CHAPTER 2

Motion

What You'll Learn

- the difference between displacement and distance
- how to calculate an object's speed
- how to graph motion

1 Describing Motion

TEKS 2(D), 4(A), 4(B)

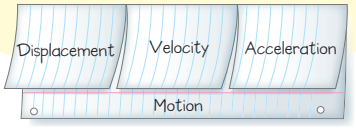
Before You Read

Have you ever been on a roller coaster? You can feel the steep drops and quick turns in your body. Write how it feels to travel up a steep hill slowly and then to go down the other side quickly.

Focus →
Highlight the main point in each paragraph in this section. Highlight in a different color a detail or example that helps explain a point.

FOLDABLES® Study Organizer

Find Main Ideas Make a three-tab book. Label it as shown. Use it to organize your notes about motion.



Read to Learn

Motion and Position

Distance and time are important in describing a race. The winner covers the distance in the shortest amount of time. It takes more time to run a 10-km race than to run a 5-km race because 10-km is a longer distance.

How are motion and position related?

You don't need to see something move to know that it has moved. Suppose you see a mail truck stopped next to a mailbox. When you look again later, the truck is farther down the street by a tree. You didn't see the truck move, but you know that motion has taken place because of the truck's new position.

What is a reference point?

A reference point is needed to determine the position of an object. Motion occurs when an object goes from one reference point to another. In the example above, the mailbox was the first reference point for the mail truck. The tree was the second reference point.

After a reference point is chosen, a frame of reference can be created. A frame of reference is a coordinate system in which the position of the objects is measured. A coordinate system is like a map. The reference point is at the origin and each object's position can be described with its coordinates.

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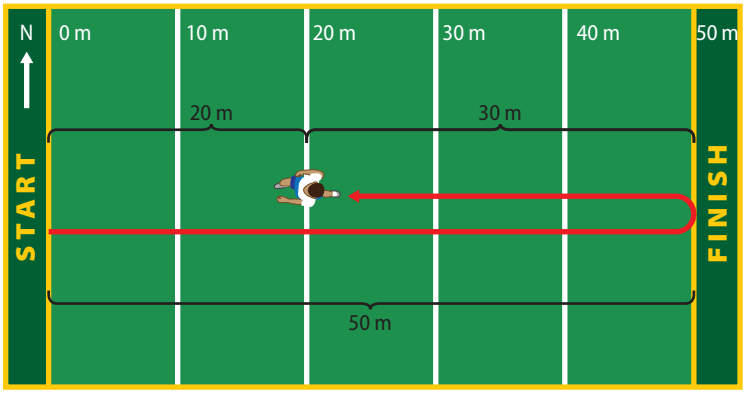
Change in Position

Distance is how far something has moved. It is important in describing motion. In the 50-m dash, a runner travels 50 m between the start line and the finish line. The distance is 50 m.

The SI unit of length or distance is the meter (m). Long distances are measured in kilometers (km). One kilometer is equal to 1,000 meters. Short distances are measured in centimeters (cm). One meter is equal to 100 centimeters.

Not all motion is in a straight line. In the figure, the runner jogged 50 m to the east. Then she turned around and jogged 30 m to the west. The total distance she jogged is 80 m. She is 20 m from the starting point. **Displacement** is the distance and direction of an object's position relative to the starting point. The runner's displacement is 20 m east.



Take a Look

1. **Describe** another way a runner could have a displacement of 20 m east.

Speed

So far, motion has been described by the distance something has moved and by displacement from the starting point. You might also want to tell how fast something is moving. To do this, you need to know how far it travels in a certain amount of time. **Speed** is the distance an object travels per unit of time.

How is speed calculated?

The SI unit of distance is the meter (m). The SI unit of time is the second (s). So, in SI, speed is measured in meters per second (m/s). Sometimes it is easier to express speed in other units so that the numbers will not be very large or very small. Something that moves very quickly, such as a rocket, can be measured in kilometers per second (km/s). Very low speeds, such as geological plate movements, can be measured in centimeters per year (cm/y).

To calculate the speed of an object, divide the distance it traveled by the time it took to travel the distance. Here is a formula for calculating speed.

$$\text{speed (in meters/second)} = \frac{\text{distance (in meters)}}{\text{time (in seconds)}}, \; s = \frac{d}{t}$$

Apply Math

2. **Calculate** A train traveling at a constant speed covers a distance of 960 meters in 30 s. What is the train's speed? Show your work.

