Solution Manual for Physics for Scientists and Engineers Foundations and Connections Volume 1 1st Edition Katz 0534466753 9780534466756

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Solution Manual:

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One-Dimensional Motion

1. No. The path is nearly circular when viewed from the north celestial pole, indicating a two-dimensional motion.

2. The tracks could be used to create a motion diagram, but there are a couple limitations. The footsteps could cross, which might lead to difficulty in knowing which path is correct, and there is no information about the time between footsteps.

3. (a) The particle positions are:

$$\boxed{\begin{aligned} x_A &= -6\text{ m} \\ x_B &= 0 \\ x_C &= 4\text{ m} \end{aligned}}$$

(b) The particle positions are:

$$\boxed{\begin{aligned} z_A &= 0 \\ z_B &= 6\text{ m} \\ z_C &= 10\text{ m} \end{aligned}}$$

4. You can't make a position versus time plot because there is no information about the time between footsteps.

5. (a) The vector component is $\boxed{\vec{v} = 35.0\,\hat{j}\text{ m/s}}$, the scalar component $\boxed{v_y = 35.0\text{ m/s}}$, is

and the magnitude is $\boxed{v = 35.0\text{ m/s}}$.

(b) The vector component is $\boxed{\vec{v} = 53.0\hat{i}\text{ m/s}}$, the scalar component is $\boxed{v_x = 53.0\text{ m/s}}$, and the magnitude is $\boxed{v = 53.0\text{ m/s}}$.

(c) The vector component is $\vec{v} = -3.50\hat{\boldsymbol{k}}$ m/s, the scalar component $v_z = -3.50$ m/s, is and the magnitude is $v = 3.50$ m/s.

(d) The vector component is $\vec{v} = -5.30\hat{\boldsymbol{i}}$ m/s, the scalar component $v_x = -5.30$ m/s, is and the magnitude is $v = 53.0$ m/s.

6. (a) They walk slowly away from home, quickly through the woods, and slowly past the deer. They rest on the fallen log and walk quickly through woods before resting at the ginger bread house. They run home, slowing down only once they are near home.

(b) In particular, the times when they are at rest are ambiguous, as we cannot determine how long they were at rest.

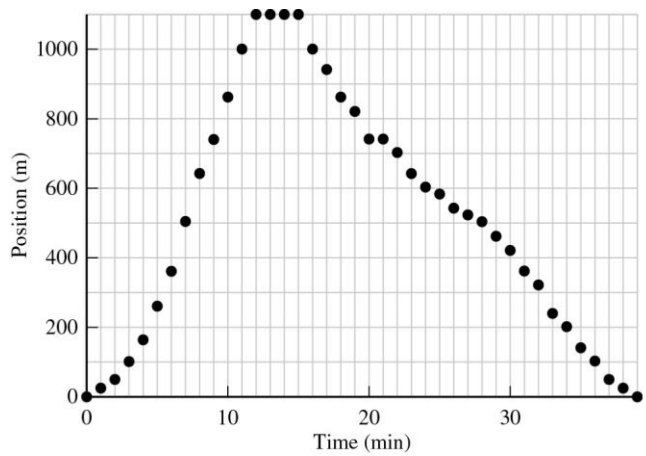

Figure P2.6ANS

(c) The plot is consistent with the description above.

7. (a) At time t_1, the slope of the graph for cadet B is less than than that for cadet A, and thus B has a lesser speed at that time.

(b) From just before to just after time t_2, the graph for cadet B is getting steeper. This means that the speed of cadet B is increasing.

(c) Cadet B experiences a lesser change in position during this time interval, and thus has a lower average speed. A straight line connecting t = 0 and t = 60 s on the graph for B would have a smaller slope than the graph of A.

8. (a) From the position versus time plot, we can determine the coordinate system used.

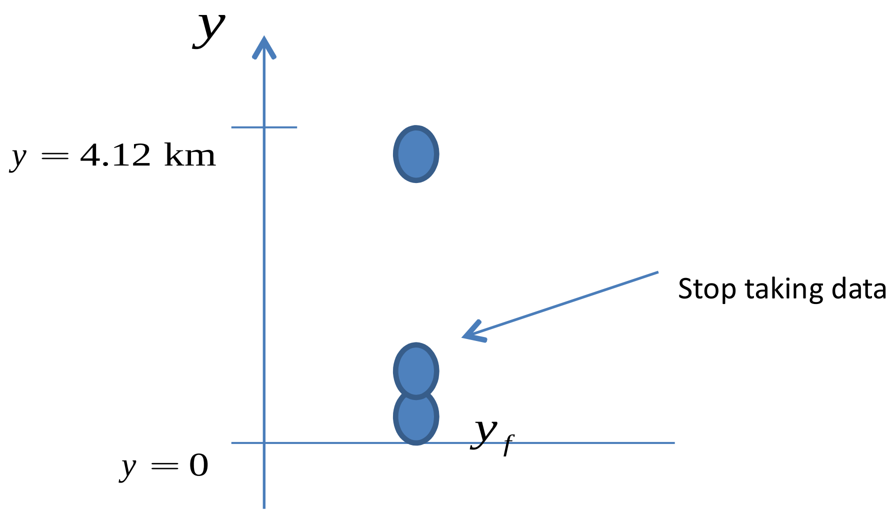

Figure P2.8aANS

(b) Her speed increases for the first few seconds, remains constant for about 55 seconds, and she finally slows down, nearly stopping, for the last 10 seconds.

(c) A motion diagram has points at equal time intervals. See Fig P2.8cANS.

