

Chapter 2 – Student Solutions Manual

1. We use Eq. 2-2 and Eq. 2-3. During a time t_c when the velocity remains a positive constant, speed is equivalent to velocity, and distance is equivalent to displacement, with $\Delta x = v t_c$.

(a) During the first part of the motion, the displacement is $\Delta x_1 = 40$ km and the time interval is

$$t_1 = \frac{(40 \text{ km})}{(30 \text{ km/h})} = 1.33 \text{ h.}$$

During the second part the displacement is $\Delta x_2 = 40$ km and the time interval is

$$t_2 = \frac{(40 \text{ km})}{(60 \text{ km/h})} = 0.67 \text{ h.}$$

Both displacements are in the same direction, so the total displacement is

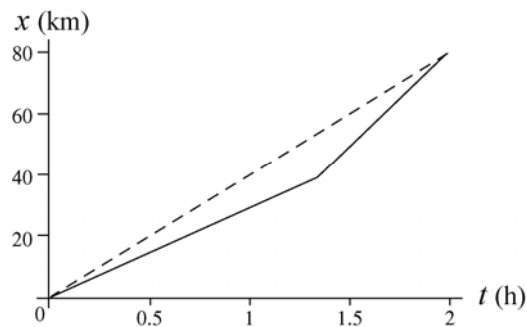
$$\Delta x = \Delta x_1 + \Delta x_2 = 40 \text{ km} + 40 \text{ km} = 80 \text{ km.}$$

The total time for the trip is $t = t_1 + t_2 = 2.00$ h. Consequently, the average velocity is

$$v_{\text{avg}} = \frac{(80 \text{ km})}{(2.0 \text{ h})} = 40 \text{ km/h.}$$

(b) In this example, the numerical result for the average speed is the same as the average velocity 40 km/h.

(c) As shown below, the graph consists of two contiguous line segments, the first having a slope of 30 km/h and connecting the origin to $(t_1, x_1) = (1.33 \text{ h}, 40 \text{ km})$ and the second having a slope of 60 km/h and connecting (t_1, x_1) to $(t, x) = (2.00 \text{ h}, 80 \text{ km})$. From the graphical point of view, the slope of the dashed line drawn from the origin to (t, x) represents the average velocity.



5. Using $x = 3t - 4t^2 + t^3$ with SI units understood is efficient (and is the approach we will use), but if we wished to make the units explicit we would write

$$x = (3 \text{ m/s})t - (4 \text{ m/s}^2)t^2 + (1 \text{ m/s}^3)t^3.$$

We will quote our answers to one or two significant figures, and not try to follow the significant figure rules rigorously.

(a) Plugging in $t = 1 \text{ s}$ yields $x = 3 - 4 + 1 = 0$.

(b) With $t = 2 \text{ s}$ we get $x = 3(2) - 4(2)^2 + (2)^3 = -2 \text{ m}$.

(c) With $t = 3 \text{ s}$ we have $x = 0 \text{ m}$.

(d) Plugging in $t = 4 \text{ s}$ gives $x = 12 \text{ m}$.

For later reference, we also note that the position at $t = 0$ is $x = 0$.

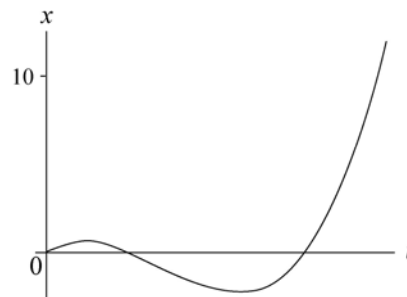
(e) The position at $t = 0$ is subtracted from the position at $t = 4 \text{ s}$ to find the displacement $\Delta x = 12 \text{ m}$.

(f) The position at $t = 2 \text{ s}$ is subtracted from the position at $t = 4 \text{ s}$ to give the displacement $\Delta x = 14 \text{ m}$. Eq. 2-2, then, leads to

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{14 \text{ m}}{2 \text{ s}} = 7 \text{ m/s}.$$

(g) The horizontal axis is $0 \leq t \leq 4$ with SI units understood.

Not shown is a straight line drawn from the point at $(t, x) = (2, -2)$ to the highest point shown (at $t = 4 \text{ s}$) which would represent the answer for part (f).



19. We represent its initial direction of motion as the $+x$ direction, so that $v_0 = +18 \text{ m/s}$ and $v = -30 \text{ m/s}$ (when $t = 2.4 \text{ s}$). Using Eq. 2-7 (or Eq. 2-11, suitably interpreted) we find

$$a_{\text{avg}} = \frac{(-30 \text{ m/s}) - (+1 \text{ m/s})}{2.4 \text{ s}} = -20 \text{ m/s}^2$$

which indicates that the average acceleration has magnitude 20 m/s^2 and is in the opposite direction to the particle's initial velocity.

