Chapter 1
Concepts of Motion and Mathematical Background

Topics:

- Motion diagrams
- Position and time
- Velocity
- Scientific notation and units
- Vectors and motion

Sample question:

As this snowboarder moves in a graceful arc through the air, the direction of his motion, and the distance between each of his positions and the next, is constantly changing. What language should we use to describe this motion?

Reading Quiz

1. What is the difference between speed and velocity?
   A. Speed is an average quantity while velocity is not.
   B. Velocity contains information about the direction of motio while speed does not.
   C. Speed is measured in mph, while velocity is measured in m/s.
   D. The concept of speed applies only to objects that are neither speeding up nor slowing down, while velocity applies to every kind of motion.
   E. Speed is used to measure how fast an object is moving i straight line, while velocity is used for objects moving alo curved paths.

Reading Quiz

2. The quantity 2.67×10^3 m/s has how many significant figures'
   A. 1
   B. 2
   C. 3
   D. 4
   E. 5

Reading Quiz

3. If Sam walks 100 m to the right, then 200 m to the left, his net displacement vector points

   A. to the right.

   B. to the left.

   C. has zero length.

   D. Cannot tell without more information.

Reading Quiz

4. Velocity vectors point
   A. in the same direction as displacement vectors.
   B. in the opposite direction as displacement vectors.
   C. perpendicular to displacement vectors.
   D. in the same direction as acceleration vectors.
   E. Velocity is not represented by a vector.

