HW 2b.

1. A seagull drops a shell from rest at a height of 14 m, how fast is the shell moving when it hits the rocks?

Solution: 1. Define downward to be positive x direction, \( x = 0 \) at 14 m above the ground.

   2. Identify initial & final location.
      Initial: \( x = 0 \), Final: \( x = 14 \text{ m} \).

   3. Fill the chart.
      \[
      \begin{array}{|c|c|c|c|c|}
      \hline
      \text{V}_0 & \Delta t & \Delta x & \text{V}_f \\
      \hline
      0 & 9.8 \text{ m/s}^2 & ? & 14 \text{ m} \\
      \hline
      \end{array}
      \]

   4. To find \( \text{V}_f \), use the equation without \( t \),
      \[
      V^2 - V_0^2 = 2a(\Delta x), \quad V^2 = V_0^2 + 2a(\Delta x) = 2a(\Delta x) \\
      V = \sqrt{2a(\Delta x)} = \sqrt{2 \times 9.8 \times 14} = 17.0 \text{ (m/s)}
      \]

2. Walker3 2.P.072. [544508]

Bill steps off a 2.5 m high diving board and drops to the water below. At the same time, Ted jumps upward with a speed of 4.4 m/s from a 1.0 m high diving board. Choosing the origin to be at the water's surface, and upward to be the positive x direction, write the x-versus-t of motion for both Bill and Ted. (Use g and t, as necessary.)

<table>
<thead>
<tr>
<th>Bill</th>
<th>[2.5 - (1/2 \ g \ t^2)] m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ted</td>
<td>[1.0 + 4.4t - (1/2 \ g \ t^2)] m</td>
</tr>
</tbody>
</table>

**Picture the Problem:** The two divers move vertically under the influence of gravity.

**Strategy:** In both cases we wish to write the equation of motion for position as a function of time and acceleration (equation 2-11). In Bill's case, the initial height \( x_0 = 3.0 \text{ m} \), but the initial velocity is zero because he steps off the diving board. In Ted's case the initial height \( x_0 = 1.0 \text{ m} \) and the initial velocity is 4.2 m/s. In both cases the acceleration is \(-9.81 \text{ m/s}^2\).

**Solution:** 1. Equation 2-11 for Bill:
   \[x = x_0 + v_0 t + \frac{1}{2} a t^2 = 3.0 \text{ m} + 0 + \frac{1}{2}(-9.81 \text{ m/s}^2)t^2\]
   \[x = (3.0 \text{ m}) - (4.9 \text{ m/s}^2)t^2\]

2. Equation 2-11 for Ted:
   \[x = x_0 + v_0 t + \frac{1}{2} a t^2 = 1.0 \text{ m} + (4.2 \text{ m/s})t + \frac{1}{2}(-9.81 \text{ m/s}^2)t^2\]
   \[x = (1.0 \text{ m}) + (4.2 \text{ m/s})t - (4.9 \text{ m/s}^2)t^2\]

**Insight:** The different initial velocities result in significantly different trajectories for Bill and Ted.
3. A hot air balloon is raising upward with a constant speed of 20 m/s when the balloon is 5 m above the ground, the balloonist accidentally looks over the side.

1) How much time elapses before it hits the ground?
2) What is its speed just before it hits the ground?
3) How high above the ground is the balloon when the compass hits the ground?

Define up to be positive direction, x=0 to be ground.

For the compass, \( v_0 = 20 \text{ m/s} \) upward, positive.

\( a = -9.8 \text{ m/s}^2 \) downward, negative.

From balloon to the ground, initial \( x=5 \text{ m} \), final location \( x_f = 0 \).

<table>
<thead>
<tr>
<th>( v_0 )</th>
<th>( a )</th>
<th>( t )</th>
<th>( \Delta x ) (from top to ground)</th>
<th>( v_f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 m/s</td>
<td>-9.8 m/s²</td>
<td>?</td>
<td>-5 m</td>
<td>?</td>
</tr>
</tbody>
</table>

(i) To find \( t \) from balloon to ground, use the equation without \( v_f \):

\[ \Delta x = v_0 t + \frac{1}{2} at^2 \]

\[-5 = 20t - \frac{9.8}{2} t^2 ; \]

solve the equation,

\[ 4.9t^2 - 20t - 5 = 0 \]

\[ t = 4.32 \text{ (s)} \]

(ii) To find \( |v_f| \) at the moment of hitting the ground.

\( v = \sqrt{v^2 + 2a\Delta x} \)

\[ v = \sqrt{20^2 + 2(-9.8)(-5)} \]

\[ v = \sqrt{20^2 + 2 \times 9.8 \times 5} = 22.3 \text{ (m/s)} \]

\( v \) is negative because it was downward.

The question asks only the speed, how fast, not velocity.

How fast? \( |v_f| = 22.3 \text{ (m/s)} \)

Type 22.3 into the box.

Method two, use the time found in part a, \( t = 4.32 \text{ (s)} \).

\[ v = v_0 + at \]

\[ v = 20 + (-9.8) \times 4.32 \]

\[ v = -22.3 \text{ (m/s)} \]

This is more risky. If \( t \) found in part a was off a little, this step will be wrong. Method one is better.

(3) The balloon had no acceleration, it moves up with constant velocity.

\( \Delta x = v_0 t \) (For the balloon)

\( \Delta x = 20 \times 4.32 = 86.2 \text{ m} \)

The balloon is above the ground for 86.2 + 5 = 91.2 m.

