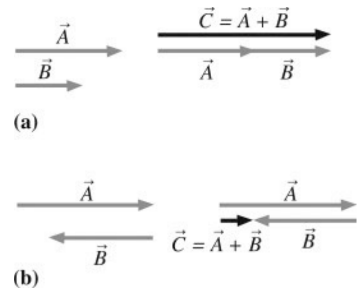
Physics 2A
Chapter 3 HW Solutions

Chapter 3
Conceptual Question: 4, 6, 8, 12
Problems: 5, 11, 18, 27, 31, 44, 46, 69, 70, 73

Q3.4. **Reason:** **(a)** $C = A + B$ only if $\vec{A}$ and $\vec{B}$ are in the same direction. Size does not matter.

(b) $C = A - B$ if $\vec{A}$ and $\vec{B}$ are in the opposite direction to each other. Size matters only in that $A > B$ because C as a magnitude can only be positive.

Assess: Visualize the situation with arrows.



Q3.6. **Reason:** The acceleration of the ball is due to gravity, so the acceleration the ball experiences is always straight downward.

(a) The velocity vector of the ball always has a component in the horizontal direction since it was thrown at an angle of 40°. The horizontal component of the ball's velocity is constant throughout its trajectory. Since the velocity vector always has a component in the horizontal direction, it is never pointing entirely straight up or down. So there is no point on the trajectory where the acceleration and velocity are parallel. Note that if the ball were thrown straight up or down instead of at 40°, the ball's velocity and acceleration would be parallel.

(b) The acceleration of the ball is always straight downward. For the velocity vector to be perpendicular to the acceleration vector, the velocity must point entirely in the horizontal direction. The velocity vector always has a component in the horizontal direction, as reasoned in part **(a)**. It has a component in the vertical direction during most of its motion also since the ball travels upward and downward in the vertical direction. There is one point where the ball is not traveling up or down, and that is at the top of its trajectory. This is the only point where the velocity and acceleration are perpendicular.

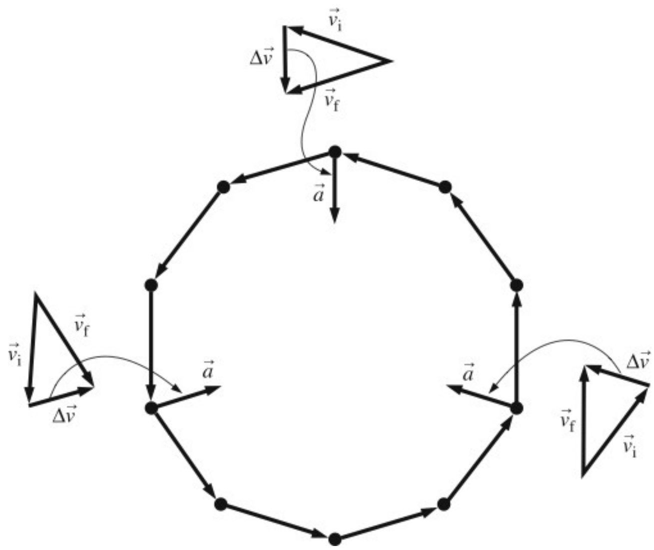
Assess: The acceleration due to gravity always points straight downward. See Figure 3.30, which shows the average velocity vectors and acceleration along the trajectory of a tossed ball.

Q3.8. **Reason:** Running while throwing a ball increases the distance of the throw because it increases the horizontal component of the ball's velocity without changing the time of flight. Relative to the ground, the ball's horizontal velocity component is increased by an amount equal to the speed of the runner. Since the velocity of the runner is purely horizontal, the vertical velocity component of the ball is unchanged and so the time of flight of the ball is unchanged. It is interesting to note that since, relative to the ground, the ball has a greater horizontal component of velocity, the angle of the ball's velocity is higher relative to the person throwing the ball than relative to the ground. However, neither relative to the ground, nor relative to the person throwing the ball will a launch angle of 45˚ give the maximum range. The angle 45˚ gives the maximum range for a ball launched by someone not moving because it gives the best compromise between having a high time of flight and a large horizontal component of velocity. But when the person is running, the horizontal component of velocity gets an advantage so the time of flight can be greater at the expense of the horizontal component of velocity. Thus the best angle relative to the person is greater than 45˚.

