#1

For part a) just put t=0.25 into the equations for x and y:

\[
x = (1.3 \text{ m/s})(0.25\text{s}) = 0.325\text{m}
\]

\[
y = 1.25\text{m} + (0 \text{ m/s})(0.25\text{s}) + (\frac{1}{2})(-9.8 \text{ m/s}^2)(0.25\text{s})^2 = 0.94\text{m}
\]

For part b) try the same thing with t=0.55s. You get:

\[
x = 0.65\text{m}
\]

\[
y = -0.23\text{m}
\]

Negative value for y means the ball is below the ground!! – so it already landed. We can’t really say where the ball is for this part because we don’t know what it’s going to do while it is in contact with the ground (how high does it bounce, does friction slow it down, etc). So this was a trick question :)

Part c) we can calculate the components of the velocity at t=0.5s:

\[
v_x = v_{0,x} = 1.3 \text{ m/s} \quad (\text{the horizontal component of velocity is constant})
\]

\[
v_y = 0 \text{ m/s} + (-9.8 \text{ m/s}^2)(0.5\text{s}) = -4.9 \text{ m/s}
\]

Use Pythagorean theorem to get the magnitude of the velocity (the speed):

\[
v^2 = (1.3)^2 + (-4.9)^2 \rightarrow v = 5.1 \text{ m/s}
\]

Use the tangent to get the angle:

\[
\Theta = \tan^{-1}(4.9/1.3) = 75^\circ \text{ below horizontal}
\]

#2

Compare the components of the velocity for each diver. The vertical motions are identical (both start with \(v_y = 0\) and then free-fall). However the horizontal motions are not the same – Diver #2 is running at the start, so he is moving faster the whole time. So the answer is a).
#3

**EXAMPLE 4–4 Jumping a Crevasse**

A mountain climber encounters a crevasse in an ice field. The opposite side of the crevasse is 2.75 m lower, and is separated horizontally by a distance of 4.10 m. To cross the crevasse, the climber gets a running start and jumps in the horizontal direction. (a) What is the minimum speed needed by the climber to safely cross the crevasse? If, instead, the climber’s speed is 6.00 m/s, (b) where does the climber land, and (c) what is the climber’s speed on landing?

Picture the Problem
The mountain climber jumps from \( x_0 = 0 \) and \( y_0 = h = 2.75 \) m. The landing site for part (a) is \( x = w = 4.10 \) m and \( y = 0 \). Note that the \( y \) position of the climber decreases by \( h \), and therefore \( \Delta y = -h = -2.75 \) m. As for the initial velocity, we are given that \( v_{0y} = v_0 \) and \( \dot{v}_{0y} = 0 \). Finally, with our choice of coordinates it follows that \( a_x = 0 \) and \( a_y = -g \).

**Strategy**
(a) From Equation 4–7 we have that \( x = v_0t \) and \( y = h - \frac{1}{2}gt^2 \).

Setting \( y = 0 \) determines the time of landing. Using this time in the \( x \) equation gives the horizontal landing position in terms of the initial speed.

(b) We can now use the relation from part (a) to find \( x \) in terms of \( v_0 = 6.00 \) m/s.

(c) We already know \( v_{0y} \) since it remains constant, and we can calculate \( v_y \) using \( v_y^2 = -2g\Delta y \) (Equation 4–7). With the velocity components known, we can use the Pythagorean theorem to find the speed.

**Solution**

**Part (a)**
1. Set \( y = h - \frac{1}{2}gt^2 \) equal to zero (landing condition) and solve for the corresponding time \( t \):

\[ t = \sqrt{\frac{2h}{g}} \]

\[ x = v_0t = v_0\sqrt{\frac{2h}{g}} \]

2. Substitute this expression for \( t \) into the \( x \) equation of motion, \( x = v_0t \), and solve for the speed, \( v_y \):

\[ v_0 = x\sqrt{\frac{g}{2h}} \]

\[ v_0 = x\sqrt{\frac{g}{2(2.75)}} = 4.10\sqrt{\frac{9.81 \text{ m/s}^2}{2(2.75)}} = 5.48 \text{ m/s} \]

3. Substitute numerical values in this expression:

**Part (b)**
4. Substitute \( v_0 = 6.00 \text{ m/s} \) into the expression for \( x \) obtained in step 2, \( x = v_0\sqrt{2k/g} \):

\[ x = v_0\sqrt{\frac{2k}{g}} = (6.00 \text{ m/s})\sqrt{\frac{2(2.75)}{9.81 \text{ m/s}^2}} = 4.49 \text{ m} \]

**Part (c)**
5. Use the fact that the \( x \) component of velocity does not change to determine \( v_x \) and use \( v_y^2 = -2g\Delta y \) to determine \( v_y \). For \( v_x \), note that we choose the minus sign for the square root, because the climber is moving downward:

\[ v_x = v_0 = 6.00 \text{ m/s} \]

\[ v_y = -\sqrt{-2g\Delta y} = -\sqrt{-2(9.81 \text{ m/s}^2)(-2.75 \text{ m})} = 7.35 \text{ m/s} \]

6. Use the Pythagorean theorem to determine the speed:

\[ v = \sqrt{v_x^2 + v_y^2} \]

\[ v = \sqrt{(6.00 \text{ m/s})^2 + (7.35 \text{ m/s})^2} = 9.49 \text{ m/s} \]

**Insight**
The minimum speed needed to safely cross the crevasse is 5.48 m/s. If the initial horizontal speed is 6.00 m/s, the climber will land 4.49 m - 4.10 m = 0.39 m beyond the edge of the crevasse with a speed of 9.49 m/s.

