Answers to Even Numbered Problems

2. (a) $2 \times 10^{-7} \text{ m/s}, 1 \times 10^{-6} \text{ m/s}$  
   (b) $5 \times 10^8 \text{ yr}$

4. 12.2 m/h

6. (a) 5.00 m/s  
   (b) 1.25 m/s  
   (c) -2.50 m/s  
   (d) -3.33 m/s  
   (e) 0

8. (a) 2.3 min  
   (b) 64 mi

10. 1.32 h

12. (a) $1.3 \times 10^2$ s  
   (b) 13 m

14. 0.18 mi west of the flagpole

16. (b) 41.0 m/s, 41.0 m/s, 41.0 m/s  
   (c) $v_{av} = 17.0$ m/s, much less than the results of (b)

18. (a) 52.4 ft/s, 55.0 ft/s, 55.5 ft/s, 57.4 ft/s  
   (b) 0.598 ft/s$^2$

20. 0.75 m/s$^2$

22. (a) 0, 1.6 m/s$^2$, 0.80 m/s$^2$  
   (b) 0, 1.6 m/s$^2$, 0

24. -1.33 m/s$^2$

26. (a) 6.61 m/s  
   (b) -0.448 m/s$^2$

28. (a) 12.5 s  
   (b) -2.29 m/s$^2$  
   (c) 13.1 s

30. (a) 35 s  
   (b) 16 m/s

32. (a) 20.0 s  
   (b) No, the minimum distance to stop = 1.00 km

34. (a) 5.51 km  
   (b) 20.8 m/s, 41.6 m/s, 20.8 m/s; 38.7 m/s

36. (a) 107 m  
   (b) 1.49 m/s$^2$

38. 29.1 s

40. Idea (a) is not true unless the acceleration is zero. Idea (b) is true for all constant values of acceleration.
42. 96 m
44. (a) 510 m  (b) 20.4 s
46. Hardwood Floor: $a = 2.0 \times 10^3 \text{ m/s}^2, \Delta t = 1.4 \text{ m/s}$
    Carpeted Floor: $a = 3.9 \times 10^2 \text{ m/s}^2, \Delta t = 7.1 \text{ m/s}$
48. (a) 9.80 m/s  (b) 4.90 m
50. (a) 2.3 s  (b) -33 m/s
52. (a) 4.0 m/s, 1.0 m/s  (b) 0.82 m
54. (a) 4.53 s  (b) 14.1 m/s
56. (a) $-4.90 \times 10^5 \text{ m/s}^2$  (b) $3.57 \times 10^{-4} \text{ s}$  (c) 0.180 m
58. 1.03 s
60. 3.10 m/s
62. (a) 3.00 s  (b) -15.2 m/s  (c) -31.4 m/s, -34.8 m/s
64. (a) 2.2 s  (b) -21 m/s  (c) 2.3 s
66. 0.51 s
68. $\sim 10^3 \text{ m/s}^2$, assumes the ball drops 1.5 m and compresses $\approx 1.0 \text{ cm}$ upon hitting the floor
70. Yes, her maximum acceleration is more than sufficient.
2.5 (a) Displacement \( = (85.0 \text{ km/h}) \left( \frac{35.0 \text{ h}}{60.0 \text{ h}} \right) + 130 \text{ km} \)

\[ \Delta x = (49.6 + 130) \text{ km} = 180 \text{ km} \]

(b) Average velocity \( \frac{\text{displacement}}{\text{elapsed time}} = \left( \frac{(49.6 + 130) \text{ km}}{(35.0 + 15.0) \text{ h} + 2.00} \right) \text{ h} = 63.4 \text{ km/h} \)

2.6 (a) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{10.0 \text{ m} - 0}{2.00 \text{ s} - 0} = 5.00 \text{ m/s} \)

(b) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{5.00 \text{ m} - 0}{4.00 \text{ s} - 0} = 1.25 \text{ m/s} \)

(c) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{5.00 \text{ m} - 10.0 \text{ m}}{4.00 \text{ s} - 2.00 \text{ s}} = -2.50 \text{ m/s} \)

(d) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{-5.00 \text{ m} - 5.00 \text{ m}}{7.00 \text{ s} - 4.00 \text{ s}} = -3.33 \text{ m/s} \)

(e) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{x_{f} - x_{i}}{t_{f} - t_{i}} = \frac{0 - 0}{8.00 \text{ s} - 0} = 0 \)