Assess: While the best launch angle is no longer 45°, it is still true that running increases the range of the ball.

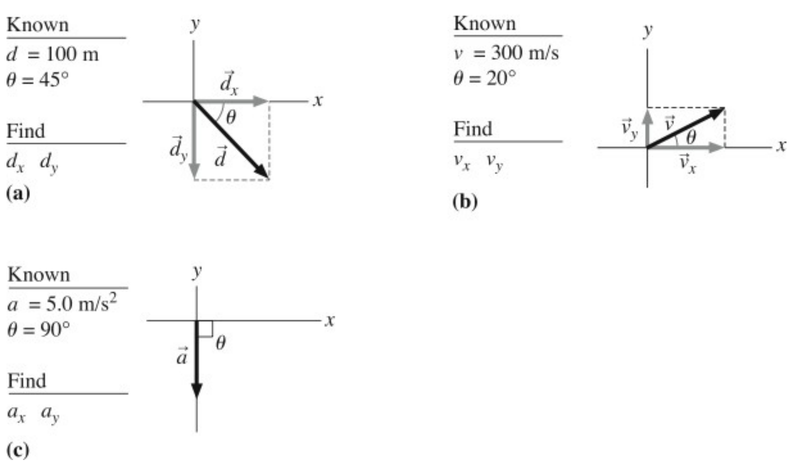
Q3.12. Reason: The time for an object to hit the ground does not depend on its horizontal speed, but only on its height and initial vertical speed. When the pilot goes twice as fast, all that changes is the horizontal speed of the projectile. Therefore the time of flight will be the same in both cases, 2.0 s. However the distance travelled horizontally will be doubled since the horizontal speed is doubled and the time of flight is the same. At the doubled speed, the weight will travel twice as far, or 200 m.
Assess: The above answer assumed no air resistance. Actually the greater speed of the faster projectile will slightly increase the time of flight since a faster object experiences more air resistance.

P3.5. Prepare: Acceleration is found by the method of Tactics Box 3.2.
Solve: The acceleration vector at each location points directly toward the center of the Ferris wheel's circular motion.



Assess: As we will learn later, this acceleration that is directed toward the center is called centripetal acceleration.

P3.11. Prepare: We will follow rules given in the Tactics Box 3.3.



Solve: **(a)** Vector $\vec{d}$ points to the right and down, so the components d_x and d_y are positive and negative, respectively:

$$d_x = d\ \cos\theta = (100\text{ m})\ \cos 45° = 70.7\text{ m} \qquad d_y = -d\ \sin\theta = -(100\text{ m})\ \sin 45° = -71\text{ m}$$

(b) Vector $\vec{v}$ points to the right and up, so the components v_x and v_y are both positive:

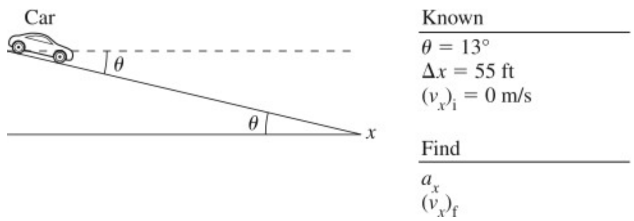
$$v_x = v\cos\theta = (300\text{ m/s})\cos 20° = 280\text{ m/s} \qquad v_y = v\sin\theta = (300\text{ m/s})\sin 20° = 100\text{ m/s}$$

(c) Vector $\vec{a}$ has the following components:

$$a_x = -a\cos\theta = -(5.0\text{ m/s}^2)\cos 90° = 0\text{ m/s}^2 \qquad a_y = -a\sin\theta = -(5.0\text{ m/s}^2)\sin 90° = -5.0\text{ m/s}^2$$

Assess: The components have same units as the vectors. Note the minus signs we have manually inserted according to the Tactics Box 3.3.

