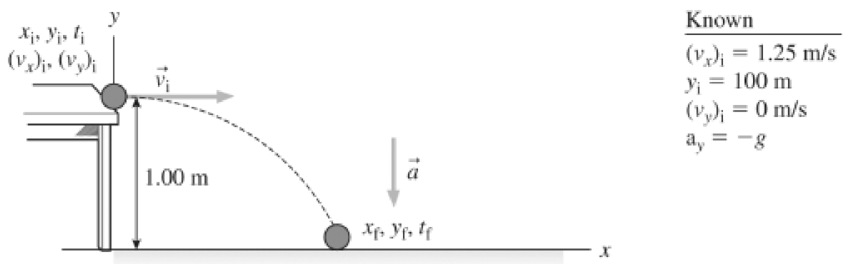
P3.28. Strategize: We can use the vertical part of the motion to calculate the time it takes the ball to hit the floor and the horizontal part of the motion to find out how far from the bench it lands.

Prepare: We can use the vertical-position equation from Synthesis 3.1 to find the time it takes the ball to reach the floor: $y_f = y_i + (v_y)_i \Delta t - \frac{1}{2}g(\Delta t)^2$. The distance the ball travels horizontally is governed by the horizontal-position equation from Synthesis 3.1.

$$x_f = x_i + (v_x)_i \Delta t$$

Solve: Refer to the visual overview shown.



The initial vertical velocity is zero. Take the floor as the origin of coordinates. The ball falls from $y_i = 1.00$ m and lands at $y_f = 0$ m.

(a) Rearranging to solve for time, and inserting the given values, we have

$$\Delta t = \sqrt{\frac{-2\Delta y}{g}} = \sqrt{\frac{-2(-1.00 \text{ m})}{9.80 \text{ m/s}^2}} = 0.452 \text{ s}$$

(b) Inserting the result from (a), we have

$$x_f = x_i + (v_x)_i \Delta t = (0.0 \text{ m}) + (1.25 \text{ m/s})(0.452 \text{ s}) = 0.565 \text{ m}.$$

Assess: This seems reasonable for a ball rolling off a table.

P3.31. Strategize: This problem involves constant acceleration (as in projectile motion). So we can use the kinematic equations in the horizontal and vertical directions.

Prepare: If we consider half the motion from the launch to the peak height, then we can use Equation 2.13 to determine the initial velocity in the vertical direction (which we will call y). Then we can use Equation 2.11 to determine the time that the mountain lion was in the air. We also know that there is no acceleration in the x direction (ignoring air resistance). So once we have that hang time, we can easily determine the initial velocity in the horizontal direction using $(v_x)_\text{i} = \Delta x / \Delta t$.

Solve: (a) Considering only half the trip such that the "final" time is at the peak height, Equation 2.13 yields $(v_y)_\text{f}^2 = (v_y)_\text{i}^2 + 2a_y\Delta y \Rightarrow (v_y)_\text{i} = \sqrt{-2a_y\Delta y} = \sqrt{-2(-9.8\text{ m/s}^2)(3.0\text{ m})} = 7.67\text{ m/s}.$

Now, employing Equation 2.11 to the same time interval, we find

$$(v_y)_\text{f} = (v_y)_\text{i} + a_y\Delta t \Rightarrow \Delta t = -(v_y)_\text{i} / a_y = -(7.67\text{ m/s})/(-9.8\text{ m/s}^2) = 0.782\text{ s}.$$

But note that this is the time for only half the projectile motion of the mountain lion. By symmetry, the full time should be twice that: 1.56 s.

Finally, using $(v_x)_\text{i} = \Delta x / \Delta t$ (because there is no acceleration in the horizontal direction), we find $(v_x)_\text{i} = \Delta x / \Delta t = (10\text{ m})/(1.56\text{ s}) = 6.4\text{m/s}.$

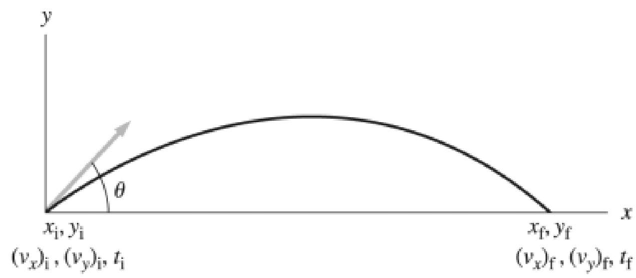
Now that we have the horizontal and vertical components of the velocity, we can find its magnitude (the speed) using the Pythagorean Theorem: $v_\text{i} = \sqrt{(v_x)_\text{i}^2 + (v_y)_\text{i}^2} = \sqrt{(6.4\text{ m/s})^2 + (7.67\text{ m/s})^2} = 10\text{ m/s}.$