2.7 (a) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{4.0 \text{ m} - 0}{1.0 \text{ s} - 0} = +4.0 \text{ m/s} \)

(b) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{-2.0 \text{ m} - 0}{4.0 \text{ s} - 0} = -0.50 \text{ m/s} \)

(c) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{0 - 4.0 \text{ m}}{5.0 \text{ s} - 1.0 \text{ s}} = -1.0 \text{ m/s} \)

(d) \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{0 - 0}{5.0 \text{ s} - 0} = 0 \)

2.11 The total time for the trip is \( t = t_{i} + 22.0 \text{ min} = t_{i} + 0.367 \text{ h} \), where \( t_{i} \) is the time spent traveling at \( 89.5 \text{ km/h} \). Thus, the distance traveled is

\[ x = v_{av}t = (89.5 \text{ km/h})t_{i} = (77.8 \text{ km/h})(t_{i} + 0.367 \text{ h}) \]

or, \( (89.5 \text{ km/h})t_{i} = (77.8 \text{ km/h})t_{i} + 28.5 \text{ km} \)
From which, \( t_1 = 2.44 \text{ h} \) for a total time of \( t = t_1 + 0.367 \text{ h} = 2.80 \text{ h} \).

Therefore, \( x = v_{av} t = (77.8 \text{ km/h})(2.80 \text{ h}) = 218 \text{ km} \).

### 2.13
The maximum time to complete the trip is

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

The time spent in the first half of the trip is

\[
t_1 = \frac{\text{half distance}}{v_{av,1}} = \frac{800 \text{ m}}{230 \text{ km/h}} \left( \frac{1 \text{ km/h}}{0.278 \text{ m/s}} \right) = 12.5 \text{ s}
\]

Thus, the maximum time that can be spent on the second half of the trip is \( t_2 = t - t_1 = 23.0 \text{ s} - 12.5 \text{ s} = 10.5 \text{ s} \), and the required average speed on the second half is

\[
\left( v_{av,2} \right) = \frac{\text{half distance}}{t_2} = \frac{800 \text{ m}}{10.5 \text{ s}} \left( \frac{1 \text{ km/h}}{0.278 \text{ m/s}} \right) = 274 \text{ km/h}
\]

### 2.21
From \( \frac{\Delta v}{\Delta t} \), we have \( \Delta t = \frac{\Delta v}{a} = \frac{(60 - 55) \text{ m/s}}{0.60 \text{ m/s}^2} \left( \frac{0.447 \text{ m/s}}{1 \text{ m/s}} \right) = 3.7 \text{ s} \).

### 2.22
(a) From \( t = 0 \) to \( t = 5.0 \text{ s} \),

\[
a_{av} = \frac{v - v_0}{t - t_0} = \frac{0 - 0}{5.0 \text{ s} - 0} = 0
\]

From \( t = 5.0 \text{ s} \) to \( t = 15 \text{ s} \),

\[
a_{av} = \frac{8.0 \text{ m/s} - (-8.0 \text{ m/s})}{15 \text{ s} - 5.0 \text{ s}} = 1.6 \text{ m/s}^2
\]

and from \( t = 0 \) to \( t = 20 \text{ s} \),

\[
a_{av} = \frac{8.0 \text{ m/s} - (-8.0 \text{ m/s})}{20 \text{ s} - 0} = 0.80 \text{ m/s}^2
\]

(b) At \( t = 2.0 \text{ s} \), the slope of the tangent line to the curve is 0. At \( t = 10 \text{ s} \), the slope of
the tangent line is \(1.6 \text{ m/s}^2\), and at \(t = 18\) s, the slope of the tangent line is \(0\).

2.23 (a) The average acceleration can be found from the curve, and its value will be
\[
a_{av} = \frac{\Delta v}{\Delta t} = \frac{16 \text{ m/s}}{2 \text{ s}} = 8 \text{ m/s}^2
\]

(b) The instantaneous acceleration at \(t = 15\) s equals the slope of the tangent line to the curve at that time. This slope is about \(12 \text{ m/s}^2\).

