Solutions to Practice Problems Chapter 2

Responses to Questions

Q2.5 a) Yes. For an object to be slowing down, all that is required is that the acceleration be nonzero and for the velocity and acceleration to be in opposite directions. The magnitude of the acceleration determines the rate at which the speed is changing. b) Yes. For an object to be speeding up, all that is required is that the acceleration be nonzero and for the velocity and acceleration to be in the same direction. The magnitude of the acceleration determines the rate at which the speed is changing. But for any nonzero acceleration the speed is increasing when the velocity and acceleration are in the same direction. a) Yes. For an object to be slowing down, all that is required is that the acceleration be nonzero and for the velocity and acceleration to be in opposite directions. The magnitude of the acceleration determines the rate at which the speed is changing. b) Yes. For an object to be speeding up, all that is required is that the acceleration be nonzero and for the velocity and acceleration to be in the same direction. The magnitude of the acceleration determines the rate at which the speed is changing. But for any nonzero acceleration the speed is increasing when the velocity and acceleration are in the same direction.

Q2.9 The answer to the first question is no. Average velocity is displacement divided by the time interval. If the displacement is zero, then the average velocity must be zero. The answer to the second question is yes. Zero displacement means the object has returned to its starting point, but its speed at that point need not be zero. See Fig. Q2.9.

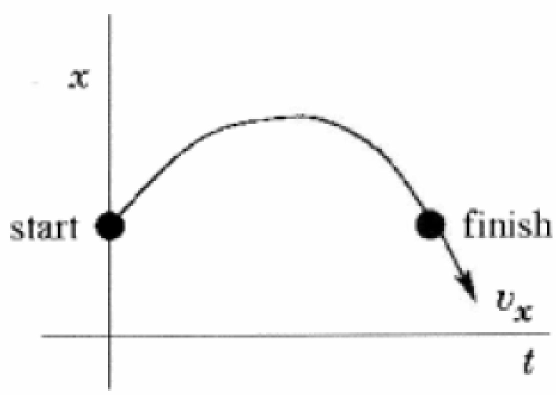

Fig. Q2.9

Q2.14 This is true only when the acceleration is constant. The average velocity is defined to be the displacement divided by the time interval. If the acceleration is not constant, objects can have the same initial and final velocities but different displacements and therefore different average velocities.

Solutions to Problems

P2.1. **IDENTIFY:** $\Delta x = v_{\text{av-}x}\Delta t$

SET UP: We know the average velocity is 6.25 m/s.

EXECUTE: $\Delta x = v_{\text{av-}x}\Delta t = 25.0\text{ m}$

EVALUATE: In round numbers, 6 m/s × 4 s = 24 m ≈ 25 m, so the answer is reasonable.

P2.6. **IDENTIFY:** The average velocity is $v_{\text{av-}x} = \dfrac{\Delta x}{\Delta t}$. Use $x(t)$ to find x for each t.

SET UP: $x(0) = 0$, $x(2.00\text{ s}) = 5.60\text{ m}$, and $x(4.00\text{ s}) = 20.8\text{ m}$

EXECUTE: **(a)** $v_{\text{av-}x} = \dfrac{5.60\text{ m} - 0}{2.00\text{ s}} = +2.80\text{ m/s}$

(b) $v_{\text{av-}x} = \dfrac{20.8\text{ m} - 0}{4.00\text{ s}} = +5.20\text{ m/s}$

(c) $v_{\text{av-}x} = \dfrac{20.8\text{ m} - 5.60\text{ m}}{2.00\text{ s}} = +7.60\text{ m/s}$

EVALUATE: The average velocity depends on the time interval being considered.

P2.7. **(a) IDENTIFY:** Calculate the average velocity using Eq. (2.2).

SET UP: $v_{\text{av-}x} = \dfrac{\Delta x}{\Delta t}$ so use $x(t)$ to find the displacement Δx for this time interval.