#4

The answer is (b) decrease. Since \( h \) is larger, the time spent in the air increases, so that the horizontal speed could decrease and get the same horizontal distance traveled.

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#5

First find the x and y components of the initial velocity:

\[ V_{0,x} = 20 \cos(35°) = 16.4 \text{ m/s} \] and \[ V_{0,y} = 20 \sin(35°) = 11.5 \text{ m/s}. \]

For part a) use your formulas for x and y to find the position at t=0.5:

\[ x(0.5) = 8.2 \text{m} \] and \[ y(0.5) = 4.5 \text{m}. \]

For part b) find the components of the velocity at t=0.5:

\[ v_x = 16.4 \text{ (this will be constant because there is no acceleration in the x-direction)} \]

\[ v_y = 6.6 \text{ m/s} \text{ (gravity slows the ball down in the y-direction)} \]

Finally, use the Pythagorean theorem to find the speed \[ v = 17.7 \text{ m/s} \], and use the tangent to find the angle \[ \theta = \tan^{-1}(6.6/16.4) = 21.9° \text{ above horizontal}. \]

#6

Chipping from the rough, a golfer sends the ball over a 3.00 m-high tree that is 14.0 m away. The ball lands at the same level from which it was struck after traveling a horizontal distance of 17.8 m—one on the green, of course. (a) If the ball left the club 54.0° above the horizontal and landed on the green 2.24 s later, what was its initial speed? (b) How high was the ball when it passed over the tree?

**Picture the Problem**

Our sketch shows the ball taking flight from the origin, with a launch angle of 54.0°, and arcing over the tree. The individual points along the parabolic trajectory correspond to equal time intervals.

**Strategy**

(a) Since the projectile moves with constant speed in the x direction, the x component of velocity is simply horizontal distance divided by time. Knowing \( v_x \) and \( \theta \), we can find \( v_x \) from \( v_x = v_0 \cos \theta \).

(b) We can use \( x = (v_0 \cos \theta)t \) to find the time when the ball is at \( x = 14.0 \text{ m} \). Substituting this time into \( y = (v_0 \sin \theta)t - \frac{1}{2}gt^2 \) gives the height.

**Solution**

1. (a) Divide the horizontal distance, \( d \), by the time of flight, \( t \), to obtain \( v_x \):

\[ v_x = \frac{d}{t} = \frac{17.8 \text{ m}}{2.24 \text{ s}} = 7.95 \text{ m/s} \]

2. Use \( v_x = v_0 \cos \theta \) to find \( v_0 \), the initial speed:

\[ v_0 = \frac{v_x}{\cos \theta} \]

3. (b) Use \( x = (v_0 \cos \theta)t \) to find the time when \( x = 14.0 \text{ m} \):

\[ t = \frac{x}{v_0 \cos \theta} = \frac{14.0 \text{ m}}{7.95 \text{ m/s}} = 1.76 \text{ s} \]

4. Evaluate \( y = (v_0 \sin \theta)t - \frac{1}{2}gt^2 \) at the time found in step 3:

\[ y = (v_0 \sin \theta)t - \frac{1}{2}g(1.76 \text{ s})^2 = [(13.5 \text{ m/s}) \sin 54.0°](1.76 \text{ s}) - \frac{1}{2}(9.81 \text{ m/s}^2)(1.76 \text{ s})^2 \]

\[ = 4.03 \text{ m} \]

**Insight**

The ball clears the top of the tree by 1.03 m and lands on the green 0.48 s later. When it lands, its speed (in the absence of air resistance) is again 13.5 m/s—the same as when it was launched. This result will be verified in the next section.

**Practice Problem**

What are the speed and direction of the ball when it passes over the tree? [Answer: To find the ball's speed and direction, note that \( v_x = 7.95 \text{ m/s} \) and \( v_y = v_0 \sin \theta - gt = 6.34 \text{ m/s} \). It follows that \( v = \sqrt{v_x^2 + v_y^2} = 10.2 \text{ m/s} \) and \( \theta = \tan^{-1}(v_y/v_x) = -38.6° \).]
#7

A golfer hits a ball with an initial speed of 30.0 m/s at an angle of 50.0° above the horizontal. The ball lands on a green that is 5.00 m above the level where the ball was struck.

(a) How long is the ball in the air?

(b) How far has the ball traveled in the horizontal direction when it lands?

(c) What is the speed and direction of motion of the ball just before it lands?

---

**Solution** *(Test your understanding by performing the calculations indicated in each step.)*

**Part (a)**

1. Let \( y = (v_0 \sin \theta)t - \frac{1}{2}gt^2 = 5.00 \text{ m} \)
   and solve for \( t \):
   \[
   t = 0.229 \text{ s}, \quad 4.46 \text{ s}
   \]

2. When \( t = 0.229 \text{ s} \) the ball is moving upward; when \( t = 4.46 \text{ s} \) the ball is on the way down. Choose the later time:
   \[ t = 4.46 \text{ s} \]

**Part (b)**

3. Substitute \( t = 4.46 \text{ s} \) into \( x = (v_0 \cos \theta)t \):
   \[ x = 86.0 \text{ m} \]

**Part (c)**

4. Use \( v_x = v_0 \cos \theta \) to calculate \( v_x \):
   \[ v_x = 19.3 \text{ m/s} \]

5. Substitute \( t = 4.46 \text{ s} \) into \( v_y = v_0 \sin \theta - gt \) to find \( v_y \):
   \[ v_y = -20.8 \text{ m/s} \]

6. Calculate \( v \) and \( \theta \):
   \[ v = 28.4 \text{ m/s}, \quad \theta = -47.1^\circ \]