2.30 (a) The time for the truck to reach \(20 \text{ m/s}\) is found from \(v = v_0 + at\) as
\[
t = \frac{v - v_0}{a} = \frac{20 \text{ m/s} - 0}{2 \text{ m/s}^2} = 10 \text{ s}
\]
The total time is \(t_{\text{total}} = 10 \text{ s} + 20 \text{ s} + 5 \text{ s} = 35 \text{ s}\)

(b) The distance traveled during the first 10 s is
\[
(\Delta x)_1 = (v_{x0})_1 \cdot t = \left(\frac{0 + 20 \text{ m/s}}{2}\right)(10 \text{ s}) = 100 \text{ m}
\]
The distance traveled during the next 20 s (with \(a = 0\)) is
\[
(\Delta x)_2 = (v_0)_2 \cdot \frac{1}{2} a t^2 = (20 \text{ m/s})(20 \text{ s}) + 0 = 400 \text{ m}
\]
The distance traveled in the last 5.0 s is
\[
(\Delta x)_3 = (v_{x0})_3 \cdot t = \left(\frac{20 \text{ m/s} + 0}{2}\right)(5.0 \text{ s}) = 50 \text{ m}
\]
The total displacement is then
\[
\Delta x = (\Delta x)_1 + (\Delta x)_2 + (\Delta x)_3 = 100 \text{ m} + 400 \text{ m} + 50 \text{ m} = 550 \text{ m}
\]
and the average velocity for the total motion is given by
2.37 At the end of the acceleration period, the velocity is

\[ v = v_0 + at = 7.5 \text{ m/s} + \left( -2.0 \text{ m/s}^2 \right)(3.0 \text{ s}) = 1.5 \text{ m/s} \]

This is also the initial velocity for the braking period.

(a) After braking, \( v = v_0 + at = 7.5 \text{ m/s} + \left( -2.0 \text{ m/s}^2 \right)(3.0 \text{ s}) = 1.5 \text{ m/s} \)

(b) The total distance traveled is

\[ \Delta x = \left( \frac{0 + 7.5 \text{ m/s}}{2} \right)(5.0 \text{ s}) + \left( \frac{7.5 \text{ m/s} + 1.5 \text{ m/s}}{2} \right)(3.0 \text{ s}) = 32 \text{ m} \]

2.41 The time the Thunderbird spends slowing down is

\[ \Delta t_1 = \frac{\Delta x_1}{(v)_{\text{avg}}} = \frac{2(250 \text{ m})}{0 + 71.5 \text{ m/s}} = 6.99 \text{ s} \]

The time required to regain speed after the pit stop is

\[ \Delta t_2 = \frac{\Delta x_2}{(v)_{\text{avg}}} = \frac{2(350 \text{ m})}{71.5 \text{ m/s} + 0} = 9.79 \text{ s} \]

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

\[ \Delta t = \Delta t_1 + 5.00 \text{ s} + \Delta t_2 = 6.99 \text{ s} + 5.00 \text{ s} + 9.79 \text{ s} = 21.8 \text{ s} \]

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

\[ \Delta x_M = v_0 \Delta t = \left( 71.5 \text{ m/s} \right)(21.8 \text{ s}) = 1558 \text{ m} \]

and the Thunderbird has fallen behind a distance

\[ d = \Delta x_M - \Delta x_1 - \Delta x_2 = 1558 \text{ m} - 250 \text{ m} - 350 \text{ m} = 958 \text{ m} \]

2.42 The car is distance \( d \) from the dog and has initial velocity \( v_0 \) when the brakes are applied giving it a constant acceleration \( a \).
Apply \( v_{av} = \frac{\Delta x}{\Delta t} = \frac{v + v_0}{2} \) to the entire trip (for which \( \Delta x = d + 4.0 \text{ m}, \Delta t = 10 \text{ s}, \text{ and } v = 0 \)) to obtain

\[
\frac{d + 4.0 \text{ m}}{10 \text{ s}} = \frac{0 + v_0}{2} \quad \text{or} \quad v_0 = \frac{d + 4.0 \text{ m}}{5.0 \text{ s}} \quad (1)
\]

Then, applying \( v^2 = v_0^2 + 2a(\Delta x) \) to the entire trip yields \( 0 = v_0^2 + 2a(\Delta x) \).

Substitute for \( v_0 \) from Equation (1) to find that

\[
a = -\frac{d + 4.0 \text{ m}}{50 \text{ s}^2} \quad (2)
\]

Finally, apply \( \Delta x = v_0 t + \frac{1}{2} at^2 \) to the first 8.0 s of the trip (for which \( \Delta x = d \)).

This gives

\[
d = v_0 (8.0 \text{ s}) + \frac{1}{2} a(t^2) \quad (3)
\]

Substitute Equations (1) and (2) into Equation (3) and solve for the three unknowns \( v_0, a, \) and \( d \) to find that \( v_0 = 20 \text{ m/s}, a = -2.0 \text{ m/s}^2, \) and \( d = 96 \text{ m} \).