EXECUTE: $t = 0$: $x = 0$

$t = 10.0\text{ s}$: $x = (2.40\text{ m/s}^2)(10.0\text{ s})^2 - (0.120\text{ m/s}^3)(10.0\text{ s})^3 = 240\text{ m} - 120\text{ m} = 120\text{ m}.$

Then $v_{\text{av-}x} = \dfrac{\Delta x}{\Delta t} = \dfrac{120\text{ m}}{10.0\text{ s}} = 12.0\text{ m/s}.$

(b) IDENTIFY: Use Eq. (2.3) to calculate $v_x(t)$ and evaluate this expression at each specified t.

SET UP: $v_x = \dfrac{dx}{dt} = 2bt - 3ct^2.$

EXECUTE: (i) $t = 0$: $v_x = 0$

(ii) $t = 5.0\text{ s}$: $v_x = 2(2.40\text{ m/s}^2)(5.0\text{ s}) - 3(0.120\text{ m/s}^3)(5.0\text{ s})^2 = 24.0\text{ m/s} - 9.0\text{ m/s} = 15.0\text{ m/s}.$

(iii) $t = 10.0\text{ s}$: $v_x = 2(2.40\text{ m/s}^2)(10.0\text{ s}) - 3(0.120\text{ m/s}^3)(10.0\text{ s})^2 = 48.0\text{ m/s} - 36.0\text{ m/s} = 12.0\text{ m/s}.$

(c) IDENTIFY: Find the value of t when $v_x(t)$ from part (b) is zero.

SET UP: $v_x = 2bt - 3ct^2$

$v_x = 0$ at $t = 0$.

$v_x = 0$ next when $2bt - 3ct^2 = 0$

EXECUTE: $2b = 3ct$ so $t = \dfrac{2b}{3c} = \dfrac{2(2.40\text{ m/s}^2)}{3(0.120\text{ m/s}^3)} = 13.3\text{ s}$

EVALUATE: $v_x(t)$ for this motion says the car starts from rest, speeds up, and then slows down again.

P2.11. **IDENTIFY:** Find the instantaneous velocity of a car using a graph of its position as a function of time.

SET UP: The instantaneous velocity at any point is the slope of the x versus t graph at that point. Estimate the slope from the graph.

EXECUTE: A: $v_x = 6.7$ m/s; B: $v_x = 6.7$ m/s; C: $v_x = 0$; D: $v_x = -40.0$ m/s; E: $v_x = -40.0$ m/s; F: $v_x = -40.0$ m/s; G: $v_x = 0$.

EVALUATE: The sign of v_x shows the direction the car is moving. v_x is constant when x versus t is a straight line.

P2.14. **IDENTIFY:** We know the velocity $v(t)$ of the car as a function of time and want to find its acceleration at the instant that its velocity is 16.0 m/s.

SET UP: $a_x(t) = \dfrac{dv_x}{dt} = \dfrac{d((0.860 \text{ m/s}^3)t^2)}{dt}$.

EXECUTE: $a_x(t) = \dfrac{dv_x}{dt} = (1.72 \text{ m/s}^3)t$. When $v_x = 16.0$ m/s, $t = 4.313$ s. At this time, $a_x = 7.42 \text{ m/s}^2$.

EVALUATE: The acceleration of this car is not constant.

P2.29. **IDENTIFY:** The average acceleration is $a_{\text{av-}x} = \dfrac{\Delta v_x}{\Delta t}$. For constant acceleration, Eqs. (2.8), (2.12), (2.13) and (2.14) apply.