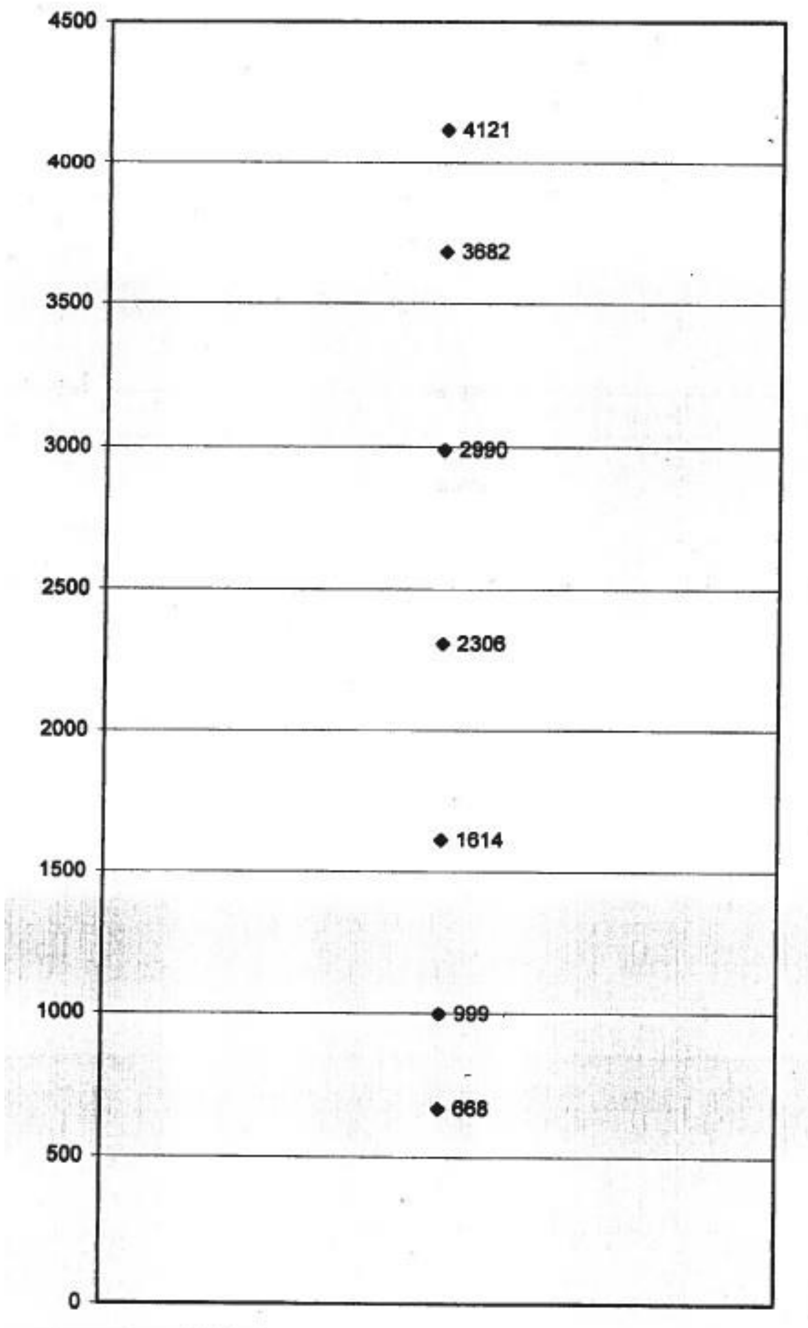

Figure P2.8cANS

(d) Yes. The first two dots are close together and the motion is slow, then there is a region of approximately equally spaced dots reflecting constant velocity, and finally a region of slower motion.

9. (a) A position versus time plot can be created by plotting the data in the table.

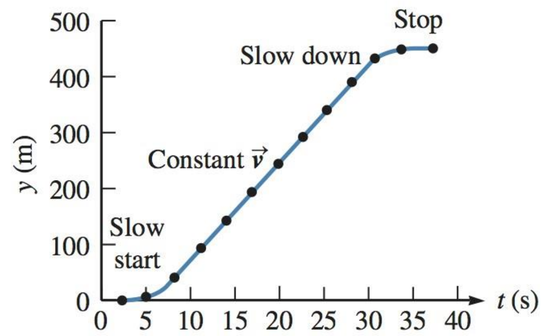

Figure P2.9ANS

(b) The elevator's speed gradually increases for the first 5 seconds, is nearly constant for about 30 seconds, and gradually decreases for the last 5 seconds.

(c) The highest speed occurs during the long period of constant speed indicated in the sketch. We can estimate this by selecting two points and computing the slope.

$$v_{\text{max}} = \frac{300\text{ m} - 100\text{ m}}{21\text{ s} - 9\text{ s}} = \boxed{17\ \frac{\text{m}}{\text{s}}}$$

This is around 40 mph.

(d) One consideration would be avoiding an uncomfortably high acceleration and deceleration at the bottom and top of the building.

10. (a) Yoon's origin is the same as Whipple's, but Yoon's coordinate axis points south, the opposite of Whipple's axis. Therefore, Yoon measures positions that are the opposite sign of Whipple.

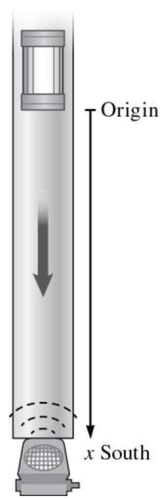

Figure P2.10aANS

Label	*t* (s)	Crall's *x* (m)	Whipple's *x* (m)	Yoon's *x* (m)
A	0.0	1.64	0	0
B	0.4	1.64	0	0
C	0.8	1.55	–0.09	0.09
D	1.2	1.45	–0.19	0.19
E	1.6	1.35	–0.29	0.29
F	2.0	1.25	–0.39	0.39
G	2.4	1.16	–0.48	0.48
H	2.8	1.06	–0.58	0.58
I	3.2	0.97	–0.67	0.67
J	3.6	0.87	–0.77	0.77
K	4.0	0.78	–0.86	0.86
L	4.4	0.69	–0.95	0.95
M	4.8	0.60	–1.04	1.04
N	5.2	0.51	–1.13	1.13
O	5.6	0.42	–1.22	1.22
P	6.0	0.33	–1.31	1.31

(b) The data from part (a) can now be plotted to create a position versus time graph.

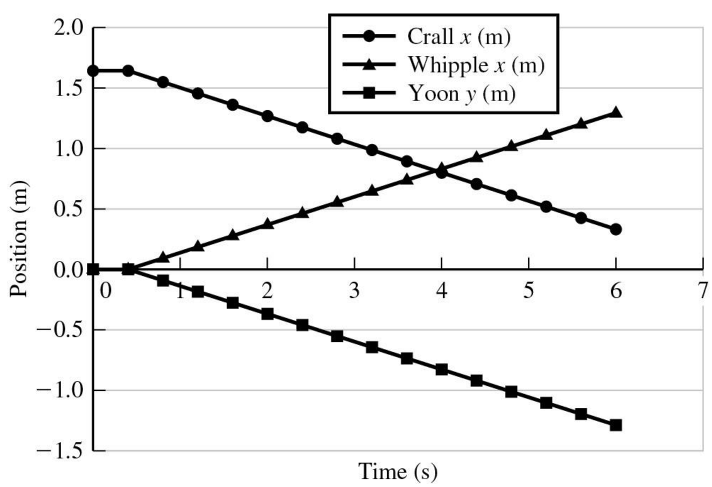

Figure P2.10bANS

11. It's *never* less. If the particle travels along a straight line always in the same direction, then they're equal. If the particle reverses direction, then the distance it travels is greater than the magnitude of its displacement.

12. (a) $\Delta \vec{x} = \vec{x}_C - \vec{x}_A = \left[4\hat{\boldsymbol{i}} - (-6\hat{\boldsymbol{i}})\right]\text{m} = \boxed{10\hat{\boldsymbol{i}}\ \text{m}}$

(b) $\Delta \vec{z} = \vec{z}_C - \vec{z}_A = \left[10\hat{\boldsymbol{i}} - (0)\right]\text{m} = \boxed{10\hat{\boldsymbol{i}}\ \text{m}}$

(c) Yes. The displacement is independent of the coordinate system.

13. The number of times the car went around the track is the total distance traveled divided by the circumference of the track.

$$N = \frac{d}{2\pi r} = \frac{825\ \text{km}}{(2\pi)(1.313\ \text{km})} = 1.00 \times 10^2$$

The car makes $\boxed{100}$ loops around the track.