P3.18. Prepare: We can find the acceleration on the ramp and then use the acceleration to find the final velocity of the car.



Solve: **(a)** The maximum possible acceleration is given by the formula $a_x = g\sin\theta.$ Plugging in the values of g and θ, we get $a_x = 2.2\text{ m/s}^2.$

(b) The final velocity can be obtained from the formula $(v_x)_f{}^2 - (v_x)_i{}^2 = 2a_x\Delta x$, using $(v_x)_i = 0$ m/s and $\Delta x = 16.8$ m, the latter being obtained by converting 55 ft: $55\text{ ft} = 55\text{ ft}\left(\frac{1\text{ m}}{3.28\text{ ft}}\right)$. $55\text{ ft} = 55\text{ ft}\left(\frac{1\text{ m}}{3.28\text{ ft}}\right)$ The solution to the first equation is $(v_x)_f = 8.6$ m/s.

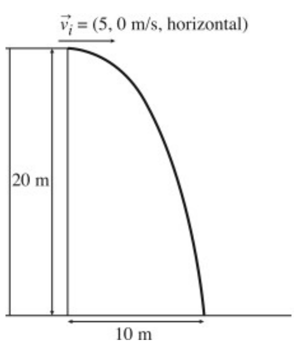
Assess: As with most ramp problems, this one was best solved by using a rotated coordinate system with the x-axis along the ramp.

P3.27. Prepare: We will assume the ball is in free fall (*i.e.*, we neglect air resistance). The trajectory of a projectile is a parabola because it is a combination of constant horizontal velocity (a_x = 0.0 m/s^2) combined with constant vertical acceleration ($a_y = -g$). In this case we see only half of the parabola.

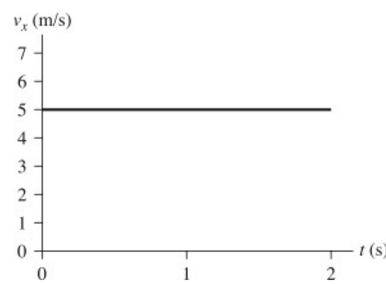
The initial speed given is all in the horizontal direction, that is, $(v_x)_\text{i}$ = 5.0 m/s and $(v_y)_\text{i}$ = 0.0 m/s.

Solve:

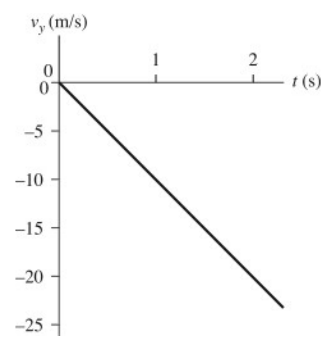
(a)



(b)



(c)



(d) This is a two-step problem. We first use the vertical direction to determine the time it takes, then plug that result into the equation for the horizontal direction.

$$\Delta y = \frac{1}{2}a_y(\Delta t)^2$$

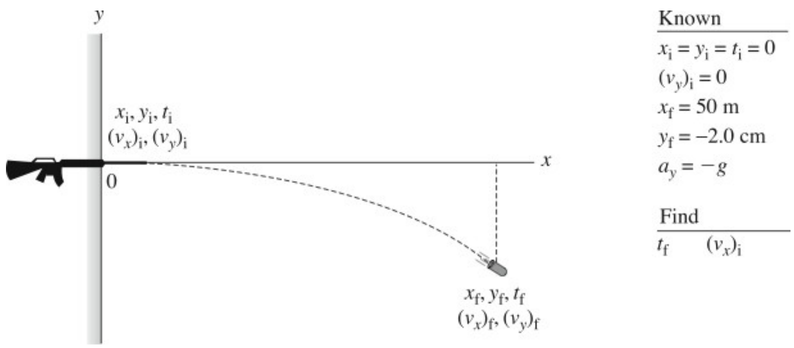
$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{2(-20\text{ m})}{-9.8\text{ m/s}^2}} = 2.0\text{ s}$$

We we use the 2.0 s in the equation for the horizontal motion.

$$\Delta x = v_x \Delta t = (5.0 \text{ m/s})(2.0 \text{ s}) = 10 \text{ m}$$

Assess: The answers seem reasonable, and we would get the same answers to two significant figures in a quick mental calculation using $g \approx 10 \text{m/s}^2$. In fact, I did this before computing the algebra so I would know how to scale the graphs.

