CHAPTER 2: Kinematics in One Dimension

Quest 1,4; Prob 1, 3,5,7,9,11,17a,18,21,25,33,37,39

Answers to Questions

1. A car speedometer measures only speed. It does not give any information about the direction, and so does not measure velocity.

4. For both cars, the time elapsed is the distance traveled divided by the average velocity. Since both cars travel the same distance, the car with the larger average velocity will have the smaller elapsed time. Consider this scenario. Assume that one car has a constant acceleration down the track. Then a graph of its speed versus time would look like line "A" on the first graph. The shaded area of the graph represents the distance traveled, and the graph is plotted to such a time that the shaded area represents the length of the track. The time for this car to finish the race is labeled "t₁".

Now let the second car have a much smaller acceleration initially, but with an increasing acceleration. A graph of its velocity, superimposed on the above graph and labeled "B", might look like the second diagram.

It is seen that at the time t₁ when the first car finished the race, the second car is going faster than the first car, because the heavy line is “higher” on the graph than the line representing the first car. However, the area under the "B" line (the distance that the second car has traveled) is smaller than the shaded area, and so is less than the full track length. For the area under the "B" line to be the same as the area under the "A" line, the graph would need to look like the third diagram, indicating a longer time for the second car to finish the race.

the object dropped first will always have a greater speed than the object dropped second, but both will have the same acceleration of 9.80 m/s².
Solutions to Problems

1. The average speed is given by:

\[ \bar{v} = \frac{d}{\Delta t} = 235 \text{ km}/3.25 \text{ h} = 72.3 \text{ km/h}. \]

3. The distance of travel (displacement) can be found by rearranging the average speed equation. Also note that the units of the velocity and the time are not the same, so the speed units will be converted.

\[ \bar{v} = \frac{d}{\Delta t} \rightarrow d = \bar{v} \Delta t = (110 \text{ km/h}) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) (2.0 \text{ s}) = 0.061 \text{ km} = 61 \text{ m} \]

5. The average velocity is given by

\[ \bar{v} = \frac{\Delta x}{\Delta t} = \frac{-4.2 \text{ cm} - 3.4 \text{ cm}}{6.1 \text{ s} - 3.0 \text{ s}} = \frac{-7.6 \text{ cm}}{3.1 \text{ s}} = -2.5 \text{ cm/s}. \]

7. The time for the first part of the trip is calculated from the initial speed and the first distance.

\[ \text{ave speed}_1 = v_1 = \frac{d_1}{\Delta t_1} \rightarrow \Delta t_1 = \frac{d_1}{v_1} = \frac{130 \text{ km}}{95 \text{ km/h}} = 1.37 \text{ h} = 82 \text{ min} \]

The time for the second part of the trip is therefore

\[ \Delta t_2 = \Delta t_{\text{total}} - \Delta t_1 = 3.33 \text{ h} - 1.37 \text{ h} = 1.96 \text{ h} = 118 \text{ min} \]

The distance for the second part of the trip is calculated from the average speed for that part of the trip and the time for that part of the trip.

\[ \text{ave speed}_2 = v_2 = \frac{d_2}{\Delta t_2} \rightarrow d_2 = v_2 \Delta t_2 = (65 \text{ km/h})(1.96 \text{ h}) = 127.5 \text{ km} = 1.3 \times 10^2 \text{ km} \]

(a) The total distance is then

\[ d_{\text{total}} = d_1 + d_2 = 130 \text{ km} + 127.5 \text{ km} = 257.5 \text{ km} = 2.6 \times 10^2 \text{ km} \]

(b) The average speed is NOT the average of the two speeds. Use the definition of average speed.

\[ \text{ave speed} = \frac{d_{\text{total}}}{\Delta t_{\text{total}}} = \frac{257.5 \text{ km}}{3.33 \text{ h}} = 77 \text{ km/h} \]

[9] The distance traveled is 2.0 miles \(8 \text{ laps} \times 0.25 \text{ mi/lap}\). The displacement is 0 because the ending point is the same as the starting point.

(a) Average speed =

\[ \frac{d}{\Delta t} = \frac{2.0 \text{ mi}}{12.5 \text{ min}} = \left( \frac{2 \text{ mi}}{12.5 \text{ min}} \right) \left( \frac{1610 \text{ m}}{1 \text{ mi}} \right) \left( \frac{1 \text{ min}}{60 \text{ s}} \right) = 4.3 \text{ m/s} \]
(b) Average velocity \( \bar{v} = \Delta x / \Delta t = 0 \text{ m/s} \)

11. Since the locomotives have the same speed, they each travel half the distance, 4.25 km. Find the time of travel from the average speed.

\[
\text{ave speed} = v = \frac{d}{\Delta t} \rightarrow \Delta t = \frac{d}{v} = \frac{4.25 \text{ km}}{95 \text{ km/h}} = 0.0447 \text{ h} \left( \frac{60 \text{ min}}{1 \text{ h}} \right) = 2.68 \text{ min} = \boxed{2.7 \text{ min}}
\]

17. (a) The average acceleration of the sprinter is \( \bar{a} = \frac{\Delta v}{\Delta t} = \frac{10.0 \text{ m/s} - 0.0 \text{ m/s}}{1.35 \text{ s}} = 7.41 \text{ m/s}^2 \).

