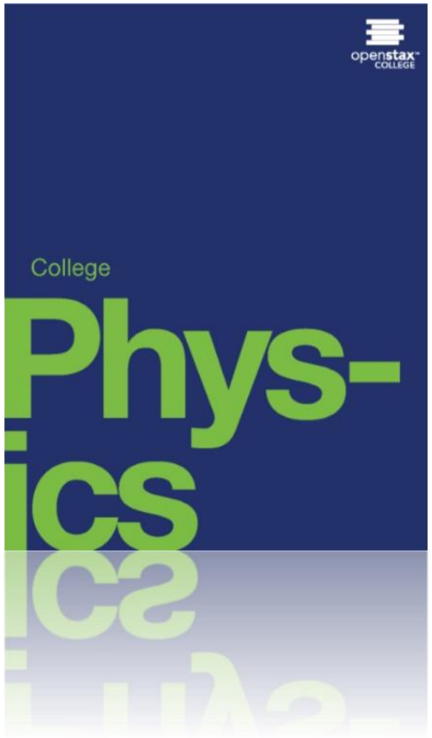
COLLEGE PHYSICS

Chapter 3 TWO-DIMENSIONAL KINEMATICS

PowerPoint Image Slideshow



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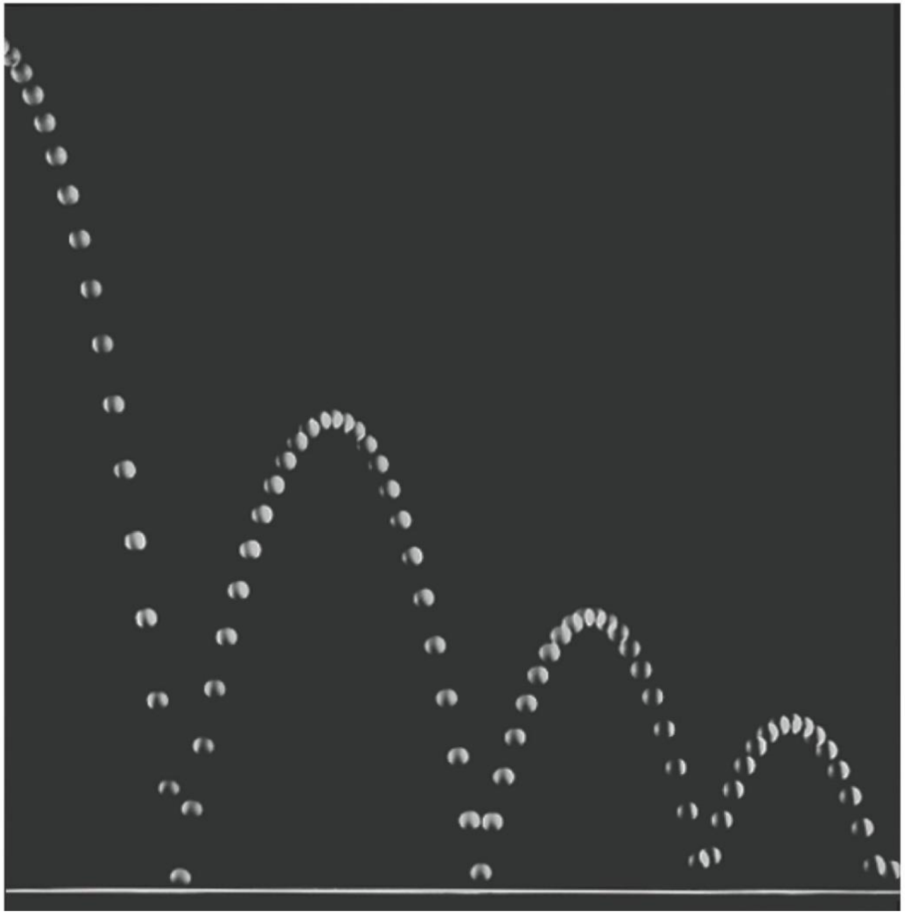
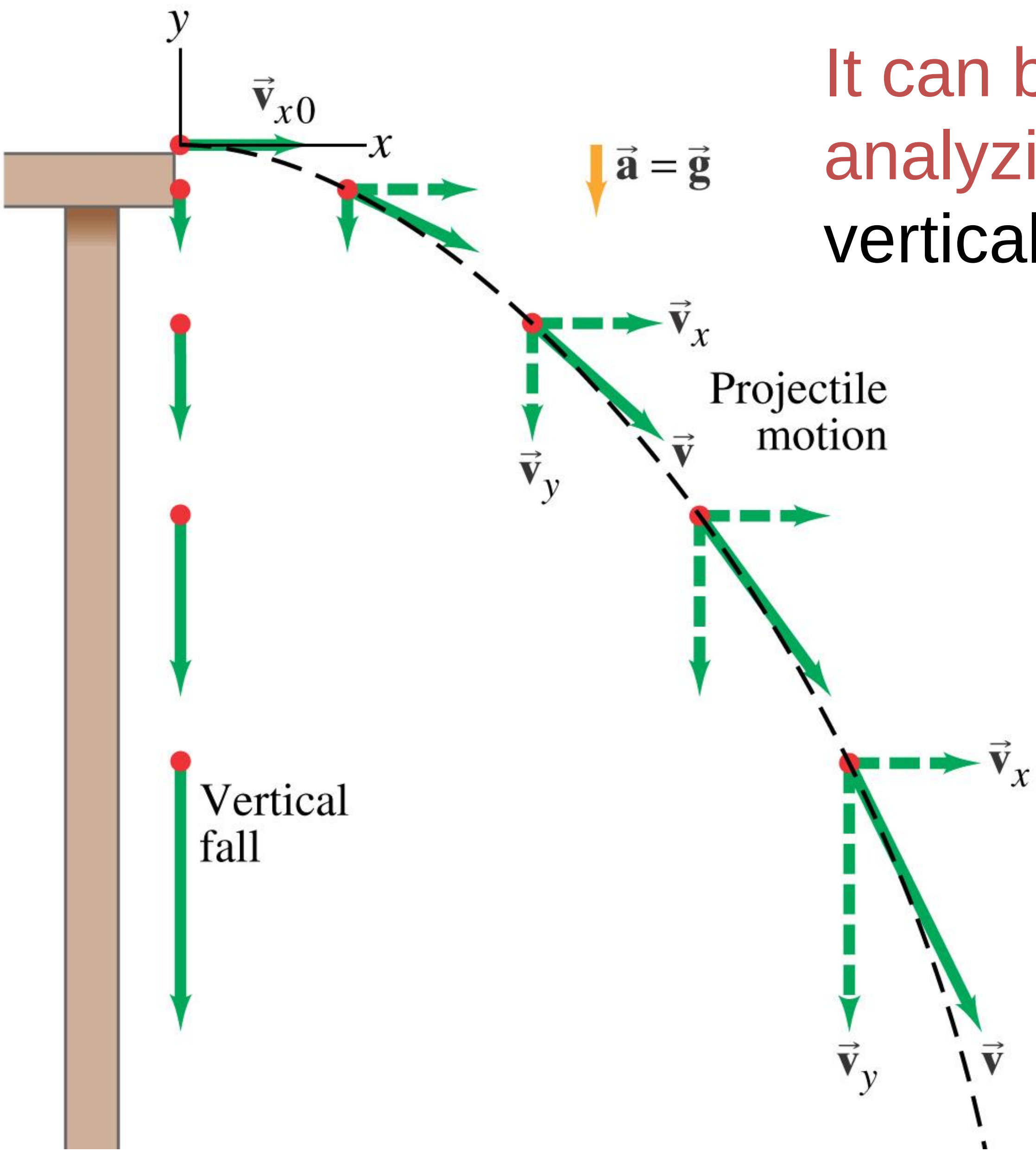
- Projectile Motion
- Solving Problems Involving Projectile Motion
- Projectile Motion Is Parabolic
- Relative Velocity