(b) Now that we know the horizontal and vertical components of the mountain lion's initial velocity, we can determine the angle from horizontal using simple trigonometry: $\tan(\theta) = opp./adj. = (v_y)_\text{i} / (v_x)_\text{i}$. So

$$\theta = \tan^{-1}\left((v_y)_\text{i} / (v_x)_\text{i}\right) = \tan^{-1}\left((7.67\text{ m/s})/(6.40\text{ m/s})\right) = 50°$$

Assess: Components of velocity equal to a few meters per second are reasonable for a mountain lion. The initial jumping angle fits expectations, since it would need to have a significant initial upward component to stay in the air 1.56 s.

P3.34. Strategize: The golf ball is a particle following projectile motion. We will apply the constant-acceleration kinematic equations to the horizontal and vertical motions as described by Synthesis 3.1.
Prepare: We will begin by drawing a diagram of the situation and identifying known and unknown quantities.



Known
$x_i = y_i = t_i = 0$
$v_i = 25$ m/s
$\theta = 30°$
$a_x = 0 \quad a_y = -g$
$g_{earth} = 9.8$ m/s^2
$g_{moon} = 1/6\, g_{earth}$

Find
x_f and t_f

Solve: (a) The distance traveled is $x_f = (v_i)_x t_f = v_i \cos\theta \times t_f$. The flight time is found from the y-equation, using the fact that the ball starts and ends at $y = 0$:

$$y_f - y_i = 0 = v_i \sin\theta\ t_f - \tfrac{1}{2}gt_f^2 = (v_i \sin\theta - \tfrac{1}{2}gt_f)\ t_f \Rightarrow t_f = \frac{2v_i \sin\theta}{g}$$

Thus the distance traveled is

$$x_f = v_i \cos\theta \times \frac{2v_i \sin\theta}{g} = \frac{2v_i^2 \sin\theta \cos\theta}{g}$$

For $\theta = 30°$, the distances are

$$(x_f)_{earth} = \frac{2v_i^2 \sin\theta \cos\theta}{g_{earth}} = \frac{2(25\text{ m/s})^2 \sin 30° \cos 30°}{9.80\text{ m/s}^2} = 55.2\text{ m}$$
$$(x_f)_{moon} = \frac{2v_i^2 \sin\theta \cos\theta}{g_{moon}} = \frac{2v_i^2 \sin\theta \cos\theta}{\frac{1}{6}g_{earth}} = 6\times\frac{2v_i^2 \sin\theta \cos\theta}{g_{earth}} = 6(x_f)_{earth} = 331.2\text{ m}$$

The flight times are

$$(t_f)_{earth} = \frac{2v_i \sin\theta}{g_{earth}} = 2.55\text{ s}$$
$$(t_f)_{moon} = \frac{2v_i \sin\theta}{g_{moon}} = \frac{2v_i \sin\theta}{\frac{1}{6}g_{earth}} = 6\ (t_f)_{earth} = 15.30\text{ s}$$

or 15 s to two significant figures.
(The ball spends $15.30\text{ s} - 2.55\text{ s} = 12.75\text{ s} = 13\text{ s}$ longer in flight on the moon.)
(b) From part **(a)**, the distance traveled on the moon is 331 m or 330 m to two significant figures.
(c) From part **(a)**, the golf ball travels $331.2\text{ m} - 55.2\text{ m} = 276\text{ m}$, or 280 m to two significant figures, farther on the moon than on earth.

P3.37. Strategize: We can use the formula for centripetal acceleration, Equation 3.20.
Prepare: We need the radius of the track which is half the diameter: $R = D/2 = (45\text{ m})/2 = 22.5\text{ m}$.
Solve:

$$a = \frac{v^2}{r} = \frac{(15\text{ m/s})^2}{22.5\text{ m}} = 10\text{ m/s}^2$$

We now convert this acceleration to units of g:

$$10\text{ m/s}^2 = 10\text{ m/s}^2 \frac{g}{9.8\text{ m/s}^2} = 1.0g$$

Assess: The greyhounds are accelerating at approximately the acceleration of free fall!

P3.40. Strategize: We can use the formula for centripetal acceleration, Equation 3.20.
Prepare: We need the radius of the track which is half the diameter: $R = D/2 = (25\text{ m})/2 = 12.5\text{ m}$. The maximum speed corresponds to the maximum acceleration in this situation.
Solve: Since $a = v^2/r$, we have

$$v^2 = ar = (0.60)(9.8\text{ m/s}^2)(12.5\text{ m}) \Rightarrow v = 74\text{ m/s}$$

Assess: Speed limits are much lower than this in roundabouts, but at this speed the car would skid.