Four Types of Motion We’ll Study

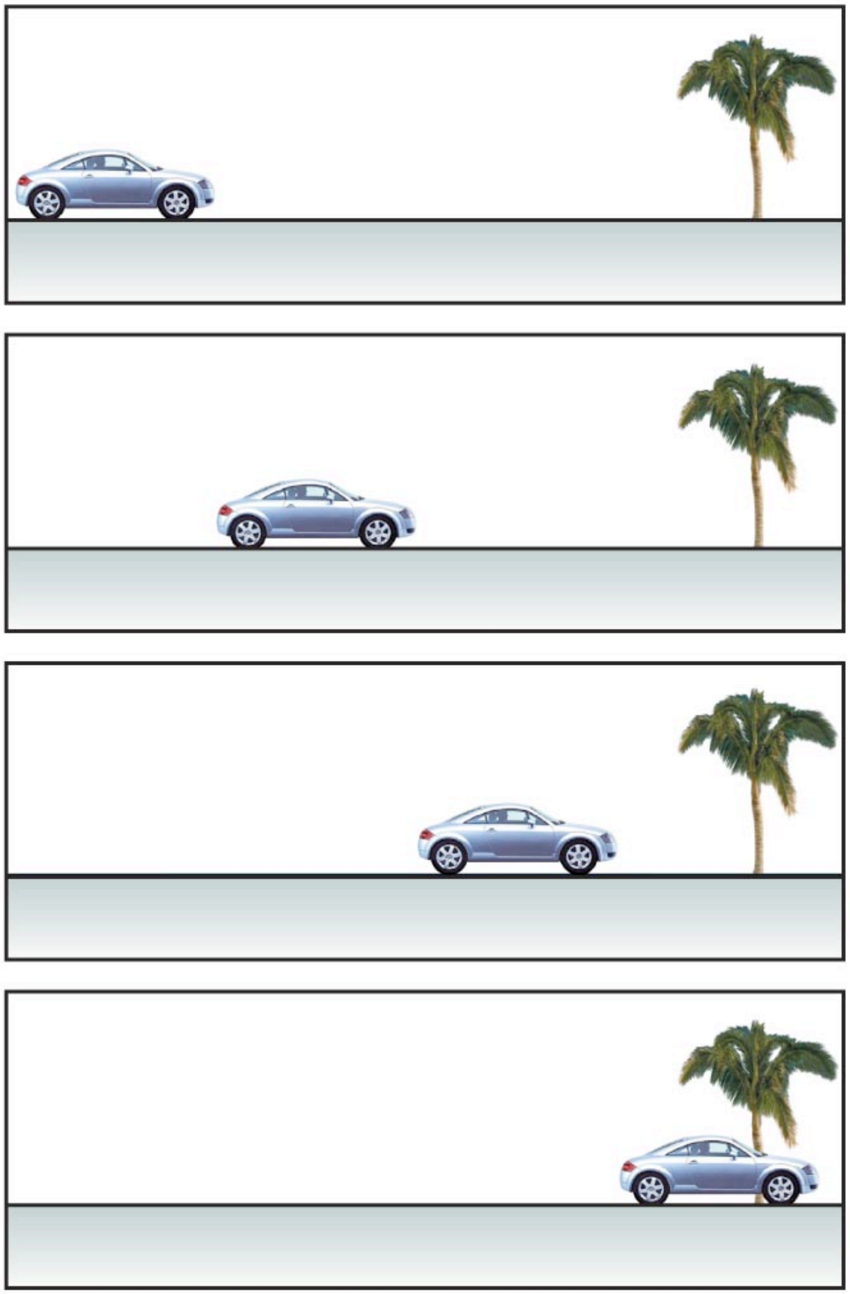
Straight-line motion

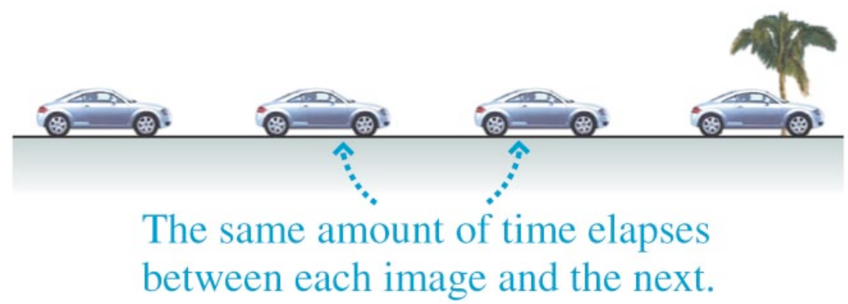
Circular motion

Projectile motion

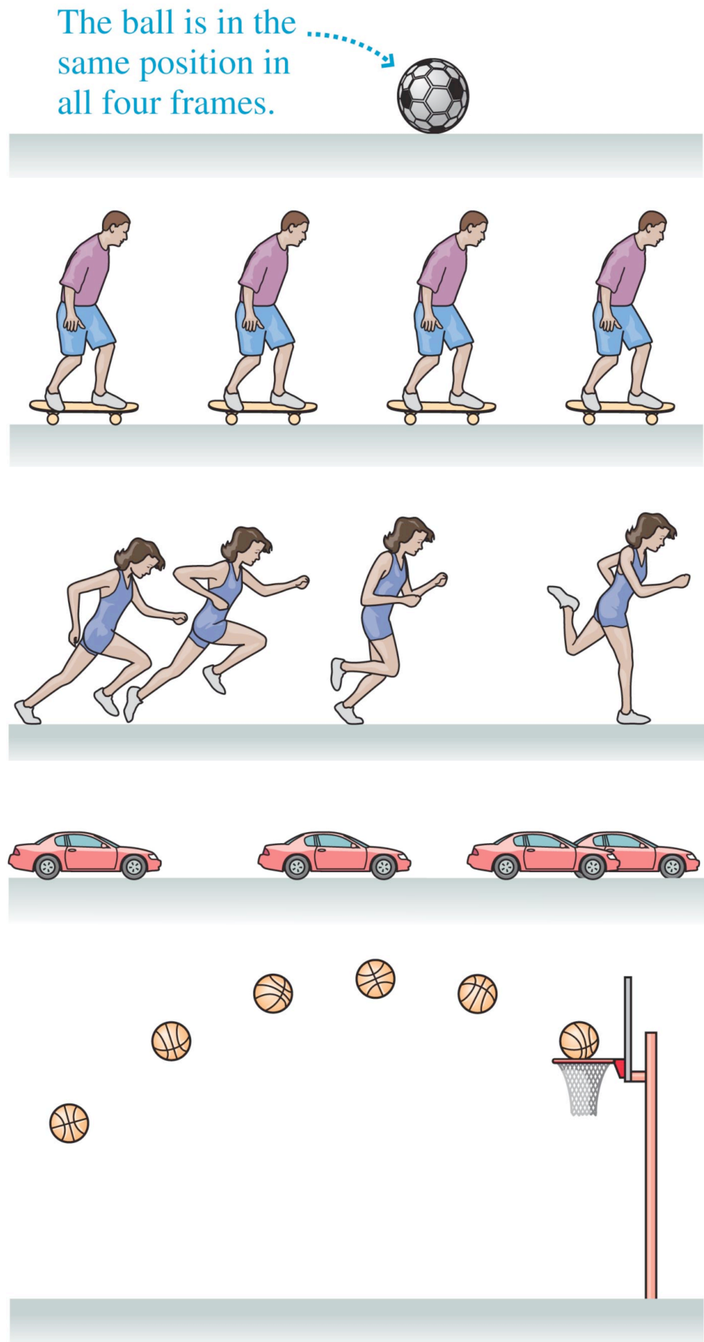
Rotational motion

Making a Motion Diagram



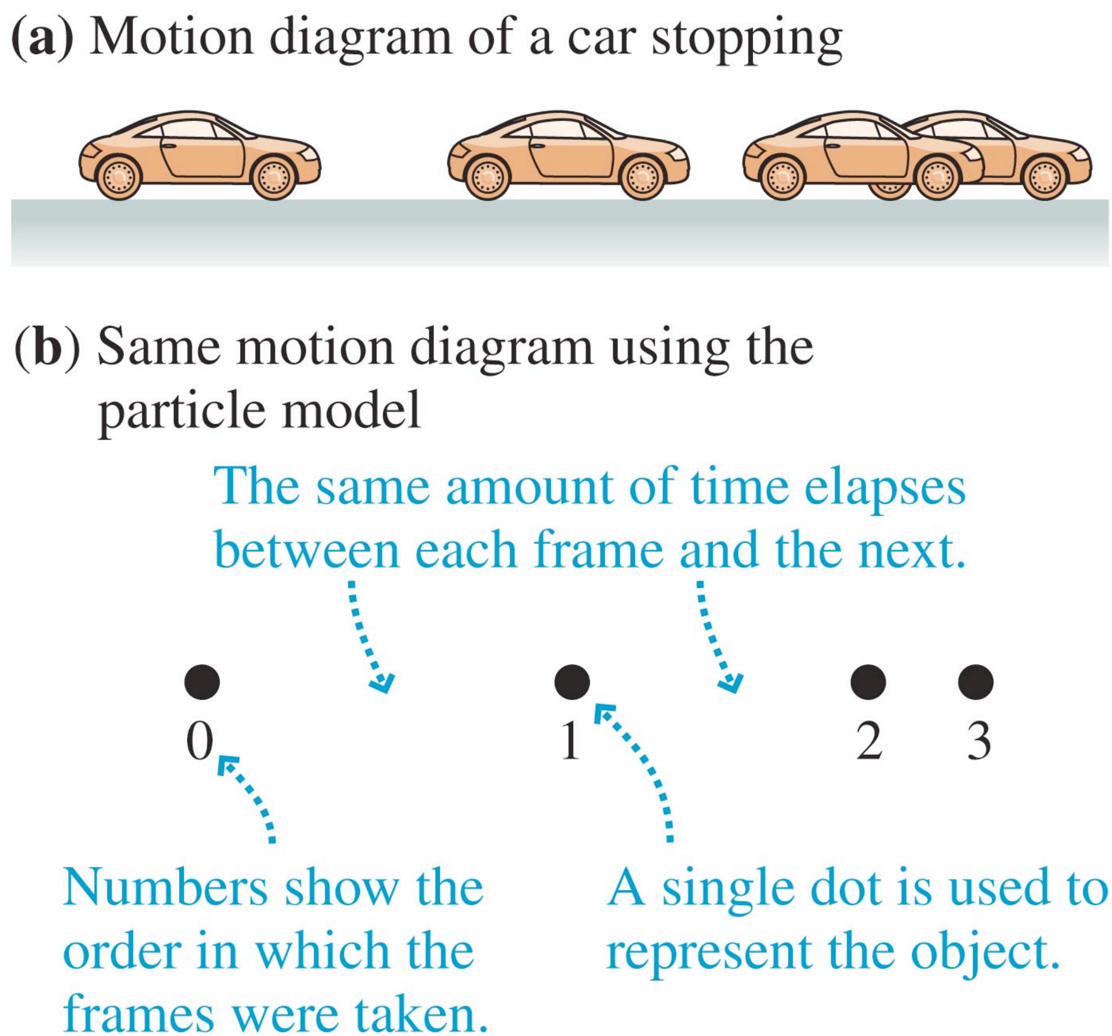


Examples of Motion Diagrams



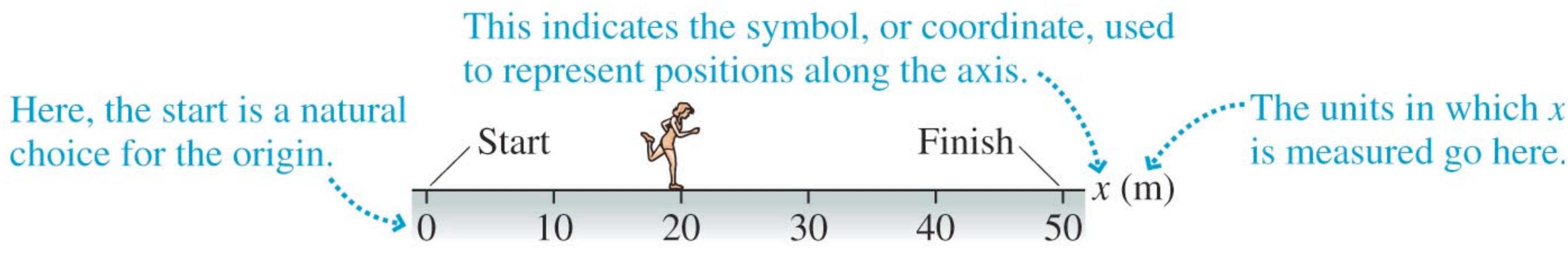
The Particle Model