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What is motion with constant speed?

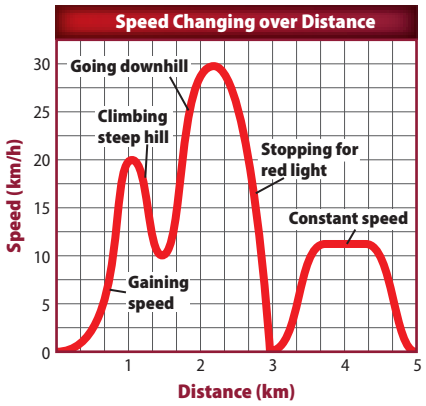
A speedometer measures the speed of a car. Suppose you look at the speedometer when you are riding on a freeway. The car's speed hardly changes. If the car is not speeding up or slowing down, it is moving at a constant speed. If you are traveling at a constant speed, you can measure your speed over any distance from millimeters to light years.

What is changing speed?

Usually, speed is not constant. The graph below shows how the speed of a cyclist changes during a 5-km ride. Follow the graph as the ride is described. As the cyclist starts off, his speed increases from 0 km/h to 20 km/h. Then he comes to a steep hill. He slows down to 10 km/h as he pedals up the hill. He speeds up to 30 km/h going down the other side of the hill. At the bottom, he stops for a red light. He speeds up when the light turns green. At the end of the ride, he slows down and then stops. The ride took 15 min.

Take a Look

3. **Describe** what is happening when the line on the graph is horizontal.



What is average speed?

Look at the graph of speed for the bicycle trip. Sometimes the bicycle was moving fast, sometimes it was moving slowly, and sometimes it was stopped. How could you describe the speed of the whole ride? Would you use the fastest speed or the slowest?

Average speed describes the speed of motion when speed is changing. **Average speed** is the total distance traveled divided by the total time of travel. It is calculated using the relationships among speed, distance, and time.

The total distance the cyclist traveled was 5 km. The total time was 15 minutes, or $\frac{1}{4}$ h. You can write $\frac{1}{4}$ h as 0.25 h. The average speed for the bicycle trip can be found using a mathematical equation.

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{5 \text{ km}}{0.25 \text{ h}} = 20 \text{ km/h}$$

Apply Math

4. **Find** the average speed in kilometers per hour of a race car that travels 260 km in 2 h.

$s = \frac{260}{2}$

$s =$ _____ km/h

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What is instantaneous speed?

The speed shown on a car's speedometer is the speed at one point in time, or one instant. **Instantaneous speed** is the speed at one point in time. If an object is moving with constant speed, the instantaneous speed doesn't change. The speed is the same at every point in time. However, when a car speeds up or slows down, its instantaneous speed is changing. The speed is different at every point in time.

GET IT?

5. **Identify** two examples of motion in which an object's instantaneous speed changes.

Graphing Motion

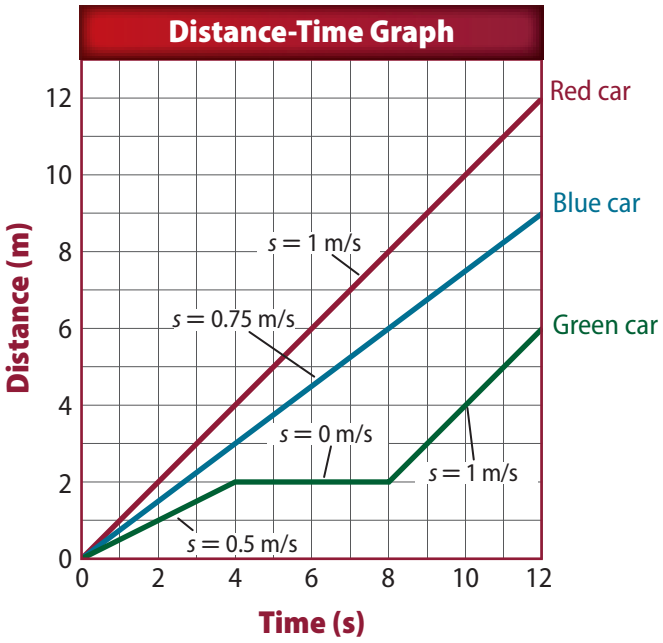
A distance-time graph shows the motion of an object over time. The graph below shows the motion of three toy cars moving across a lab floor. Time is plotted along the horizontal axis of the graph. The distance traveled is plotted along the vertical axis of the graph.