P3.44. Strategize: This problem involves relative motion, since the speed of the plane relative to Earth depends on the plane's speed relative to the wind, and the wind's speed relative to Earth.
Prepare: The 90 km/h wind subtracts from the ground speed going west and adds when going east.
Solve: Find the time to go west

$$\Delta t = \frac{\Delta x}{v} = \frac{1200\text{ km}}{880\text{ km/h} - 90\text{ km/h}} = 1.52\text{ h}$$

Find the time to go east

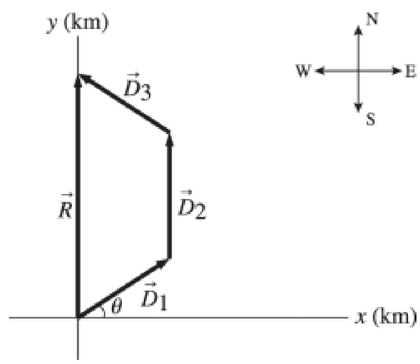
$$\Delta t = \frac{\Delta x}{v} = \frac{1200\text{ km}}{880\text{ km/h} + 90\text{ km/h}} = 1.24\text{ h}$$

Report both of these to two significant figures and then subtract to find the difference. $1.5\text{ h} - 1.2\text{ h} = 0.3\text{ h}$.
Assess: A 0.3 h difference seems reasonable. Airplanes sometimes change altitudes to find favorable tail winds.

P3.56. Strategize: The ideas of vector addition and subtraction can be used here to find the pilot's third displacement.

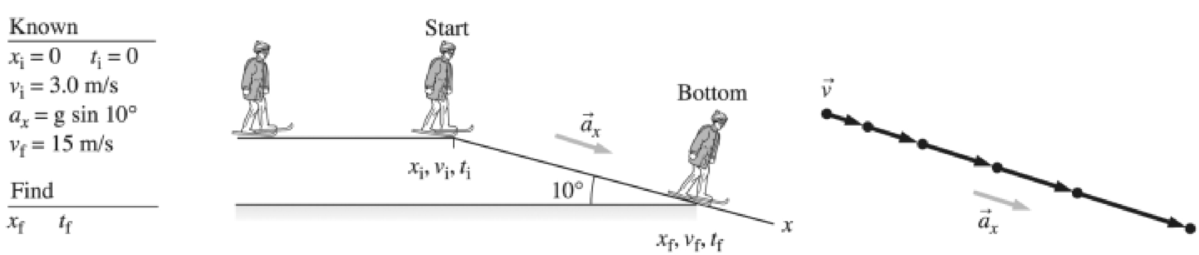
Prepare: We will begin by making a sketch of the displacement vectors involved. We will determine the unknown vector by requiring the vector sum of displacements equal the northward vector given. To achieve this, we will break the various vectors into components.

Solve: See the following diagram. We place the origin of coordinates at the origin of the plane's trip. Note that northeast means exactly 45° north of east.



P3.59. Strategize: This problem involves motion along an inclined plane. The acceleration can be described using Equation 3.16. Since this acceleration is constant, kinematics can be used.

Prepare: The skier's motion on the horizontal, frictionless snow is not of any interest to us. The skier's speed increases down the incline due to acceleration parallel to the incline, which is equal to g sin10°. A visual overview of the skier's motion that includes a pictorial representation, a motion representation, and a list of values is shown.



Solve: Using the following constant-acceleration kinematic equations,

$$v_f^2 = v_i^2 + 2a_x(x_f - x_i)$$

$$\Rightarrow (15 \text{ m/s})^2 = (3.0 \text{ m/s})^2 + 2(9.8 \text{ m/s}^2)\sin 10°(x_f - 0 \text{ m}) \Rightarrow x_f = 63 \text{ m}$$

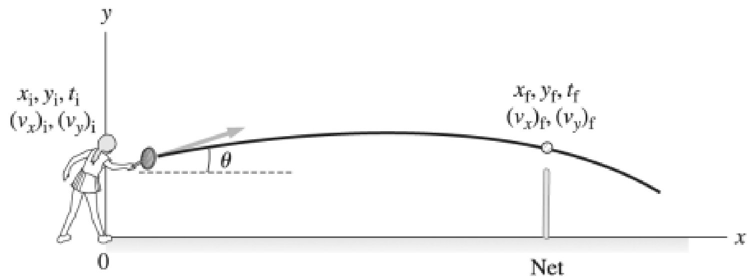
$$v_f = v_i + a_x(t_f - t_i)$$

$$\Rightarrow (15 \text{ m/s}) = (3.0 \text{ m/s}) + (9.8 \text{ m/s}^2)(\sin 10°)t_f \Rightarrow t_f = 7.1 \text{ s}$$

Assess: A time of 7.1 s to cover 63 m is a reasonable value.