2.44 (a) For the upward flight of the arrow, \( v_0 = +100 \text{ m/s}, a = -g = -9.8 \text{ m/s}^2, \) and the

final velocity is \( v = 0 \). Thus, \( v^2 = v_0^2 + 2a(\Delta y) \) yields

\[
(\Delta y)_{\text{max}} = \frac{v^2 - v_0^2}{2a} = \frac{0 - (100 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)} = 510 \text{ m}
\]

(b) The time for the upward flight is

\[
t_{up} = \frac{(\Delta y)_{\text{max}}}{v_{av}} = \frac{2(\Delta y)_{\text{max}}}{v_0 + v} = \frac{2(510 \text{ m})}{100 \text{ m/s} + 0} = 10.2 \text{ s}
\]

For the downward flight, \( \Delta y = -(\Delta y)_{\text{max}} = -510 \text{ m}, v_0 = 0, \) and \( a = -9.8 \text{ m/s}^2 \). Thus,

\[
\Delta y = v_0 t + \frac{1}{2} at^2 \quad \text{gives} \quad t_{\text{down}} = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-510 \text{ m})}{-9.8 \text{ m/s}^2}} = 10.2 \text{ s and the total time of the flight is} \quad t_{\text{total}} = t_{\text{up}} + t_{\text{down}} = 10.2 \text{ s} + 10.2 \text{ s} = 20.4 \text{ s}
\]

2.49 (a) When it reaches a height of 150 m, the speed of the rocket is
After the engines stop, the rocket continues moving upward with an initial velocity of \( v_0 = 55.7 \text{ m/s} \) and acceleration \( a = -g = -9.80 \text{ m/s}^2 \). When the rocket reaches maximum height, \( v = 0 \). The displacement of the rocket above the point where the engines stopped (that is, above the 150 m level) is

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

The maximum height above ground that the rocket reaches is then given by

\[
h_{\text{max}} = h + \Delta y = 150 \text{ m} + 158 \text{ m} = 308 \text{ m}
\]

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

\[
t_1 = \frac{\Delta y_1}{v_{av,1}} = \frac{2(150 \text{ m})}{(55.7 + 50.0) \text{ m/s}} = 2.84 \text{ s}
\]

The second interval is the time to rise 158 m starting with \( v_0 = 55.7 \text{ m/s} \) and ending with \( v = 0 \). This time is

\[
t_2 = \frac{\Delta y_2}{v_{av,2}} = \frac{2(158 \text{ m})}{0 + 55.7 \text{ m/s}} = 5.67 \text{ s}
\]

The total time of the upward flight is then

\[
t_{\text{up}} = t_1 + t_2 = (2.84 + 5.67) \text{ s} = 8.51 \text{ s}
\]

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

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

so the total time of the flight is

\[
t_{\text{total}} = t_{\text{up}} + t_{\text{down}} = (8.51 + 7.93) \text{ s} = 16.4 \text{ s}
\]
2.51 (a) The keys have acceleration \( a = -g = -9.80 \, \text{m/s}^2 \) from the release point until they are caught 1.50 s later. Thus, \( \Delta y = v_0 t + \frac{1}{2} a t^2 \) gives

\[
v_0 = \frac{\Delta y - \frac{a t^2}{2}}{t} = \frac{(+4.00 \, \text{m}) - (-9.80 \, \text{m/s}^2)(1.50 \, \text{s})^2/2}{1.50 \, \text{s}} = +10.0 \, \text{m/s}
\]

or \( v_0 = 10.0 \, \text{m/s up ward} \)

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

\[
v = v_0 + at = 10.0 \, \text{m/s} + (-9.80 \, \text{m/s}^2)(1.50 \, \text{s}) = -4.68 \, \text{m/s}
\]

or \( v = -4.68 \, \text{m/s down ward} \)

2.56 We assume that the bullet is a cylinder which slows down just as the front end pushes apart wood fibers.

(a) The acceleration is

\[
a = \frac{v_f^2 - v_0^2}{2(\Delta x)} = \frac{(280 \, \text{m/s})^2 - (420 \, \text{m/s})^2}{2(0.100 \, \text{m})} = -4.90 \times 10^5 \, \text{m/s}^2
\]