If an object moves with constant speed, the increase in distance over equal time intervals is the same. This results in a straight line on a distance-time graph. Look at the graph below. The straight red line represents the motion of the red car. The red car traveled at a constant speed of 1 m/s.

The blue line is also straight. This means that the blue car was also moving at a constant speed. The red and blue lines are different because the red and blue cars were moving at different speeds. The blue car had a slower speed than the red car. It moved at 0.75 m/s. The steepness of a line on a graph is the line's slope. The slope of a line on a distance-time graph equals the object's speed. The steeper the line, the faster the speed.

Apply Math

6. **Explain** why the slopes are different for each car.



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How is changing speed graphed?

Look back at the graph of the three cars. Unlike the other lines, the line for the green car is not straight. The green car traveled at a constant speed of 0.5 m/s for 4 seconds. Then, the green car stopped for 4 seconds. After that, the green car moved at a constant speed of 1 m/s for 4 seconds.

When the green car was stopped, its line is horizontal. A horizontal line on a distance-time graph has a zero slope. A zero slope means the object has a speed of 0 m/s.

Think it Over

7. **Recall** The vertical axis is called the *y*-axis. What is the horizontal axis called?

How do you draw a distance-time graph?

A distance-time graph plots data for distance and time. The distance traveled is plotted on the vertical axis. Time is plotted on the horizontal axis. Each axis has a scale, or a series of numbers, that covers the range of the data.

The data for the toy cars' movements were recorded for 12 seconds. The time scale for the graph must range from 0 to 12 s. The red car traveled the farthest. Since the red car traveled 12 meters, the distance scale must range from 0 to 12 m. Both the *x*-axis and the *y*-axis must be divided into equal intervals. Then, the data points are plotted on the graph. Finally, lines are drawn to connect the points.

What is a coordinate system?

When you use a map to locate a small town in a different state, you may not know where to look at first unless you have some additional information. Maps are set up with coordinate systems and an index of the towns on the map. Suppose you look up the town and next to it is the notation L6. You look on the map and see that along the top of the map are the letters of the alphabet. Along the side of the map are numbers. Using the L6 information you follow the imaginary line that passes through L down the map until it crosses the imaginary line running across the map from 6. Close to the point where they cross you should see the town.

How can you use coordinates and displacement?

Suppose you want to travel by bus from city A to city B on the map. City A is your starting point and City B is where you want to end up. In other words, City B is the displacement of the bus. The coordinate system of the map tells you what direction and how great the displacement of the bus needs to be to reach city B.

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After You Read

Mini Glossary

average speed: the total distance traveled in a unit of time

displacement: the distance and direction that something moved from a starting point

distance: a measure of how far an object has moved

instantaneous speed: the speed of an object at a one point in time

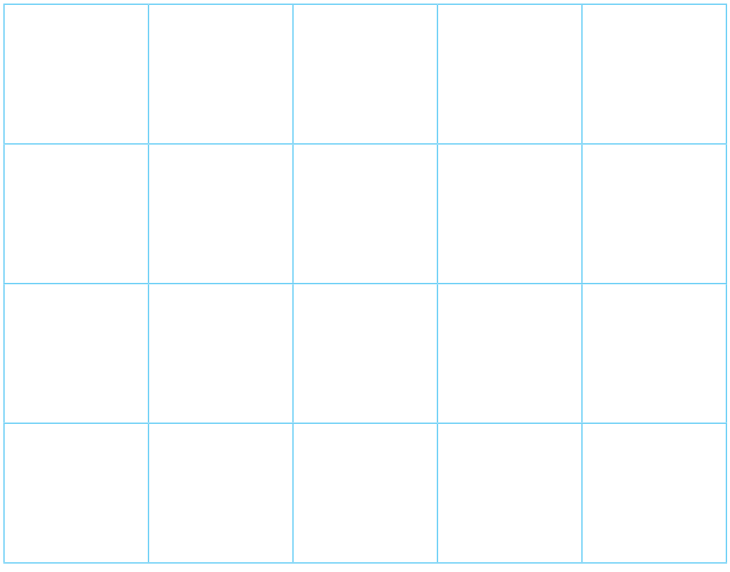
speed: the distance an object travels in an amount of time

Review

1. Use the data below to make a distance-time graph. Be sure to include labels and scales.

Bike Ride

Time (min)	Distance (m)
15	150
30	300
45	450
60	600



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