P3.69. Strategize: This problem involves projectile motion. We will apply the constant-acceleration kinematics equations to the horizontal and vertical motions of the tennis ball as described by Synthesis 3.1.

Prepare: A visual overview is shown as follows. To find whether the ball clears the net, we will determine the vertical fall of the ball as it travels to the net.



Known

$x_i = t_i = 0$

$y_i = 2.0$ m $\quad \theta = 5°$

$v_i = 20.0$ m/s

$x_f = 7.0$ m $\quad (v_x)_f = v_{xi}$

$a_y = -g$

Find

$t_f \quad y_f$

Solve: The initial velocity is

$$(v_x)_i = v_i \cos 5° = (20 \text{ m/s}) \cos 5° = 19.92 \text{ m/s}$$
$$(v_y)_i = v_i \sin 5° = (20 \text{ m/s}) \sin 5° = 1.743 \text{ m/s}$$

The time it takes for the ball to reach the net is

$$x_f = x_i + (v_x)_i(t_f - t_i) \Rightarrow 7.0 \text{ m} = 0 \text{ m} + (19.92 \text{ m/s})(t_f - 0 \text{ s}) \Rightarrow t_f = 0.351 \text{ s}$$

The vertical position at $t_f = 0.351$ s is

$$\begin{aligned} y_f &= y_i + (v_y)_i(t_f - t_i) + \tfrac{1}{2}a_y(t_f - t_i)^2 \\ &= (2.0 \text{ m}) + (1.743 \text{ m/s})(0.351 \text{ s} - 0 \text{ s}) + \tfrac{1}{2}(-9.8 \text{ m/s}^2)(0.351 \text{ s} - 0 \text{ s})^2 = 2.0 \text{ m} \end{aligned}$$

Thus the ball clears the net by 1.0 m.

Assess: The vertical free fall of the ball, with zero initial velocity, in 0.351 s is 0.6 m. The ball will clear by approximately 0.4 m if the ball is thrown horizontally. The initial launch angle of 5° provides some initial vertical velocity and the ball clears by a larger distance. The above result is reasonable.

P3.76. Strategize: This problem deals with relative motion, since we know the kayaker's required direction relative to Earth and the water's flow relative to Earth.

Prepare: The kayaker's speed of 3.0 m/s is relative to the water. Since he's being swept toward the east, he needs to point at angle θ west of north. The direction the kayaker should paddle can be obtained from the technique of Equation 3.21: $\vec{v}_{\text{kg}} = \vec{v}_{\text{kw}} + \vec{v}_{\text{wg}}$, where $\vec{v}_{\text{kg}} = (v_{\text{kg}}, \text{north})$ and $\vec{v}_{\text{wg}} = (v_{\text{wg}}, \text{east})$ with $v_{\text{wg}} = 2.0\ \text{m/s}$. Also, $\vec{v}_{\text{kw}} = [(v_{\text{kw}}\ \cos\theta,\ \text{north}) + (v_{\text{kw}}\ \sin\theta,\ \text{west})]$ with $v_{\text{kw}} = 3.0\ \text{m/s}$.

Solve: (a) $\vec{v}_{\text{kg}} = \vec{v}_{\text{kw}} + \vec{v}_{\text{wg}}$,

$$\begin{aligned}(v_{\text{kg}}, \text{north}) &= [(3.0\ \text{m/s} \cdot \cos\theta,\ \text{north}) + (3.0\ \text{m/s} \cdot \sin\theta,\ \text{west})] + (2.0\ \text{m/s},\ \text{east}) \\ &= [(-3.0\sin\theta + 2.0)\ \text{m/s},\ \text{east}] + (3.0\cos\theta\ \text{m/s},\ \text{north})\end{aligned}$$

In order to go straight north in the earth frame, the kayaker's velocity along the east must be zero. This will be true if

$$\sin\theta = \frac{2.0}{3.0} \quad\Rightarrow\quad \theta = \sin^{-1}\left(\frac{2.0}{3.0}\right) = 41.8° = 42°$$

Thus he must paddle in a direction 42° west of north.

(b) His northward speed is $v_{kg} = 3.0\ \cos(41.8°)\ \text{m/s} = 2.236\ \text{m/s}$. The time to cross is

$$t = \frac{100\ \text{m}}{2.236\ \text{m/s}} = 45\ \text{s}$$