

SECTION

1

Measuring Motion

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is motion?
- How is motion shown by a graph?
- What are speed and velocity?
- What is acceleration?

**National Science
Education Standards**
PS 2a

What Is Motion?

Look around the room for a moment. What objects are in motion? Are students writing with pencils in their notebooks? Is the teacher writing on the board? Motion is all around you, even when you can't see it. Blood is circulating throughout your body. Earth orbits around the sun. Air particles shift in the wind.

When you watch an object move, you are watching it in relation to what is around it. Sometimes the objects around the object you are watching are at rest. An object that seems to stay in one place is called a *reference point*. When an object changes position over time in relation to a reference point, the object is in **motion**. ✓

You can use *standard reference directions* (such as north, south, east, west, right, and left) to describe an object's motion. You can also use features on Earth's surface, such as buildings or trees, as reference points. The figure below shows how a mountain can be used as a reference point to show the motion of a hot-air balloon.



The hot-air balloon changed position relative to a reference point.

STUDY TIP

Describe Study each graph carefully. In the margin next to the graph, write a sentence or two explaining what the graph shows.

READING CHECK

1. Describe What is the purpose of a reference point?

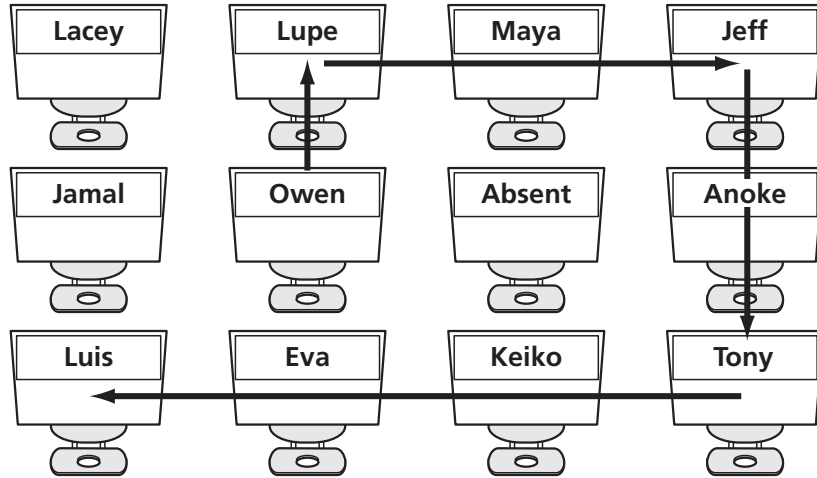
TAKE A LOOK

2. Identify What is the fixed reference point in the photos?

SECTION 1 Measuring Motion *continued*

How Can Motion Be Shown?

In the figure below, a sign-up sheet is being passed around a classroom. You can follow its path. The paper begins its journey at the reference point, the origin.



The path taken by a field trip sign-up sheet.

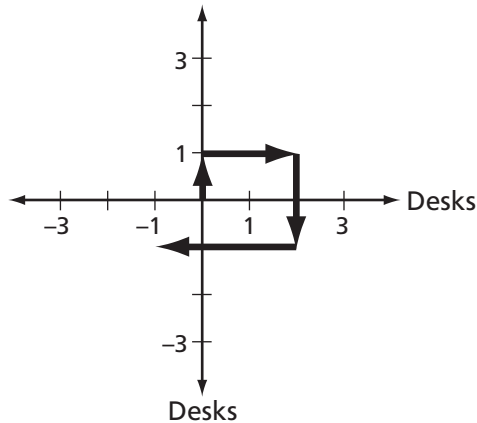
TAKE A LOOK

3. Identify What is the origin, or reference point, of the paper?

The figure below shows a graph of the position of the sign-up sheet as it is passed around the class. The paper moves in this order:

1. One positive unit on the *y*-axis
2. Two positive units on the *x*-axis
3. Two negative units on the *y*-axis
4. Three negative units on the *x*-axis

The graph provides a method of using standard reference directions to show motion.



The position of the sign-up sheet as it moves through the classroom.

STANDARDS CHECK

PS 2a The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

4. Identify What is the shortest path that the paper could take to return to Owen's desk? The paper cannot move diagonally.

SECTION 1 Measuring Motion *continued***What Is Speed?**

Speed is the rate at which an object moves. It is the distance traveled divided by the time taken to travel that distance. Most of the time, objects do not travel at a constant speed. For example, when running a race, you might begin slowly but then sprint across the finish line.

