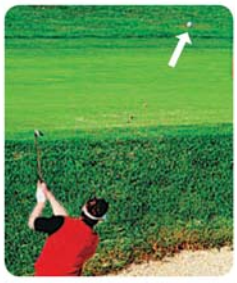
MODELING LAUNCHED OBJECTS In Lesson 4.5, the function $h = -16t^2 + h_0$ was used to model the height of a *dropped* object. For an object that is *launched or thrown*, an extra term v_0t must be added to the model to account for the object's initial vertical velocity v_0 (in feet per second). Recall that h is the height (in feet), t is the time in motion (in seconds), and h_0 is the initial height (in feet).

$h = -16t^2 + h_0$ **Object is dropped.**

$h = -16t^2 + v_0t + h_0$ **Object is launched or thrown.**

As shown below, the value of v_0 can be positive, negative, or zero depending on whether the object is launched upward, downward, or parallel to the ground.



$v_0 > 0$

$v_0 < 0$

$v_0 = 0$

EXAMPLE 5 Solve a vertical motion problem

JUGGLING A juggler tosses a ball into the air. The ball leaves the juggler's hand 4 feet above the ground and has an initial vertical velocity of 40 feet per second. The juggler catches the ball when it falls back to a height of 3 feet. How long is the ball in the air?

Solution

Because the ball is thrown, use the model $h = -16t^2 + v_0t + h_0$. To find how long the ball is in the air, solve for t when $h = 3$.

$h = -16t^2 + v_0t + h_0$	**Write height model.**
$3 = -16t^2 + 40t + 4$	**Substitute 3 for h, 40 for v_0, and 4 for h_0.**
$0 = -16t^2 + 40t + 1$	**Write in standard form.**
$t = \dfrac{-40 \pm \sqrt{40^2 - 4(-16)(1)}}{2(-16)}$	**Quadratic formula**
$t = \dfrac{-40 \pm \sqrt{1664}}{-32}$	**Simplify.**
$t \approx -0.025$ or $t \approx 2.5$	**Use a calculator.**

▶ Reject the solution -0.025 because the ball's time in the air cannot be negative. So, the ball is in the air for about 2.5 seconds.

GUIDED PRACTICE for Example 5

10. WHAT IF? In Example 5, suppose the ball leaves the juggler's hand with an initial vertical velocity of 50 feet per second. How long is the ball in the air?