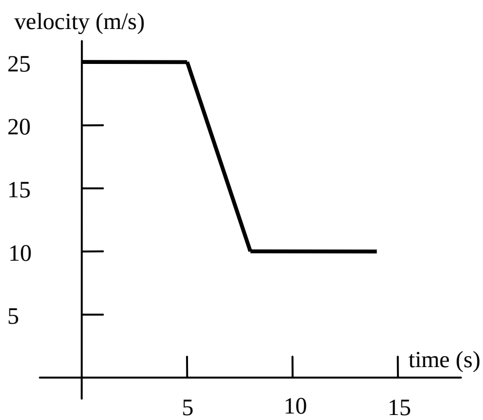
(b) $\boxed{\text{Constant velocity of } -4.0 \text{ m/s}}$.

$\boxed{52}$. (a) See the sketch on the right.

(b) The acceleration is negative as the object slows down (assume velocity is positive).

$v = v_o + at = 25 \text{ m/s} + (-5.0 \text{ m/s}^2)(3.0 \text{ s})$

$= \boxed{10 \text{ m/s}}$.



(c) $x = x_1 + x_2 + x_3$

$= (25 \text{ m/s})(5.0 \text{ s})$

$+ (25 \text{ m/s})(3.0 \text{ s}) + \tfrac{1}{2}(-5.0 \text{ m/s}^2)(3.0 \text{ s})^2$

$+ (10 \text{ m/s})(6.0 \text{ s})$

$= 237.5 \text{ m} = \boxed{2.4 \times 10^2 \text{ m}}$.

(d) $\bar{s} = \dfrac{d}{\Delta t} = \dfrac{237.5 \text{ m}}{14.0 \text{ s}} = \boxed{17 \text{ m/s}}$.

53. $72 \text{ km/h} = (72 \text{ km/h}) \times \dfrac{1000 \text{ m}}{1 \text{ km}} \times \dfrac{1 \text{ h}}{3600 \text{ s}} = 20 \text{ m/s}.$

During deceleration, $\Delta t_1 = \dfrac{\Delta v}{\bar{a}} = \dfrac{0 - 20 \text{ m/s}}{-1.0 \text{ m/s}^2} = 20 \text{ s}$; $\Delta x_1 = \bar{v}_1 \Delta t_1 = \dfrac{20 \text{ m/s} + 0}{2}(20 \text{ s}) = 200 \text{ m}.$

It would have taken the train $\dfrac{200 \text{ m}}{20 \text{ m/s}} = 10$ s to travel 200 m.

So it lost only 20 s – 10 s = 10 s during deceleration.

During acceleration, $\Delta t_2 = \dfrac{20 \text{ m/s} - 0}{0.50 \text{ m/s}^2} = 40 \text{ s}$; $\Delta x_2 = \dfrac{0 + 20 \text{ m/s}}{2}(40 \text{ s}) = 400 \text{ m}.$

It would have taken the train $\dfrac{400 \text{ m}}{20 \text{ m/s}} = 20$ s to travel 400 m. So it lost only 40 s – 20 s = 20 s during acceleration.

Therefore, the train lost 2 min + 10 s + 20 s = $\boxed{150 \text{ s}}$ in stopping at the station.

54. (c).

55. (d), because it is a parabola (depending on time squared).

56. (a). Since $v = v_o + at = 0 + at$, $\bar{v} = \dfrac{v_o + v}{2} = \frac{1}{2}at.$

57. $\boxed{\text{It is zero}}$ because the velocity is a constant.

58. $\boxed{\text{Not necessarily}}$. Even the acceleration is negative; the object can still have positive velocity and therefore a positive x.

59. Consider the displacement $(x - x_o)$ as one quantity; there are four quantities involved in each kinematic equation (Eq. 2.8, 2.10, 2.11, and 2.12). Three must be known before one can solve for any unknown. Or equivalently $\boxed{\text{all but one}}$ have to be known.

60. $\boxed{\text{No, negative acceleration would speed up an object having } -v \text{ or } v_o = 0}$.

61. The average velocity is $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{100 \text{ m}}{4.5 \text{ s}} = 22.2 \text{ m/s}.$ $\bar{v} = \dfrac{v_o + v}{2} = \dfrac{v}{2}.$

So the final velocity must be $v = 2(22.2 \text{ m/s}) = 44.4 \text{ m/s}.$

$\bar{a} = \dfrac{\Delta v}{\Delta t}$, ☞ $\Delta t = \dfrac{\Delta v}{\bar{a}} = \dfrac{44.4 \text{ m/s} - 0}{9.0 \text{ m/s}^2} = 4.9 \text{ s} > 4.5 \text{ s}.$

So $\boxed{\text{no}}$, the driver did not do it. The acceleration must be $\dfrac{44.4 \text{ m/s} - 0}{4.5 \text{ s}} = \boxed{9.9 \text{ m/s}^2}$.

$\boxed{62}$. Given: $v_o = 0$, $a = 2.0\ \text{m/s}^2$, $t = 5.00$ s. Find: v and x (take $x_o = 0$).

(a) $v = v_o + at = 0 + (2.0\ \text{m/s}^2)(5.0\ \text{s}) = \boxed{10\ \text{m/s}}$.

(b) $x = x_o + v_o t + \frac{1}{2}at^2 = 0 + 0(5.00\ \text{s}) + \frac{1}{2}(2.0\ \text{m/s}^2)(5.0\ \text{s})^2 = \boxed{25\ \text{m}}$.

63. Given: $v_o = 25$ mi/h $= 11.2$ m/s, $v = 0$, $x = 35$ m (take $x_o = 0$). Find: a and t.

(a) $v^2 = v_o^2 + 2a(x - x_o)$, ☞ $a = \dfrac{v^2 - v_o^2}{2x} = \dfrac{(0)^2 - (11.2\ \text{m/s})^2}{2(35\ \text{m})} = -1.79\ \text{m/s}^2 = -\boxed{1.8\ \text{m/s}^2}$.

The negative sign indicates that the acceleration vector is in opposite direction of velocity.

(b) $v = v_o + at$, ☞ $t = \dfrac{v - v_o}{a} = \dfrac{0 - 11.2\ \text{m/s}}{-1.79\ \text{m/s}^2} = \boxed{6.3\ \text{s}}$.

64. Given: $v_o = 60$ km/h $= 16.7$ m/s, $v = 40$ km/h $= 11.1$ m/s, $x = 50$ m (take $x_o = 0$). Find: a.

$v^2 = v_o^2 + 2a(x - x_o)$, ☞ $a = \dfrac{v^2 - v_o^2}{2x} = \dfrac{(11.1\ \text{m/s})^2 - (16.7\ \text{m/s})^2}{2(50\ \text{m})} = \boxed{-1.6\ \text{m/s}^2}$.