P3.31. Prepare: We will apply the constant-acceleration kinematic equations to the horizontal and vertical motions as described by Equations 3.25. The effect of air resistance on the motion of the bullet is neglected.



Solve: **(a)** Using $y_f = y_i + (v_y)_i(t_f - t_i) + \frac{1}{2}a_y(t_f - t_i)^2$, we obtain

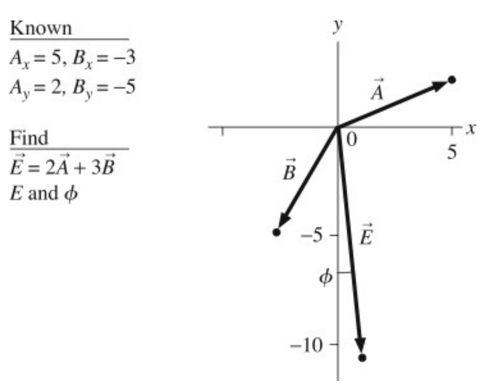
$$(-2.0 \times 10^{-2} \text{ m}) = 0 \text{ m} + 0 \text{ m} + \tfrac{1}{2}(-9.8 \text{ m/s}^2)(t_f - 0 \text{ s})^2 \Rightarrow t_f = 0.0639 \text{ s}$$

(b) Using $x_f = x_i + (v_x)_i(t_f - t_i) + \frac{1}{2}a_x(t_f - t_i)^2$,

$$(50 \text{ m}) = 0 \text{ m} + (v_x)_i(0.0639 \text{ s} - 0 \text{ s}) + 0 \text{ m} \Rightarrow (v_x)_i = 782 \text{ m/s}$$

Assess: The bullet falls 2 cm during a horizontal displacement of 50 m. This implies a large initial velocity, and a value of 782 m/s is not surprising.

P3.44. Prepare: Because $\vec{A} = \vec{A}_x + \vec{A}_y$, and $\vec{B} = \vec{B}_x + \vec{B}_y$, so the components of the resultant vector are $E_x = 2A_x + 3B_x$ and $E_y = 2A_y + 3B_y$. The vectors $\vec{A}$, $\vec{B}$, and $\vec{E} = 2\vec{A} + 3\vec{B}$ are shown.



Solve: **(a)** With $A_x = 5$, $A_y = 2$, $B_x = -3$, and $B_y = -5$, we have $E_x = 1$ and $E_y = -11$.

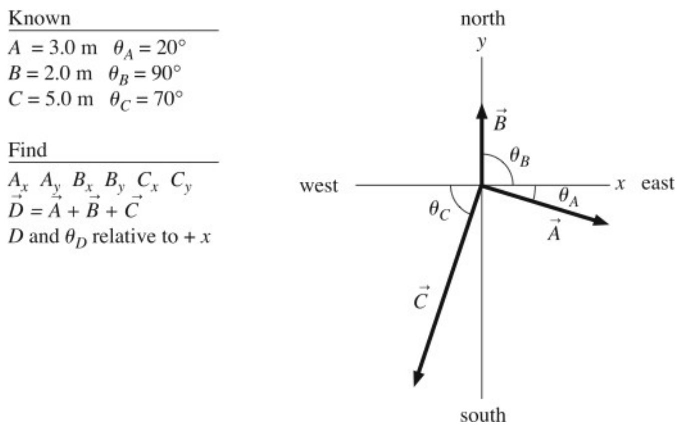
(b) Vectors $\vec{A}$, $\vec{B}$, and $\vec{E}$ are shown in the above figure.