14. (a)

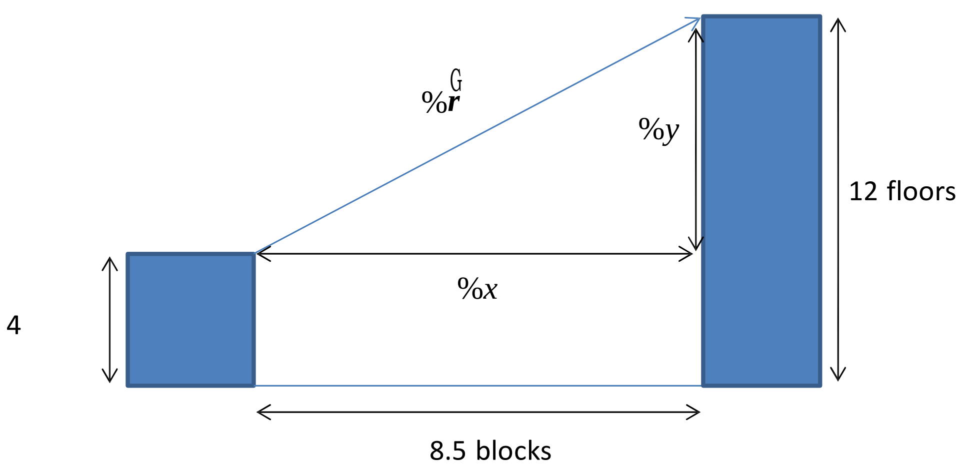

Figure P2.14ANS

(b) Traveling down to the ground: $4 \times 4\ \text{m} = 16\ \text{m}$
Walking on the street: $8.5 \times 146.6\ \text{m} = 1246\ \text{m}$
Climbing the stairs in the office building: $12 \times 5.5\ \text{m} = 66\ \text{m}$
The total distance is the sum, approximately $\boxed{1328\ \text{m}}$.

(c) Her displacement is

$$\Delta r = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$

$$\Delta r = \sqrt{(1246\ \text{m})^2 + (66\ \text{m} - 16\ \text{m})^2} = \boxed{1247\ \text{m}}$$

Since the distance along the street is much larger than the vertical displacement, the total displacement is nearly equal to the distance traveled on the street.

15. (a) We first convert those magnitudes from miles into meters and then add the magnitudes.

$$d_1 = 293 \text{ miles} \times \left(\frac{1609 \text{ m}}{1 \text{ mile}}\right) = 4.71437 \times 10^5 \text{ m}$$

$$d_2 = 107 \text{ miles} \times \left(\frac{1609 \text{ m}}{1 \text{ mile}}\right) = 1.72163 \times 10^5 \text{ m}$$

$$d_{tot} = d_1 + d_2 = \boxed{6.44 \times 10^5 \text{ m}}$$

(b) The displacement depends only on the initial and final positions of the train. The total displacement is in the positive x direction.

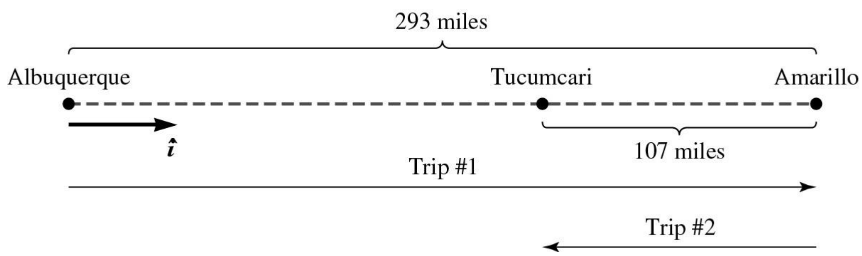

Figure P2.15ANS

$$\Delta x = d_1 - d_2 = 2.99 \times 10^5 \text{ m}$$

$$\Delta \vec{x} = \boxed{2.99 \times 10^5 \hat{\boldsymbol{i}} \text{ m}}$$

16. The distance is approximately $\boxed{\text{120 miles or 200,000 m East}}$.

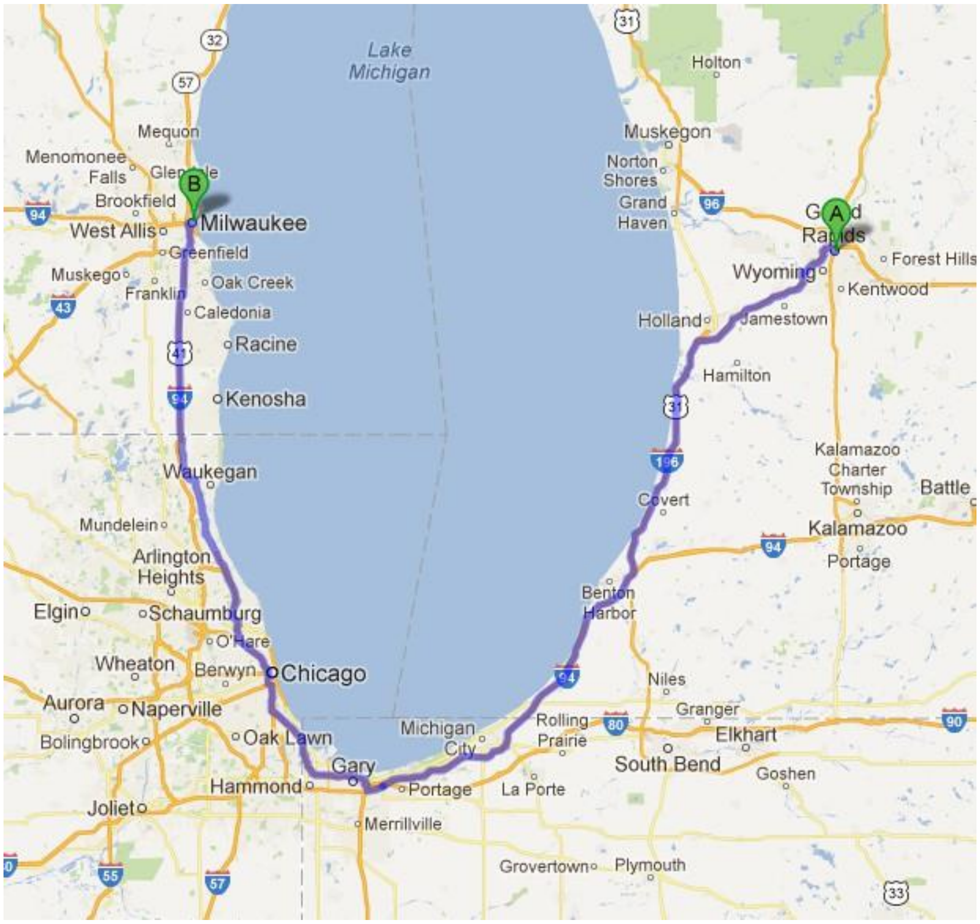

Figure P2.16ANS

17. (a) We can substitute $t = 0$ into the position equation given.

$$\vec{y}(0) = \left(y_0 \cos \omega t\right)\hat{\boldsymbol{j}} = \left(14.5\ \text{cm} \cos(0)\right)\hat{\boldsymbol{j}} = \boxed{14.5\,\hat{\boldsymbol{j}}\ \text{cm}}$$

(b) We can now substitute $t = 9.0$ s into the position equation.

$$\vec{y}(9.0) = \left(y_0 \cos \omega t\right)\hat{\boldsymbol{j}} = \left(14.5\ \text{cm} \cos\left(18.85\ \frac{\text{rad}}{\text{s}} \times 9.0\ \text{s}\right)\right)\hat{\boldsymbol{j}} = \boxed{14.5\,\hat{\boldsymbol{j}}\ \text{cm}}$$

18. (a) The y axis points upwards and at $t = 0$ s, the particle is at $+y_0$.