65. (a) Given: $v_o = 100$ km/h $= 27.78$ m/s, $a = -6.50\ \text{m/s}^2$, $x = 20.0$ m (take $x_o = 0$). Find: v.

$v^2 = v_o^2 + 2a(x - x_o) = (27.78\ \text{m/s})^2 + 2(-6.50\ \text{m/s}^2)(20.0\ \text{m}) = 511.6\ \text{m}^2/\text{s}^2$,

So $v = 22.62\ \text{m/s} = \boxed{81.4\ \text{km/h}}$.

(b) $v = v_o + at$, ☞ $t = \dfrac{v - v_o}{a} = \dfrac{22.62\ \text{m/s} - 27.78\ \text{m/s}}{-6.50\ \text{m/s}^2} = \boxed{0.794\ \text{s}}$.

$\boxed{66}$. Given: $v_o = 0$, $v = 560$ km/h $= 155.6$ m/s, $x = 400$ m (take $x_o = 0$). Find: t and a.

(a) $x = x_o + \bar{v}\,t = \dfrac{v_o + v}{2}t$, ☞ $t = \dfrac{2x}{v_o + v} = \dfrac{2(400\ \text{m})}{0 + 155.6\ \text{m/s}} = \boxed{5.14\ \text{s}}$.

(b) $v = v_o + at$, ☞ $a = \dfrac{v - v_o}{t} = \dfrac{155.6\ \text{m/s} - 0}{5.14\ \text{s}} = \boxed{30.3\ \text{s}}$.

67. Given: $v_o = 250$ km/h $= 69.44$ m/s, $a = -8.25\ \text{m/s}^2$, $x = 175$ m (Take $x_o = 0$). Find: t.

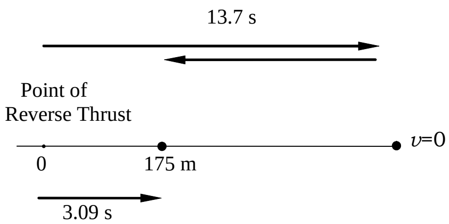
$x = x_o + v_o t + \frac{1}{2}at^2$, so

$175\ \text{m} = 0 + (69.44\ \text{m/s})t + \frac{1}{2}(-8.25\ \text{m/s}^2)t^2$.

Reduce to quadratic equation,

$4.125\,t^2 - 69.44\,t + 175 = 0$.

Solving, $t = \boxed{3.09\ \text{s and}\ 13.7\ \text{s}}$.



The 13.7 s answer is physically possible but not likely in reality. After 3.09 s, it is 175 m from where the reverse thrust was applied, but the rocket keeps traveling forward while slowing down. Finally it stops. However, if the reverse thrust is continuously applied (which is possible, but not likely), it will reverse its direction and be back to 175 m from the point where the initial reverse thrust was applied; a process that would take 13.7 s.

68. (a) Given: Car A: $a_A = 3.00\text{ m/s}^2$, $v_o = 2.50\text{ m/s}$, $t = 10\text{ s}$.

Car B: $a_B = 3.00\text{ m/s}^2$, $v_o = 5.00\text{ m/s}$, $t = 10\text{ s}$.

Find: Δx (taking $x_o = 0$).

From $x = x_o + v_o t + \frac{1}{2}at^2$, $x_A = 0 + (2.50\text{ m/s})(10\text{ s}) + \frac{1}{2}(3.00\text{ m/s})^2(10\text{ s})^2 = 175\text{ m}$,

$x_B = 0 + (5.00\text{ m/s})(10\text{ s}) + \frac{1}{2}(3.00\text{ m/s})^2(10\text{ s})^2 = 200\text{ m}$.

So $\Delta x = x_B - x_A = 200\text{ m} - 175\text{ m} = \boxed{25\text{ m}}$.

(b) From $v = v_o + at$, $v_A = 2.50\text{ m/s} + (3.00\text{ m/s})(10\text{ s}) = 32.5\text{ m/s}$,

$v_B = 5.00\text{ m/s} + (3.00\text{ m/s})(10\text{ s}) = 35.0\text{ m/s}$.

So $\boxed{\text{car B}}$ is faster.

69. If the acceleration is less than 4.90 m/s^2, then there is friction.

Given: $v_o = 0$, $x = 15.00\text{ m}$ (take $x_o = 0$), $t = 3.0\text{ s}$. Find: a.

$x = x_o + v_o t + \frac{1}{2}at^2$, ☞ $15.00\text{ m} = 0 + \frac{1}{2}a(3.0\text{ s})^2$.

$a = 3.33\text{ m/s}^2$. So the answer is $\boxed{\text{no}}$, the incline is not frictionless.

70. (a) $\boxed{\text{(3) The object will travel in the }+x\text{-direction and then reverse its direction}}$. This is because the object has initial velocity in the $+x$-direction, and it takes time for the object to decelerate, stop, and then reverse direction. We take $x_o = 0$.

Given: $v_o = 40\text{ m/s}$, $a = -3.5\text{ m/s}^2$, $x = 0$ ("returns to the origin"). Find: t and v.

(b) $x = x_o + v_o t + \frac{1}{2}at^2$, ☞ $0 = 0 + (40\text{ m/s})t + \frac{1}{2}(-3.5\text{ m/s}^2)t^2$.

Reduce to quadratic equation: $1.75t^2 - 40t = 0$. Solving, $t = 0$ or 22.9 s.

The $t = 0$ answer corresponds to the initial time. So the answer is $t = \boxed{23\text{ s}}$.

(c) $v = v_o + at = 40\text{ m/s} + (-3.5\text{ m/s}^2)(22.9\text{ s}) = -40\text{ m/s} = \boxed{40\text{ m/s in the }-x\text{-direction}}$.

71. Given: $v_o = 330\text{ m/s}$, $v = 0$, $x = 25\text{ cm} = 0.25\text{ m}$ (Take $x_o = 0$). Find: a.

$v^2 = v_o^2 + 2a(x - x_o)$, ☞ $a = \frac{v^2 - v_o^2}{2x} = \frac{(0)^2 - (330\text{ m/s})^2}{2(0.25\text{ m})} = -\boxed{2.2 \times 10^5\text{ m/s}^2}$.

The negative sign here indicates that the acceleration vector is in the opposite direction of velocity.

$\boxed{72}$. $40 \text{ km/h} = (40 \text{ km/h}) \times \dfrac{1000 \text{ m}}{1 \text{ km}} \times \dfrac{1 \text{ h}}{3600 \text{ s}} = 11.11 \text{ m/s}.$

During reaction, the car travels a distance of $d = (11.11 \text{ m/s})(0.25 \text{ s}) = 2.78 \text{ m}$.

