**Describing Motion**

**Speed and Velocity**

**Before You Read**

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you’ve read this lesson, reread the statements to see if you have changed your mind.

<table>
<thead>
<tr>
<th>Before</th>
<th>Statement</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Constant speed is the same thing as average speed.</td>
<td></td>
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<tr>
<td>4.</td>
<td>Velocity is another name for speed.</td>
<td></td>
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**Read to Learn**

**What is speed?**

How fast do you walk when you are hungry and you smell good food in the kitchen? How fast do you move when you have a difficult chore to do? Sometimes you move quickly. Other times you might move slowly. One way you can describe how fast you move is to determine your speed. **Speed** *is the measure of the distance an object travels per unit of time.*

**Units of Speed**

To calculate speed, divide the distance traveled by the time it takes to travel that distance. The units of speed are units of distance divided by units of time. The SI unit for speed is meters per second (m/s).

There are other units of speed. Different units of distance and time can be used to express the speed an object is moving. The speed of an airplane might be expressed in kilometers per hour (km/h). The speed of a car on a highway might be expressed in miles per hour (mph).

The typical speed of an airplane can be expressed as 245 m/s, or 882 km/h, or 548 mph. Similarly, the typical speed of a person walking can be expressed as 1.3 m/s, or 4.7 km/h, or 2.9 mph.
Constant Speed

What happens to a car’s speed as the driver moves from one place to another? If the car is traveling on a highway, it might move at a steady speed. As a car moves away from a stop sign, the car’s speed increases. The driver slows the car down to pull into a parking space.

Think specifically about a time when a car’s speed does not change. For example, the car in the top figure is moving at the same speed. In 1 s, the car moves 11 m. In 2 s, it moves 22 m. Each second, the car moves 11 m. Because the car moves the same distance each second, its speed is not changing. The speed of the car is constant. **Constant speed** is the rate of change of position in which the same distance is traveled each second. The car is moving at a constant speed of 11 m/s.

Changing Speed

The bottom half of the figure shows a car moving away from a stop sign with increasing speed. Between 0 s and 2 s, the car at the bottom travels about 10 m. However, between 4 s and 6 s, the car travels more than 30 m. The car travels a different distance each second. Its speed is changing.

If an object’s speed is not constant, you might want to know its speed at a certain moment. **Instantaneous speed** is speed at a specific instant in time. You can see a car’s instantaneous speed on its speedometer.

**Visual Check**

2. **Identify** Look at the speedometer of the bottom car. What is its instantaneous speed at 6 s?

**Reading Check**

3. **Calculate** How would the distance the car travels each second change if it were slowing down?
Average Speed

Describing an object’s speed is easy if the speed is constant. But how can you describe the speed of an object when it is speeding up or slowing down? One way is to calculate the object’s average speed. **Average speed is the total distance traveled divided by the total time taken to travel that distance.**

The SI unit for speed, meters per second (m/s), is used in the equation below. You can use the equation to calculate average speed. You could use other units of distance and time, such as kilometers and hours, in the average speed equation.

**Average Speed Equation**

\[
\text{average speed (in m/s)} = \frac{\text{total distance (in m)}}{\text{total time (in s)}}
\]

**Distance-Time Graphs**

During the Kentucky Derby, horses run a distance of 2 km. The speed of the horses changes many times during the race. You can create a graph that charts these changes in speed. But sometimes it is helpful to graph an object’s motion if its speed does not change.

The graph below describes what the motion of horse A and horse B might be if their speeds did not change. Notice that distance measurements are made every 20 seconds. Follow the height of the line from the left side of the graph to the right side. You can see how the distance that each horse ran changed over time.

Graphs like the one on the left show how one measurement compares to another. In the study of motion, the two measurements that are compared are time and distance. Graphs that show comparisons between time and distance are called distance-time graphs. Notice that the change in the distance the horses ran around the track is the same each second on the graph. This means the horses were moving at a constant speed. Constant speed is shown as a straight line on distance-time graphs.

**Visual Check**

5. **Apply** How far did Horse A travel in 80 s?

**Reading Check**

6. **State** How is constant speed shown on a distance-time graph?
Comparing Speeds on a Distance-Time Graph

You can use distance-time graphs to compare the motion of two objects. The distance-time graph on the previous page compares the motion of two horses that ran the Kentucky Derby.

