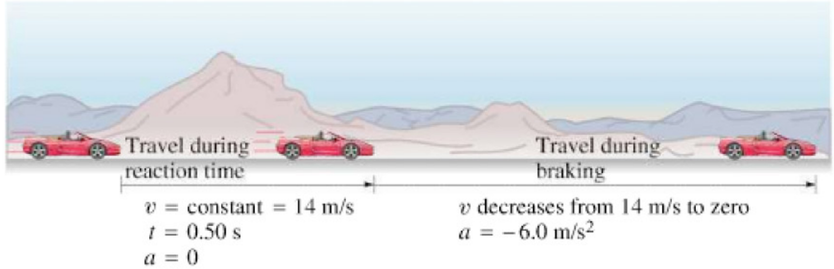

FIGURE 2–15 Example 2–9: stopping distance for a braking car.

PHYSICS APPLIED
Braking distances

EXAMPLE 2–9 ESTIMATE **Braking distances.** Estimate the minimum stopping distance for a car, which is important for traffic safety and traffic design. The problem is best dealt with in two parts, two separate time intervals. (1) The first time interval begins when the driver decides to hit the brakes, and ends when the foot touches the brake pedal. This is the "reaction time" during which the speed is constant, so $a = 0$. (2) The second time interval is the actual braking period when the vehicle slows down ($a \neq 0$) and comes to a stop. The stopping distance depends on the reaction time of the driver, the initial speed of the car (the final speed is zero), and the acceleration of the car. For a dry road and good tires, good brakes can decelerate a car at a rate of about $5\,\mathrm{m/s^2}$ to $8\,\mathrm{m/s^2}$. Calculate the total stopping distance for an initial velocity of 50 km/h ($14\,\mathrm{m/s} \approx 31\,\mathrm{mi/h}$) and assume the acceleration of the car is $-6.0\,\mathrm{m/s^2}$ (the minus sign appears because the velocity is taken to be in the positive x direction and its magnitude is decreasing). Reaction time for normal drivers varies from perhaps 0.3 s to about 1.0 s; take it to be 0.50 s.

APPROACH During the "reaction time," part (1), the car moves at constant speed of 14 m/s, so $a = 0$. Once the brakes are applied, part (2), the acceleration is $a = -6.0\,\mathrm{m/s^2}$ and is constant over this time interval. For both parts a is constant, so we can use Eqs. 2–11.

Part 1: Reaction time

Known	Wanted
$t = 0.50\,\mathrm{s}$	x
$v_0 = 14\,\mathrm{m/s}$	
$v = 14\,\mathrm{m/s}$	
$a = 0$	
$x_0 = 0$	

SOLUTION Part (1). We take $x_0 = 0$ for the first part of the problem, in which the car travels at a constant speed of 14 m/s during the time interval when the driver is reacting (0.50 s). See Fig. 2–15 and the Table in the margin. To find x, the position of the car at $t = 0.50\,\mathrm{s}$ (when the brakes are applied), we cannot use Eq. 2–11c because x is multiplied by a, which is zero. But Eq. 2–11b works:

$$x = v_0 t + 0 = (14\,\mathrm{m/s})(0.50\,\mathrm{s}) = 7.0\,\mathrm{m}.$$

Thus the car travels 7.0 m during the driver's reaction time, until the moment the brakes are applied. We will use this result as input to part (2).

Part 2: Braking

Known	Wanted
$x_0 = 7.0\,\mathrm{m}$	x
$v_0 = 14\,\mathrm{m/s}$	
$v = 0$	
$a = -6.0\,\mathrm{m/s^2}$	

Part (2). Now we consider the second time interval, during which the brakes are applied and the car is brought to rest. We have an initial position $x_0 = 7.0\,\mathrm{m}$ (result of part (1)), and other variables are shown in the Table in the margin. Equation 2–11a doesn't contain x; Eq. 2–11b contains x but also the unknown t. Equation 2–11c, $v^2 - v_0^2 = 2a(x - x_0)$, is what we want; after setting $x_0 = 7.0\,\mathrm{m}$, we solve for x, the final position of the car (when it stops):

$$\begin{aligned} x &= x_0 + \frac{v^2 - v_0^2}{2a} \\ &= 7.0\,\mathrm{m} + \frac{0 - (14\,\mathrm{m/s})^2}{2(-6.0\,\mathrm{m/s^2})} = 7.0\,\mathrm{m} + \frac{-196\,\mathrm{m^2/s^2}}{-12\,\mathrm{m/s^2}} \\ &= 7.0\,\mathrm{m} + 16\,\mathrm{m} = 23\,\mathrm{m}. \end{aligned}$$

The car traveled 7.0 m while the driver was reacting and another 16 m during the braking period before coming to a stop. The total distance traveled was then 23 m. Figure 2–16 shows a graph of v vs. t: v is constant from $t = 0$ to $t = 0.50\,\mathrm{s}$ and decreases linearly, to zero, after $t = 0.50\,\mathrm{s}$.

NOTE From the equation above for x, we see that the stopping distance after you hit the brakes $(= x - x_0)$ increases with the *square* of the initial speed, not just linearly with speed. If you are traveling twice as fast, it takes four times the distance to stop.

FIGURE 2–16 Example 2–9. Graph of v vs. t.