Chapter 2

1. An airplane travels at a constant speed, relative to the ground, of 900.0 km/h.
   a. How far has the airplane traveled after 2.0 h in the air?

   \[ d = vt \]
   \[ = (900.0 \text{ km/h})(2.0 \text{ h}) \]
   \[ = 1800 \text{ km} \]

   b. How long does it take for the airplane to travel between City A and City B if the cities are 3240 km apart?

   \[ t = \frac{d}{v} \]
   \[ = \frac{3240 \text{ km}}{900.0 \text{ km/h}} \]
   \[ = 3.600 \text{ h} \]

   c. If a second plane leaves 1 h after the first, and travels at 1200 km/h, which flight will arrive at City B first?

   \[ t = \frac{d}{v} \]
   \[ = \frac{3240 \text{ km}}{1200 \text{ km/h}} \]
   \[ = 2.7 \text{ h} \]

   The second plane arrives 3.7 h after the first plane departs, so the first plane arrives before the second.

2. You and your friend start jogging around a \(2.00 \times 10^3\)-m running track at the same time. Your average running speed is 3.15 m/s, while your friend runs at 3.36 m/s. How long does your friend wait for you at the finish line?

   \[ t = \frac{d}{v} \]
   \[ t_1 = \frac{2.00 \times 10^3 \text{ m}}{3.15 \text{ m/s}} = 635 \text{ s (your time)} \]
   \[ t_2 = \frac{2.00 \times 10^3 \text{ m}}{3.36 \text{ m/s}} = 595 \text{ s (friend’s time)} \]

   Your friend’s wait time is:
   \(635 \text{ s} - 595 \text{ s} = 4.0 \times 10^1 \text{ s}\)
Chapter 2 continued

3. The graph to the right shows the distance versus time for two cars traveling on a straight highway.
   a. What can you determine about the relative direction of travel of the cars?
      The cars are traveling in opposite directions.
   b. At what time do they pass one another?
      They pass 5 h after starting.
   c. Which car is traveling faster?
      Car A is traveling faster because the slope of its line has a larger magnitude. The slope represents \( \frac{\Delta d}{\Delta t} \), or speed.
   d. What is the speed of the slower car?
      The speed is equal to the slope of the line \( \frac{\Delta d}{\Delta t} \), which is calculated from two points on the graph as 20 km/h.

4. You drop a ball from a height of 2.0 m. It falls to the floor, bounces straight upward 1.3 m, falls to the floor again, and bounces 0.7 m.
   a. Use vector arrows to show the motion of the ball.

   b. At the top of the second bounce, what is the total distance that the ball has traveled?
      \[
      d = d_1 + d_2 + d_3 + d_4 \\
      = 2.0 \text{ m} + 1.3 \text{ m} + 1.3 \text{ m} + 0.7 \text{ m} \\
      = 5.3 \text{ m}
      \]
Chapter 2 continued

c. At the top of the second bounce, what is the ball’s displacement from its starting point?
\[ \Delta d = d_1 + (-d_2) + d_4 + (-d_4) \]
\[ = 2.0 \text{ m} - 1.3 \text{ m} + 1.3 \text{ m} - 0.7 \text{ m} \]
\[ = 1.3 \text{ m downward} \]
d. At the top of the second bounce, what is the ball’s displacement from the floor?
0.7 m upward

5. You are making a map of some of your favorite locations in town. The streets run north–south and east–west and the blocks are exactly 200 m long. As you map the locations, you walk three blocks north, four blocks east, one block north, one block west, and four blocks south.

a. Draw a diagram to show your route.

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b. What is the total distance that you traveled while making the map?
\[ d_{\text{total}} = d_1 + d_2 + d_3 + d_4 + d_5 \]
\[ = 3 \text{ blocks} + 4 \text{ blocks} + 1 \text{ block} + 1 \text{ block} + 4 \text{ blocks} \]
\[ = 13 \text{ blocks} \]
\[ 13 \text{ blocks} \times 200 \text{ m/block} = 2600 \text{ m} \]

c. Use your diagram to determine your final displacement from your starting point.
3 blocks × 200 m/block = 600 m
The displacement is 600 m east from the starting point.
d. What vector will you follow to return to your starting point?
600 m toward the west.
6. An antelope can run 90.0 km/h. A cheetah can run 117 km/h for short distances. The cheetah, however, can maintain this speed only for 30.0 s before giving up the chase.

a. Can an antelope with a 150.0-m lead outrun a cheetah?

\[ d = vt \]

\[ t = 30 \text{ s} \]

\[ v_{\text{antelope}} = (90.0 \text{ km/h}) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \]

\[ = 25.0 \text{ m/s} \]

\[ v_{\text{cheetah}} = (117 \text{ km/h}) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \]

\[ = 32.5 \text{ m/s} \]

\[ d_{\text{antelope}} = 25.0 \text{ m/s} \times 30.0 \text{ s} \]

\[ = 750 \text{ m} \]

\[ d_{\text{cheetah}} = 32.5 \text{ m/s} \times 30.0 \text{ s} \]

\[ = 975 \text{ m} \]

The cheetah can run 225 m farther than the antelope in 30.0 s, so a 150.0-m lead is not sufficient.

b. What is the closest that the antelope can allow a cheetah to approach and remain likely to escape?