Projectile Motion



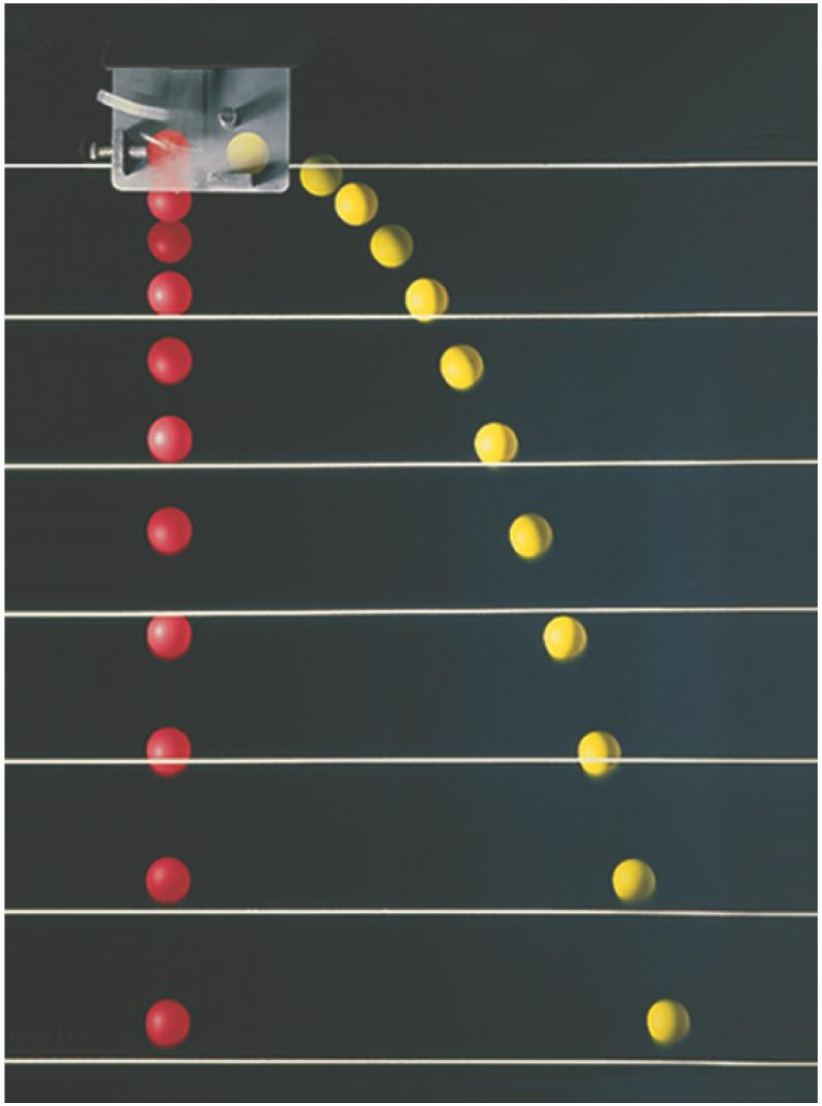
A projectile is an object moving in two dimensions under the influence of Earth's gravity; its path is a parabola.

Projectile Motion



It can be understood by analyzing the horizontal and vertical motions separately.