25. The constant acceleration stated in the problem permits the use of the equations in Table 2-1.

(a) We solve $v = v_0 + at$ for the time:

$$t = \frac{v - v_0}{a} = \frac{\frac{1}{10}(3.0 \times 10^8 \text{ m/s})}{9.8 \text{ m/s}^2} = 3.1 \times 10^6 \text{ s}$$

which is equivalent to 1.2 months.

(b) We evaluate $x = x_0 + v_0 t + \frac{1}{2}at^2$, with $x_0 = 0$. The result is

$$x = \frac{1}{2} (9.8 \text{ m/s}^2) (3.1 \times 10^6 \text{ s})^2 = 4.6 \times 10^{13} \text{ m}.$$

27. Assuming constant acceleration permits the use of the equations in Table 2-1. We solve $v^2 = v_0^2 + 2a(x - x_0)$ with $x_0 = 0$ and $x = 0.010 \text{ m}$. Thus,

$$a = \frac{v^2 - v_0^2}{2x} = \frac{(5.7 \times 10^5 \text{ m/s})^2 - (1.5 \times 10^5 \text{ m/s})^2}{2(0.010 \text{ m})} = 1.62 \times 10^{15} \text{ m/s}^2.$$

33. The problem statement (see part (a)) indicates that $a = \text{constant}$, which allows us to use Table 2-1.

(a) We take $x_0 = 0$, and solve $x = v_0 t + \frac{1}{2}at^2$ (Eq. 2-15) for the acceleration: $a = 2(x - v_0 t)/t^2$. Substituting $x = 24.0 \text{ m}$, $v_0 = 56.0 \text{ km/h} = 15.55 \text{ m/s}$ and $t = 2.00 \text{ s}$, we find

$$a = \frac{2(24.0 \text{ m} - (15.55 \text{ m/s})(2.00 \text{ s}))}{(2.00 \text{ s})^2} = -3.56 \text{ m/s}^2,$$

or $|a| = 3.56 \text{ m/s}^2$. The negative sign indicates that the acceleration is opposite to the direction of motion of the car. The car is slowing down.

(b) We evaluate $v = v_0 + at$ as follows:

$$v = 15.55 \text{ m/s} - (3.56 \text{ m/s}^2)(2.00 \text{ s}) = 8.43 \text{ m/s}$$

which can also be converted to 30.3 km/h.

45. We neglect air resistance, which justifies setting $a = -g = -9.8 \text{ m/s}^2$ (taking *down* as the $-y$ direction) for the duration of the fall. This is constant acceleration motion, which justifies the use of Table 2-1 (with Δy replacing Δx).

(a) Starting the clock at the moment the wrench is dropped ($v_0 = 0$), then $v^2 = v_0^2 - 2g\Delta y$ leads to

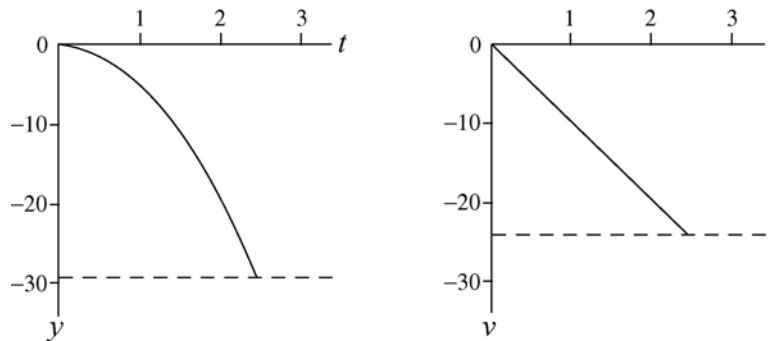
$$\Delta y = -\frac{(-24 \text{ m/s})^2}{2(9.8 \text{ m/s}^2)} = -29.4 \text{ m}$$

so that it fell through a height of 29.4 m.

(b) Solving $v = v_0 - gt$ for time, we find:

$$t = \frac{v_0 - v}{g} = \frac{0 - (-24 \text{ m/s})}{9.8 \text{ m/s}^2} = 2.45 \text{ s}.$$

(c) SI units are used in the graphs, and the initial position is taken as the coordinate origin. In the interest of saving space, we do not show the acceleration graph, which is a horizontal line at -9.8 m/s^2 .



47. We neglect air resistance for the duration of the motion (between “launching” and “landing”), so $a = -g = -9.8 \text{ m/s}^2$ (we take downward to be the $-y$ direction). We use the equations in Table 2-1 (with Δy replacing Δx) because this is $a = \text{constant}$ motion.