So the car really has only 13 m – 2.78 m = 10.2 m to come to rest.

Let's calculate the stopping distance of the car. We take $x_o = 0$.

Given: $v_o = 11.1$ m/s, $v = 0$, $a = -8.0 \text{ m/s}^2$. Find: x. (Take $x_o = 0$.)

$$v^2 = v_o^2 + 2a(x - x_o), \quad ☞ \quad x = \frac{v^2 - v_o^2}{2a} = \frac{0 - (11.1 \text{ m/s})^2}{2(-8.0 \text{ m/s}^2)} = 7.70 \text{ m}.$$

So it takes the car only 2.78 m + 7.70 m = $\boxed{10.5 \text{ m}}$ (< 13 m) to stop.

$\boxed{\text{Yes}}$, the car will stop before hitting the child.

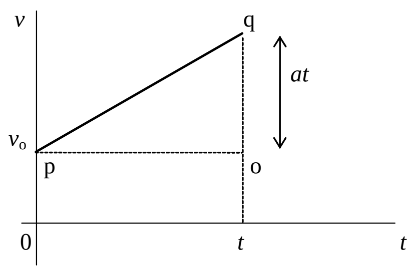
73. Repeat the calculation of Exercise 2.72. $d = (11.1 \text{ m/s})(0.50 \text{ s}) = 5.55 \text{ m}$.

5.55 m + 7.70 m = $\boxed{13.3 \text{ m}}$ > 13 m. $\boxed{\text{No}}$, the car will not stop before hitting the child.

74. Given: $v_o = 350$ m/s, $v = 210$ m/s, $x = 4.00$ cm = 0.0400 m (take $x_o = 0$). Find: t.

$$x = x_o + \bar{v}\, t = \frac{v_o + v}{2}\, t, \quad ☞ \quad t = \frac{2x}{v_o + v} = \frac{2(0.0400 \text{ m})}{350 \text{ m/s} + 210 \text{ m/s}} = \boxed{1.43 \times 10^{-4} \text{ s}}.$$

75. (a) For constant acceleration, the v vs. t plot is a straight line. Point p has coordinates of $(0, v_o)$ and point q has coordinates of $(t, v_o + at)$. The distance from point q to point o is therefore at. The area under the curve is the area of the triangle $\frac{1}{2}(at)t$ plus the area of the rectangle $v_o t$.



So $A = v_o t + \frac{1}{2}at^2 = x - x_o$. (Here $x - x_o$ is displacement.)

(b) The total area consists of two triangles from 0 to 4.0 s and from 10.0 s to 18.0 s and a rectangle from 4.0 s to 10.0 s.

$$x - x_o = A = \tfrac{1}{2}(4.0 \text{ s} - 0)(8.0 \text{ m/s}) + (10.0 \text{ s} - 4.0 \text{ s})(8.0 \text{ m/s}) + \tfrac{1}{2}(18.0 \text{ s} - 10.0 \text{ s})(8.0 \text{ m/s}) = \boxed{96 \text{ m}}.$$

$\boxed{76}$. (a) $\boxed{(3)\ t_1 > t_2}$. Since the object is accelerating, it will spend less time in traveling the second 3.00 m.

(b) For the first 3.00 m: Given: $v_o = 0$, $a = 2.00 \text{ m/s}^2$, $x = 3.00$ m (take $x_o = 0$). Find: t.

$$x = x_o + v_o t + \tfrac{1}{2}at^2 = 0 + 0 + \tfrac{1}{2}at^2, \quad ☞ \quad t_1 = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2(3.00 \text{ m})}{2.00 \text{ m/s}^2}} = \boxed{1.73 \text{ s}}.$$

At the end of the first 3.00 m, the velocity of the object is $v = v_o + at = 0 + (2.00 \text{ m/s}^2)(1.73 \text{ s}) = 3.46 \text{ m/s}$.

This is then the initial velocity for the second 3.00 m.

For the second 3.00 m: Given: $v_o = 3.46$ m/s, $a = 2.00$ m/s^2, $x = 3.00$ m. Find: t.

$x = x_o + v_o t + \frac{1}{2}at^2$, ☞ $3.00\text{ m} = 0 + (3.46\text{ m/s})t_2 + \frac{1}{2}(2.00\text{ m/s}^2)t_2^2$.

Reducing to quadratic equation, $t^2 + 3.46t - 3.00 = 0$.

Solving, $t_2 = \boxed{0.718\text{ s}}$ or –4.18 s.

77. (a) At the end of phase 1, the change in velocity is $v_1 - 0 = v_1$. At the end of phase 2, the change in velocity is $v_2 - v_1$. Since the object is accelerating, it spends less time in phase 2 than in phase 1. Since the change in velocity is equal to acceleration times the time, the change in velocity is greater in phase 1 than in phase 2. Or $v_1 > v_2 - v_1$. That is $2v_1 > v_2$.

Therefore, $v_1 > \frac{1}{2}v_2$. The answer is $\boxed{(3)\ v_1 > \frac{1}{2}v_2}$.

(b) For phase 1: $v_o = 0$, $a = 0.850$ m/s^2, $x = 50.0$ m (take $x_o = 0$). Find: v.

$v^2 = v_o^2 + 2a(x - x_o) = 0^2 + 2(0.850\text{ m/s}^2)(50.0\text{ m}) = 85.0\text{ m}^2/\text{s}^2$, ☞ $v_1 = \boxed{9.22\text{ m/s}}$.

For phase 2: $v_o = 9.22$ m/s, $a = 0.850$ m/s^2, $x = 50.0$ m (take $x_o = 0$). Find: v.

$v^2 = v_o^2 + 2a(x - x_o) = (9.22\text{ m/s})^2 + 2(0.850\text{ m/s}^2)(50.0\text{ m}) = 170\text{ m}^2/\text{s}^2$, ☞ $v_2 = \boxed{13.0\text{ m/s}}$.

So $v_1 = 9.22\text{ m/s} > \frac{1}{2}v_2 = \frac{1}{2}(13.0\text{ m/s}) = 6.50$ m/s.

78. Take $x_o = 0$. During acceleration: $v_o = 0$, $a = 1.5$ m/s^2, $t = 6.0$ s.

$x_1 = x_o + v_o t + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}(1.5\text{ m/s}^2)(6.0\text{ s})^2 = 27$ m,

$v = v_o + at = 0 + (1.5\text{ m/s}^2)(6.0\text{ s}) = 9.0$ m/s.