So, it is useful to calculate *average speed*. We use the following equation:

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

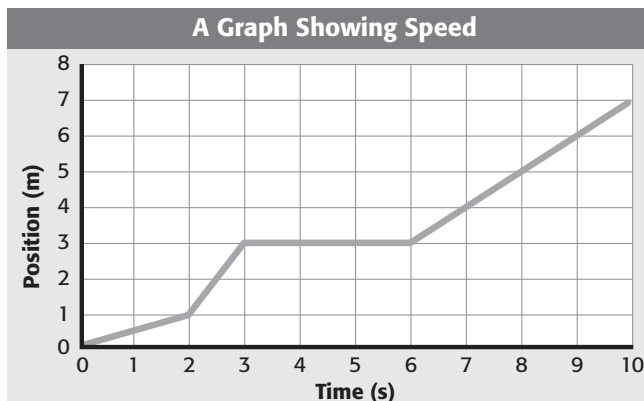
Suppose that it takes you 2 s to walk 4 m down a hallway. You can use the equation above to find your average speed:

$$\text{average speed} = \frac{4 \text{ m}}{2 \text{ s}} = 2 \text{ m/s}$$

Your speed is 2 m/s. Units for speed include meters per second (m/s), kilometers per hour (km/h), feet per second (ft/s), and miles per hour (mi/h).

How Can You Show Speed on a Graph?

You can show speed on a graph by showing how the position of an object changes over time. The x -axis shows the time it takes to move from place to place. The y -axis shows distance from the reference point.



A graph of position versus time also shows the dog's speed during his walk. The more slanted the line, the faster the dog walked.

Suppose you watched a dog walk beside a fence. The graph above shows the total distance the dog walked in 10 s. The line is not straight because the dog did not walk the same distance in each second. The dog walked slowly for 2 s and then quickly for 1 s. From 3 s to 5 s, the dog did not move.

Critical Thinking

5. Explain The average flight speed of a bald eagle is about 50 km/h. A scientist has measured an eagle flying 80 km/h. How is this possible?

Math Focus

6. Calculate Suppose you walk 10 m down a hallway in 2.5 s. What is your average speed? Show your work.

TAKE A LOOK

7. Apply Concepts Suppose the dog walks at a constant speed the whole way. On the graph, draw a line showing that the dog walks at a constant speed during the walk.

SECTION 1 Measuring Motion *continued*

The average speed of the dog is:

$$\text{average speed} = \frac{\text{total distance walked}}{\text{total time}} = \frac{7 \text{ m}}{10 \text{ s}} = .07 \text{ m/s}$$

What Is Velocity?

Suppose that two birds leave the same tree at the same time. They both fly at 10 km/h for 5 min, then 5 km/h for 10 min. However, they don't end up in the same place. Why not?

The birds did not end up in the same place because they flew in different directions. Their speeds were the same, but because they flew in different directions, their velocities were different. **Velocity** is the speed of an object and its direction. ✓

The velocity of an object is constant as long as both speed and direction are constant. If a bus driving at 15 m/s south speeds up to 20 m/s south, its velocity changes. If the bus keeps moving at the same speed but changes direction from south to east, its velocity also changes. If the bus brakes to a stop, the velocity of the bus changes again.

The table below shows that velocity is a combination of both the speed of an object and its direction.

Speed	Direction	Velocity
15 m/s	south	15 m/s south
20 m/s	south	20 m/s south
20 m/s	east	20 m/s east
0 m/s	east	0 m/s east

Velocity changes when the speed changes, when the direction changes, or when both speed and direction change. The table below describes various situations in which the velocity changes.

Situation	What changes
Raindrop falling faster and faster	
Runner going around a turn on a track	direction
Car taking an exit off a highway	speed and direction
Train arriving at a station	speed
Baseball being caught by a catcher	speed
Baseball hit by a batter	
	speed and direction

 **READING CHECK**

8. Analyze Someone tells you that the velocity of a car is 55 mi/h. Is this correct? Explain your answer.

 **Say It**

Share Experiences Have you ever experienced a change in velocity on an amusement park ride? In pairs, share an experience. Explain how the velocity changed—was it a change in speed, direction, or both?

TAKE A LOOK

9. Identify Fill in the empty boxes in the table.

SECTION 1 Measuring Motion *continued*



This cyclist moves faster and faster as he peddles his bike south.

TAKE A LOOK

10. Identify Is the cyclist accelerating? How do you know?

What Is Acceleration?

Acceleration is how quickly velocity changes. An object accelerates if its speed changes, its direction changes, or both its speed and direction change.