(b) The average velocity as the front of the bullet passes through the board is

\[
(v_{av})_{board} = \frac{v + v_0}{2} = 350 \, \text{m/s}
\]

and the total time of contact with the board is

\[
t = \frac{(\Delta x)_{board}}{(v_{av})_{board}} = \frac{0.100 \, \text{m}}{350 \, \text{m/s}} + \frac{0.0200 \, \text{m}}{280 \, \text{m/s}} = 3.57 \times 10^{-4} \, \text{s}
\]

(c) From \( v^2 = v_f^2 + 2a(\Delta x) \), with \( v = 0 \), gives the required thickness as

\[
\Delta x = \frac{v_f^2 - v_0^2}{2a} = \frac{0 - (420 \, \text{m/s})^2}{2(-4.90 \times 10^5 \, \text{m/s}^2)} = 0.180 \, \text{m}
\]

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

\[-(15 \, \text{m} - h) = 0 - \frac{1}{2} gt^2, \text{ or } h = 15 \, \text{m} - \frac{1}{2} gt^2 \quad (1)\]
Applying $\Delta y = v_y t + \frac{1}{2} a t^2$ to the rising ball gives $h = (25 \text{ m/s}) t - \frac{1}{2} gt^2$  \hspace{1cm} (2)

Combining equations (1) and (2) gives $t = \frac{15 \text{ m}}{25 \text{ m/s}} = 0.60 \text{ s}$

2.59  \hspace{1cm} (a) When either ball reaches the ground, its net displacement is $\Delta y = -19.6 \text{ m}$

Applying $\Delta y = v_y t + \frac{1}{2} a t^2$ to the motion of the first ball gives

$-19.6 \text{ m} = (-14.7 \text{ m/s}) t_1 + \frac{1}{2}(-9.80 \text{ m/s}^2) t_1^2$ which has a positive solution of $t_1 = 1.00 \text{ s}$.

Similarly, applying this relation to the motion of the second ball gives

$-19.6 \text{ m} = (+14.7 \text{ m/s}) t_2 + \frac{1}{2}(-9.80 \text{ m/s}^2) t_2^2$ which has a single positive solution of $t_2 = 4.00 \text{ s}$.

Thus, the difference in the time of flight for the two balls is $\Delta t = t_2 - t_1 = (4.00 - 1.00) \text{ s} = 3.00 \text{ s}$

(b) When the balls strike the ground, their velocities are:

$v_1 = (v_y)_1 - gt_1 = -14.7 \text{ m/s} - (9.80 \text{ m/s}^2)(1.00 \text{ s}) = -24.5 \text{ m/s}$

and

$v_2 = (v_y)_2 - gt_2 = +14.7 \text{ m/s} - (9.80 \text{ m/s}^2)(4.00 \text{ s}) = -24.5 \text{ m/s}$

(c) At $t = 0.800 \text{ s}$, the displacement of each ball from the balcony is:

$\Delta y_1 = y_1 - 0 = v_1 t - \frac{1}{2} gt^2 = (-14.7 \text{ m/s})(0.800 \text{ s}) - (-9.80 \text{ m/s}^2)(0.800 \text{ s})^2$

$\Delta y_2 = y_2 - 0 = v_2 t - \frac{1}{2} gt^2 = (14.7 \text{ m/s})(0.800 \text{ s}) - (-9.80 \text{ m/s}^2)(0.800 \text{ s})^2$

These yield $y_1 = -14.9 \text{ m}$ and $y_2 = +8.62 \text{ m}$. Therefore the distance separating the two balls at this time is

$d = y_2 - y_1 = 8.62 \text{ m} - (-14.9 \text{ m}) = 23.5 \text{ m}$
2.61 When Kathy has been moving for \( t \) seconds, Stan’s elapsed time is \( t + 1.00 \text{ s} \). At this time, the displacements of the two cars are

\[
(\Delta x)_{\text{kathy}} = (v_0)_{\text{kathy}} t + \frac{1}{2} a_{\text{kathy}} t^2 = 0 + \frac{1}{2} (4.90 \text{ m/s}^2) t^2
\]

and

\[
(\Delta x)_{\text{stan}} = (v_0)_{\text{stan}} t + \frac{1}{2} a_{\text{stan}} (t + 1.00 \text{ s})^2 = 0 + \frac{1}{2} (3.50 \text{ m/s}^2) (t + 1.00 \text{ s})^2
\]

(a) When Kathy overtakes Stan, \((\Delta x)_{\text{kathy}} = (\Delta x)_{\text{stan}}\), or

\[
(4.90 \text{ m/s}^2) t^2 = (3.50 \text{ m/s}^2) (t + 1.00 \text{ s})^2
\]

which gives the time as \( t = 5.46 \text{ s} \)