(b) \( \bar{a} = \left(7.41 \text{ m/s}^2\right) \left( \frac{1 \text{ km}}{1000 \text{ m}} \right) \left( \frac{3600 \text{ s}}{1 \text{ h}} \right)^2 = 9.60 \times 10^4 \text{ km/h}^2 \)

[18] The time can be found from the average acceleration, \( \bar{a} = \frac{\Delta v}{\Delta t} \).

\[
\Delta t = \frac{\Delta v}{\bar{a}} = \frac{110 \text{ km/h} - 80 \text{ km/h}}{1.6 \text{ m/s}^2} = \frac{\left(30 \text{ km/h}\right) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right)}{1.6 \text{ m/s}^2} = 5.208 \text{ s} = \boxed{5 \text{ s}}
\]

21. By definition, the acceleration is \( \alpha = \frac{v - v_0}{t} = \frac{25 \text{ m/s} - 13 \text{ m/s}}{6.0 \text{ s}} = \boxed{2.0 \text{ m/s}^2} \).

The distance of travel can be found from Eq. 2-11b.

\[
x - x_0 = v_0 t + \frac{1}{2} \alpha t^2 = (13 \text{ m/s})(6.0 \text{ s}) + \frac{1}{2}(2.0 \text{ m/s}^2)(6.0 \text{ s})^2 = 114 \text{ m}
\]

25. The words “slowing down uniformly” implies that the car has a constant acceleration. The distance of travel is found from combining Eqs. 2-7 and 2-8.

\[
x - x_0 = \frac{v_0 + v}{2} t = \left( \frac{21.0 \text{ m/s} + 0 \text{ m/s}}{2} \right)(6.00 \text{ sec}) = 63.0 \text{ m}.
\]

33. Choose downward to be the positive direction, and take \( y_0 = 0 \) at the top of the cliff. The initial velocity is \( v_0 = 0 \), and the acceleration is \( a = 9.80 \text{ m/s}^2 \). The displacement is found from equation (2-11b), with \( x \) replaced by \( y \).

\[
y = y_0 + v_0 t + \frac{1}{2} \alpha t^2 \quad \rightarrow \quad y - 0 = 0 + \frac{1}{2}(9.80 \text{ m/s}^2)(3.25 \text{ s})^2 \quad \rightarrow \quad y = 51.8 \text{ m}
\]

37. Choose upward to be the positive direction, and take \( y_0 = 0 \) to be the height from which the ball was
thrown. The acceleration is \( a = -9.80 \text{ m/s}^2 \). The displacement upon catching the ball is 0, assuming

it was caught at the same height from which it was thrown. The starting speed can be found from Eq. 2-11b, with \( x \) replaced by \( y \).

\[
y = y_0 + v_0 t + \frac{1}{2} at^2 = 0 
\rightarrow
v_0 = \frac{y - y_0 - \frac{1}{2} at^2}{t} = -\frac{1}{2}a = -\frac{1}{2}(9.80 \text{ m/s}^2)(3.0 \text{ s}) = 14.7 \text{ m/s} = 15 \text{ m/s}
\]

The height can be calculated from Eq. 2-11c, with a final velocity of \( v = 0 \) at the top of the path.

\[
v^2 = v_0^2 + 2a(y - y_0) \rightarrow y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (14.7 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 11 \text{ m}
\]

39. Choose downward to be the positive direction, and take \( y_0 = 0 \) to be the height where the object was released. The initial velocity is \( v_0 = -5.20 \text{ m/s}^2 \), the acceleration is \( a = 9.80 \text{ m/s}^2 \), and the displacement of the package will be \( y = 125 \text{ m} \). The time to reach the ground can be found from Eq. 2-11b, with \( x \) replaced by \( y \).

\[
y = y_0 + v_0 t + \frac{1}{2} at^2 \rightarrow t^2 + \frac{2v_0}{a} t - \frac{2y}{a} = 0 \rightarrow t^2 + \frac{2(-5.2 \text{ m/s})}{9.80 \text{ m/s}^2} t - \frac{2(125 \text{ m})}{9.80 \text{ m/s}^2} = 0 \rightarrow
\]

\[
t = 5.61 \text{ s}, -4.55 \text{ s}
\]

The correct time is the positive answer, \( t = 5.61 \text{ s} \).