Projectile Motion

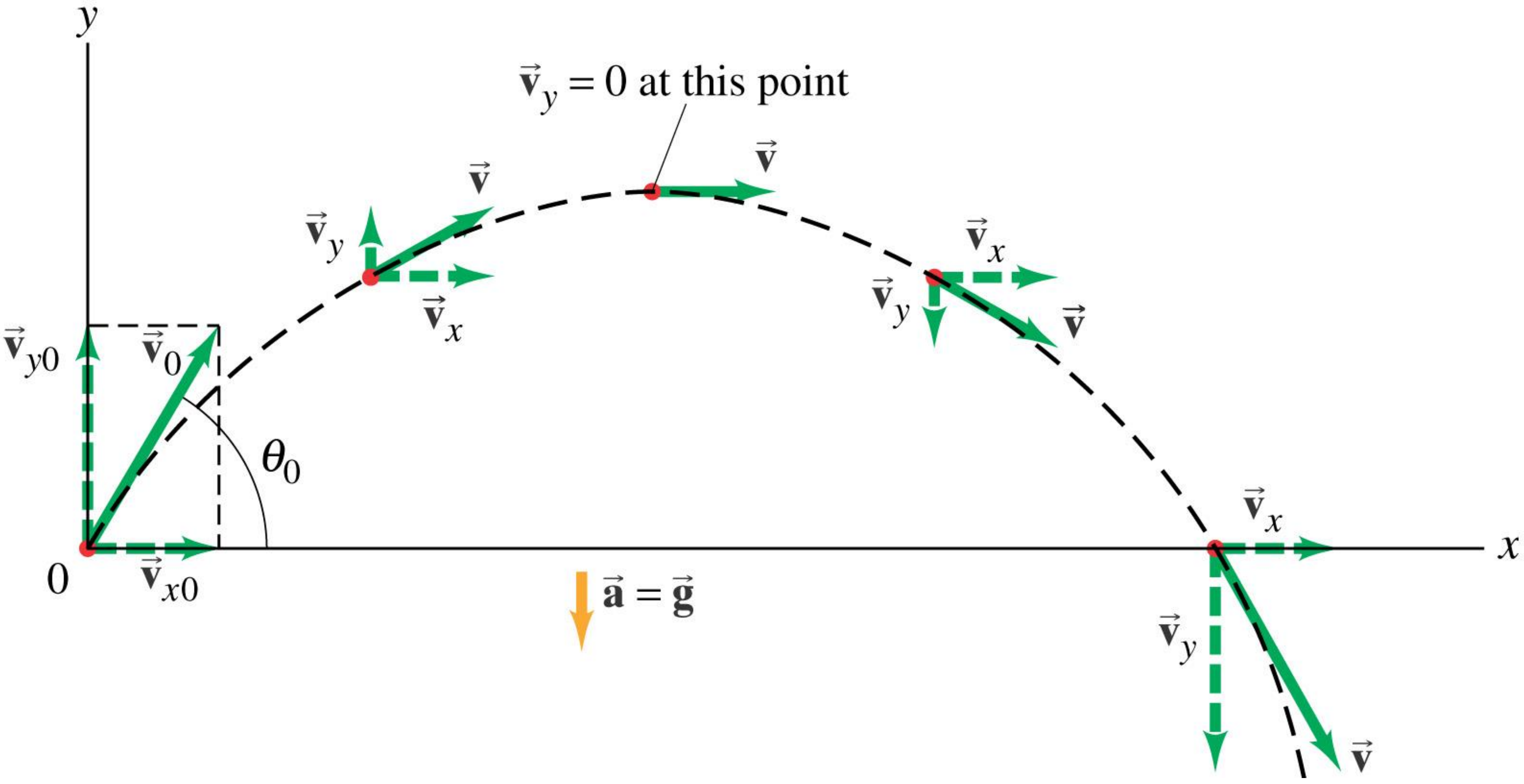


The speed in the *x*-direction is constant; in the *y*-direction the object moves with constant acceleration *g*.

This photograph shows two balls that start to fall at the same time. The one on the right has an initial speed in the *x*-direction. It can be seen that vertical positions of the two balls are identical at identical times, while the horizontal position of the yellow ball increases linearly.

Projectile Motion

If an object is launched at an initial angle of θ_0 with the horizontal, the analysis is similar except that the initial velocity has a vertical component.



Kinematic Equations for Projectile Motion

Horizontal Motion ($a_x = 0$, $v_x =$ constant)
$v_x = v_{x0}$
$x = x_0 + v_{x0} t$

Kinematic Equations for Projectile Motion

VERTICAL MOTION

$$(a_y = -g = \text{constant})$$

$$v_y = v_{y0} - gt$$

$$y = y_0 + v_{y0}t - \tfrac{1}{2}gt^2$$

$$v_y^2 = v_{y0}^2 - 2g(y - y_0)$$

Solving Problems Involving Projectile Motion

1. Read the problem carefully, and choose the object(s) you are going to analyze.
2. Draw a diagram.
3. Choose an origin and a coordinate system.
4. Decide on the time interval; this is the same in both directions, and includes only the time the object is moving with constant acceleration g.
5. Examine the x and y motions separately.

Solving Problems Involving Projectile Motion

6. **List** known and unknown quantities. Remember that v_x never changes, and that $v_y = 0$ at the highest point.

7. **Plan** how you will proceed. Use the appropriate equations; you may have to combine some of them.

3-7 Projectile Motion Is Parabolic

In order to demonstrate that projectile motion is parabolic, we need to write *y* as a function of *x*. When we do, we find that it has the form:

$$y = Ax - Bx^2$$

This is indeed the equation for a parabola.

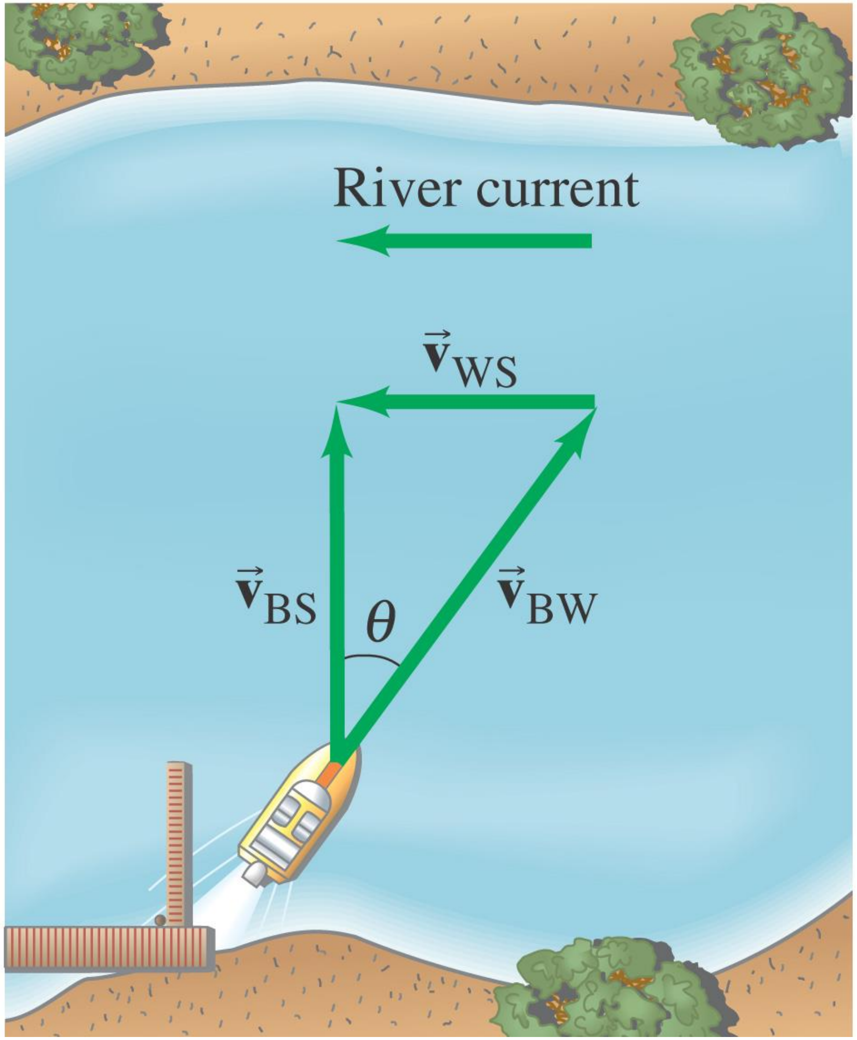
Relative Velocity

We already considered relative speed in one dimension; it is similar in two dimensions except that we must add and subtract velocities as vectors.