A simplifying *model* in which we treat the object as if all its mass were concentrated at a single point. This model helps us concentrate on the *overall* motion of the object.

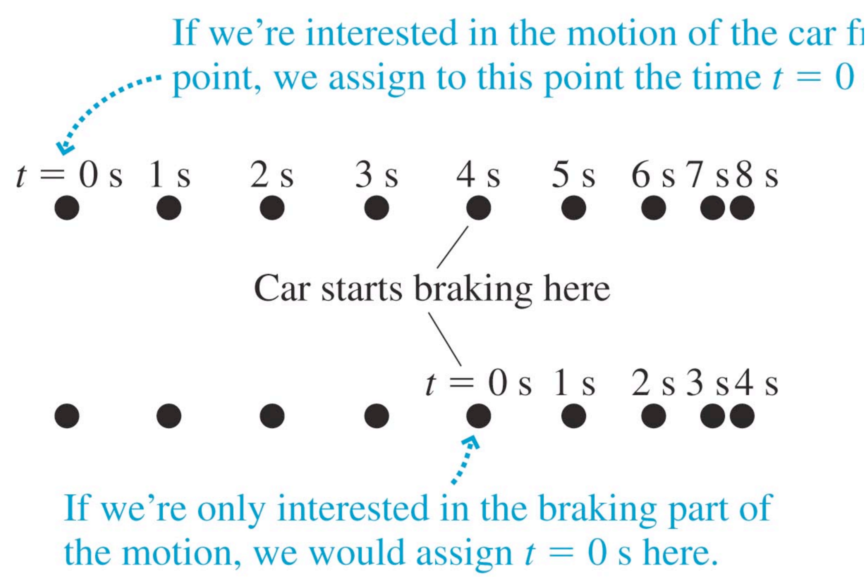


Position and Time

The position of an object is located along a *coordinate system.*

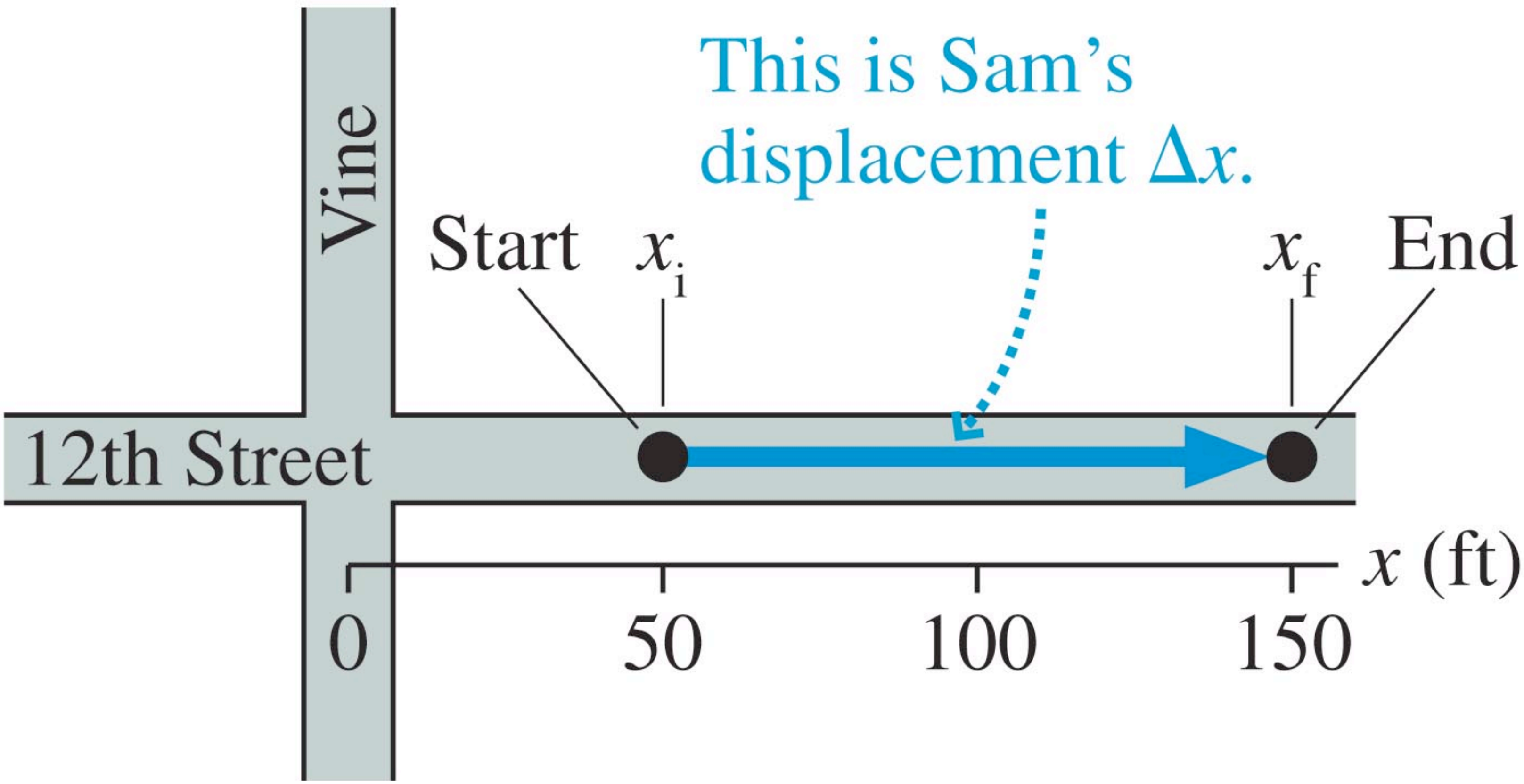


At each time *t*, the object is at some particular position. We are free to choose the origin of time (i.e., when $t = 0$).