(b)

$$\vec{y}(t = 0) = \left(y_0 \cos 0\right)\hat{\boldsymbol{j}} = y_0\,\hat{\boldsymbol{j}}$$

$$\vec{y}\left(t = \frac{T}{2}\right) = \left(y_0 \cos\frac{\pi T}{T}\right)\hat{\boldsymbol{j}} = -y_0\,\hat{\boldsymbol{j}}$$

$$\vec{y}(t = T) = \left(y_0 \cos\frac{2\pi T}{T}\right)\hat{\boldsymbol{j}} = y_0\hat{\boldsymbol{j}}$$

$$\vec{y}\left(t = \frac{3T}{2}\right) = \left(y_0 \cos\frac{3\pi T}{T}\right)\hat{\boldsymbol{j}} = -y_0\,\hat{\boldsymbol{j}}$$

$$\vec{y}(t = 2T) = \left(y_0 \cos\frac{4\pi T}{T}\right)\hat{\boldsymbol{j}} = y_0\hat{\boldsymbol{j}}$$

$$\vec{y}\left(t = \frac{5T}{2}\right) = \left(y_0 \cos\frac{5\pi T}{T}\right)\hat{\boldsymbol{j}} = -y_0\,\hat{\boldsymbol{j}}$$

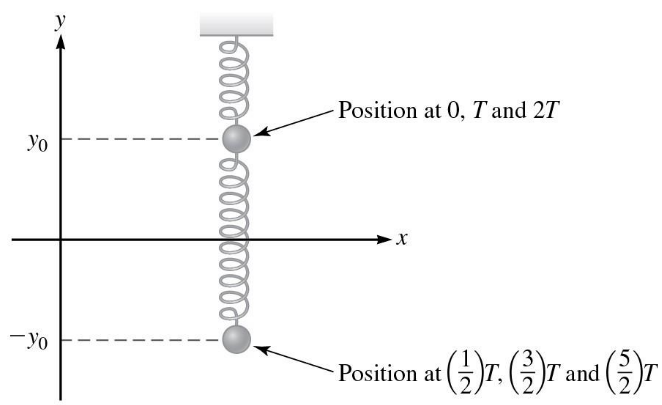

Figure P2.18ANS

19. (a) $\Delta\vec{\boldsymbol{y}} = \vec{\boldsymbol{y}}_{9s} - \vec{\boldsymbol{y}}_{0s} = \boxed{0}$. The particle is at the same position at both times, therefore the displacement is zero.

(b) Each time the argument of the cosine term changes by 2π, the particle has oscillated and returned to its starting position, covering a total distance of 58 cm (from +14.5 cm to –14.5 cm and back). The number of oscillations is the total number of radians traversed divided by 2π per oscillation:

$$\frac{18.85\ \text{rad/s} \times 9.0\ \text{s}}{2\pi} = 27$$

The total distance traveled is $27 \times 0.58\text{ m} = \boxed{15.7\text{ m}}$. This is the total path length, which increases as the particle moves, while the displacement depends only on the initial and final positions.

(c) Atoms in a solid may be modeled by particles attached by springs.

20. There was a moment when the particle was at rest. If the average speed is greater than the magnitude of the average velocity it means that the particle must have turned around at some point during its movement. A particle cannot reverse direction instantaneously without first coming to rest. If the particle travels along a straight line always in the same direction, then the average speed and magnitude of the average velocity are equal.

21. (a) The average velocity is found by dividing the distance by time. The direction of the velocity is north, along the positive *y* direction.

$$\vec{v}_{\text{av},\,y} = \frac{\Delta \vec{y}}{\Delta t} = \frac{2.0 \times 10^{2}\,\hat{\boldsymbol{j}}\text{ m}}{22.23\text{ s}} = \boxed{9.0\,\hat{\boldsymbol{j}}\text{ m/s}}$$

(b) In this case, you finish at the starting position, which means that there is no displacement for the entire race. The average velocity for the race is 0 m/s.

$$\vec{v}_{\text{av},\,y} = \frac{\Delta \vec{y}}{\Delta t} = \frac{0\,\hat{\boldsymbol{j}}\text{ m}}{46.38\text{ s}} = \boxed{0}$$

22. The average speed is always greater than or equal to the magnitude of the average velocity. If the particle travels along a straight line always in the same direction, then they're equal. If the particle reverses direction, then its average speed is greater than the magnitude of its average velocity.

23. (a) Let's arbitrarily assume the photon is traveling in the *x* direction from a light that is approximately 5 meters from you.

$$v = \frac{\Delta x}{\Delta t}$$

$$\Delta t = \frac{\Delta x}{c} = \frac{5\text{ m}}{3\times 10^{8}\text{ m/s}} = 1.7\times 10^{-8}\text{ s}$$

This is around 20 ns.

(b)

$$\Delta t = \frac{\Delta x}{c} = \frac{1.5\times 10^{11}\text{ m}}{3\times 10^{8}\text{ m/s}} = \boxed{500\text{ s}}$$

This is approximately 8.3 minutes.

(c) The photon travels so quickly that we would need to observe it travel a large distance to be able to easily measure the elapsed time.

24. (a) The time equals the distance divided by the speed of the photon.

$$\Delta t = \frac{\Delta x}{c} = \frac{8.18\times 10^{16}\text{ m}}{3.00\times 10^{8}\text{ m/s}} = 2.73\times 10^{8}\text{ s}$$

Using the fact that there are 3.16×10^7 seconds in a year,

$$\Delta t = \frac{2.73\times 10^{8}\text{ s}}{3.16\times 10^{7}\text{ s/year}} = \boxed{8.64\text{ years}}$$

(b) A light year is the distance light travels in one year.

$$\Delta x = c\Delta t = \left(3.00\times 10^{8}\text{ m/s}\right)\left(3.16\times 10^{7}\text{ s}\right) = 9.48\times 10^{15}\text{m}$$

Dividing the distance to Sirius by this value results in a distance of $\boxed{8.64\text{ ly}}$.

25. (a) The distance the sound travels in 8 seconds can be calculated using the speed of sound.

$$\Delta x = v\Delta t = \left(343\text{ m/s}\right)\left(8\text{ s}\right) = 2744\text{ m} \approx \boxed{3\times 10^{3}\text{ m}}$$

(b) The speed of light can be used to determine the time for light to travel the same distance.

$$\Delta t = \frac{\Delta x}{c} = \frac{\left(343\text{ m/s}\right)\left(8\text{ s}\right)}{3.00\times 10^{8}\text{ m/s}} = \boxed{9\times 10^{-6}\text{ s}}$$

Yes, we can neglect this time as it is around 10^6 times shorter than the time for sound to travel.

(c) Since the time is only known to one significant figure, knowing the speed of sound to three significant figures is unnecessary.