SET UP: Assume the shuttle travels in the $+x$ direction. $161 \text{ km/h} = 44.72 \text{ m/s}$ and $1610 \text{ km/h} = 447.2 \text{ m/s}$. $1.00 \text{ min} = 60.0 \text{ s}$

EXECUTE: **(a)** (i) $a_{\text{av-}x} = \dfrac{\Delta v_x}{\Delta t} = \dfrac{44.72 \text{ m/s} - 0}{8.00 \text{ s}} = 5.59 \text{ m/s}^2$

(ii) $a_{\text{av-}x} = \dfrac{447.2 \text{ m/s} - 44.72 \text{ m/s}}{60.0 \text{ s} - 8.00 \text{ s}} = 7.74 \text{ m/s}^2$

(b) (i) $t = 8.00$ s, $v_{0x} = 0$, and $v_x = 44.72$ m/s. $x - x_0 = \left(\dfrac{v_{0x} + v_x}{2}\right)t = \left(\dfrac{0 + 44.72 \text{ m/s}}{2}\right)(8.00 \text{ s}) = 179 \text{ m}$.

(ii) $\Delta t = 60.0 \text{ s} - 8.00 \text{ s} = 52.0 \text{ s}$, $v_{0x} = 44.72$ m/s, and $v_x = 447.2$ m/s.

$x - x_0 = \left(\dfrac{v_{0x} + v_x}{2}\right)t = \left(\dfrac{44.72 \text{ m/s} + 447.2 \text{ m/s}}{2}\right)(52.0 \text{ s}) = 1.28 \times 10^4 \text{ m}$.

EVALUATE: When the acceleration is constant the instantaneous acceleration throughout the time interval equals the average acceleration for that time interval. We could have calculated the distance in part (a) as $x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2 = \frac{1}{2}(5.59 \text{ m/s}^2)(8.00 \text{ s})^2 = 179 \text{ m}$, which agrees with our previous calculation.

P2.38. **IDENTIFY:** The putty has a constant downward acceleration of 9.80 m/s^2. We know the initial velocity of the putty and the distance it travels.

SET UP: We can use the kinematics formulas for constant acceleration.

EXECUTE: **(a)** v_{0y} = 9.50 m/s and $y - y_0$ = 3.60 m, which gives

$$v_y = \sqrt{v_{0y}^2 + 2a_y(y - y_0)} = -\sqrt{(9.50 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(3.60 \text{ m})} = 4.44 \text{ m/s}$$

(b) $t = \dfrac{v_y - v_{0y}}{a_y} = \dfrac{4.44 \text{ m/s} - 9.50 \text{ m/s}}{-9.8 \text{ m/s}^2} = 0.517 \text{ s}$

EVALUATE: The putty is stopped by the ceiling, not by gravity.

P2.44. **IDENTIFY:** Apply constant acceleration equations to the vertical motion of the sandbag.

SET UP: Take $+y$ upward. $a_y = -9.80 \text{ m/s}^2$. The initial velocity of the sandbag equals the velocity of the balloon, so $v_{0y} = +5.00 \text{ m/s}$. When the balloon reaches the ground, $y - y_0 = -40.0 \text{ m}$. At its maximum height the sandbag has $v_y = 0$.

EXECUTE: **(a)** $t = 0.250 \text{ s}$: $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2 = (5.00 \text{ m/s})(0.250 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(0.250 \text{ s})^2 = 0.94 \text{ m}$. The sandbag is 40.9 m above the ground.

$v_y = v_{0y} + a_y t = +5.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(0.250 \text{ s}) = 2.55 \text{ m/s}$.

$t = 1.00 \text{ s}$: $y - y_0 = (5.00 \text{ m/s})(1.00 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(1.00 \text{ s})^2 = 0.10 \text{ m}$. The sandbag is 40.1 m above the ground. $v_y = v_{0y} + a_y t = +5.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(1.00 \text{ s}) = -4.80 \text{ m/s}$.

(b) $y - y_0 = -40.0 \text{ m}$, $v_{0y} = 5.00 \text{ m/s}$, $a_y = -9.80 \text{ m/s}^2$. $y - y_0 = v_{0y}t + \frac{1}{2}a_y t^2$ gives

$-40.0 \text{ m} = (5.00 \text{ m/s})t - (4.90 \text{ m/s}^2)t^2$. $(4.90 \text{ m/s}^2)t^2 - (5.00 \text{ m/s})t - 40.0 \text{ m} = 0$ and

$t = \dfrac{1}{9.80}\left(5.00 \pm \sqrt{(-5.00)^2 - 4(4.90)(-40.0)}\right) \text{ s} = (0.51 \pm 2.90) \text{ s}$. t must be positive, so $t = 3.41 \text{ s}$.