During constant velocity: $x_2 = (9.0\text{ m/s})(8.0\text{ s}) = 72$ m.

So $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{27\text{ m} + 72\text{ m}}{14\text{ s}} = \boxed{7.1\text{ m/s}}$.

79. (a) $v(8.0\text{ s}) = \boxed{-12\text{ m/s}}$; $v(11.0\text{ s}) = \boxed{-4.0\text{ m/s}}$.

(b) Use the result of Exercise 2.75a. The total area consists of a rectangle from 0 to 1.0 s, a triangle from 1.0 s to 5.0 s, a trapezoid from 5.0 s to 11.0 s, and a triangle from 6.0 s to 9.0 s with baseline at –4.0 m/s.

$$x - x_o = A = 0 + \tfrac{1}{2}(5.0\text{ s} - 1.0\text{ s})(8.0\text{ m/s}) + \frac{(11.0\text{ s} - 6.0\text{ s}) + (11.0\text{ s} - 5.0\text{ s})}{2} \times (-4.0\text{ m/s})$$

$$+ \tfrac{1}{2}(9.0\text{ s} - 6.0\text{ s})[(-12.0\text{ m/s}) - (-4.0\text{ m/s})] = \boxed{-18\text{ m}}.$$

(c) The total distance (not displacement) is the addition of the absolute values of the areas.

$$d = \Sigma A_i = 0 + \tfrac{1}{2}(5.0\text{ s} - 1.0\text{ s})(8.0\text{ m/s}) + \frac{(11.0\text{ s} - 6.0\text{ s}) + (11.0\text{ s} - 5.0\text{ s})}{2} \times (4.0\text{ m/s})$$

$$+ \tfrac{1}{2}(9.0\text{ s} - 6.0\text{ s})[(12.0\text{ m/s} - 4.0\text{ m/s}] = \boxed{50\text{ m}}.$$

80. (a) $v^2 = v_o^2 + 2a(x - x_o)$, ☞ $x - x_o = \dfrac{v^2 - v_o^2}{2a} = \dfrac{0^2 - v_o^2}{2a} = -\dfrac{v_o^2}{2a}$.

Taking $x_o = 0$, so $(x - x_o) = x$ is proportional to v_o^2 . If v_o doubles, then x becomes 4 times as large.

The answer is then $\boxed{(3)\ 4x}$.

(b) $\dfrac{x_2}{x_1} = \dfrac{v_{2o}^2}{v_{1o}^2} = \dfrac{60^2}{40^2} = 2.25$. So $x_2 = 2.25\, x_1 = 2.25\ (3.00\ \text{m}) = \boxed{6.75\ \text{m}}$.

81. (a) Given: $a = 3.00\ \text{m/s}^2$, $t = 1.40$ s, $x = 20.0$ m (take $x_o = 0$). Find: v_o.

$x = x_o + v_o t + \frac{1}{2} a t^2$, ☞ $20.0\ \text{m} = 0 + v_o(1.40\ \text{s}) + \frac{1}{2}(3.00\ \text{m/s}^2)(1.40\ \text{s})^2$.

Solving, $v_o = \boxed{12.2\ \text{m/s}}$.

$v = v_o + at = 12.2\ \text{m/s} + (3.00\ \text{m/s}^2)(1.40\ \text{s}) = \boxed{16.4\ \text{m/s}}$.

(b) Given: $v_o = 0$, $a = 3.00\ \text{m/s}^2$, $v = 12.2$ m/s. Find: x (take $x_o = 0$).

$v^2 = v_o^2 + 2a(x - x_o)$, ☞ $x - x_o = \dfrac{v^2 - v_o^2}{2a} = \dfrac{(12.2\ \text{m/s})^2 - 0^2}{2(3.00\ \text{m/s}^2)} = \boxed{24.8\ \text{m}}$.

(c) $v = v_o + at$, ☞ $t = \dfrac{v - v_o}{a} = \dfrac{12.2\ \text{m/s} - 0}{3.00\ \text{m/s}^2} = \boxed{4.07\ \text{s}}$.

82. 75.0 mi/h = 33.5 m/s.

(a) Given: $v_o = 33.5$ m/s, $a = -1.00\ \text{m/s}^2$, $x = 100$ m (take $x_o = 0$). Find: v.

$v^2 = v_o^2 + 2a(x - x_o) = (33.5\ \text{m/s})^2 + 2(-1.00\ \text{m/s}^2)(100\ \text{m}) = 922\ \text{m}^2/\text{s}^2$.

So $v = \boxed{30.4\ \text{m/s}}$.

(b) The initial velocity on dry concrete is then 30.4 m/s. Consider on dry concrete.

Given: $v_o = 30.4$ m/s, $a = -7.00\ \text{m/s}^2$, $v = 0$ m. Find: x.

$v^2 = v_o^2 + 2ax$, ☞ $x = \dfrac{v^2 - v_o^2}{2a} = \dfrac{0^2 - (30.4\ \text{m/s})^2}{2(-7.00\ \text{m/s}^2)} = 66.0$ m.

So the total distance is 100 m + 66.0 m = $\boxed{166\ \text{m}}$.

(c) Use $v = v_o + at$.

On ice: $t_1 = \dfrac{v - v_o}{a} = \dfrac{30.4\ \text{m/s} - 33.5\ \text{m/s}}{-1.00\ \text{m/s}^2} = 3.10$ s,

On dry concrete: $t_2 = \dfrac{0 - 30.4\ \text{m/s}}{-7.00\ \text{m/s}^2} = 4.34$ s.

So the total time is 3.10 s + 4.34 s = $\boxed{7.44\ \text{s}}$.

83. (d).

84. (d). Free fall is a motion under the gravitational acceleration. The initial velocity does not matter.

85. (c). It accelerates at 9.80 m/s^2, so it increases its speed by 9.80 m/s in each second.

86. (a). The acceleration is not zero. It is 9.80 m/s^2 downward.

87. (c). It is always accelerates at 9.80 m/s^2 downward.

88. When it reaches the highest point, its velocity is $\boxed{\text{zero}}$ (velocity changes from up to down, so it has to be zero), and its acceleration is still the constant $\boxed{9.8\text{ m/s}^2\text{ downward}}$.

89. $\boxed{\text{The ball moves with a constant velocity}}$, because there is no gravitational acceleration in deep space. If the gravitational acceleration is zero, $g = 0$, then v = constant.

$\boxed{90}$. Taking $y_o = 0$, $y = y_o + v_o t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$.

So $y_1 = -\frac{1}{2}gt^2$ and $y_2 = -\frac{1}{2}g(t-1)^2$.