Each velocity is labeled first with the object, and second with the reference frame in which it has this velocity. Therefore, v_{WS} is the velocity of the water in the shore frame, v_{BS} is the velocity of the boat in the shore frame, and v_{BW} is the velocity of the boat in the water frame.

Relative Velocity

In this case, the relationship between the three velocities is:

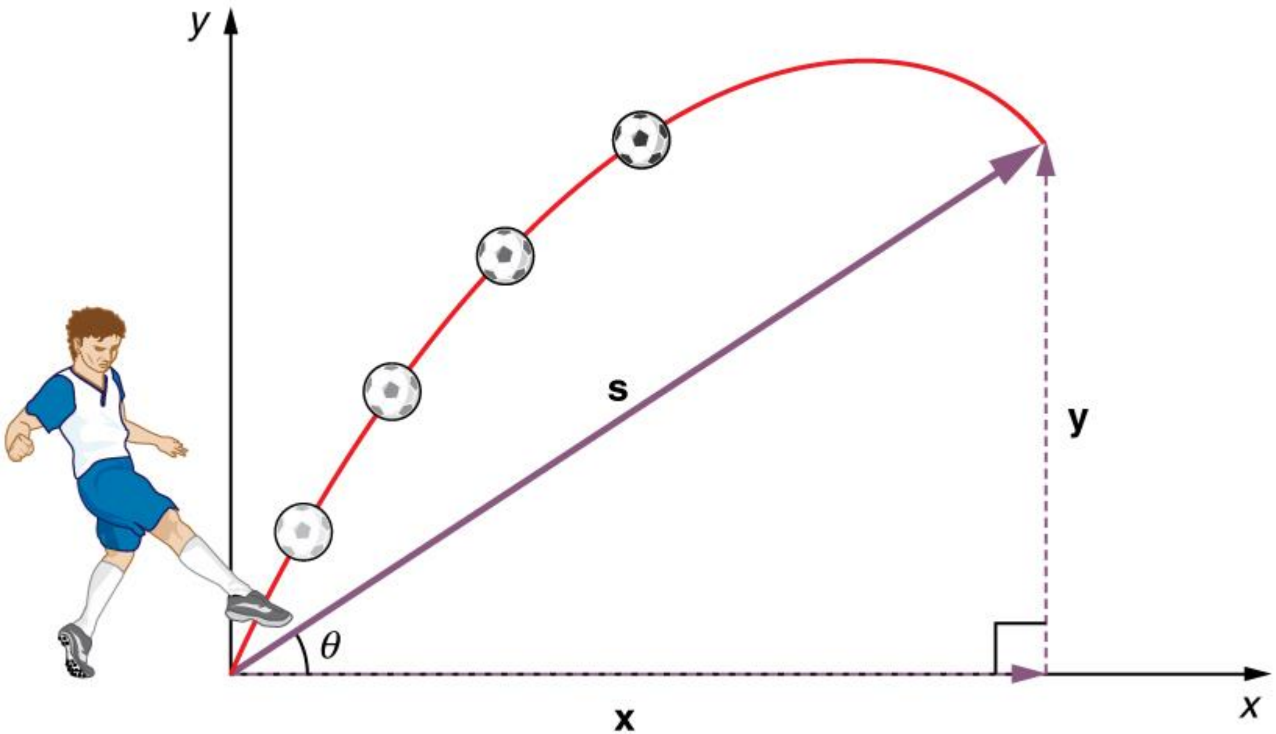


$$\vec{\mathbf{v}}_{BS} = \vec{\mathbf{v}}_{BW} + \vec{\mathbf{v}}_{WS}$$

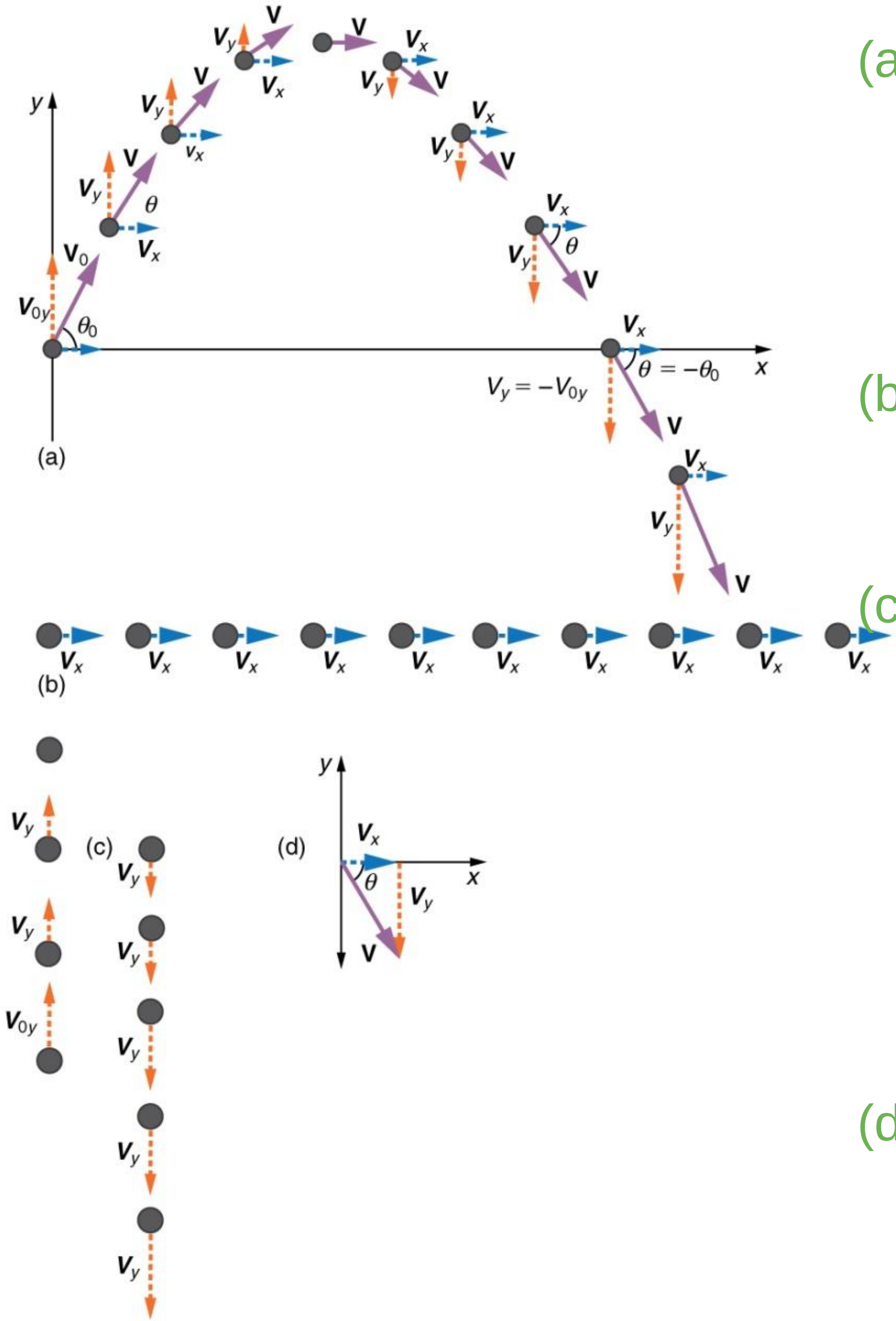
Solving Problems Involving Projectile Motion

Projectile motion is motion with constant acceleration in two dimensions, where the acceleration is *g* and is down.