Displacement

The *change* in the position of an object as it moves from initial position x_i to final position x_f is its *displacement* $\Delta x = x_f - x_i$.



Checking Understanding

Maria is at position x = 23 m. She then undergoes a displacemer Δx = –50 m. What is her final position?

A. –27 m

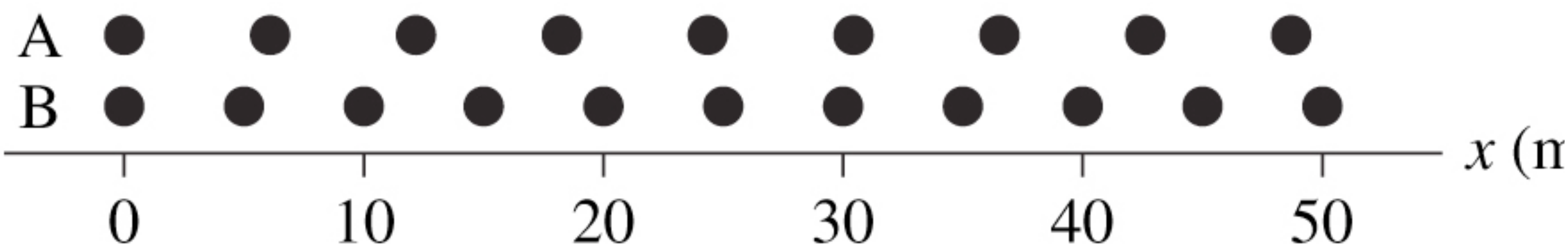
B. –50 m

C. 23 m

D. 73 m

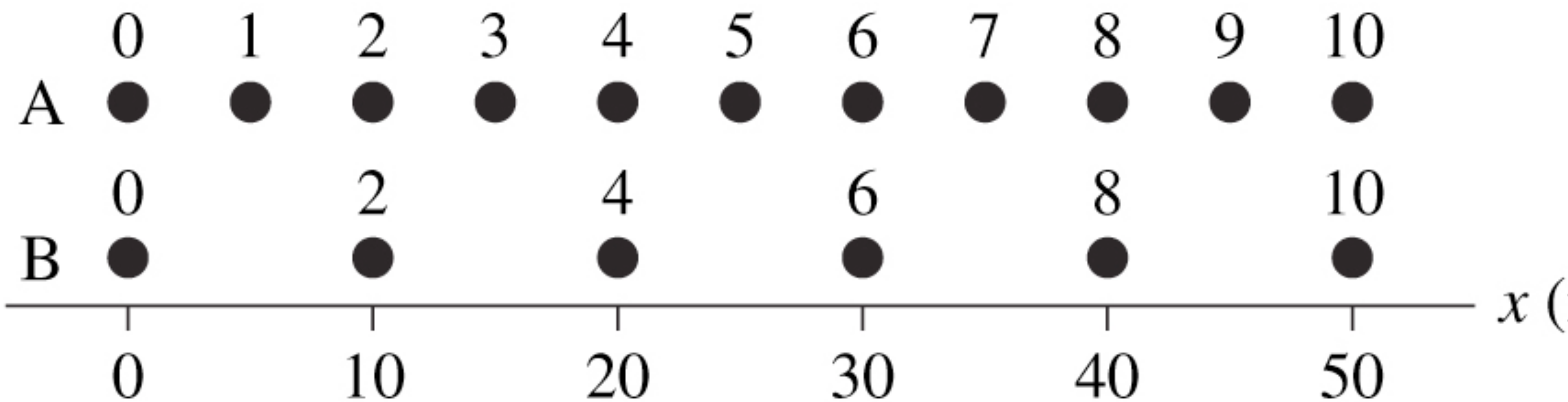
Checking Understanding

Two runners jog along a track. The positions are shown at 1 s time intervals. Which runner is moving faster?



Checking Understanding

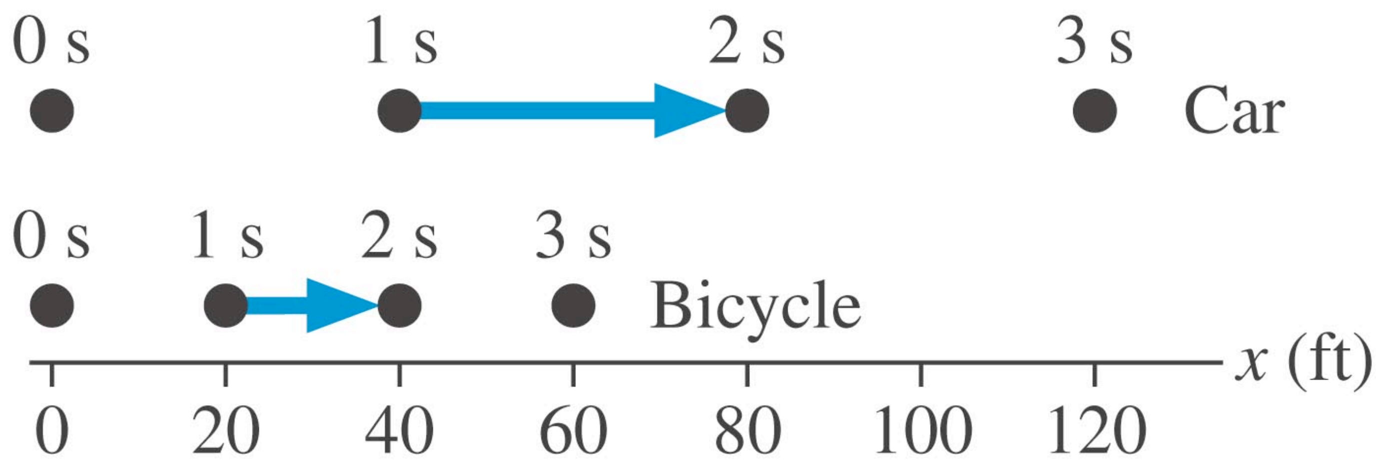
Two runners jog along a track. The times at each position are shown. Which runner is moving faster?