The distance between the two positions is

$\Delta y = y_1 - y_2 = -\frac{1}{2}g\,[t^2 - (t-1)^2] = -\frac{1}{2}g\,[t^2 - t^2 + 2t - 1] = -\frac{1}{2}g\,[2t - 1]$.

Therefore, Δy $\boxed{\text{increases}}$ as t increases.

91. First of all, the gravitational acceleration on the Moon is only 1/6 of that on the Earth.

Or $\boxed{g_M = g_E/6}$.

Secondly, there is no air resistance on the Moon.

92. (a) Given: $v_o = 0$, $t = 2.8$ s. Find: v (take $y_o = 0$).

$v = v_o - gt = 0 - (9.80\text{ m/s}^2)(2.8\text{ s}) = -\boxed{27\text{ m/s}}$.

(b) $y = y_o + v_o t - \frac{1}{2}gt^2 = 0 + 0 - \frac{1}{2}(9.80\text{ m/s}^2)(2.8\text{ s})^2 = -\boxed{38\text{ m}}$.

93. (a) We take $y_o = 0$. $y = y_o + v_o t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$. So y is proportional to the time squared.

Therefore twice the time means $\boxed{\text{(3) four times}}$ the height.

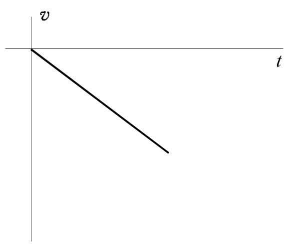
Given: $v_o = 0$, $t = 1.80$ s. Find: y_A and y_B.

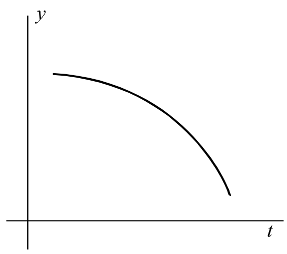
(b) $y_A = -\frac{1}{2}(9.80\text{ m/s}^2)(1.80\text{ s})^2 = -15.9\text{ m}$.

So the height of cliff A above the water is 15.88 m = $\boxed{15.9\text{ m}}$.

$$y_B = \frac{y_A}{4} = \frac{15.88\text{ m}}{4} = \boxed{3.97\text{ m}}.$$

94. (a) A straight line (linear), slope = $-g$. (b) A parabola.





95. Given: $v_o = 0$, $y = -0.157$ m (take $y_o = 0$). Find: t.

$$y - y_o = v_o t - \tfrac{1}{2}gt^2 = -\tfrac{1}{2}gt^2, \quad ☞ \quad t = \sqrt{\frac{2y}{-g}} = \sqrt{\frac{2(-0.157\text{ m})}{-9.80\text{ m/s}^2}} = 0.18\text{ s} < 0.20\text{ s}.$$

It takes less than the average human reaction time for the dollar bill to fall.

So the answer is $\boxed{\text{no, not a good deal}}$.

$\boxed{96}$. Given: $v_o = 15$ m/s, $v = 0$ (maximum height). Find: y. (Take $y_o = 0$.)

$$v^2 = v_o^2 - 2g(y - y_o), \quad ☞ \quad y = \frac{v_o^2 - v^2}{2g} = \frac{(15\text{ m/s})^2 - (0)^2}{2(9.80\text{ m/s}^2)} = \boxed{11\text{ m}}.$$

97. From Exercise 2.96, $y = \dfrac{v_o^2 - v^2}{2g} = \dfrac{(15\text{ m/s})^2 - (0)^2}{2(1.67\text{ m/s}^2)} = \boxed{67\text{ m}}$.

98. The maximum initial velocity corresponds to the apple reaching maximum height just below the ceiling.

Given: $v = 0$ (max height), $(y - y_o) = 3.75\text{ m} - 0.50\text{ m} = 3.25\text{ m}$. Find: v_o.

$$v^2 = v_o^2 - 2g(y - y_o), \quad ☞ \quad v_o = \sqrt{v^2 + 2g(y - y_o)} = \sqrt{0 + 2(9.80\text{ m/s}^2)(3.25\text{ m})} = 7.98\text{ m/s}.$$

Therefore it is $\boxed{\text{slightly less than 8.0 m/s}}$.

99. Taking $y_o = 0$, $y = y_o + v_o t - \frac{1}{2}gt^2 = 0 + 0 - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$, so $t = \sqrt{\dfrac{-2y}{g}}$.

For $y = -452$ m, $t = 9.604$ s; for $y = -443$ m, $t = 9.508$ s. So $\Delta t = 9.604\text{ s} - 9.508\text{ s} = \boxed{0.096\text{ s}}$.

100. Given: $v_o = 6.0$ m/s, $y = -12$ m (take $y_o = 0$). Find: t and v.

(a) $y = y_o + v_o t - \frac{1}{2} g t^2$, ☞ $-12 \text{ m} = 0 + (6.0 \text{ m/s})t - \frac{1}{2}(9.80 \text{ m/s}^2)t^2$.

Or $4.9t^2 - 6.0t - 12 = 0$. Solving, $t = \boxed{2.3 \text{ s}}$ or -1.1 s. The negative time is discarded.

(b) $v = v_o - gt = 6.0 \text{ m/s} - (9.80 \text{ m/s}^2)(2.29 \text{ s}) = -\boxed{16 \text{ m/s}}$.

101. (a) When the ball rebounds, it is a free fall with an initial upward velocity. At the maximum height, the velocity is zero. Taking $y_o = 0$,

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $y = \dfrac{v_o^2 - v^2}{2g}$. So $y_{max} = \dfrac{v_o^2}{2g}$.

Therefore, the height depends on the initial velocity squared. 95% = 0.95 and $0.95^2 = 0.90 < 0.95$.

The ball would bounce $\boxed{\text{(1) less than 95\%}}$ of the initial height.

(b) First calculate the speed just before impact.

Given: $v_o = 0$, $y = -4.00$ m. Find: v.

$v^2 = v_o^2 - 2gy = 0^2 - 2(9.80 \text{ m/s}^2)(-4.00 \text{ m}) = 78.4 \text{ m}^2/\text{s}^2$,

so $v = -\sqrt{78.4 \text{ m}^2/\text{s}^2} = -8.85$ m/s.

Therefore the speed right after the rebound is 0.950(8.85 m/s) = 8.41 m/s.

Now consider the rising motion.

Given: $v_o = 8.41$ m/s, $v = 0$ (max height). Find: y.

$v^2 = v_o^2 - 2gy$, ☞ $y = \dfrac{v_o^2 - v^2}{2g} = \dfrac{(8.41 \text{ m/s})^2 - 0^2}{2(9.80 \text{ m/s}^2)} = \boxed{3.61 \text{ m}}$.