Or: \( x_f = x_0 + \Delta x \)

\( x_f = x + v_0 t = 5 + 20 \times 4.32 = 91.2 \text{ (m)} \)
4. A diver springs upward with an initial speed of 5 m/s from a diving board that is 2 m above the water.

   a) What is the maximum height the diver reaches above the water?

   b) Find the total time the diver is airborne.

   i) Define up to be positive. Water level to be x = 0

   ii) Identify initial location △ at the diving board.

   iii) Identify the "final" location, huh, water depending on what part of motion we study, the final location is different!!!

   iv) Fill the chart

<table>
<thead>
<tr>
<th>V_0</th>
<th>a</th>
<th>∆x</th>
<th>t</th>
<th>V_f</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5 m/s</td>
<td>-9.8 m/s^2</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

   (4) Solve part a, study the part of motion from diving board to the maximum height. Final location is at △, maximum height.

   At maximum height, V_f = 0

   To solve ∆x, use equation without t,

   \[ V_f^2 = V_0^2 + 2a(\Delta x) \]

   \[ \Delta x = \frac{V_f^2 - V_0^2}{2a} = \frac{0 - 5^2}{-2 \times 9.8} = 1.28 \text{ m} \]

   \[ x_f = x_0 + \Delta x = 2 + 1.28 = 3.28 \text{ m} \]

   (5) Solve part b, study the entire process from △, the diving board to water level.

   Use equation without V_f to find t,

   \[ \Delta x = V_0 t + \frac{1}{2}at^2; \]

   \[ -2 = 5t - \frac{9.8}{2} t^2; \]

   \[ t = 1.33 \text{ s} \]

   (c) Will the diver spend more time travelling upwards or downwards? Explain.

   No. The time spent upward from board to maximum height will be the same as the time spent downward from maximum height to the board. And downward motion has 2 extra meters to go from the board to water. So, actually downward has more time.
5. Walker3 2.P.032. [544619]

A motorcycle moves according to the velocity-versus-time graph shown in Figure 2-31. (The vertical axis is marked in increments of 5 m/s and the horizontal axis is marked in increments of 9 s.) Find the average acceleration of the motorcycle during each of the segments of motion, A, B, and C.

\[
a_A = 1.11 \text{ m/s}^2
\]

\[
a_B = 0 \text{ m/s}^2
\]

\[
a_C = -0.278 \text{ m/s}^2
\]

**Figure 2-31**

*Picture the Problem:* Following the motion specified in the velocity-versus-time graph, the motorcycle is speeding up, then moving at constant speed, then slowing down.

**Strategy:** Determine the acceleration from the slope of the graph.

**Solution:** 1. (a) Find the slope at A:

\[
a_a = \frac{\Delta v}{\Delta t} = \frac{10 \text{ m/s}}{5.0 \text{ s}} = 2.0 \text{ m/s}^2
\]

2. (b) Find the slope of the graph at B:

\[
a_b = \frac{\Delta v}{\Delta t} = \frac{0 \text{ m/s}}{10.0 \text{ s}} = 0 \text{ m/s}^2
\]

3. (c) Find the slope of the graph at C:

\[
a_c = \frac{\Delta v}{\Delta t} = \frac{-5.0 \text{ m/s}}{10.0 \text{ s}} = -0.50 \text{ m/s}^2
\]

**Insight:** The acceleration during segment A is larger than the acceleration during segments B and C because the slope there has the greatest magnitude.
A person on horseback moves according to the velocity-versus-time graph shown in Figure 2-32. (The vertical axis is marked in increments of 3 m/s and the horizontal axis is marked in increments of 8 s.) Find the displacement of the person for each of the segments A, B, and C.

\[
\begin{align*}
S_A & = 24 \text{ m} \\
S_B & = 48 \text{ m} \\
S_C & = 96 \text{ m}
\end{align*}
\]

**Figure 2-32**

**Picture the Problem:** Following the motion specified in the velocity-versus-time graph, the person on horseback is speeding up, then accelerating at an even greater rate, then slowing down.

**Strategy:** We could determine the acceleration from the slope of the graph, and then use the acceleration and initial velocity to determine the displacement. Alternatively, we could use the initial and final velocities in each segment to determine the average velocity and the time elapsed to find the displacement during each interval.

**Solution:**
1. (a) Use the average velocity during interval A to calculate the displacement: 
   \[
   \Delta x = \frac{1}{2}(v_0 + v)t = \frac{1}{2}(0 + 2.0 \text{ m/s})(10 \text{ s}) = 10 \text{ m}
   \]
2. (b) Find the slope of the graph at B: 
   \[
   \Delta x = \frac{1}{2}(v_0 + v)t = \frac{1}{2}(2.0 + 6.0 \text{ m/s})(5.0 \text{ s}) = 20 \text{ m}
   \]
3. (c) Find the slope of the graph at C: 
   \[
   \Delta x = \frac{1}{2}(v_0 + v)t = \frac{1}{2}(6.0 + 2.0 \text{ m/s})(10 \text{ s}) = 40 \text{ m}
   \]

**Insight:** There are often several ways to solve motion problems involving constant acceleration, some easier than others.
A 27 pound meteorite struck a car, leaving a dent 27 cm deep in the trunk. If the meteorite struck the car with a speed of 560 m/s, what was the magnitude of its deceleration, assuming it to be constant?

\[ 5.81 \times 10^5 \text{ m/s}^2 \]

50. **Picture the Problem**: The meteorite accelerates from a high speed to rest after impacting the car.

**Strategy**: Employ the relationship between acceleration, displacement, and velocity (equation 2-12) to find the acceleration.

**Solution**: Solve equation 2-12 for acceleration:

\[ a = \frac{v^2 - v_0^2}{2 \Delta x} = \frac{0^2 - (130 \text{ m/s})^2}{2 (0.22 \text{ m})} = 3.8 \times 10^4 \text{ m/s}^2 \]

**Insight**: The high stiffness of steel is responsible for the tremendous (negative) acceleration of the meteorite.