2-1 Position, Displacement, and Distance

In describing an object's motion, we should first talk about position – where is the object? A position is a vector because it has both a magnitude and a direction: it is some distance from a zero point (the point we call **the origin**) in a particular direction. With one-dimensional motion, we can define a straight line along which the object moves. Let's call this the *x*-axis, and represent different locations on the *x*-axis using variables such as $\vec{x}_0$ and $\vec{x}_1$, as in Figure 2.1.

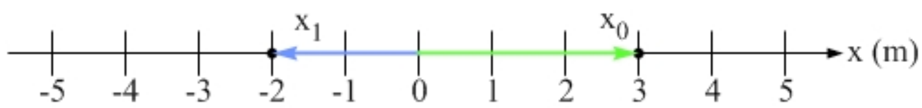

Figure 2.1: Positions $\vec{x}_0$ = +3 m and $\vec{x}_1$ = –2 m, where the + and – signs indicate the direction.

If an object moves from one position to another we say it experiences a **displacement**.

Displacement: a vector representing a change in position. A displacement is measured in length units, so the MKS unit for displacement is the meter (m).

We generally use the Greek letter capital delta (Δ) to represent a change. If the initial position is $\vec{x}_i$ and the final position is $\vec{x}_f$ we can express the displacement as:

$$\Delta\vec{x} = \vec{x}_f - \vec{x}_i \ .$$ (Equation 2.1: **Displacement in one dimension**)

In Figure 2.1, we defined the positions $\vec{x}_0$ = +3 m and $\vec{x}_1$ = –2 m. What is the displacement in moving from position $\vec{x}_0$ to position $\vec{x}_1$? Applying Equation 2.1 gives $\Delta\vec{x} = \vec{x}_1 - \vec{x}_0 = -2\text{ m} - (+3\text{ m}) = -5\text{ m}$. This method of adding vectors to obtain the displacement is shown in Figure 2.2. Note that the negative sign comes from the fact that the displacement is directed left, and we have defined the positive *x*-direction as pointing to the right.

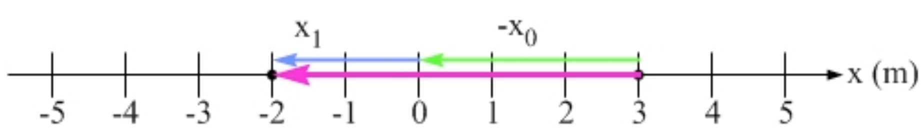

Figure 2.2: The displacement is –5 m when moving from position $\vec{x}_0$ to position $\vec{x}_1$. Equation 2.1, the displacement equation, tells us that the displacement is $\Delta\vec{x} = \vec{x}_1 - \vec{x}_0$, as in the figure. The bold arrow on the axis is the displacement, the vector sum of the vector $\vec{x}_1$ and the vector $-\vec{x}_0$.

To determine the displacement of an object, you only have to consider the change in position between the starting point and the ending point. The path followed from one point to the other does not matter. For instance, let's say you start at $\vec{x}_0$ and you then have a displacement of 8 meters to the left followed by a second displacement of 3 meters right. You again end up at $\vec{x}_1$, as shown in Figure 2.4. The total distance traveled is the sum of the magnitudes of the individual displacements, 8 m + 3 m = 11 m. The net displacement (the vector sum of the individual displacements), however, is still 5 meters to the left: $\Delta\vec{x} = -8\text{ m} + (+3\text{ m}) = -5\text{ m} = \vec{x}_1 - \vec{x}_0$.

Figure 2.3: The net displacement is still –5 m, even though the path taken from $\vec{x}_0$ to $\vec{x}_1$ is different from the direct path taken in Figure 2.2.

EXAMPLE 2.1 – Interpreting graphs

Another way to represent positions and displacements is to graph the position as a function of time, as in Figure 2.4. This graph could represent your motion along a sidewalk.

(a) What happens at a time of $t = 40$ s?

(b) Draw a diagram similar to that in Figure 2.3, to show your motion along the sidewalk. Add circles to your diagram to show your location at 10-second intervals, starting at $t = 0$.

Using the graph in Figure 2.4, find (c) your net displacement and (d) the total distance you covered during the 50-second period.

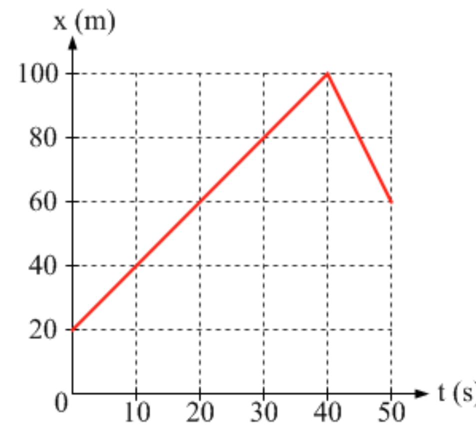

Figure 2.4: A graph of the position of an object versus time over a 50-second period. The graph represents your motion in a straight line as you travel along a sidewalk.

SOLUTION

(a) At a time of $t = 40$ s, the graph shows that your motion changes from travel in the positive x-direction to travel in the negative x-direction. In other words, at $t = 40$ s you reverse direction.

(b) Figure 2.5 shows one way to turn the graph in Figure 2.4 into a vector diagram to show how a series of individual displacements adds together to a net displacement. Figure 2.5 shows five separate displacements, which break your motion down into 10-second intervals.

(c) The displacement can be found by subtracting the initial position, +20 m, from the final position, +60 m. This gives a net displacement of $\Delta\vec{x}_{net} = \vec{x}_f - \vec{x}_i = +60 \text{ m} - (+20 \text{ m}) = +40 \text{ m}$.

A second way to find the net displacement is to recognize that the motion consists of two displacements, one of +80 m (from +20 m to +100 m) and one of –40 m (from +100 m to +60 m). Adding these individual displacements gives $\Delta\vec{x}_{net} = \Delta\vec{x}_1 + \Delta\vec{x}_2 = +80 \text{ m} + (-40 \text{ m}) = +40 \text{ m}$.

(d) The total distance covered is the sum of the magnitudes of the individual displacements. Total distance = 80 m + 40 m = 120 m.

Related End-of-Chapter Exercises: 7 and 9

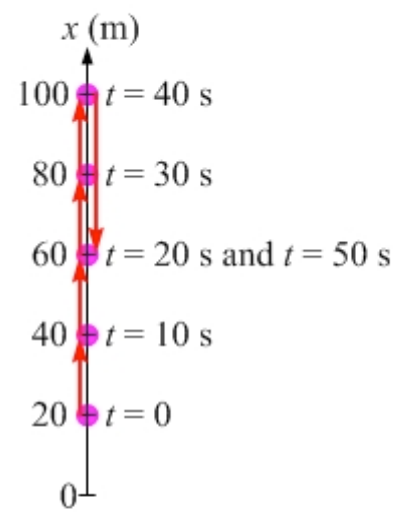

Figure 2.5: A vector diagram to show your displacement, as a sequence of five 10-second displacements over a 50-second period. The circles show your position at 10-second intervals.

Essential Question 2.1: In the previous example, the magnitude of the displacement is less than the total distance covered. Could the magnitude of the displacement ever be larger than the total distance covered? Could they be equal? Explain. *(The answer is at the top of the next page.)*