The motion of horse A is shown by the solid line. The motion of horse B is shown by the dashed line. When horse A reached the finish line at 2 km from the starting point, horse B was 1.5 km from the starting point of the race.

Recall that average speed is distance traveled divided by time. Horse A traveled a greater distance than horse B in the same amount of time. This means that horse A had greater average speed.

Compare how steep the lines are on the graph. The measure of steepness is the slope. The line for horse A is steeper than the line for horse B. Steeper lines on distance-time graphs indicate faster speeds.

Using a Distance-Time Graph to Calculate Speed

You can use distance-time graphs to calculate the average speed of an object. The graph below represents the motion of a trail horse traveling at a constant speed. The steps on the graph explain how to calculate average speed from a distance-time graph.

Complete steps 1–4. Then divide the difference in distance by the difference in time:

300 m/60 s = 5 m/s. This value is the average speed of the horse from 60 s to 120 s.
Distance-Time Graph and Changing Speed

A straight line on a distance-time graph means that the object moved at a constant speed. The graph for the motion of a train is shown below. The graph is different because the speed of the train is not constant. The train speeded up, slowed down, and stopped. When the changes in speed are graphed, the train’s motion is shown as a curved line.

Slowing Down Notice the shape of the solid line on the graph. The line rises steeply at first. Then it levels off between 2 and 3 minutes. This means that the train is slowing down.

Stopping Between 3 and 5 minutes, the graph line is horizontal. The train’s distance from the starting point remains at 4 km. This horizontal line means that there is no motion. The train stopped between minutes 3 and 5.

Speeding Up Between about 5 minutes and 10 minutes, the slope of the line increases. The upward curve means that the train was speeding up.

Average Speed Even when an object’s speed is not constant, you can calculate its average speed from a distance-time graph. To calculate the average speed between any two points on the graph, follow these steps:

- Choose a starting point and ending point.
- Figure the change in distance between the two points.
- Figure the change in time between the two points.
- Substitute these values into the average speed equation.

The slope of the dashed line shown above represents the train’s average speed between 0 minutes and 10 minutes.
Velocity

Describing the speed of a moving object does not completely describe its motion. Motion is more than just speed. It also includes direction. **Velocity is the speed and the direction of a moving object.**

**Representing Velocity**

In Lesson 1, an arrow represented the displacement of an object from a reference point. An arrow can also be used to represent the velocity of an object. The length of the arrow indicates the speed. A greater speed is shown by a longer arrow. The arrow points in the direction of the object’s motion.

Imagine two people walking in the same direction at the same speed. They would have equal velocities. Arrows representing the people would point in the same direction and be the same length. But if the people were walking in opposite directions at the same speed, they would have different velocities. Arrows representing them would be the same length but be pointing in opposite directions.

**Changes in Velocity**

Look at the bouncing ball in the figure below. The arrows show the velocity of the ball. From one position to the next, the arrows change direction and length. This means that the velocity is changing. Velocity changes when the speed changes, the direction changes, or both the speed and the direction change. The velocity of the ball changes continually because both the speed and the direction of the ball change as the ball bounces.

**Key Concept Check**

10. **Explain** How can velocity change?

**Visual Check**

11. **Identify** Are there any positions of the bouncing ball in which the velocity is the same? Explain.

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**Diagram:**

![Diagram of a bouncing ball showing velocity vectors at different positions.](image-url)
Mini Glossary

**average speed:** the total distance traveled divided by the total time taken to travel that distance

**speed:** the measure of the distance an object travels per unit of time

**constant speed:** the rate of change of position in which the same distance is traveled each second

**velocity:** the speed and the direction of a moving object

**instantaneous speed:** the speed at a specific instant in time

1. Review the terms and their definitions in the Mini Glossary. Write a one-sentence example of two objects traveling at the same speed but with different velocities.

2. On the graph below, find point (20, 200). Label it A. Next find point (40, 400). Label it B. Draw a dotted line from point A along the 200 km line to the 40 s line. Next, draw a dotted line from point B along the 40 s line to the 200 km line. Use this graph to solve for average speed.

   ![Graph](image)

   a. Difference in distance between points A and B: ____________

   b. Difference in time between points A and B: ____________

   c. Average speed = ____________ ÷ ____________

   d. Average speed = ____________ km/s

3. Which idea that you and your partner discussed was hardest to understand? Write a question and the answer on the lines below to show that you understand the idea.

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**What do you think?**

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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