26. (a)

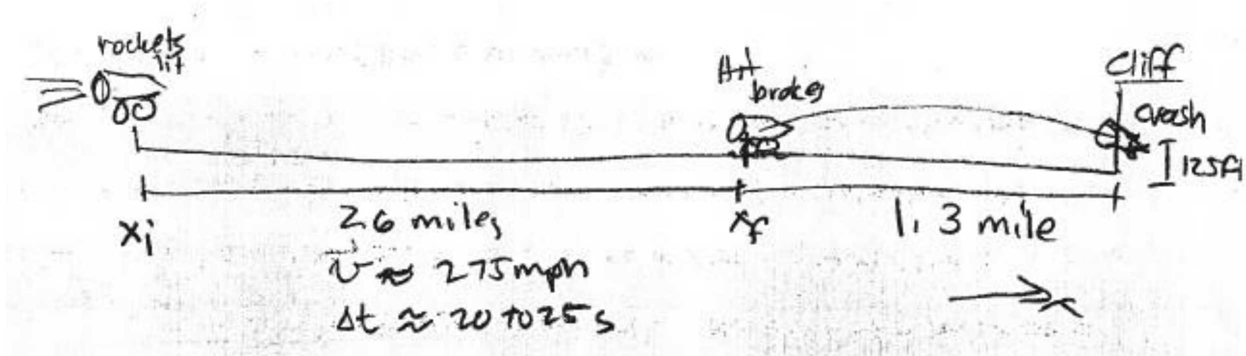

Figure P2.26ANS

(b)

$$\vec{x}_i = \boxed{0}$$
$$\vec{x}_f \approx 2.6\hat{\boldsymbol{i}}\text{ mi} \approx \boxed{4.2\hat{\boldsymbol{i}}\text{ km}}$$
$$\vec{v} = 275\hat{\boldsymbol{i}}\text{ mi/h} \approx \boxed{123\hat{\boldsymbol{i}}\text{ m/s}}$$
$$\Delta t \approx \boxed{25\text{ s}}$$

A time of 25 seconds corresponds to the maximum time the vehicle was reportedly traveling on the ground.

(c) $\Delta\vec{x} = \vec{v}\Delta t = (123\hat{\boldsymbol{i}}\text{ m/s})(25\text{ s}) = \boxed{3.1\times 10^3\hat{\boldsymbol{i}}\text{ m}}$

This displacement is smaller than the distance the vehicle reportedly covered (which was over 4 km). Therefore, they are not consistent.

(d) One possibility is that the actual time was larger than 25 seconds. A time of 34 seconds would be consistent with the other facts and it seems reasonable that no one would know exactly how many seconds the vehicle was driving.

27. We can convert 519 kilometers to inches and use $d = v\Delta t$ and solve for Δt.

$$519\text{ km}\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{100\text{ cm}}{1\text{ m}}\right)\left(\frac{1\text{ in.}}{2.54\text{ cm}}\right) = 2.04\times 10^7\text{ in.}$$

$$\Delta t = \frac{d}{v} = \frac{2.04\times 10^7\text{ in.}}{4.0\text{ in./yr}} = \boxed{5.1\times 10^6\text{ years}}$$

28. (a) The distance between a person's ears is around 20 cm, or 0.2 m.

$$\Delta t_{max} = \frac{d}{v} = \frac{0.2 \text{ m}}{343 \text{ m/s}} \approx 6\times 10^{-4} \text{ s} = \boxed{0.6 \text{ ms}}$$

(b) The higher sound speed in water leads to a smaller time for sound to travel from one ear to the other.

$$\Delta t_{max} = \frac{d}{v} = \frac{0.2 \text{ m}}{1531 \text{ m/s}} \approx 1.3\times 10^{-4} \text{ s} = \boxed{0.13 \text{ ms}}$$

(c) Since the time difference is about five times larger in air, it is easier for your brain to distinguish the time difference in air. In water, the time difference would be much smaller and you would perceive the sound as being nearly in front or behind you.

29. (a) $\vec{v}_1 = \frac{(\Delta x)_1}{(\Delta t)_1}\hat{j} = \boxed{+\frac{L}{t_1}\hat{j}}$

(b) $\vec{v}_2 = \frac{(\Delta x)_2}{(\Delta t)_2}\hat{j} = \boxed{-\frac{L}{t_2}\hat{j}}$

(c) The total displacement is zero, therefore the average velocity is zero.

(d) The average speed is the total distance traveled divided by the total time.

$$\bar{v}_{trip} = \frac{|(\Delta x)_1| + |(\Delta x)_2|}{t_1 + t_2} = \boxed{\frac{2L}{t_1 + t_2}}$$

30. Set the derivative of the speed equal to zero and solve for t to find the time that results in the maximum value of speed. Then substitute this time into the speed function.

$$\frac{dv(t)}{dt} = a\left[e^{-5t} - 5te^{-5t}\right] = 0$$

$$1 - 5t = 0$$

$$t = 0.2s$$

$v(t) = ate^{-5t} = a(0.2s)e^{-5(0.2s)} = \boxed{0.0736a}$ This speed has units of m/s.

31. (a) The particle is moving in the negative *y* direction and speeding up.

(b) $\vec{v}_y(0) = \boxed{0 \text{ m/s}}$

$$\vec{v}_y(10.0s) = -0.758\hat{j}\ \frac{\text{m}}{\text{s}^2} \times 10.0 \text{ s} = \boxed{-7.58\hat{j} \text{ m/s}}$$

$$\vec{v}_y(5.00\,\text{min}) = -0.758\hat{j}\ \frac{\text{m}}{\text{s}^2} \times 300 \text{ s} = \boxed{-2.27 \times 10^2 \text{ m/s}}$$

(c) The speed is the magnitude of the velocity; therefore the corresponding speeds are $\boxed{0 \text{ m/s, } 7.58 \text{ m/s, and } 2.27\times10^2 \text{ m/s}}$.

32. The slope of a position-versus-time graph at any point in time is equal to the instantaneous velocity of the object in motion. The slope of the position-versus-time graph must start off positive, decrease until it reaches 0 m/s, and then become increasingly negative as it travels in the negative *x* direction.

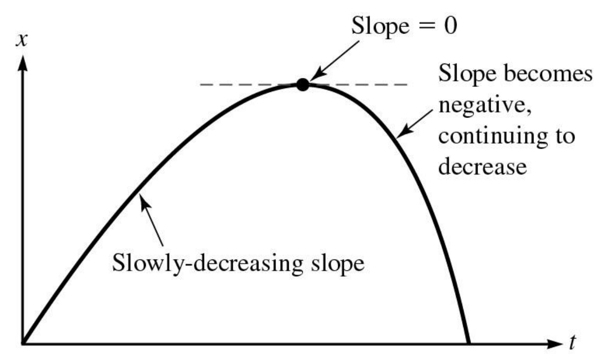

Figure P2.32ANS

33. (a) At t = 1.00 s, y = 7.5 m (point *A*), and at t = 3.50 s, y = 18 m (point *B*).

$$\vec{v}_{\text{avg}} = \frac{y_f - y_i}{t_f - t_i} = \frac{18\hat{j} \text{ m} - 7.5\hat{j} \text{ m}}{3.50 \text{ s} - 1.00 \text{ s}} = \boxed{4.2\hat{j} \text{ m/s}}$$

(b) The slope of the tangent line can be found from points *C* and *D*:

$t_C = 0$, $y_C = 2.0$ m, and $t_D = 3.00$ s, $y_S = 20$ m

$$\vec{v} \approx \frac{y_D - y_C}{t_D - t_C} = \frac{20\hat{j} \text{ m} - 2.0\hat{j} \text{ m}}{3.00 \text{ s} - 0.0 \text{ s}} = \boxed{6.0\hat{j} \text{ m/s}}$$

(c) The velocity is zero when the slope of the tangent line is zero. This occurs at $\boxed{t \approx 3.7\text{s}}$.

34. (a) The velocity is the derivative of the position with respect to time.

$$v_z(t) = \frac{dz}{dt} = \boxed{-\left(15.0\,\text{m/s}^2\right) t}$$

(b) The particle is speeding up. The speed is increasing linearly in time.