226 m

7. The position-time graph to the right represents the motion of three people in an airport moving toward the same departure gate.

a. Which person travels the farthest during the period shown?

person A

b. Which person travels fastest by riding a motorized cart? How can you tell?

person B. The magnitude of the slope is largest for line B when the person is traveling.

c. Which person starts closest to the departure gate?

Person B and person C start 400 m from the gate.

d. Which person appears to be going to the wrong gate?

person C
8. A radio signal takes 1.28 s to travel from a transmitter on the Moon to the surface of Earth. The radio waves travel at $3.00 \times 10^8$ m/s. What is the distance, in kilometers, from the Moon to Earth?

\[
d = vt
= (3.00 \times 10^8 \text{ m/s}) \times 1.28 \text{ s}
= 3.84 \times 10^8 \text{ m}
= (3.84 \times 10^8 \text{ m}) \times \left(\frac{1 \text{ km}}{1000 \text{ m}}\right)
= 3.84 \times 10^5 \text{ km}
\]

9. You start to walk toward your house eastward at a constant speed of 5.0 km/h. At the same time, your sister leaves your house, driving westward at a constant speed of 30.0 km/h. The total distance from your starting point to the house is 3.5 km.

a. Draw a position-time graph that shows both your motion and your sister’s motion.

b. From the graph, determine how long you travel before you meet your sister.

0.1 h

c. How far do you travel in that time?

0.5 km

10. A bus travels on a northbound street for 20.0 s at a constant velocity of 10.0 m/s. After stopping for 20.0 s, it travels at a constant velocity of 15.0 m/s for 30.0 s to the next stop, where it remains for 15.0 s. For the next 15.0 s, the bus continues north at 15.0 m/s.

a. Construct a $d$-$t$ graph of the motion of the bus.

b. What is the total distance traveled?

\[
d = v_1 t_1 + v_2 t_2 + v_3 t_3 + v_4 t_4 + v_5 t_5
= (10.0 \text{ m/s})(20.0 \text{ s}) + (0.00 \text{ m/s})(20.0 \text{ s}) + (15.0 \text{ m/s})(30.0 \text{ s}) + (0.00 \text{ m/s})(15.0 \text{ s}) + (15.0 \text{ m/s})(15.0 \text{ s})
= 875 \text{ m}
\]

c. What is the average velocity of the bus for this period?

\[
v_{\text{ave}} = \frac{\Delta t}{\Delta d}
= \frac{875 \text{ m}}{100.0 \text{ s}}
= 8.75 \text{ m/s}
\]
Chapter 3

1. Use the velocity-time graph below to calculate the velocity of the object whose motion is plotted on the graph.

![Velocity-time graph](image)

a. What is the acceleration between the points on the graph labeled A and B?

\[
a = \frac{\Delta v}{t} = \frac{(v_f - v_i)}{t}
\]

\[
= \frac{300.0 \text{ m/s} - 0.0 \text{ m/s}}{20.0 \text{ s}}
\]

\[
= 15.0 \text{ m/s}^2
\]

b. What is the acceleration between the points on the graph labeled B and C?

\[
\Delta v = 0, \text{ therefore } a = 0
\]

(no acceleration)

c. What is the acceleration between the points on the graph labeled D and E?

\[
a = \frac{\Delta v}{t} = \frac{(v_f - v_i)}{t}
\]

\[
= \frac{0.0 \text{ m/s} - 500.0 \text{ m/s}}{40.0 \text{ s}}
\]

\[
= -125 \text{ m/s}^2
\]

d. What is the total distance that the object travels between points B and C?

\[
d = vt
\]

\[
= 300.0 \text{ m/s} \times 10.0 \text{ s}
\]

\[
= 3.00 \times 10^3 \text{ m}
\]

2. If you throw a ball straight upward, it will rise into the air and then fall back down toward the ground. Imagine that you throw the ball with an initial velocity of 13.7 m/s.
Chapter 3 continued

4. A hot air balloon is rising at a constant speed of 1.00 m/s. The pilot accidentally drops his pen 10.0 s into the flight.
   a. How far does the pen drop?