(b) Kathy’s displacement at this time is

\[
(\Delta x)_{\text{kathy}} = \frac{1}{2} (4.90 \text{ m/s}^2) (5.46 \text{ s})^2 = 73.0 \text{ m}
\]

(c) At this time, the velocities of the two cars are

\[
v_{\text{kathy}} = (v_0)_{\text{kathy}} + a_{\text{kathy}} t = 0 + (4.90 \text{ m/s}^2) (5.46 \text{ s}) = 26.7 \text{ m/s}
\]

and \( v_{\text{stan}} = (v_0)_{\text{stan}} + a_{\text{stan}} (t + 1.00 \text{ s}) = 0 + (3.50 \text{ m/s}^2) (6.46 \text{ s}) = 22.6 \text{ m/s} \)

2.63 (a) The displacement \( \Delta x_1 \) of the sled during the time \( t_1 \) that it has acceleration

\[
a_1 = +40 \text{ ft/s}^2 \text{ is: } \Delta x_1 = (0) t_1 + \frac{1}{2} a_1 t_1^2 = (20 \text{ ft/s}^2) t_1^2 \text{ or } \Delta x_1 = (20 \text{ ft/s}^2) t_1^2 \tag{1}
\]

At the end of time \( t_1 \), the sled had achieved a velocity of

\[
v = v_0 + a_1 t_1 = 0 + (40 \text{ ft/s}^2) t_1 \text{ or } v = (40 \text{ ft/s}^2) t_1 \tag{2}
\]

The displacement of the sled while moving at constant velocity \( v \) for time \( t_2 \) is

\[
\Delta x_2 = vt_2 = [(40 \text{ ft/s}^2) t_1] t_2 \text{ or } \Delta x_2 = (40 \text{ ft/s}^2) t_1 t_2 \tag{3}
\]

It is known that \( \Delta x_1 + \Delta x_2 = 17,500 \text{ ft} \), and substitutions from Equations (1) and (3) give:

\[
(20 \text{ ft/s}^2) t_1^2 + (40 \text{ ft/s}^2) t_1 t_2 = 17500 \text{ ft}
\]
or \[ \ddot{t} + 2\dot{t} t = 875 \text{ s}^2 \]  \hspace{1cm} (4)

Also, it is known that: \( t_1 + t_2 = 90 \text{ s} \)  \hspace{1cm} (5)

Solving Equations (4) and (5) simultaneously yields \( t_1 = 50 \text{ s} \) and \( t_2 = 85 \text{ s} \)

(b) From Equation (2) above, \( v = (40 \text{ ft/s}^2) \dot{t}_1 = (40 \text{ ft/s}^2)(50 \text{ s}) = 2000 \text{ ft/s} \)

(c) The displacement \( \Delta x_1 \) of the sled as it comes to rest (with acceleration \( a_1 = -20 \text{ ft/s}^2 \) ) is: \( \Delta x_1 = \frac{0 - v^2}{2a_1} = \frac{-(200 \text{ ft/s})^2}{2(-20 \text{ ft/s}^2)} = 1000 \text{ ft} \)

Thus, the total displacement for the trip (measured from the starting point) is \( \Delta x_{\text{total}} = (\Delta x_1 + \Delta x_2) + \Delta x_3 = 17500 \text{ ft} + 1000 \text{ ft} = 18500 \text{ ft} \)

(d) The time required to come to rest from velocity \( v \) (with acceleration \( a_j \) ) is \[ t_j = \frac{0 - v}{a_j} = \frac{-200 \text{ ft/s}}{-20 \text{ ft/s}^2} = 10 \text{ s} \]

so the duration of the entire trip is: \( t_{\text{total}} = t_1 + t_2 + t_3 = 50 \text{ s} + 85 \text{ s} + 10 \text{ s} = 100 \text{ s} \)

2.67 The time required for the woman to fall 3.00 m, starting from rest, is found from \( \Delta y = \frac{1}{2} a t^2 \) as \(-3.00 \text{ m} = 0 + \frac{1}{2} (-9.80 \text{ m/s}^2) t^2 \), giving \( t = 0.782 \text{ s} \)

(a) With the horse moving with constant velocity of \( 10.0 \text{ m/s} \), the horizontal distance is \( \Delta x = v_{\text{horse}} t = (10.0 \text{ m/s})(0.782 \text{ s}) = 7.82 \text{ m} \)

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