$\boxed{102}$. (a) Given: $v_o = 80.00$ mi/h = 35.76 m/s, $v = 0$ (max height), Find: $(y - y_o)$.

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $y - y_o = \dfrac{v_o^2 - v^2}{2g} = \dfrac{0^2 - (35.76 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = 65.2$ m.

Therefore the minimum ceiling height is 65.2 m + 1.00 m = $\boxed{66.2 \text{ m}}$.

(b) $y - y_o = 65.2 \text{ m} - 10.0 \text{ m} = 55.2$ m. With $v = 0$,

$v_o = \sqrt{2g(y - y_o)} = \sqrt{2(9.80 \text{ m/s}^2)(55.2 \text{ m})} = \boxed{32.9 \text{ m/s}}$.

103. (a) Given: $v_o = 0$, $t = 1.26$ s, $(y - y_o) = -1.30$ m (downward). Find: g.

$y = y_o + v_o t - \frac{1}{2} g t^2$, ☞ $-1.30 \text{ m} = 0 - \frac{1}{2} g (1.26 \text{ s})^2$.

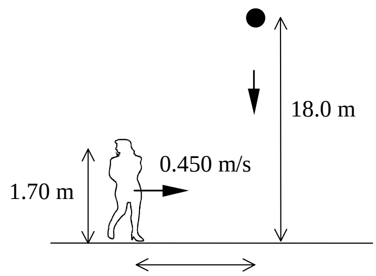
Solving, $g = \boxed{1.64 \text{ m/s}^2}$.

(b) $v = v_o - gt = 0 - (1.64 \text{ m/s}^2)(1.26 \text{ s}) = -20.7 \text{ m/s} = \boxed{2.07 \text{ m/s}}$ downward.

104. First find the time it takes for the ball to reach the level of the professor's head.

Given: $(y - y_o) = -(18.0\text{ m} - 1.70\text{ m}) = -16.3\text{ m}$, $v_o = 0$. Find: t.

From $y = y_o + v_o t - \frac{1}{2}gt^2 = y_o + -\frac{1}{2}gt^2$,



$$t = \sqrt{-\frac{2(y - y_o)}{g}} = \sqrt{-\frac{2(-16.3\text{ m})}{9.80\text{ m/s}^2}} = 1.824\text{ s}.$$

During this time, the professor advances a distance equal to

$(0.450\text{ m/s})(1.824\text{ s}) = 0.821\text{ m} < 1.00\text{ m}$. $\boxed{\text{No}}$, it does not hit her.

Now calculate the time it takes for the ball to hit the ground.

$$t = \sqrt{-\frac{2(-18.0\text{ m})}{9.80\text{ m/s}^2}} = 1.917\text{ s}.$$

During this time, the professor advances a distance of $(0.450\text{ m/s})(1.917\text{ s}) = 0.862\text{ m} < 1.00\text{ m}$.

So the ball hits $1.00\text{ m} - 0.862\text{ m} = 0.14\text{ m} = \boxed{\text{14 cm in front of the professor}}$.

105. (a) Given: $v_o = 12.50$ m/s (ascending), $y = -60.0$ m (take $y_o = 0$). Find: t.

$y = y_o + v_o t - \frac{1}{2}gt^2$, ☞ $-60.0\text{ m} = 0 + (12.50\text{ m/s})t - (4.90\text{ m/s}^2)t^2$.

Reduce to a quadratic equation: $4.90t^2 - 12.50t - 60.0 = 0$.

Solve for $t = \boxed{5.00\text{ s}}$ or -2.45 s, which is physically meaningless.

(b) $v = v_o - gt = 12.50\text{ m/s} - (9.80\text{ m/s}^2)(5.00\text{ s}) = -36.5\text{ m/s} = \boxed{36.5\text{ m/s}}$ downward.

106. (a) We take $y_o = 0$. The answer is $\boxed{(1)\sqrt{6}}$.

$y = y_o + v_o t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2$, ☞ $t = \sqrt{-\frac{2y}{g}}$. $\frac{t_M}{t_E} = \frac{\sqrt{1/g_M}}{\sqrt{1/g_E}} = \sqrt{\frac{g_E}{g_M}} = \sqrt{6}$.

(b) Given: $v_o = 18.0$ m/s, $v = 0$ ("max height"). Find: y and t.

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $y = \frac{v_o^2 - v^2}{2g} = \frac{v_o^2}{2g}$. So $\frac{y_M}{y_E} = \frac{g_E}{g_M} = 6$.

For the total trip (up and down), the final position is zero ($y = 0$).

So $y = y_o + v_o t - \frac{1}{2}gt^2 = 0$, ☞ $t = \frac{2v_o}{g}$.

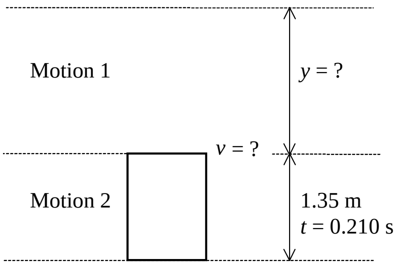
Therefore $\frac{t_M}{t_E} = \frac{g_E}{g_M} = 6$.

On the Earth, $y_E = \frac{(18.0\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = \boxed{16.5\text{ m}}$. $t_E = \frac{2(18.0\text{ m/s})}{9.80\text{ m/s}^2} = \boxed{3.67\text{ s}}$.

On the Moon, $y_M = 6\,y_E = \boxed{99.2\text{ m}}$. $t_M = 6\,t_E = \boxed{22.0\text{ s}}$.

107. The key to this exercise is to find the velocity of the object when it reaches the top of the window (it is not zero). This velocity is the initial velocity for Motion 1 and the final velocity for Motion 2.

Consider Motion 2 first. Taking $y_o = 0$.



Given: $y = -1.35$ m, $t = 0.210$ s. Find: v_o.

Apply $y = y_o + v_o t - \frac{1}{2}gt^2$,

$v_o = \frac{y}{t} + \frac{1}{2}gt = \frac{-1.35\text{ m}}{0.210\text{ s}} + (4.90\text{ m/s}^2)(0.210\text{ s}) = -5.40$ m/s.

Now consider Motion 1. Also take $y_o = 0$.

Given: $v_o = 0$, $v = -5.40$ m. Find: y.

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $y = \frac{v_o^2 - v^2}{2g} = \frac{0 - (-5.40\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = 1.49$ m.

So, it is $\boxed{\text{1.49 m above the top of the window}}$.

$\boxed{108}$. (a) Given: $v_o = 0$, $(y - y_o) = -10.0$ m (downward). Find: v.