   The pen falls from the altitude of the balloon at 10 s.
   \[ d = vt \]
   \[ = (1.00 \text{ m/s})(10.0 \text{ s}) \]
   \[ = 10.0 \text{ m} \]

   b. How fast is the pen traveling when it hits the ground, ignoring air resistance?

   \[ v_f^2 = v_i^2 + 2a(d_f - d_i) \]
   \[ = 0 + 2(9.80 \text{ m/s}^2)(10.0 \text{ m} - 0.00 \text{ m}) \]
   \[ = 196 \text{ m}^2/\text{s}^2 \]
   \[ v = 14.0 \text{ m/s} \]

5. A sudden gust of wind increases the velocity of a sailboat relative to the water surface from 3.0 m/s to 5.5 m/s over a period of 30.0 s.
   a. What is the average acceleration of the sailboat?

   \[ a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t} \]
   \[ = \frac{5.5 \text{ m/s} - 3.0 \text{ m/s}}{30.0 \text{ s}} \]
   \[ = 0.083 \text{ m/s}^2 \]

   b. How far does the sailboat travel during the period of acceleration?

   \[ d_f = d_i + v_it + \frac{1}{2}at^2 \]
   \[ = 0.0 \text{ m} + \frac{3.0 \text{ m/s}}{30.0 \text{ s}} + \frac{1}{2}(0.083 \text{ m/s}^2)(30.0 \text{ s})^2 \]
   \[ = 130 \text{ m} \]

6. During a serve, a tennis ball leaves a racket at 180 km/h after being accelerated for 80.0 ms.
   a. What is the average acceleration on the ball during the serve in m/s²?

   \[ v_f = \frac{180 \text{ km/h}}{1 \text{ km/3600 s}} \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) \]
   \[ = 5.0 \times 10^1 \text{ m/s} \]
Chapter 3 continued

\[ a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t} \]
\[ = \frac{5.0 \times 10^1 \text{ m/s} - 0.0 \text{ m/s}}{8.0 \times 10^{-2} \text{ s}} \]
\[ = 630 \text{ m/s}^2 \]

b. How far does the ball move during the period of acceleration?
\[ d_f = d_i + v_i t + \frac{1}{2} a t^2 \]
\[ = 0.0 \text{ m} + (0.0 \text{ m/s})(0.080 \text{ s}) + \]
\[ \frac{1}{2}(630 \text{ m/s}^2)(0.0800 \text{ s})^2 \]
\[ = 2.0 \text{ m} \]

7. Anna walks off the end of a 10.0-m diving platform.
   a. What is her acceleration in m/s² toward the pool?
   
   Her acceleration due to gravity is 9.80 m/s².
   b. How long does it take her to reach the water?
\[ d_f = d_i + v_i t + \frac{1}{2} a t^2, \quad v_i \text{ and } d_i = 0 \]

Solve for \( t \):
\[ t = \sqrt{\frac{2d}{a}} \]
\[ = \sqrt{\frac{2 \times 10.0 \text{ m}}{9.80 \text{ m/s}^2}} \]
\[ = 1.43 \text{ s} \]

c. What is her velocity when she reaches the water?
\[ v_f = v_i + a t \]
\[ = 0.0 \text{ m/s} + (9.80 \text{ m/s}^2)(1.43 \text{ s}) \]
\[ = 14.0 \text{ m/s} \]

8. A rocket used to lift a satellite into orbit undergoes a constant acceleration of 6.25 m/s². When the rocket reaches an altitude of 45 km above the surface of Earth, it is traveling at a velocity of 625 m/s. How long does it take for the rocket to reach this speed?

Solve \( d_f = d_i + v_i t + \frac{1}{2} a t^2 \) for \( t \)
(let \( v_i \) and \( d_i = 0 \))

\[ t = \sqrt{\frac{2d}{a}} \]
\[ = \sqrt{\frac{(2 \times 45 \text{ km})(1000 \text{ m})}{6.25 \text{ m/s}^2}} \]
\[ = 120 \text{ s} \]

9. The table below shows the velocity of a student walking down the hallway between classes.

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>10.0</td>
<td>1.5</td>
</tr>
<tr>
<td>20.0</td>
<td>1.5</td>
</tr>
<tr>
<td>30.0</td>
<td>1.5</td>
</tr>
<tr>
<td>31.0</td>
<td>0.0</td>
</tr>
<tr>
<td>40.0</td>
<td>0.0</td>
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<tr>
<td>50.0</td>
<td>3.0</td>
</tr>
<tr>
<td>60.0</td>
<td>3.0</td>
</tr>
<tr>
<td>61.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

a. What is happening to the student’s speed during \( t = 60.0 \text{ s} \) and \( t = 61.0 \text{ s} \)?
   He is slowing down.