(c) From the $\vec{E}$ vector, $E_x = 1$ and $E_y = -11$. Therefore, the magnitude and direction of $\vec{E}$ are

$$E = \sqrt{(1)^2 + (-11)^2} = 11 \qquad \phi = \tan^{-1}\left(\frac{E_x}{|E_y|}\right) = \tan^{-1}\left(\frac{1}{11}\right) = 5.2°$$

Assess: Note that ϕ is the angle made with the y-axis, and that is why $\phi = \tan^{-1}(E_x/|E_y|)$ rather than $\tan^{-1}(|E_y|/E_x)$ which would be the case if ϕ were the angle made with the x-axis.

P3.46. Prepare: The vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ are shown. We will first calculate the x- and y-components of each vector and then obtain the magnitude and the direction of the vector $\vec{D}$.



Solve: **(a)** The vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ are drawn above.

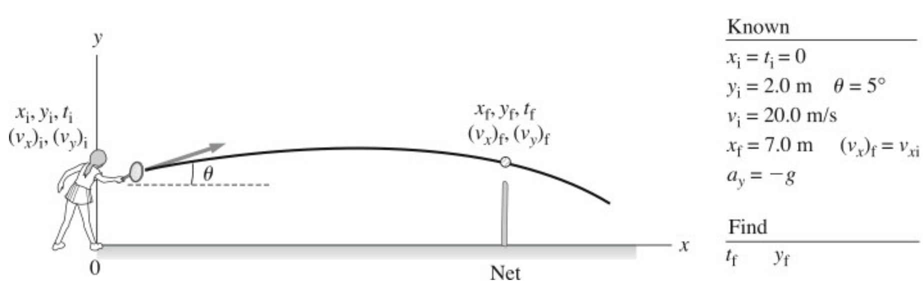
(b) The components of the vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ are $A_x = (3\text{ m})\cos 20° = 2.82\text{ m}$ and $A_y = -(3\text{ m})\sin 20° = -1.03\text{ m}$; $B_x = 0\text{ m}$ and $B_y = 2\text{ m}$; $C_x = -(5\text{ m})\cos 70° = -1.71\text{ m}$ and $C_y = -(5\text{ m})\sin 70° = -4.70\text{ m}$.

(c) We have $\vec{D} = \vec{A} + \vec{B} + \vec{C} = \vec{D}_x + \vec{D}_y$, which means $D_x = 1.11$ and $D_y = -3.73$.

$$D = \sqrt{(1.11\text{ m})^2 + (3.73\text{ m})^2} = 3.9\text{ m} \qquad \theta = \tan^{-1}\frac{3.73}{1.11} = \tan^{-1} 3.36 = 73°$$

The direction of $\vec{D}$ is south of east, 73° below the positive x-axis.

P3.69. Prepare: We will apply the constant-acceleration kinematics equations to the horizontal and vertical motions of the tennis ball as described by Equations 3.25. 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.



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

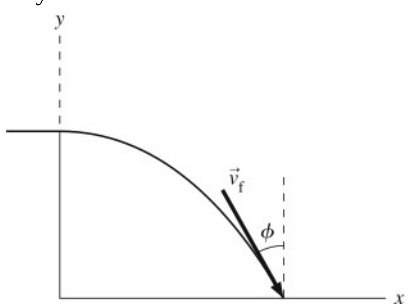
$$x_f = x_i + (v_x)_i(t_f - t_i) \Rightarrow 7.0\text{ m} = 0\text{ m} + (19.92\text{ m/s})(t_f - 0\text{ s}) \Rightarrow t_f = 0.351\text{ s}$$

The vertical position at $t_f = 0.351$ s is

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

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.

P3.70. **Prepare:** We can use the equation for vertical motion at constant acceleration to find the time of fall and then use the time to find the final velocity.