(c) At a time of 6.50 minutes, or 390 seconds,

$$z(390\text{ s}) = -\left(7.50\,\text{m/s}^2\right)(390\text{ s})^2 = \boxed{1.14\times 10^6\text{ m}}$$

$$v_z(390\text{ s}) = -\left(15.0\,\text{m/s}^2\right)(390\text{ s}) = \boxed{-5.85\times 10^3\text{ m/s}}$$

The speed is the magnitude of the velocity, $\boxed{5.85\times 10^3\text{m/s}}$.

35. (a)

$$\vec{\boldsymbol{v}}(1.5\text{ s}) = -\left(15.0\hat{\boldsymbol{k}}\,\text{m/s}^2\right)(1.5\text{ s}) = \boxed{-22.5\hat{\boldsymbol{k}}\text{ m/s}}$$

$$\vec{\boldsymbol{v}}(3.5\text{ s}) = -\left(15.0\hat{\boldsymbol{k}}\,\text{m/s}^2\right)(3.5\text{ s}) = \boxed{-52.5\hat{\boldsymbol{k}}\text{ m/s}}$$

(b) Since the speed is increasing linearly, the average velocity during the interval is simply the average of the velocities at the start and end of the interval. (This can be confirmed by instead calculating the position of the particle at 1.5 s and 3.5 s and calculating the change in distance over time.)

$$\bar{\boldsymbol{v}} = \frac{\left(-22.5\hat{\boldsymbol{k}}\text{ m/s}\right)+\left(-52.5\hat{\boldsymbol{k}}\text{ m/s}\right)}{2} = \boxed{-37.5\hat{\boldsymbol{k}}\text{ m/s}}$$

36. (a) Their average velocities would always be equal since two sprinters run the same displacement during the same amount of time.

(b) No. One sprinter might go faster during one part of the race and slower during the other part.

(c) No. The final velocity is just the instantaneous velocity at the moment a sprinter crosses the finish line, which can vary between the two sprinters. Only the average velocity for the entire race must be the same.

37. Choosing the upward direction as positive, we write the acceleration as the change in velocity divided by the total time interval:

$$a = \frac{v_f - v_i}{\Delta t} = \frac{20.0 \text{ m/s} - (-33.0 \text{ m/s})}{4.00\times10^{-3} \text{ s}} = \boxed{1.33\times10^4 \text{ m/s}^2}$$

38. (i): Since the velocity is downward, and the student is speeding up, the acceleration must be downward as well. This is due to Earth's gravitational pull.

(ii): The velocity is still downward, but the speed is now decreasing. The acceleration must be upward. This is mainly due to the upward pull of the taut bungee cord.

(iii): At the low point, the acceleration is upward. Just before the low point the velocity was downward; just after, it is upward.

(iv): Now the student has an upward velocity that is increasing in magnitude. The acceleration is thus upward as well.

(v): The acceleration now opposes the velocity, and must point downward.

39. (a) No, the advice is bad. While it is true that the velocity of an object is zero when the slope of a position versus time graph is equal to 0, the slope of the velocity versus time graph is not necessarily zero at the same time. An object might have zero velocity and non-zero acceleration, for instance at the highest point.

(b) For instance, consider an object initially moving upwards under constant acceleration due to gravity. Eventually, the object would reach the peak height, where the velocity is instantaneously zero, and then begin to fall, gaining an increasing downward velocity. The acceleration is always 9.81 m/s^2 downward.

40. (a)

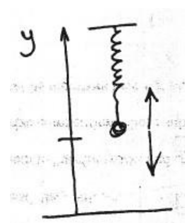

Figure P2.40aANS

(b) The given function for position can be plotted versus time.

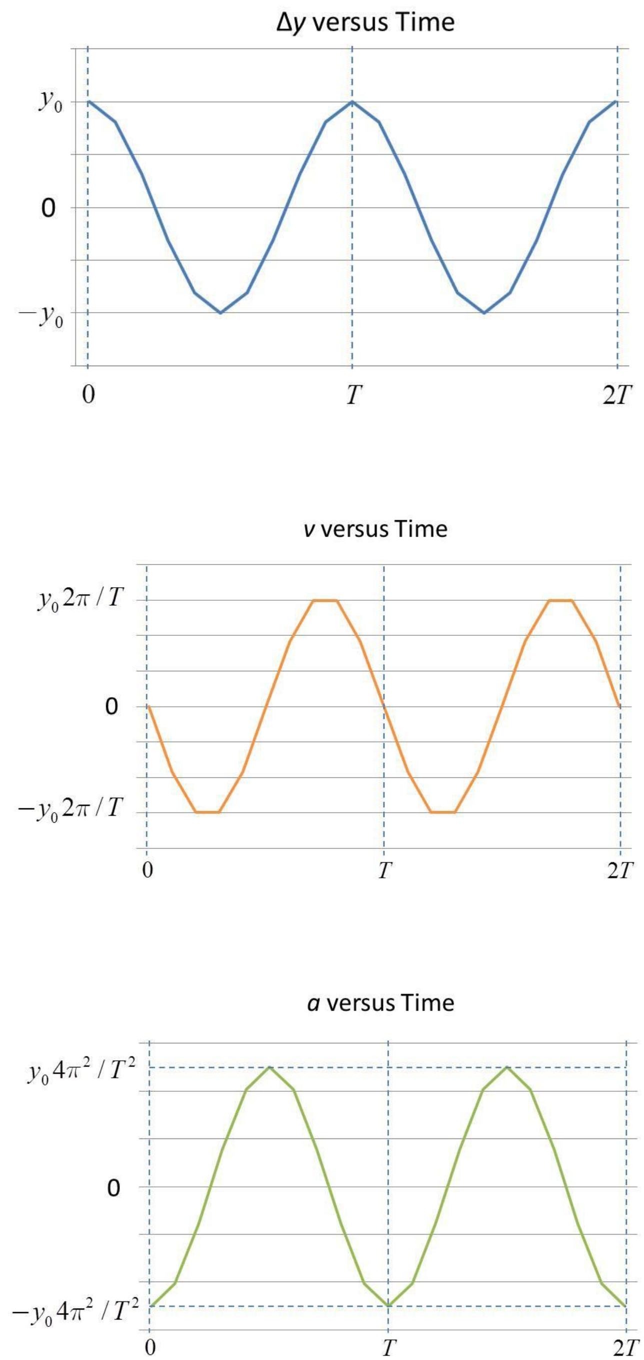

Figure P2.40bANS

(c) The velocity is calculated as the derivative of the position.

$$\vec{\boldsymbol{v}} = \frac{d\vec{\boldsymbol{y}}}{dt} = \left(-y_0 \frac{2\pi}{T} \sin \frac{2\pi t}{T}\right)\hat{\boldsymbol{j}}$$

(d) The acceleration is the derivative of the velocity from part (c).

$$\vec{\boldsymbol{a}} = \frac{d\vec{\boldsymbol{v}}}{dt} = \left(-y_0 \frac{4\pi^2}{T^2}\cos\frac{2\pi t}{T}\right)\hat{\boldsymbol{j}}$$

(e) The speed is maximum when $\sin\frac{2\pi t}{T} = 1$, which occurs at $t = \frac{\pi}{4}T$ and $t = \frac{3\pi}{4}T$. This occurs when $y = 0$, as the spring passes through the equilibrium position.