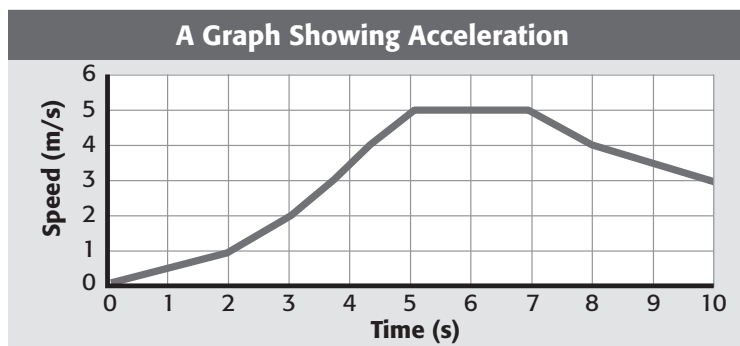
The units for acceleration are the units for velocity divided by a unit for time. The resulting unit is often meters per second per second ($m/s/s$ or m/s^2).

Looking at the figure above, you can see that the speed increases by $1\ m/s$ during each second. This means that the cyclist is accelerating at $1\ m/s^2$.

An increase in speed is referred to as *positive acceleration*. A decrease in speed is referred to as *negative acceleration* or *deceleration*. ✓

Acceleration can be shown on a graph of speed versus time. Suppose you are operating a remote control car. You push the lever on the remote to move the car forward. The graph below shows the car's acceleration as the car moves east. For the first 5 s, the car increases in speed. The car's acceleration is positive because the speed increases as time passes.

For the next 2 s, the speed of the car is constant. This means the car is no longer accelerating. Then the speed of the car begins to decrease. The car's acceleration is then negative because the speed decreases over time.



The graph of speed versus time also shows that the acceleration of the car was positive and negative. Between 5 s and 7 s, it had no acceleration.

READING CHECK

11. Explain What happens to an object when it has negative acceleration?

Math Focus

12. Interpret Graphs Is the slope positive or negative when the car's speed increases? Is the slope positive or negative when the car's speed decreases?

Section 1 Review

NSES PS 2a

SECTION VOCABULARY

acceleration the rate at which the velocity changes over time; an object accelerates if its speed, direction, or both change

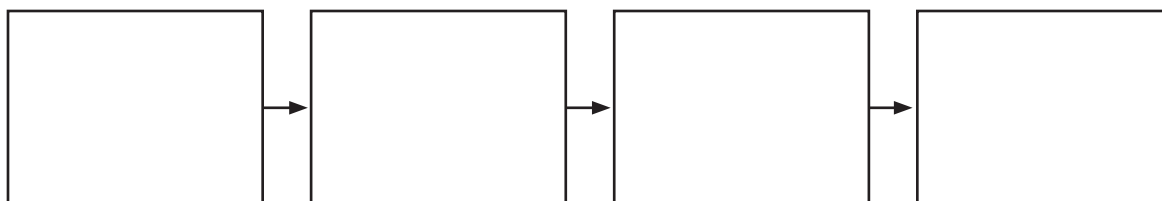
speed the distance traveled divided by the time interval during which the motion occurred

motion an object's change in position relative to a reference point

velocity the speed of an object in a particular direction

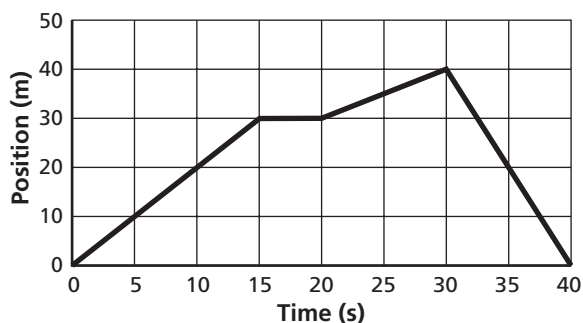
1. **Identify** What is the difference between speed and velocity?

2. **Complete a Graphic Organizer** Fill in the graphic organizer for a car that starts from one stop sign and approaches the next stop sign. Use the following terms: constant *velocity*, *positive acceleration*, *deceleration*, and *at rest*.



3. **Interpret a Graph** Describe the motion of the skateboard using the graph below. Write what the skateboard does from time = 0 s to time = 40 s.

Position Verses Time for a Skateboard



4. **Calculate** The graph above shows that the skateboard went a total distance of 80 m. What was the average speed of the skateboard? Show your work.