C. They are both moving at the same speed.

Speed

$$\text{speed} = \frac{\text{distance traveled in a given time interval}}{\text{time interval}}$$



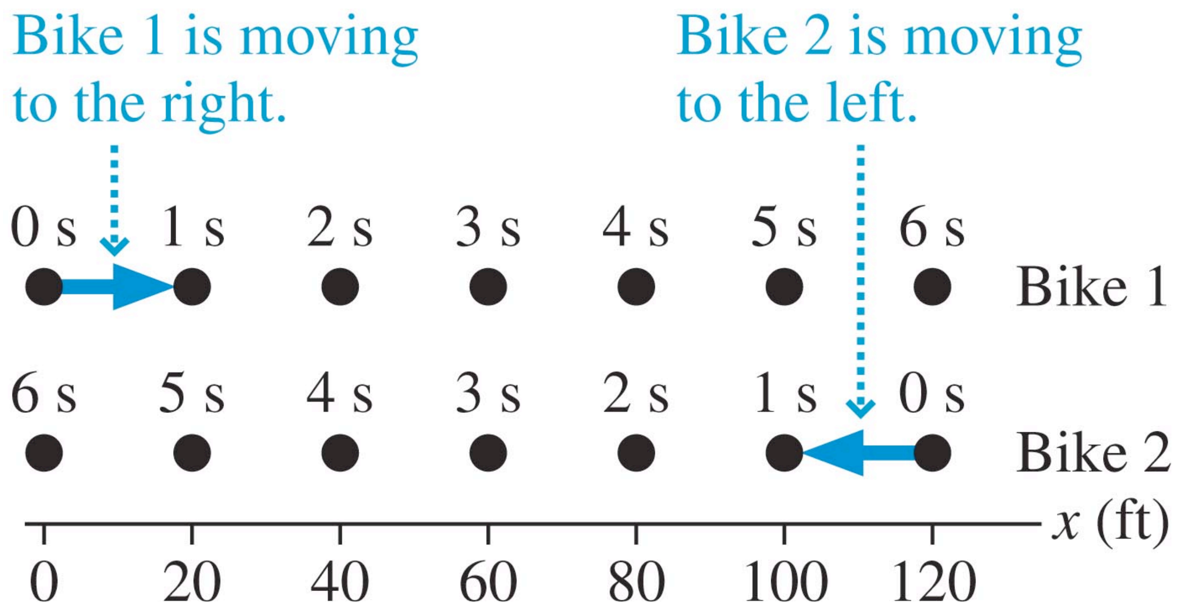
The car moves 40 m in 1 s. Its speed is $\frac{40\text{ m}}{1\text{ s}} = 40\ \frac{\text{m}}{\text{s}}$.

The bike moves 20 m in 1 s. Its speed is $\frac{20\text{ m}}{1\text{ s}} = 20\ \frac{\text{m}}{\text{s}}$.

Velocity

$$\text{velocity} = \frac{\text{displacement}}{\text{time interval}} = \frac{\Delta x}{\Delta t}$$

Velocity of a moving object



$$e_{\text{max}} = 1 - \frac{T_C}{T_H}$$

Theoretical maximum efficiency of a heat engine

Significant figures

Multiplying two numbers:

Three significant figures

$$3.73 \times 5.7 = 21$$

Two significant figures

Answer should have the *lower* of the two, or two significant figures.

Adding two numbers:

$$\begin{array}{r} 18.54 \\ +106.6 \\ \hline =125.1 \end{array}$$

18.54 — Two decimal places

+106.6 — One decimal place

=125.1 ← Answer should have the *lower* of the two, or one decimal place.

Scientific Notation

To convert a number into scientific notation:

1. For a number greater than 10, move the decimal point to the left un only one digit remains to the left of the decimal point. The remaini number is then multiplied by 10 to a power; this power is given by number of spaces the decimal point was moved. Here we convert diameter of the earth to scientific notation:

We move the decimal point until there is only one digit to its left, counting the number of steps.

Since we moved the decimal poi 6 steps, the power of ten is 6.

$$6\,370\,000 \text{ m} = 6.37 \times 10^{6} \text{ m}$$

The number of digits here equals the number of significant figures.

Scientific Notation (continued)

❷ For a number less than 1, move the decimal point to the right unti passes the first digit that isn't a zero. The remaining number is then m tiplied by 10 to a negative power; the power is given by the number spaces the decimal point was moved. For the diameter of a red blood c we have

We move the decimal point until it passes the first digit that is not a zero, counting the number of steps.

Since we moved the decimal p 6 steps, the power of ten is −6

$$0.000\,007\,5\ \text{m} = 7.5 \times 10^{-6}\ \text{m}$$

The number of digits here equals the number of significant figures.

Unit Conversions

❶ Start with the quantity you wish to convert.

❷ Multiply by the appropriate conversion factor. Because this conversion factor is equal to one, multiplying by it does not change the value of the quantity—only its units.

❺ Remember to convert you answer to the correct number significant figures!

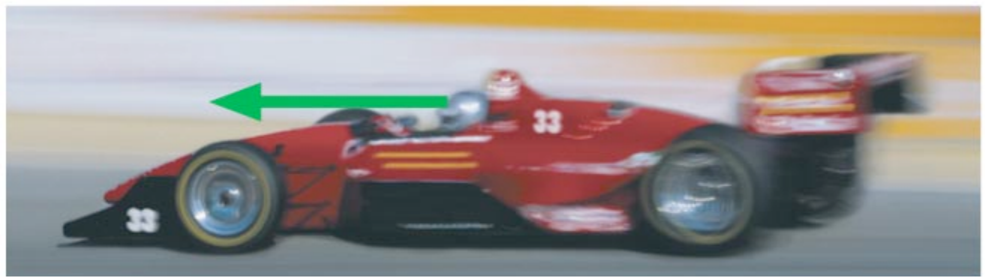
$$60\ \text{mi} = 60\ \cancel{\text{mi}} \times \frac{1.609\ \text{m}}{1\ \cancel{\text{mi}}} = 96.54\ \text{km} = 97\ \text{km}$$

❸ You can cancel the original unit (here, miles) because it appears in both the numerator and the denominator.