(c) $v_y = v_{0y} + a_y t = +5.00 \text{ m/s} + (-9.80 \text{ m/s}^2)(3.41 \text{ s}) = -28.4 \text{ m/s}$

(d) $v_{0y} = 5.00 \text{ m/s}$, $a_y = -9.80 \text{ m/s}^2$, $v_y = 0$. $v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$ gives

$y - y_0 = \dfrac{v_y^2 - v_{0y}^2}{2a_y} = \dfrac{0 - (5.00 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 1.28 \text{ m}$. The maximum height is 41.3 m above the ground.

(e) The graphs of a_y, v_y, and y versus t are given in Figure 2.44. Take $y = 0$ at the ground.

EVALUATE: The sandbag initially travels upward with decreasing velocity and then moves downward with increasing speed.

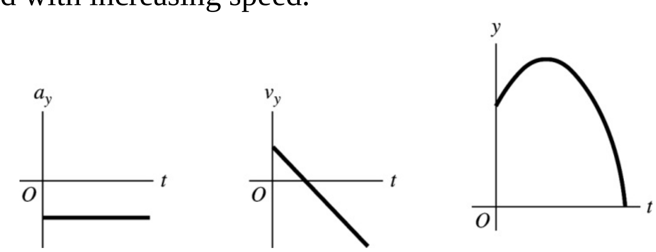

Figure 2.44

P2.58. **IDENTIFY:** We know the vertical position of the lander as a function of time and want to use this to find its velocity initially and just before it hits the lunar surface.

SET UP: By definition, $v_y(t)=\frac{dy}{dt}$, so we can find v_y as a function of time and then evaluate it for the desired cases.

EXECUTE: **(a)** $v_y(t)=\frac{dy}{dt}=-c+2dt$. At $t=0$, $v_y(t)=-c=-60.0\text{ m/s}$. The initial velocity is 60.0 m/s downward.

(b) $y(t)=0$ says $b-ct+dt^2=0$. The quadratic formula says $t=28.57\text{ s}\ \pm 7.38\text{ s}$. It reaches the surface at

$t=21.19\text{ s}$. At this time, $v_y=-60.0\text{ m/s}+2(1.05\text{ m/s}^2)(21.19\text{ s})=-15.5\text{ m/s}$.

EVALUATE: The given formula for $y(t)$ is of the form $y=y_0+v_{0y}t+\frac{1}{2}at^2$. For part (a), $v_{0y}=-c=-60\text{m/s}$.

P2.64. **IDENTIFY:** Use constant acceleration equations to find $x-x_0$ for each segment of the motion.

SET UP: Let $+x$ be the direction the train is traveling.

EXECUTE: $t=0$ to 14.0 s: $x-x_0=v_{0x}t+\frac{1}{2}a_xt^2=\frac{1}{2}(1.60\text{ m/s}^2)(14.0\text{ s})^2=157\text{ m}$.

At $t=14.0\text{ s}$, the speed is $v_x=v_{0x}+a_xt=(1.60\text{ m/s}^2)(14.0\text{ s})=22.4\text{ m/s}$. In the next 70.0 s, $a_x=0$ and $x-x_0=v_{0x}t=(22.4\text{ m/s})(70.0\text{ s})=1568\text{ m}$.

For the interval during which the train is slowing down, $v_{0x}=22.4\text{ m/s}$, $a_x=-3.50\text{ m/s}^2$ and $v_x=0$. $v_x^2=v_{0x}^2+2a_x(x-x_0)$ gives $x-x_0=\frac{v_x^2-v_{0x}^2}{2a_x}=\frac{0-(22.4\text{ m/s})^2}{2(-3.50\text{ m/s}^2)}=72\text{ m}$.