$v^2 = v_o^2 - 2g(y - y_o) = -2(9.80\text{ m/s}^2)(-10.0\text{ m}) = 196\text{ m}^2/\text{s}^2$. So $v = -14.0$ m/s = $\boxed{14.0\text{ m/s}}$ downward.

(b) Given: $v = 0$ (max height), $(y - y_o) = 4.00$ m. Find: v_o.

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $v_o = \sqrt{v^2 + 2g(y - y_o)} = \sqrt{0 + 2(9.80\text{ m/s}^2)(4.00\text{ m})} = \boxed{8.85\text{ m/s}}$.

(c) Falling: $v = v_o - gt$, ☞ $t_1 = \frac{v_o - v}{g} = \frac{0 - (-14.0\text{ m/s})}{9.80\text{ m/s}^2} = 1.43$ s.

Rising: $t_2 = \frac{8.85\text{ m/s} - 0}{9.80\text{ m/s}^2} = 0.90$s .

Therefore the total time is 1.43 s + 0.903 s = $\boxed{2.33\text{ s}}$.

109. (a) Given: $v_o = 0$, $a = 12.0\text{ m/s}^2$, $(y - y_o) = 1000$ m. Find: v.

$v^2 = v_o^2 + 2a(y - y_o) = 0 + 2(12.0\text{ m/s}^2)(1000\text{ m}) = 24\,000\text{ m}^2/\text{s}^2$. So $v = 154.9$ m/s = $\boxed{155\text{ m/s}}$.

(b) Given: $v_o = 154.9$ m/s, $v = 0$ (maximum height). Find: $(y - y_o)$.

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $y - y_o = \frac{v_o^2 - v^2}{2g} = \frac{(154.9\text{ m/s})^2 - 0^2}{2(9.80\text{ m/s}^2)} = 1224$ m.

So the maximum altitude is 1000 m + 1224 m = $\boxed{2.22 \times 10^3\text{ m}}$.

(c) Accelerating at 12.0 m/s^2. $v = v_o + at$, ☞ $t_1 = \frac{v - v_o}{a} = \frac{154.9\text{ m/s} - 0}{12.0\text{ m/s}^2} = 12.9$ s.

Free falling (still going up). $v = v_o - gt$, ☞ $t_2 = \frac{v_o - v}{g} = \frac{154.9\text{ m/s} - 0}{9.80\text{ m/s}^2} = 15.8$ s.

So the total time is 12.9 s + 15.8 s = $\boxed{28.7\text{ s}}$.

110. (a) When the rocket has fuel, the motion is *not* a free fall but rather a motion with constant acceleration of $2g$.

Given: $v_o = 0$, $a = 2g$, $t = t$. Find: v, and y (take $y_o = 0$).

$v = v_o + at = 0 + 2gt = \boxed{2gt}$. $y = y_o + v_o t + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}(2g)t^2 = \boxed{gt^2}$.

(b) When the fuel runs out, the rocket is moving upward with a speed of $2gt$ and at a height of gt^2. From that point on, the acceleration experienced by the rocket is gravitational acceleration.

Given: $v_o = 2gt$, $v = 0$ (maximum height), $a = -g$, $y_o = gt^2$. Find: y.

$v^2 = v_o^2 - 2g(y - y_o)$, ☞ $y_{max} = y_o + \dfrac{v_o^2 - v^2}{2g} = gt^2 + \dfrac{v_o^2}{2g} = gt^2 + \dfrac{(2gt)^2}{2g} = gt^2 + 2gt^2 = \boxed{3gt^2}$.

(c) $y_{max} = 3gt^2 = 3(9.80\text{ m/s}^2)(30.0\text{ s})^2 = \boxed{2.65 \times 10^4\text{ m}}$.

111. (a) Take $x_o = 0$ and use $x = x_o + v_o t + \frac{1}{2}at^2$.

For car: $d = 0 + \frac{1}{2}(3.70\text{ m/s}^2)t^2$. Eq. (1)

For motorcycle: $d + 25.0\text{ m} = 0 + \frac{1}{2}(4.40\text{ m/s}^2)t^2$. Eq. (2)

Eq. (2) − Eq. (1) gives: $25.0\text{ m} = (0.35\text{ m/s}^2)t^2$. Solving, $t = \boxed{8.45\text{ s}}$.

(b) For car: $x_C = \frac{1}{2}(3.70\text{ m/s}^2)(8.45\text{ s})^2 = \boxed{132\text{ m}}$. For motorcycle: $x_M = x_C + 25.0\text{ m} = \boxed{157\text{ m}}$.

(c) During 8.45 s + 2.00 s = 10.45 s, the motorcycle will be ahead of the car by

$\Delta x = x_M - x_C = \frac{1}{2}[(4.40\text{ m/s}^2) - (3.70\text{ m/s}^2)](10.45\text{ s})^2 - 25.0\text{ m} = \boxed{13\text{ m}}$.

112. (a) Jogger A time: $t_A = \dfrac{d_A}{\bar{s}_A} = \dfrac{150\text{ m}}{2.70\text{ m/s}} = 55.56\text{ s}$, jogger B time: $t_A = \dfrac{\pi r}{\bar{s}_B} = \dfrac{\pi(150\text{ m})/2}{2.70\text{ m/s}} = 87.22\text{ s}$.

So jogger A will arrive before jogger B by 87.22 s – 55.56 s = $\boxed{32.7\text{ s}}$.

(b) $d_B = \pi(150\text{ m})/2 = 236\text{ m} > d_A = 100\text{ m}$.

(c) Their displacements are the same. Both are $\Delta x = \boxed{150\text{ m north}}$.

(d) $\bar{v}_A = \dfrac{\Delta x}{\Delta t} = \dfrac{150\text{ m north}}{55.56\text{ s}} = \boxed{2.70\text{ m/s north}}$. $\bar{v}_B = \dfrac{150\text{ m north}}{87.22\text{ s}} = \boxed{1.72\text{ m/s north}}$

113. (a) Given: $a = -2.50\text{ m/s}^2$, $x = 300\text{ m}$ (taking $x_o = 0$), $v = 0$ (come to rest). Find: v_o.

$v^2 = v_o^2 + 2a(x - x_o)$, ☞ $v_o = \sqrt{-2a(x - x_o)} = \sqrt{-2(-2.50\text{ m/s}^2)(300\text{ m})} = \boxed{38.7\text{ m/s}}$.

(b) $v = v_o + at$, ☞ $t = \dfrac{v - v_o}{a} = \dfrac{0 - 38.7\text{ m/s}}{-2.50\text{ m/s}^2} = \boxed{15.5\text{ s}}$.

(c) $v_o = 38.7\text{ m/s} + 4.47\text{ m/s} = 43.2\text{ m/s}$.