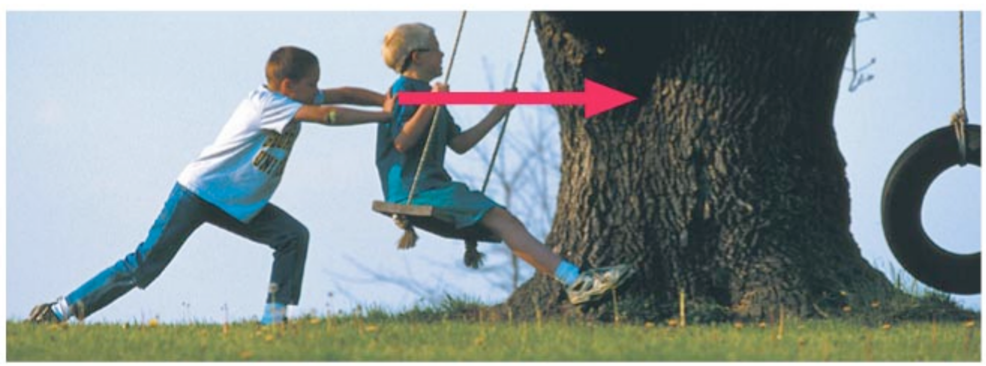
❹ Calculate the answer; it is in the desired units. Remember, 60 mi and 96.54 km are the same distance; they are simply in different units.

Vectors and Motion

A quantity that requires both a magnitude (or size) and a directio
can be represented by a *vector*. Graphically, we represent a vect
by an arrow.



The velocity of this car is **100 m/s** (magnitude) to the **left** (directi

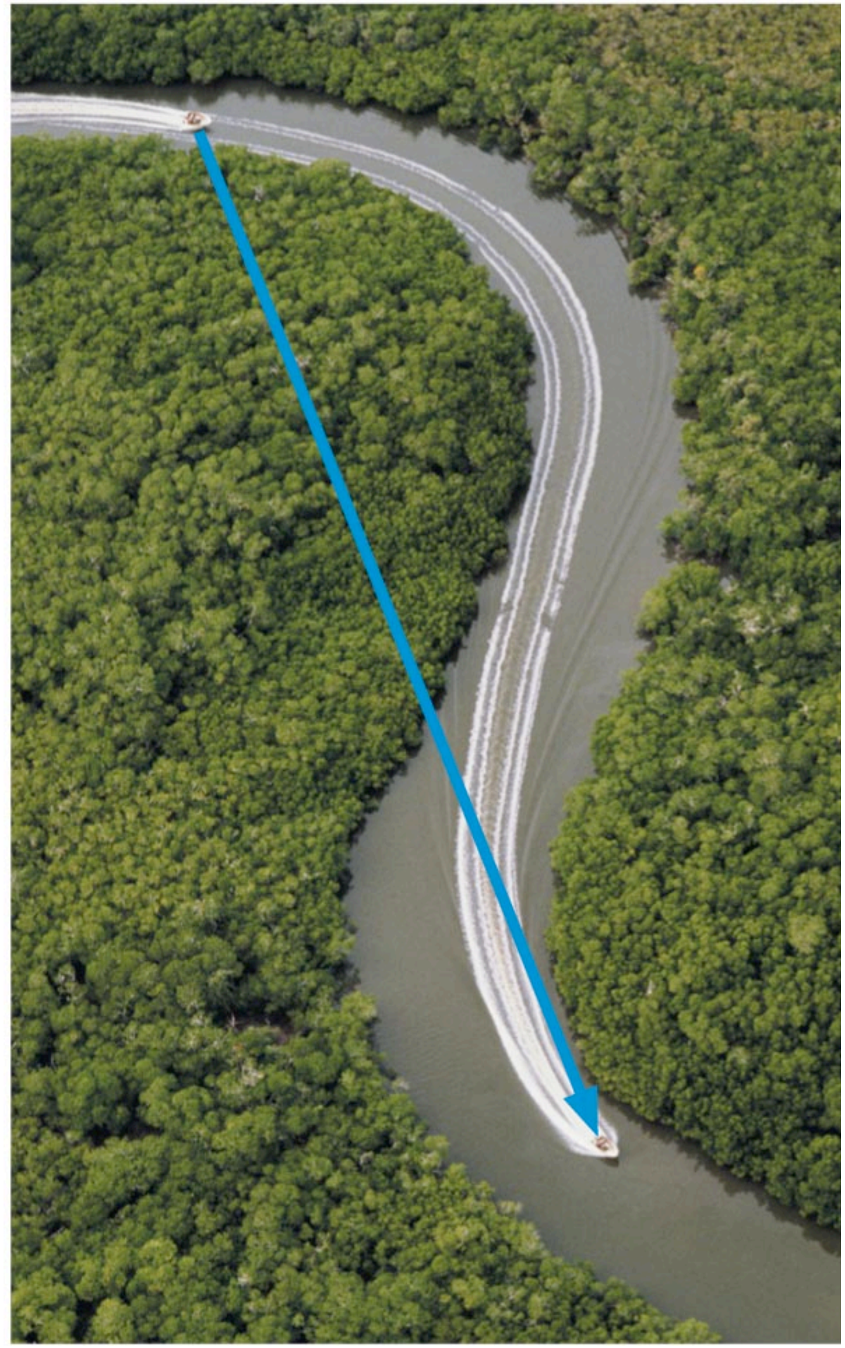


This boy pushes on his friend with a force of **25 N** to the **right**.

Displacement Vectors

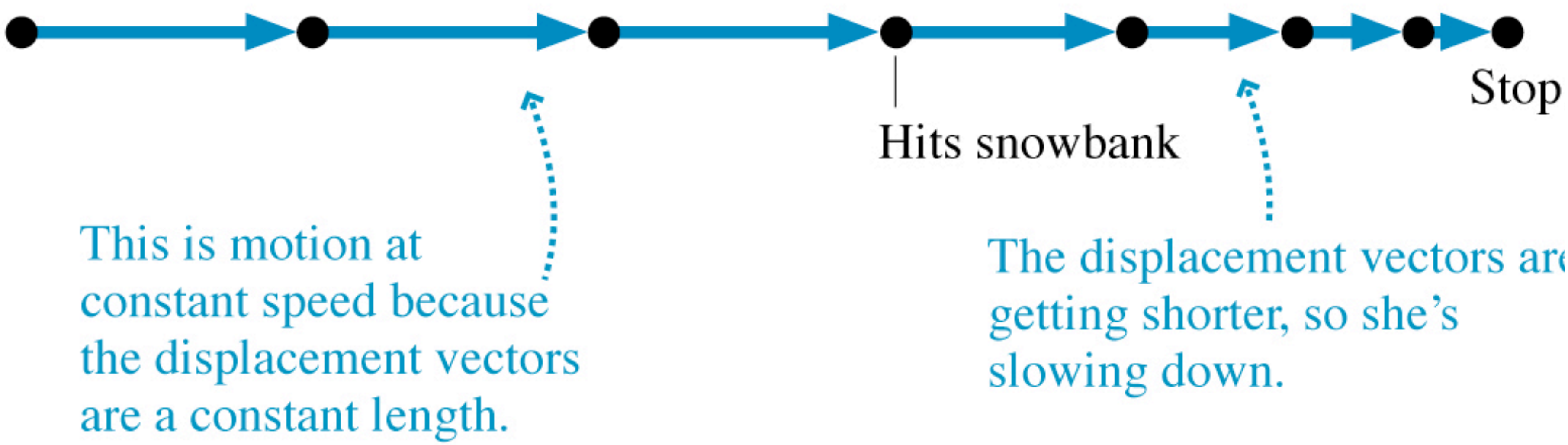
A *displacement vector* starts at an object's initial position and ends at its final position. It doesn't matter what the object did in between these two positions.