b. What is his acceleration between \( t = 10 \text{ s} \) and \( t = 20 \text{ s} \)?
\[ a = \frac{\Delta v}{t} \]
\[ = \frac{v_f - v_i}{t_f - t_i} \]
\[ = \frac{1.5 \text{ m/s} - 1.5 \text{ m/s}}{200 \text{ s} - 100 \text{ s}} \]
\[ = 0.0 \text{ m/s} \]

c. What is his acceleration between \( t = 60.0 \text{ s} \) and \( t = 61.0 \text{ s} \)?
\[ a = \frac{\Delta v}{t} \]
\[ = \frac{v_f - v_i}{t_f - t_i} \]
\[ = \frac{0.0 \text{ m/s} - 3.0 \text{ m/s}}{61.0 \text{ s} - 60.3 \text{ s}} \]
\[ = 3.0 \text{ m/s} \]
Chapter 3 continued

d. Assuming constant acceleration, how far did he walk during the first 5 s?
\[
\begin{align*}
a &= \frac{\Delta v}{t} \\
    &= \frac{v_1 - v_i}{t} \\
    &= \frac{1.5 \text{ m/s} - 0.0 \text{ m/s}}{10.0 \text{ s} - 0.0 \text{ s}} \\
    &= 0.15 \text{ m/s}^2 \\
\end{align*}
\]
\[
\begin{align*}
d &= d_i + v_i t + \frac{1}{2} a t^2 \\
    &= 0.0 \text{ m} + (0.0 \text{ m/s})(5.0 \text{ s}) + \frac{1}{2}(0.15 \text{ m/s}^2)(5.0 \text{ s})^2 \\
    &= 1.9 \text{ m} \\
\end{align*}
\]

10. On the surface of Mars, the acceleration due to gravity is 0.379 times as much as that on the surface of Earth. A robot on Mars pushes a rock over a 500.0-m cliff.

a. How long does it take the rock to reach the ground below the cliff?
\[
\begin{align*}
a &= 9.80 \text{ m/s}^2 \times 0.379 \\
    &= 3.71 \text{ m/s}^2 \\
\end{align*}
\]

Solve for \(d_i = d_i + v_i t + \frac{1}{2} a t^2\) for \(t\) (let \(v_i\) and \(d_i\) = 0)
\[
\begin{align*}
t &= \sqrt{\frac{2d}{a}} \\
    &= \sqrt{\frac{2(500.0 \text{ m})}{3.71 \text{ m/s}^2}} \\
    &= 16.4 \text{ s} \\
\end{align*}
\]

b. How fast is the rock traveling when it reaches the surface?
\[
\begin{align*}
v_f &= v_i + at \\
    &= 0.0 \text{ m/s} + (3.71 \text{ m/s}^2)(16.4 \text{ s}) \\
    &= 60.8 \text{ m/s} \\
\end{align*}
\]

c. How long would it take the rock to fall the same distance on the surface of Earth?
\[
\begin{align*}
t &= \sqrt{\frac{2d}{a}} \\
    &= \sqrt{\frac{2(500.0 \text{ m})}{9.80 \text{ m/s}^2}} \\
    &= 10.1 \text{ s} \\
\end{align*}
\]

11. A sky diver jumps from an airplane 1000.0 m above the ground. He waits for 8.0 s and then opens his parachute. How far above the ground is the sky diver when he opens his parachute?
\[
\begin{align*}
d_f &= d_i + v_i t + \frac{1}{2} a t^2 \\
    &= 1000.0 \text{ m} + (0.0 \text{ m/s})(8.0 \text{ s}) + \frac{1}{2}(9.80 \text{ m/s}^2)(8.0 \text{ s})^2 \\
    &= 310 \text{ m} \\
\end{align*}
\]

\(1000.0 \text{ m} + (-310 \text{ m}) = 690 \text{ m above the ground}\)

12. A speeding car is traveling at 92.0 km/h toward a police car at rest, facing the same direction as the speeding car. If the police car begins accelerating when the speeding car is 250.0 m behind the police car, what must the police car’s acceleration be in order for the police car to reach the speeding car’s velocity at the moment the speeding car catches up? Assume that the speeding car does not slow down.
\[
\begin{align*}
\bar{a}_{\text{police}} &= \frac{\Delta v_{\text{police}}}{\Delta t} \\
\Delta t &= \frac{\Delta d}{v_{\text{speeder}}} \\
\bar{a}_{\text{police}} &= \frac{\Delta v_{\text{police}}}{\Delta d} \frac{v_{\text{speeder}}}{v_{\text{police}}} \\
= & \frac{v_{f, \text{police}} - v_{i, \text{police}}}{\frac{\Delta d}{v_{\text{speeder}}}} \\
= & \frac{(25.6 \text{ m/s} - 0.0 \text{ m/s})}{\frac{250.0 \text{ m}}{25.6 \text{ m/s}}} \\
= & 2.62 \text{ m/s}^2 \\
\end{align*}
\]