The total distance traveled is $157\text{ m}+1568\text{ m}+72\text{ m}=1800\text{ m}$.

EVALUATE: The acceleration is not constant for the entire motion but it does consist of constant acceleration segments and we can use constant acceleration equations for each segment.

P2.97. **IDENTIFY:** Apply constant acceleration equations to the motion of the two objects, the student and the bus.

SET UP: For convenience, let the student's (constant) speed be v_0 and the bus's initial position be x_0. Note that these quantities are for separate objects, the student and the bus. The initial position of the student is taken to be zero, and the initial velocity of the bus is taken to be zero. The positions of the student x_1 and the bus x_2 as functions of time are then $x_1=v_0t$ and $x_2=x_0+(1/2)at^2$.

EXECUTE: **(a)** Setting $x_1=x_2$ and solving for the times t gives $t=\frac{1}{a}\left(v_0\pm\sqrt{v_0^2-2ax_0}\right)$.

$$t=\frac{1}{(0.170\text{ m/s}^2)}\left((5.0\text{ m/s})\pm\sqrt{(5.0\text{ m/s})^2-2(0.170\text{ m/s}^2)(40.0\text{ m})}\right)=9.55\text{ s and }49.3\text{ s}.$$

The student will be likely to hop on the bus the first time she passes it (see part (d) for a discussion of the later time). During this time, the student has run a distance $v_0t=(5\text{ m/s})(9.55\text{ s})=47.8\text{ m}$.

(b) The speed of the bus is $(0.170\text{ m/s}^2)(9.55\text{ s})=1.62\text{ m/s}$.

(c) The results can be verified by noting that the *x* lines for the student and the bus intersect at two points, as shown in Figure 2.97a.

(d) At the later time, the student has passed the bus, maintaining her constant speed, but the accelerating bus then catches up to her. At this later time the bus's velocity is $(0.170\ \text{m/s}^2)(49.3\ \text{s}) = 8.38\ \text{m/s}.$

(e) No; $v_0^2 < 2ax_0,$ and the roots of the quadratic are imaginary. When the student runs at $3.5\ \text{m/s},$

Figure 2.97b shows that the two lines do *not* intersect:

(f) For the student to catch the bus, $v_0^2 > 2ax_0.$ And so the minimum speed is $\sqrt{2(0.170\ \text{m/s}^2)(40\ \text{m/s})} = 3.688\ \text{m/s}.$ She would be running for a time $\dfrac{3.69\ \text{m/s}}{0.170\ \text{m/s}^2} = 21.7\ \text{s},$ and covers a distance $(3.688\ \text{m/s})(21.7\ \text{s}) = 80.0\ \text{m}.$

However, when the student runs at $3.688\ \text{m/s},$ the lines intersect at *one* point, at $x = 80\ \text{m},$ as shown in Figure 2.97c.

EVALUATE: The graph in part (c) shows that the student is traveling faster than the bus the first time they meet but at the second time they meet the bus is traveling faster. $t_2 = t_{\text{tot}} - t_1$

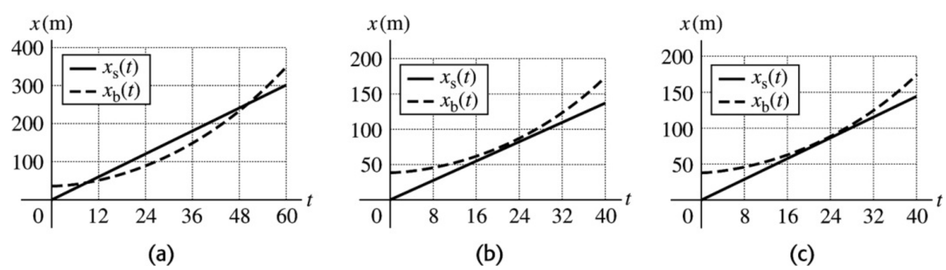

Figure 2.97