(f) The acceleration is maximum when $\cos\frac{2\pi t}{T} = 1$, which occurs at $t = 0$, $t = \frac{T}{2}$, and $t = T$. This occurs when $y = \pm y_0$, as the spring is furthest away from the equilibrium point.

41. The acceleration is constant and in the positive x direction. The scalar component of the horizontal position can be written as $x(t) = ct^2 + dt + e$. The acceleration is the second derivative of this function $a(t) = c$, where c will be a positive number given the shape of the curve.

42. (a) The cart leaves Crall's hand with a positive velocity, has zero velocity instantaneously at its highest point, and then has negative velocity on the way down. The acceleration is nearly constant for the cart on the incline. The velocity versus time graph will be a straight line.

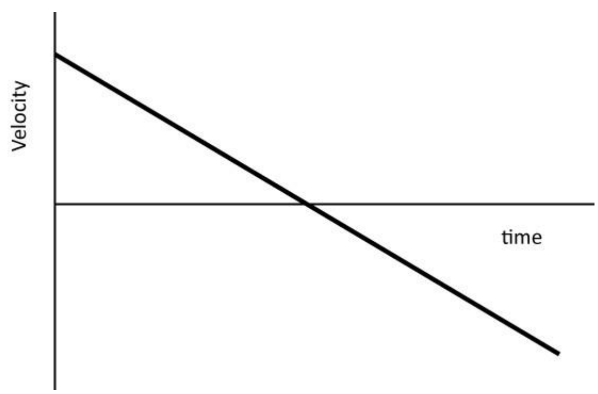

Figure P2.42aANS

(b) The acceleration is negative for the entire trajectory, analogous to an object in free fall.

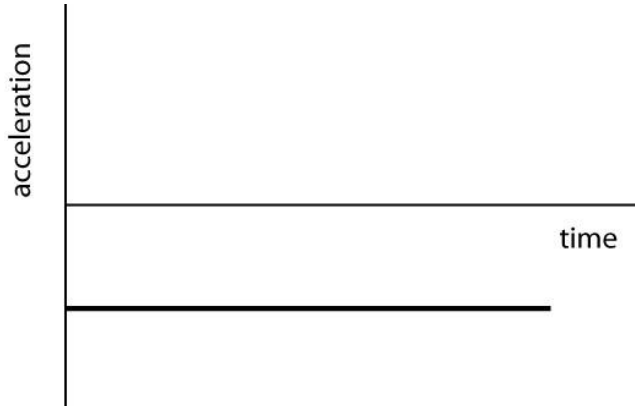

Figure P2.42bANS

43. (a) The object is slowing down; therefore the acceleration must be opposite the velocity.

(b) The acceleration is found by taking the derivative of the velocity function. The velocity function can be substituted into the result to find the desired form for the acceleration.

$$a_x(t) = \left|\frac{dv_x}{dt}\right| = \frac{bv_0}{(bt+C)^2} = \frac{bv_x^2}{v_0}$$

(c) No. The acceleration varies according to the equation in part (b), decreasing in time.

(d) A motor must be used to produce a force that cancels the drag force from the water, thus producing zero acceleration and constant velocity.

44. (a)

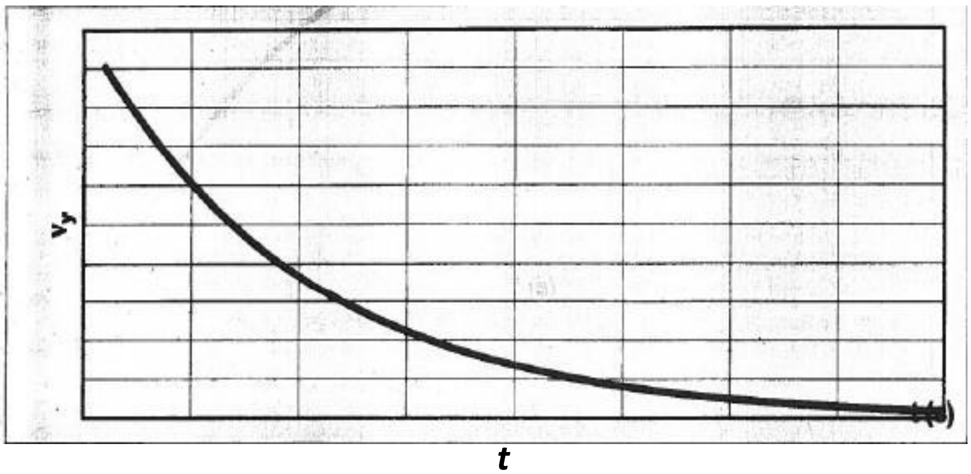

Figure P2.44aANS

(b) The acceleration is in the opposite direction of the velocity, or in the negative x direction.

(c) The acceleration is found from the derivative of the velocity.

$$a_x(t) = \frac{dv_x}{dt} = \boxed{-bv_{x0}e^{-bt}}$$

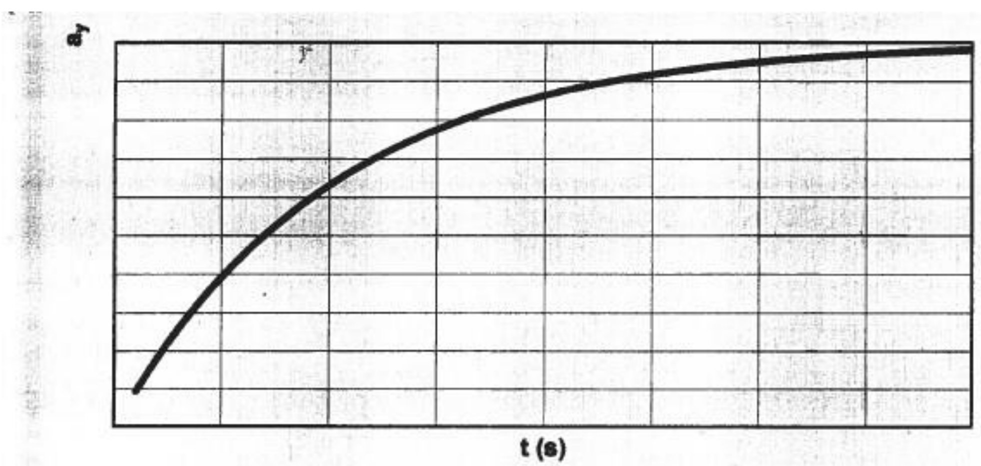

Figure P2.44cANS

(d) Using $v_x(t) = v_{x0}e^{-bt}$, $a_x(t) = -bv_x$.

45. (a) The time derivative of the position is the velocity and the time derivative of the velocity is the acceleration.

$$\vec{v}_z(t) = \frac{d\vec{z}}{dt} = \left[(246.3\ \text{m}\cdot\text{s})\left(\frac{1}{t+2.0\ \text{s}}\right)^2\right]\hat{\boldsymbol{k}}$$

$$\vec{a}_z(t) = \frac{d\vec{v}_z}{dt} = \boxed{\left[-(492.6\ \text{m}\cdot\text{s})\left(\frac{1}{t+2.0\ \text{s}}\right)^3\right]\hat{\boldsymbol{k}}}$$

(b) The train is slowing down. To see this substitute a couple of particular times such as t = 0 and 1 s. As stated in the problem, $t \geq 0$, so the velocity points in the positive z direction and the acceleration is in the negative z direction. Therefore, the train is slowing down.