FIGURE 3.36



The total displacement **s** of a soccer ball at a point along its path. The vector **s** has components **x** and **y** along the horizontal and vertical axes. Its magnitude is *s* , and it makes an angle *θ* with the horizontal.



(a) We analyze two-dimensional projectile motion by breaking it into two independent one-dimensional motions along the vertical and horizontal axes.

(b) The horizontal motion is simple, because $a_x = 0$ and v_x is thus constant.

(c) The velocity in the vertical direction begins to decrease as the object rises; at its highest point, the vertical velocity is zero. As the object falls towards the Earth again, the vertical velocity increases again in magnitude but points in the opposite direction to the initial vertical velocity.

(d) The x - and y-motions are recombined to give the total velocity at any given point on the trajectory.

FIGURE 3.38

The trajectory of a fireworks shell. The fuse is set to explode the shell at the highest point in its trajectory, which is found to be at a height of 233 m and 125 m away horizontally.

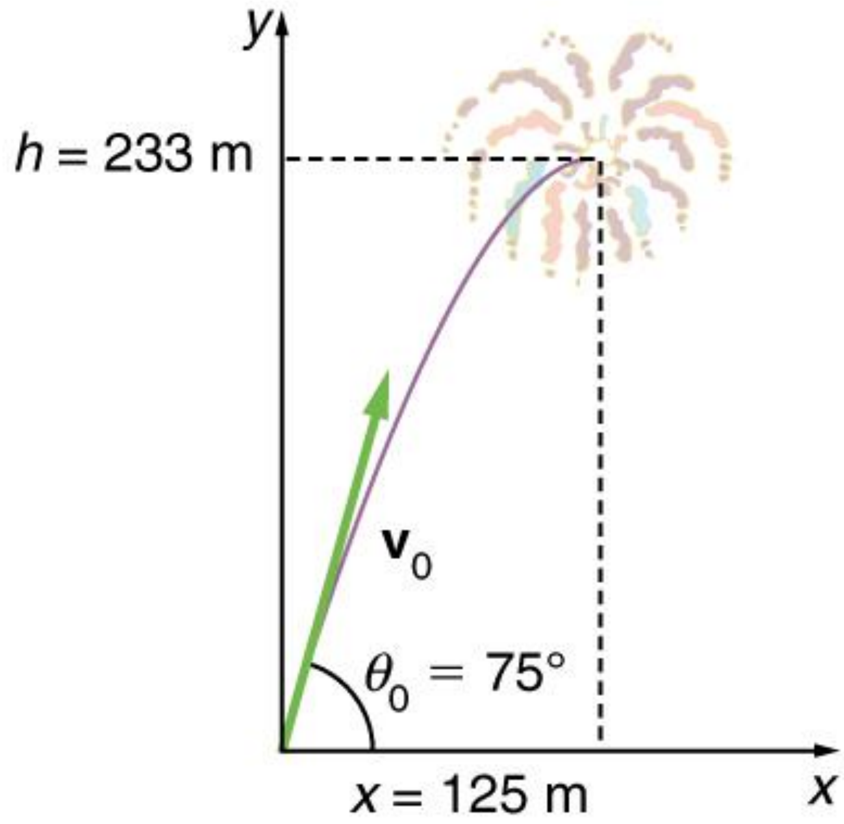
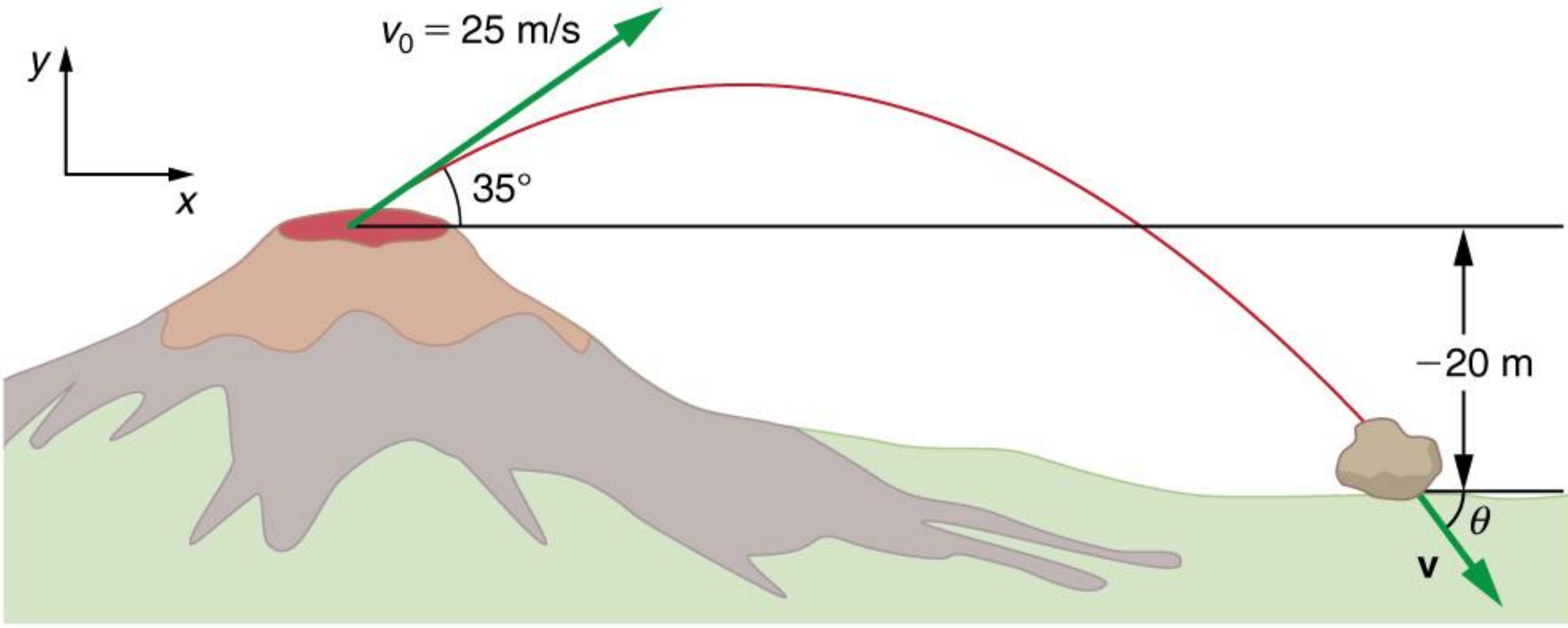
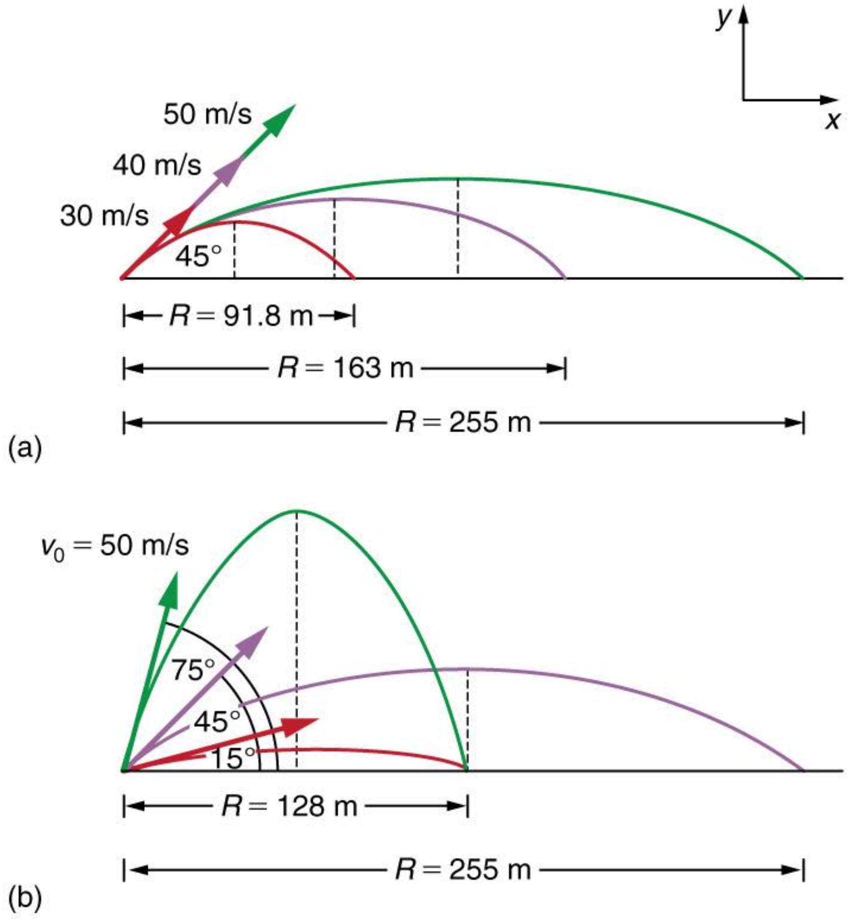