In motion diagrams, the displacement vectors span successive particle positions.

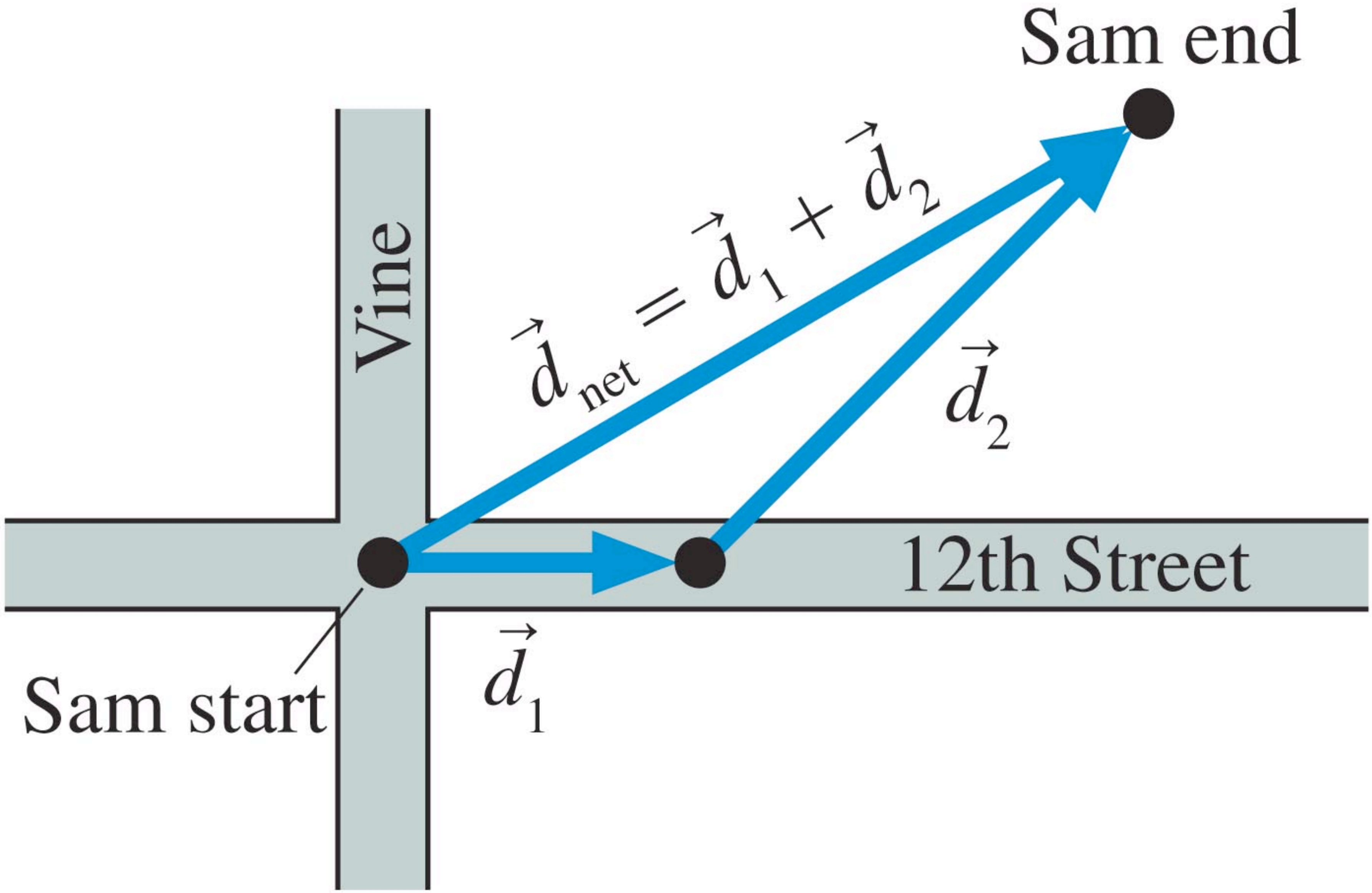


Exercise

Alice is sliding along a smooth, icy road on her sled when she suddenly runs headfirst into a large, very soft snowbank that gradually brings her to a halt. Draw a motion diagram for Alice. Show and label all displacement vectors.