$v^2 = v_o^2 + 2a(x - x_o) = (43.2\text{ m/s})^2 + 2(-2.50\text{ m/s}^2)(300\text{ m}) = 366.2\text{ m}^2/\text{s}^2$. So $v = \boxed{19.2\text{ m/s}}$.

$\boxed{114}$. The height of each floor is $\dfrac{509\text{ m}}{101} = 5.040\text{ m}$. The height for 89 floors is then $89(5.040\text{ m}) = 448.6\text{ m}$. At midpoint, the height is 224.3 m. 1008 m/min = 16.8 m/s and 610 m/min = 10.2 m/s.

(a) Up. $x = 224.3\text{ m}$ (taking $x_o = 0$), $v_o = 0$, $v = 16.8\text{ m/s}$. Find: a.

$$v^2 = v_o^2 + 2a(x - x_o)\,, \quad ☞ \quad a_{up} = \frac{v^2 - v_o^2}{2x} = \frac{(16.8\text{ m/s})^2 - 0}{2(224.3\text{ m})} = \boxed{0.629\text{ m/s}^2}.$$

Down. $x = 224.3\text{ m}$ (taking $x_o = 0$), $v_o = 0$, $v = 10.2\text{ m/s}$. Find: a.

$$a_{down} = \frac{v^2 - v_o^2}{2x} = \frac{(10.2\text{ m/s})^2 - 0}{2(224.3\text{ m})} = \boxed{0.232\text{ m/s}^2}.$$

(b) $v = v_o + at\,,\quad ☞ \quad t_{up} = \dfrac{v - v_o}{a} = \dfrac{16.8\text{ m/s} - 0}{0.629\text{ m/s}^2} = 26.70\text{ s}.$

However this is the time to accelerate to the peak speed. After that, the elevator needs to slow down to zero. So the total upward time is twice or 53.4 s. $t_{down} = \dfrac{10.2\text{ m/s} - 0}{0.232\text{ m/s}^2} = 43.97\text{ s}.$

Similarly, the total downward time is 87.94 s. The time difference is $87.94\text{ s} - 53.4\text{ s} = \boxed{34.5\text{ s}}$.

115. (a) Assume Lois falls a distance of d (taking $y_o = 0$), then Superman will move up a distance of $(300\text{ m} - d)$. Also assume he catches her t seconds after she was dropped. The initial velocity for both Lois and Superman is zero.

For Lois: $y = -d = y_o + v_o\,t - \frac{1}{2}g\,t^2 = 0 + 0 - \frac{1}{2}(9.80\text{ m/s}^2)t^2 = -(4.90\text{ m/s}^2)t^2$.

For Superman: $(300\text{ m} - d) = 0 + \frac{1}{2}(15\text{ m/s}^2)t^2 = (7.50\text{ m/s}^2)t^2$.

Therefore, $\dfrac{300\text{ m} - d}{7.50\text{ m/s}^2} = \dfrac{d}{4.90\text{ m/s}^2}$. Or $300\text{ m} - d = \dfrac{7.50\text{ m/s}^2}{4.90\text{ m/s}^2}d = 1.53d.$

So $d = \dfrac{300\text{ m}}{2.53} = 118.6\text{ m} = \boxed{119\text{ m}}$.

(b) $d = -118.6\text{ m} = -(4.90\text{ m/s}^2)t^2\,,\quad ☞ \quad t = \boxed{4.92\text{ s}}$.

(c) Lois: $v = v_o - gt = 0 - (9.80\text{ m/s}^2)(4.92\text{ s}) = -\boxed{48.2\text{ m/s}} \approx 107\text{ mi/h}.$

Superman: $v = 0 + (15\text{ m/s}^2)(4.92\text{ s}) = \boxed{73.8\text{ m/s}} \approx 165\text{ mi/h}.$ These speeds are quite high.

116. (a) Given: $a = -9.00\text{ m/s}^2$, $v_o = 45.0\text{ m/s}$, $v = 0$ (brake to a stop). Find: t.

$$v = v_o + at\,,\quad ☞ \quad t = \frac{v - v_o}{a} = \frac{0 - 45.0\text{ m/s}}{-9.00\text{ m/s}^2} = \boxed{5.00\text{ s}}.$$

(b) $x - x_o = v_o\,t + \frac{1}{2}a\,t^2 = (45.0\text{ m/s})(5.00\text{ s}) + \frac{1}{2}(-9.00\text{ m/s}^2)(5.00\text{s})^2 = \boxed{113\text{ m}}$.

(c) The time in acceleration is $15.0\text{ s} - 5.00\text{ s} = 10.0\text{ s}$. $v_o = 0$, and $v = 45.0\text{ m/s}$.

$$a = \frac{v - v_o}{t} = \frac{45.0\text{ m/s} - 0}{10.0\text{ s}} = \boxed{4.50\text{ m/s}^2}.$$

(d) $x - x_o = 0 + \frac{1}{2}(4.50\text{ m/s}^2)(10.0\text{s})^2 = \boxed{225\text{ m}}$.

117. (a) Given: $v_o = -200$ m/s, $g = 3.00$ m/s^2, $y = -8000$ m (taking $x_o = 0$). Find: v.

$v^2 = v_o^2 - 2g(y - y_o) = (-200 \text{ m/s})^2 - 2(3.00 \text{ m/s}^2)(-8000 \text{ m}) = 8.80 \times 10^3 \text{ m}^2/\text{s}^2$

So $v = \boxed{-297 \text{ m/s}}$. The negative sign indicates that the Lander is moving downward.

(b) $v_o = -297$ m/s, $v = -20.0$ m/s, $y = -12\,000$ m. Find: a.

$$v^2 = v_o^2 + 2a(y - y_o)\,, \quad ☞ \quad a = \frac{v^2 - v_o^2}{2(y - y_o)} = \frac{(-20.0 \text{ m/s})^2 - (-297 \text{ m/s})^2}{2(-12\,000 \text{ m})} = \boxed{3.66 \text{ m/s}^2}.$$

(c) $$v = v_o - gt\,, \quad ☞ \quad t_1 = \frac{v_o - v}{g} = \frac{-200 \text{ m/s} - (-297 \text{ m/s})}{3.00 \text{ m/s}^2} = 32.3 \text{ s}.$$

$$v = v_o + at\,, \quad ☞ \quad t_2 = \frac{v - v_o}{a} = \frac{-20.0 \text{ m/s} - (-297 \text{ m/s})}{3.66 \text{ m/s}^2} = 75.7 \text{ s}.$$

So the total time is $32.3 \text{ s} + 75.7 \text{ s} = \boxed{108 \text{ s}}$.