FIGURE 3.39



The trajectory of a rock ejected from the Kilauea volcano.

FIGURE 3.40

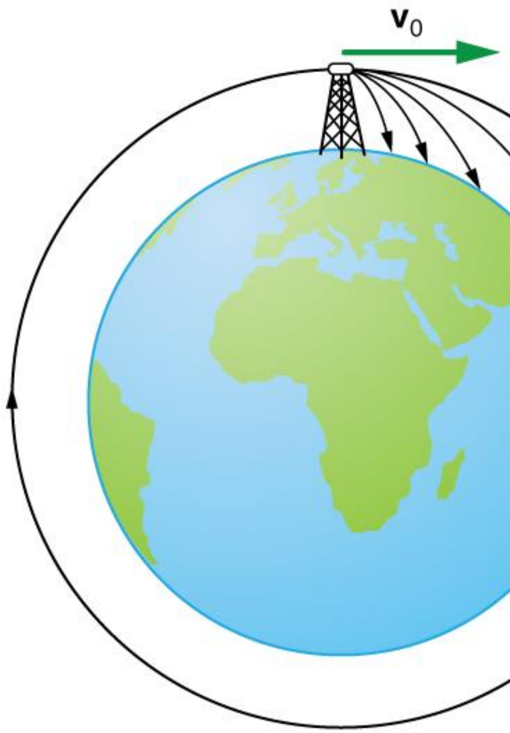


Trajectories of projectiles on level ground.

(a) The greater the initial speed v_0 , the greater the range for a given initial angle.

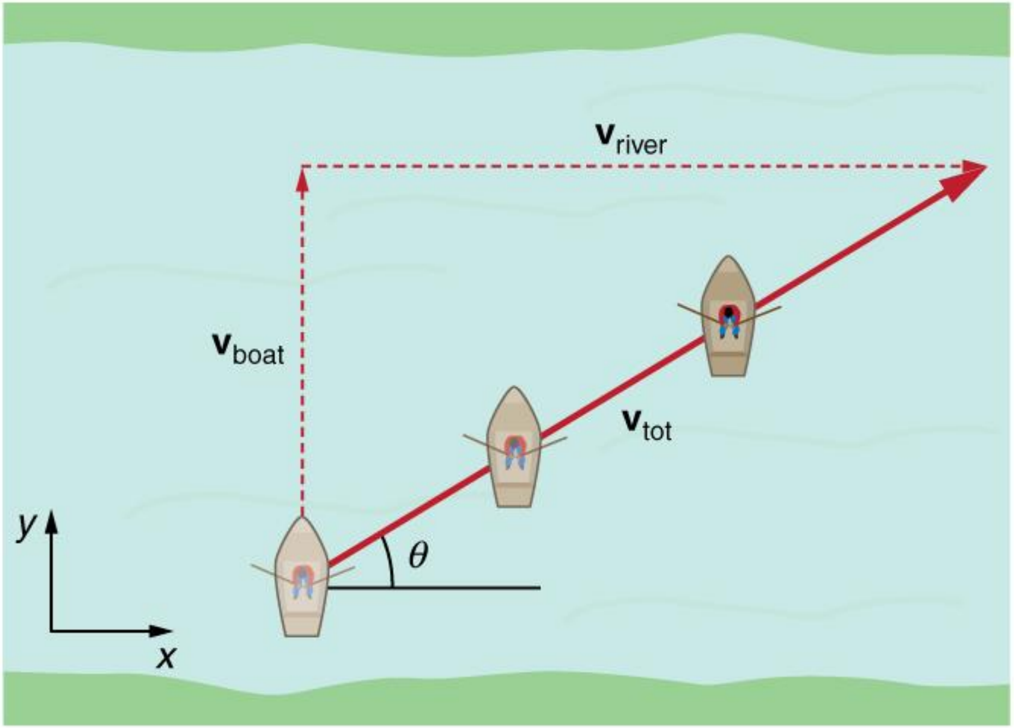
(b) The effect of initial angle θ_0 on the range of a projectile with a given initial speed. Note that the range is the same for 15º and 75º , although the maximum heights of those paths are different.