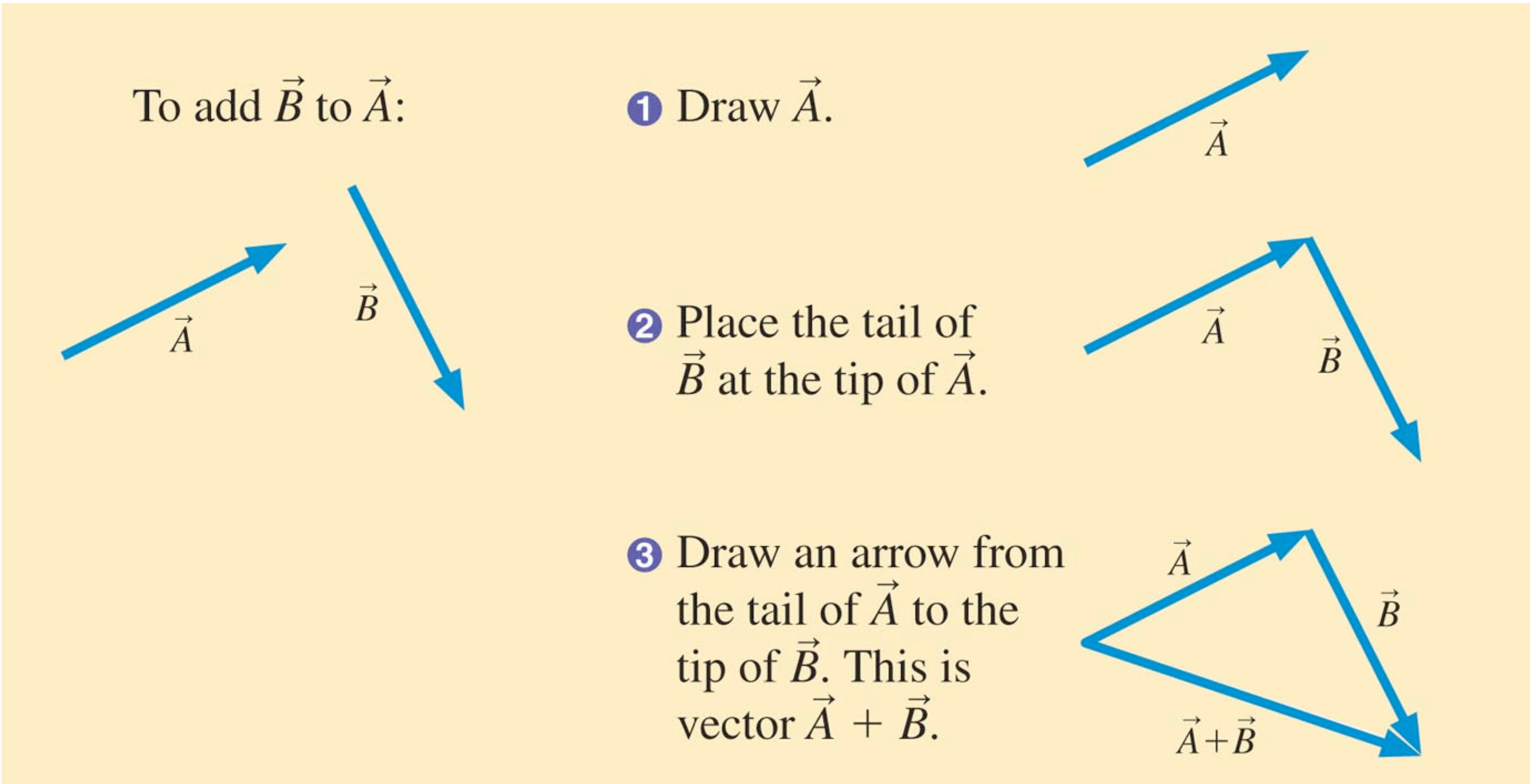
Adding Displacement Vectors



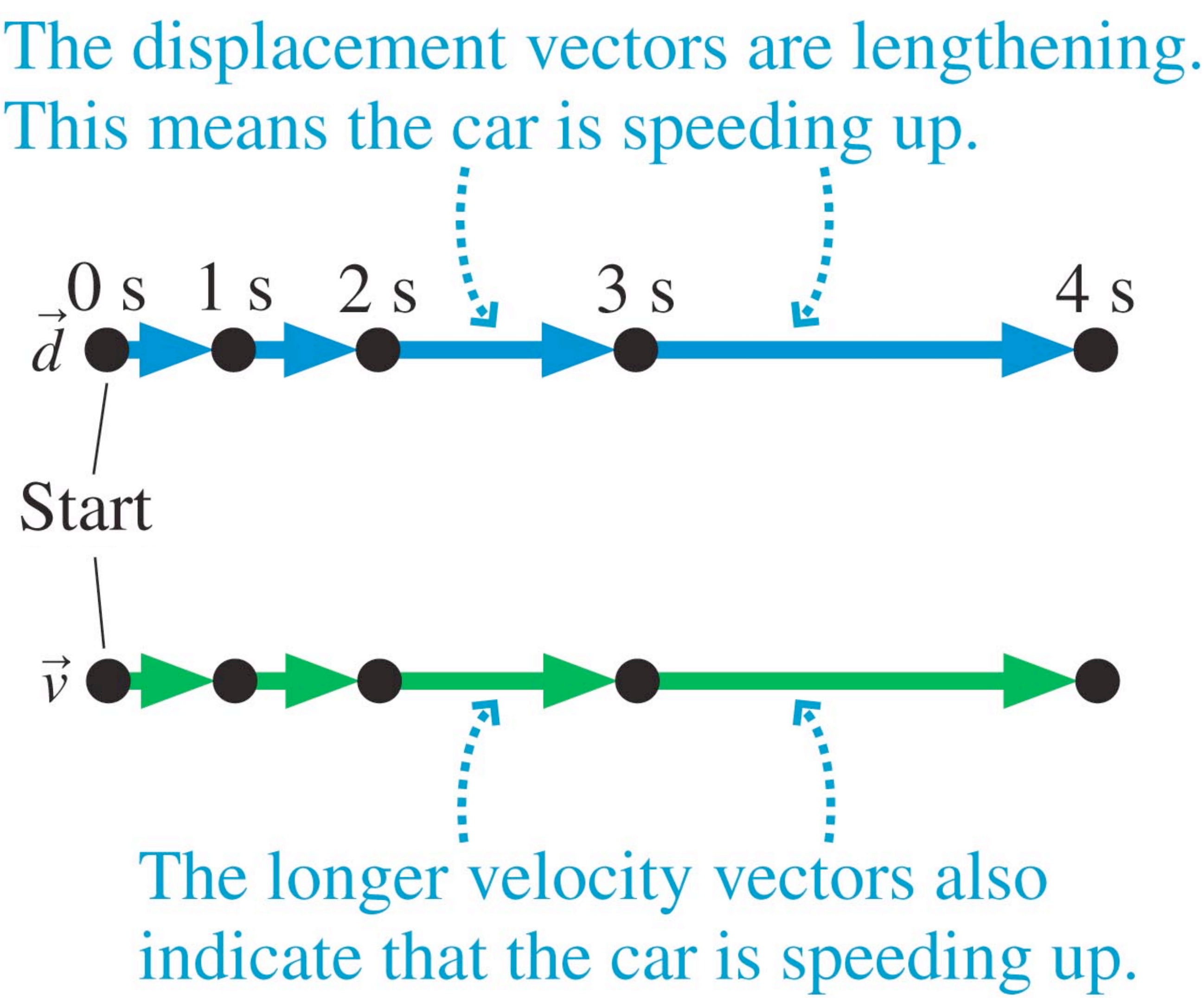
Example: Adding Displacement Vectors

Jenny runs 1 mi to the northeast, then 1 mi south. Graphically find her net displacement.

Adding Vectors Graphically



Velocity Vectors



Example: Velocity Vectors

Jake throws a ball at a 60° angle, measured from the horizontal. The ball is caught by Jim. Draw a motion diagram of the ball with velocity vectors.