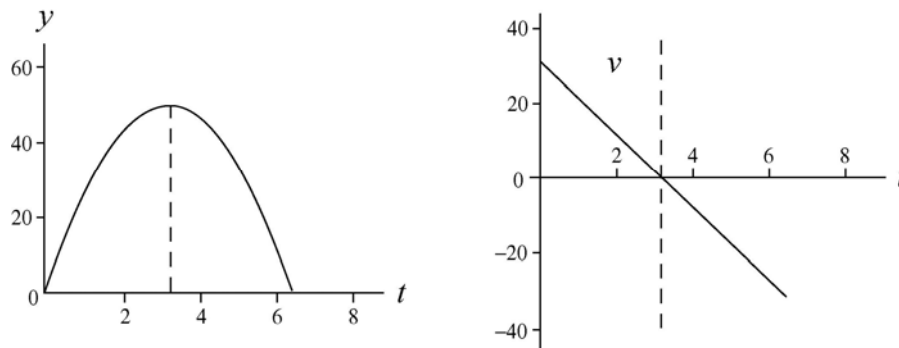
(a) At the highest point the velocity of the ball vanishes. Taking $y_0 = 0$, we set $v = 0$ in $v^2 = v_0^2 - 2gy$, and solve for the initial velocity: $v_0 = \sqrt{2gy}$. Since $y = 50 \text{ m}$ we find $v_0 = 31 \text{ m/s}$.

(b) It will be in the air from the time it leaves the ground until the time it returns to the ground ($y = 0$). Applying Eq. 2-15 to the entire motion (the rise and the fall, of total time $t > 0$) we have

$$y = v_0 t - \frac{1}{2} g t^2 \Rightarrow t = \frac{2v_0}{g}$$

which (using our result from part (a)) produces $t = 6.4$ s. It is possible to obtain this without using part (a)'s result; one can find the time just for the rise (from ground to highest point) from Eq. 2-16 and then double it.

(c) SI units are understood in the x and v graphs shown. In the interest of saving space, we do not show the graph of a , which is a horizontal line at -9.8 m/s^2 .



49. We neglect air resistance, which justifies setting $a = -g = -9.8 \text{ m/s}^2$ (taking *down* as the $-y$ direction) for the duration of the motion. We are allowed to use Table 2-1 (with Δy replacing Δx) because this is constant acceleration motion. We are placing the coordinate origin on the ground. We note that the initial velocity of the package is the same as the velocity of the balloon, $v_0 = +12 \text{ m/s}$ and that its initial coordinate is $y_0 = +80 \text{ m}$.

(a) We solve $y = y_0 + v_0 t - \frac{1}{2} g t^2$ for time, with $y = 0$, using the quadratic formula (choosing the positive root to yield a positive value for t).

$$t = \frac{v_0 + \sqrt{v_0^2 + 2gy_0}}{g} = \frac{12 + \sqrt{12^2 + 2(9.8)(80)}}{9.8} = 5.4 \text{ s}$$

(b) If we wish to avoid using the result from part (a), we could use Eq. 2-16, but if that is not a concern, then a variety of formulas from Table 2-1 can be used. For instance, Eq. 2-11 leads to

$$v = v_0 - gt = 12 - (9.8)(5.4) = -41 \text{ m/s}.$$

Its final *speed* is 41 m/s .

51. The speed of the boat is constant, given by $v_b = d/t$. Here, d is the distance of the boat from the bridge when the key is dropped (12 m) and t is the time the key takes in falling. To calculate t , we put the origin of the coordinate system at the point where the key is dropped and take the y axis to be positive in the *downward* direction. Taking the time to be zero at the instant the key is dropped, we compute the time t when $y = 45$ m. Since the initial velocity of the key is zero, the coordinate of the key is given by $y = \frac{1}{2}gt^2$. Thus

$$t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2(45 \text{ m})}{9.8 \text{ m/s}^2}} = 3.03 \text{ s}.$$

Therefore, the speed of the boat is

$$v_b = \frac{12 \text{ m}}{3.03 \text{ s}} = 4.0 \text{ m/s}.$$

55. (a) We first find the velocity of the ball just before it hits the ground. During contact with the ground its average acceleration is given by

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t}$$

where Δv is the change in its velocity during contact with the ground and $\Delta t = 20.0 \times 10^{-3} \text{ s}$ is the duration of contact. Now, to find the velocity just *before* contact, we put the origin at the point where the ball is dropped (and take $+y$ upward) and take $t = 0$ to be when it is dropped. The ball strikes the ground at $y = -15.0$ m. Its velocity there is found from Eq. 2-16: $v^2 = -2gy$. Therefore,

$$v = -\sqrt{-2gy} = -\sqrt{-2(9.8)(-15.0)} = -17.1 \text{ m/s}$$

where the negative sign is chosen since the ball is traveling downward at the moment of contact. Consequently, the average acceleration during contact with the ground is

$$a_{\text{avg}} = \frac{0 - (-17.1)}{20.0 \times 10^{-3}} = 857 \text{ m/s}^2.$$