Known
$(v_x)_i = 9.0$ m/s
$(v_y)_i = 0$ m/s
$a_x = 0$ m/s²
$a_y = -9.8$ m/s²
$\Delta y = -53$ m

Find
ϕ

Solve: Since the water is launched horizontally, its time of flight and vertical displacement are related by the equation: $\Delta y = -\frac{1}{2}g\Delta t^2$. Solving for the time, we have

$$\Delta t = \sqrt{2|\Delta y|/g} = \sqrt{2(53\text{ m})/9.8\text{ m/s}^2} = 3.29\text{ s}$$

The horizontal component of the velocity, v_x, is constant, but the vertical component is given by the equation: $(v_y)_f = (v_y)_i + a_y\Delta t$. At the moment the water strikes the pool, the vertical component is

$$(v_y)_f = 0\text{ m/s} - \left(9.8\text{ m/s}^2\right)(3.29\text{ s}) = -32.2\text{ m/s}$$

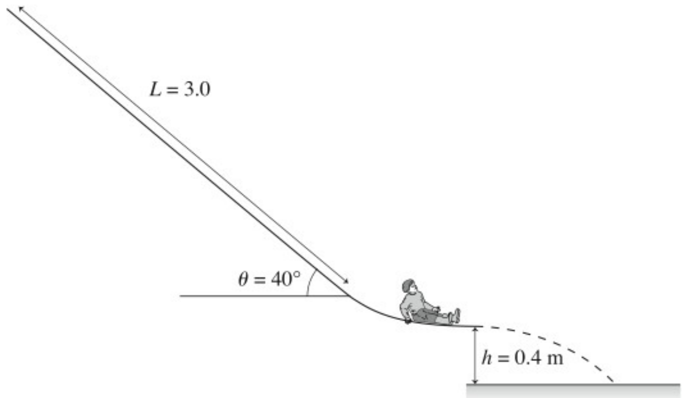
At the moment of impact the velocity of the water is: $(9.0\text{ m/s}, -32.2\text{ m/s})$. The angle that the water makes with the vertical is given by

$$\phi = \tan^{-1}((9.0\text{ m/s})/(32.2\text{ m/s})) = 16^\circ$$

The water is falling at an angle of 16° with the vertical.

Assess: Even though the water is launched at a fairly high speed (9.0 m/s is about 20 mi/hr), it is close to the vertical when it lands because it spends such a long time in the air during which time the absolute value of v_y increases steadily.

P3.73. **Prepare:** First draw a picture.



In part **(a)** use tilted axes so the *x*-axis runs down the slide. The acceleration will be $a_x = g \sin \theta$.
Part **(b)** is a familiar two-step projectile motion problem where we use the vertical direction to determine the time of flight and then plug it into then equation for constant horizontal velocity. Use axes that are *not* tilted for part **(b)**.

Solve: **(a)** We use Equation 2.13 with $(v_x)_\text{i} = 0.0$ m/s.

$$(v_x)_\text{f}^2 = 2a_x\Delta x$$

$$(v_x)_\text{f} = \sqrt{2(g\ \sin\theta)\Delta x} = \sqrt{2(9.8\ \text{m/s}^2)(\sin 40^\circ)(3.0\ \text{m})} = 6.1\ \text{m/s}$$

(b) We use Equation 2.14 to find the time for an object to fall 0.4 m from rest: $\Delta y = -0.4\text{m}$.

$$\Delta y = \frac{1}{2}a_y(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2\Delta y}{-g}} = \sqrt{\frac{2(-0.4\ \text{m})}{-9.8\ \text{m/s}^2}} = 0.286\ \text{s}$$

At last we combine this information into the equation for constant horizontal velocity.

$$\Delta x = v_x\Delta t = (6.15\ \text{m/s})(0.286\ \text{s}) = 1.8\ \text{m}$$

Assess: We reported the speed at the bottom of the slide to two significant figures, but kept track of a third to use as a guard digit because this result is also an intermediate result for the final answer. We also kept a third significant figure on the Δt as a guard digit.
The result of landing 1.8 m from the end of the frictionless slide seems just a bit large because this slide was frictionless and real slides aren’t, but it doesn’t seem to be too far out of expectation, so our result is probably correct.