FIGURE 3.41



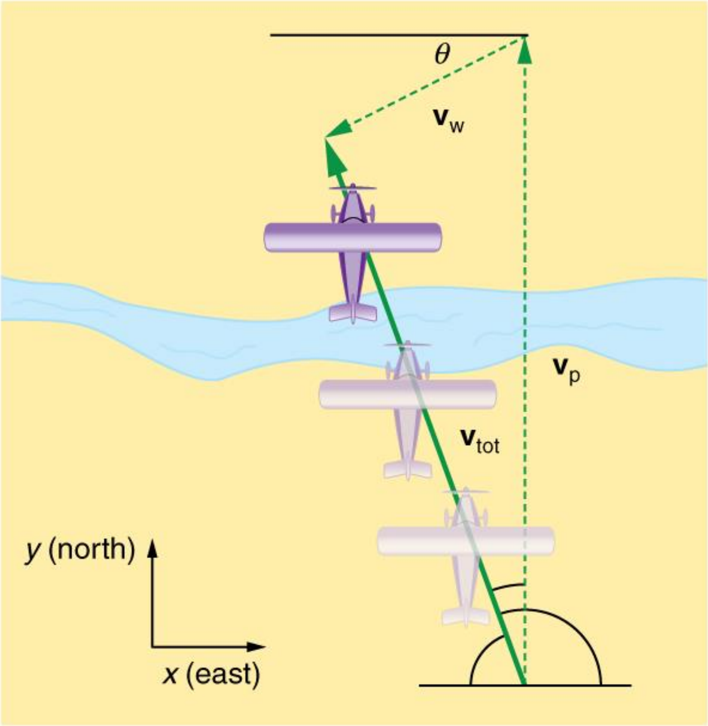
Projectile to satellite. In each case shown here, a projectile is launched from a very high tower to avoid air resistance. With increasing initial speed, the range increases and becomes longer than it would be on level ground because the Earth curves away underneath its path. With a large enough initial speed, orbit is achieved.

FIGURE 3.43



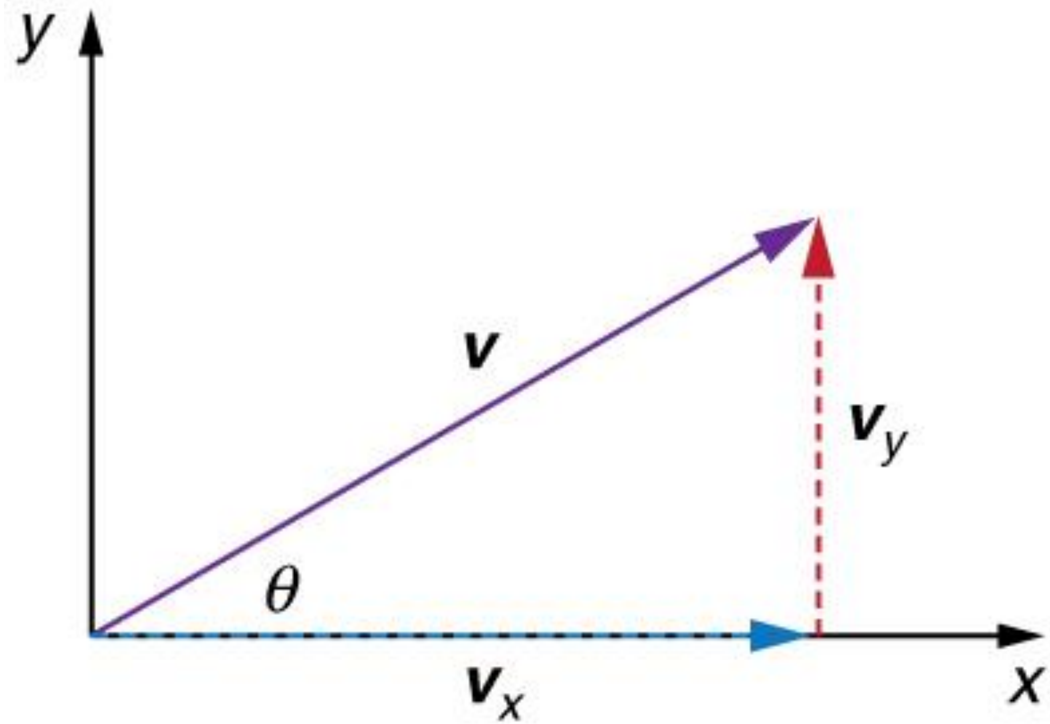
A boat trying to head straight across a river will actually move diagonally relative to the shore as shown. Its total velocity (solid arrow) relative to the shore is the sum of its velocity relative to the river plus the velocity of the river relative to the shore.