89. Integrating (from $t = 2 \text{ s}$ to variable $t = 4 \text{ s}$) the acceleration to get the velocity (and using the velocity datum mentioned in the problem, leads to

$$v = 17 + \frac{1}{2}(5)(4^2 - 2^2) = 47 \text{ m/s}.$$

91. We take $+x$ in the direction of motion, so

$$v = (60 \text{ km/h}) \left(\frac{1000 \text{ m/km}}{3600 \text{ s/h}} \right) = +16.7 \text{ m/s}$$

and $a > 0$. The location where it starts from rest ($v_0 = 0$) is taken to be $x_0 = 0$.

(a) Eq. 2-7 gives $a_{\text{avg}} = (v - v_0)/t$ where $t = 5.4 \text{ s}$ and the velocities are given above. Thus, $a_{\text{avg}} = 3.1 \text{ m/s}^2$.

(b) The assumption that $a = \text{constant}$ permits the use of Table 2-1. From that list, we choose Eq. 2-17:

$$x = \frac{1}{2}(v_0 + v)t = \frac{1}{2}(16.7 \text{ m/s})(5.4 \text{ s}) = 45 \text{ m}.$$

(c) We use Eq. 2-15, now with $x = 250 \text{ m}$:

$$x = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2(250 \text{ m})}{3.1 \text{ m/s}^2}}$$

which yields $t = 13 \text{ s}$.

97. The (ideal) driving time before the change was $t = \Delta x/v$, and after the change it is $t' = \Delta x/v'$. The time saved by the change is therefore

$$t - t' = \Delta x \left(\frac{1}{v} - \frac{1}{v'} \right) = \Delta x \left(\frac{1}{55} - \frac{1}{65} \right) = \Delta x(0.0028 \text{ h/mi})$$

which becomes, converting $\Delta x = 700/1.61 = 435 \text{ mi}$ (using a conversion found on the inside front cover of the textbook), $t - t' = (435)(0.0028) = 1.2 \text{ h}$. This is equivalent to 1 h and 13 min.

99. We neglect air resistance, which justifies setting $a = -g = -9.8 \text{ m/s}^2$ (taking *down* as the $-y$ direction) for the duration of the motion. We are allowed to use Table 2-1 (with Δy replacing Δx) because this is constant acceleration motion. When something is thrown straight up and is caught at the level it was thrown from (with a trajectory similar to that shown in Fig. 2-31), the time of flight t is half of its time of ascent t_a , which is given by Eq. 2-18 with $\Delta y = H$ and $v = 0$ (indicating the maximum point).

$$H = vt_a + \frac{1}{2}gt_a^2 \Rightarrow t_a = \sqrt{\frac{2H}{g}}$$

Writing these in terms of the total time in the air $t = 2t_a$ we have

$$H = \frac{1}{8}gt^2 \Rightarrow t = 2\sqrt{\frac{2H}{g}}.$$

We consider two throws, one to height H_1 for total time t_1 and another to height H_2 for total time t_2 , and we set up a ratio:

$$\frac{H_2}{H_1} = \frac{\frac{1}{8}gt_2^2}{\frac{1}{8}gt_1^2} = \left(\frac{t_2}{t_1}\right)^2$$

from which we conclude that if $t_2 = 2t_1$ (as is required by the problem) then $H_2 = 2^2H_1 = 4H_1$.

107. (a) The wording of the problem makes it clear that the equations of Table 2-1 apply, the challenge being that v_0 , v , and a are not explicitly given. We can, however, apply $x - x_0 = v_0t + \frac{1}{2}at^2$ to a variety of points on the graph and solve for the unknowns from the simultaneous equations. For instance,

$$16 - 0 = v_0(2.0) + \frac{1}{2}a(2.0)^2$$

$$27 - 0 = v_0(3.0) + \frac{1}{2}a(3.0)^2$$

lead to the values $v_0 = 6.0$ m/s and $a = 2.0$ m/s².

(b) From Table 2-1,

$$x - x_0 = vt - \frac{1}{2}at^2 \Rightarrow 27 - 0 = v(3.0) - \frac{1}{2}(2.0)(3.0)^2$$

which leads to $v = 12$ m/s.

(c) Assuming the wind continues during $3.0 \leq t \leq 6.0$, we apply $x - x_0 = v_0t + \frac{1}{2}at^2$ to this interval (where $v_0 = 12.0$ m/s from part (b)) to obtain

$$\Delta x = (12.0)(3.0) + \frac{1}{2}(2.0)(3.0)^2 = 45 \text{ m}.$$