(c) No, the train does not turn around and move in the opposite direction. It is always moving forward, though its speed becomes vanishingly small as time goes on.

46. (a) The velocity can be found by taking the time derivative of the position. The acceleration is equal to the derivative of the velocity with respect to time.

$$\vec{v}(t) = \frac{d\vec{y}}{dt} = \frac{2}{3}\left(R_\oplus^{3/2} + 3\sqrt{\frac{g}{2}}R_\oplus t\right)^{-1/3}\left(3\sqrt{\frac{g}{2}}R_\oplus\right)\hat{\boldsymbol{j}}$$

$$\vec{v}(t) = \frac{d\vec{y}}{dt} = \boxed{2\sqrt{\frac{g}{2}}R_\oplus\left(R_\oplus^{3/2} + 3\sqrt{\frac{g}{2}}R_\oplus t\right)^{-1/3}\hat{\boldsymbol{j}}}$$

$$\vec{a}(t) = \frac{d\vec{v}}{dt} = -\frac{1}{3}\left(2\sqrt{\frac{g}{2}}R_\oplus\right)\left(R_\oplus^{3/2} + 3\sqrt{\frac{g}{2}}R_\oplus t\right)^{-4/3}\left(3\sqrt{\frac{g}{2}}R_\oplus\right)\hat{\boldsymbol{j}}$$

$$\vec{a}(t) = \boxed{-\left(gR_\oplus^2\right)\left(R_\oplus^{3/2} + 3\sqrt{\frac{g}{2}}R_\oplus t\right)^{-4/3}\hat{\boldsymbol{j}}}$$

(b) The functions from part (a) can now be plotted.

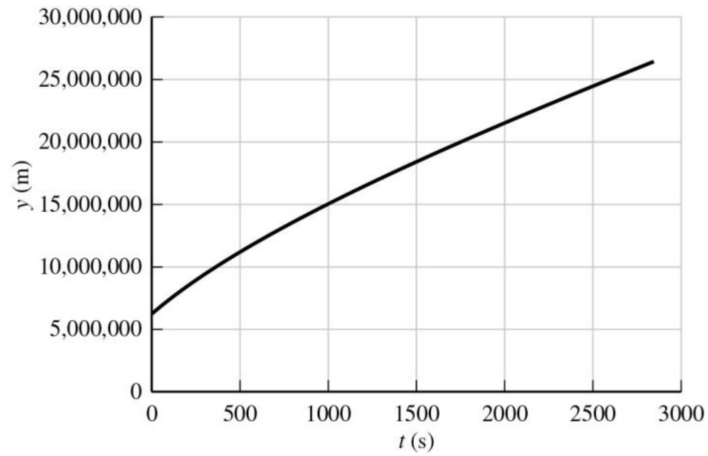

Figure P2.46ANS (Graph 1)

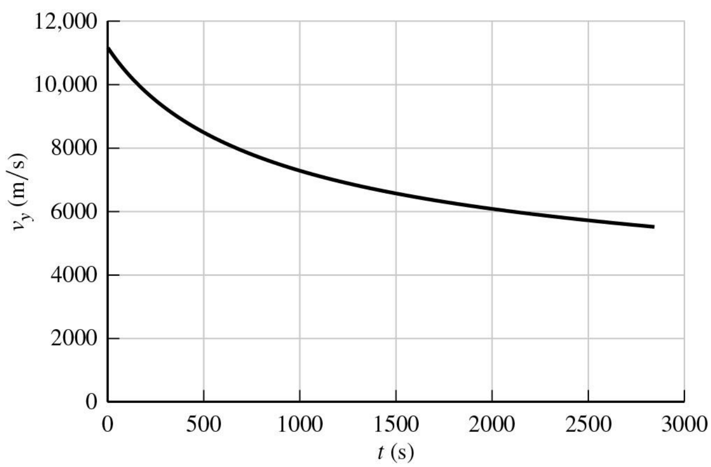

Figure P2.46ANS (Graph 2)

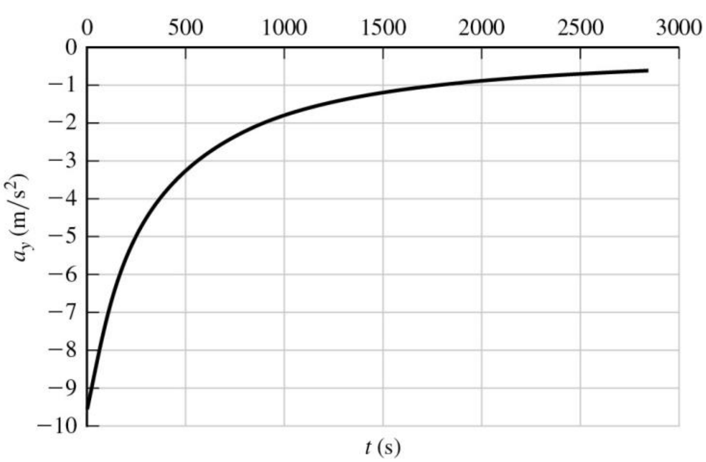

Figure P2.46ANS (Graph 3)

(c) The radius of the Earth is about 6400 km. From the graph, the rocket reaches 25,000 km around 2600 s. We can calculate this precisely as well and confirm this result.

$$4R_{\oplus} = \left(R_{\oplus}^{3/2} + 3\sqrt{\frac{g}{2}} R_{\oplus} t \right)^{2/3}$$

$$\left(4R_{\oplus}\right)^{3/2} = R_{\oplus}^{3/2} + 3\sqrt{\frac{g}{2}} R_{\oplus} t$$

$$t = \frac{4^{3/2} - 1}{3}\sqrt{\frac{2R_{\oplus}}{g}} = \boxed{2661 \text{ s}}$$

(d) We can now calculate the velocity and acceleration at the time calculated in part (c), or estimate the value using the graph.

$$\vec{v}(t) = \boxed{5590\,\hat{\boldsymbol{j}}\ \frac{\text{m}}{\text{s}}}$$

$$\vec{a}(t) = \boxed{-0.613\,\hat{\boldsymbol{j}}\ \frac{\text{m}}{\text{s}^2}}$$

At a distance of $4R_{\oplus}$, the acceleration is approximately 1/16th the value at the surface of the Earth, consistent with what we expect for the inverse square law.

47. We choose $t = 0$ for the instant when the rocket is 5.00 m above the ground traveling at a speed of 15.0 m/s. At $t = 1.50$ s, $x_f = 58.0$ m.

$$x_f - x_i = v_i t + \frac{1}{2}at^2$$

$$58.0 \text{ m} - 5.00 \text{ m} = (15.0 \text{ m/s})(1.50 \text{ s}) + \frac{1}{2}a(1.50 \text{ s})^2$$

$$a = \boxed{27.1 \text{ m/s}^2}$$

48. (a) Yes. If the acceleration is opposite the direction of the velocity, then the speed will be decreasing, as the object is decelerating.

(b) Yes. If the acceleration is opposite the direction of the velocity, the debris will slow down, stop instantaneously, and reverse direction.

49. (a) The velocity increases at a constant rate.

$$\vec{v} = v_{0x} + a_x t = 0 \text{ m/s} + \left(6.851\hat{\boldsymbol{i}} \text{ m/s}^2\right)\left(4.55 \text{ s}\right) = \boxed{31.2\hat{\boldsymbol{i}} \text{ m/s}}$$