FIGURE 3.44



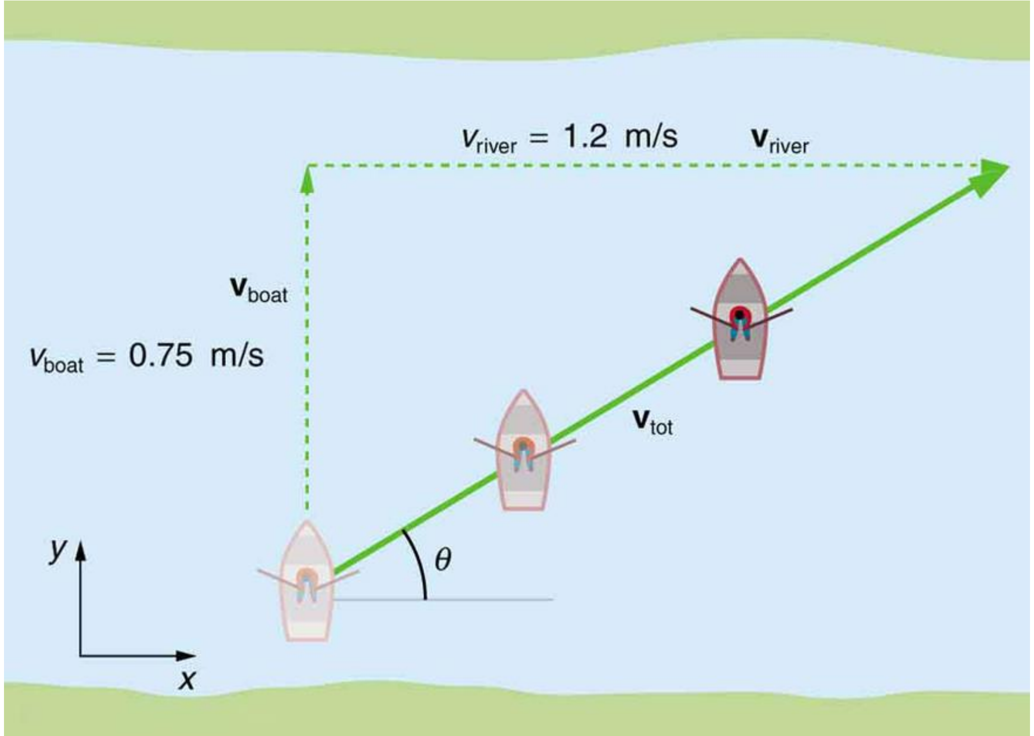
An airplane heading straight north is instead carried to the west and slowed down by wind. The plane does not move relative to the ground in the direction it points; rather, it moves in the direction of its total velocity (solid arrow).

FIGURE 3.45



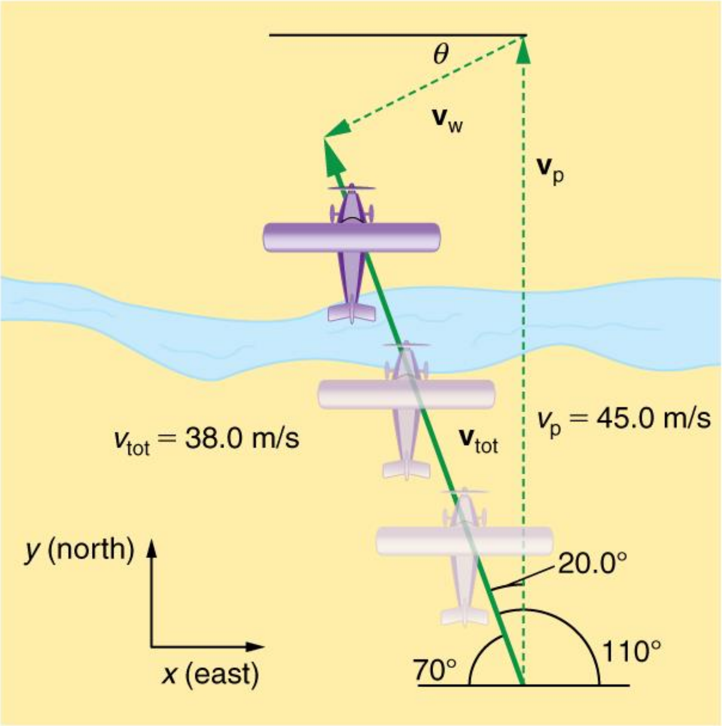
The velocity, *v* , of an object traveling at an angle *θ* to the horizontal axis is the sum of component vectors $\mathbf{v}_x$ and $\mathbf{v}_y$.

FIGURE 3.46



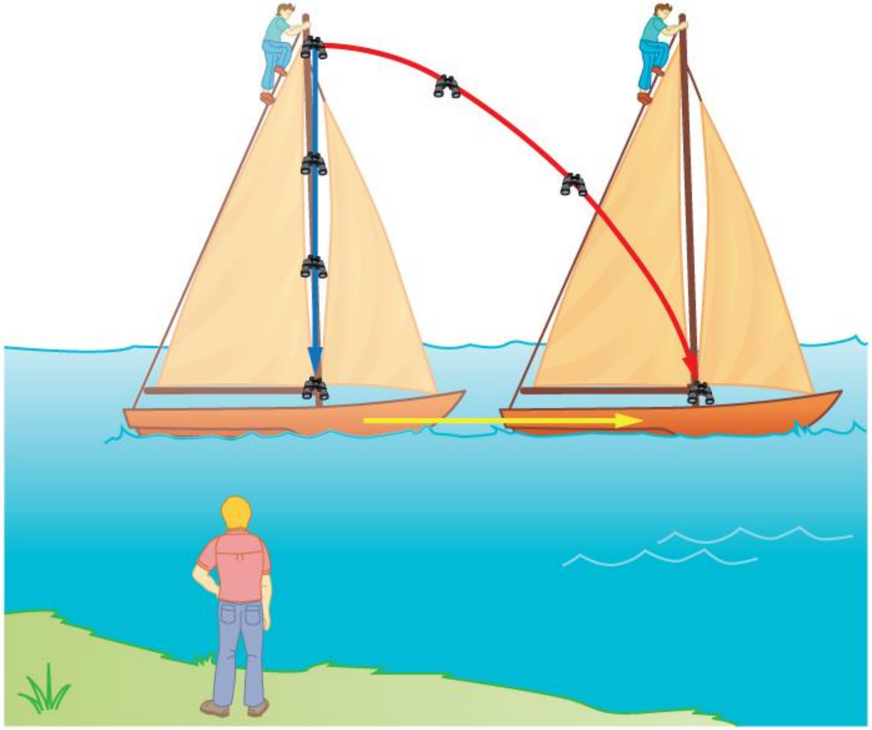
A boat attempts to travel straight across a river at a speed 0.75 m/s. The current in the river, however, flows at a speed of 1.20 m/s to the right. What is the total displacement of the boat relative to the shore?

FIGURE 3.47



An airplane is known to be heading north at 45.0 m/s, though its velocity relative to the ground is 38.0 m/s at an angle west of north. What is the speed and direction of the wind?

FIGURE 3.48



Classical relativity. The same motion as viewed by two different observers. An observer on the moving ship sees the binoculars dropped from the top of its mast fall straight down. An observer on shore sees the binoculars take the curved path, moving forward with the ship. Both observers see the binoculars strike the deck at the base of the mast. The initial horizontal velocity is different relative to the two observers. (The ship is shown moving rather fast to emphasize the effect.)

Summary

- A quantity with magnitude and direction is a vector.
- A quantity with magnitude but no direction is a scalar.
- Vector addition can be done either graphically or using components.
- The sum is called the resultant vector.
- Projectile motion is the motion of an object near the Earth's surface under the influence of gravity.