Name _____ Class _____ Date _____

CHAPTER 11 Motion

SECTION 2

Acceleration

KEY IDEAS

As you read this section, keep these questions in mind:

- What two things may change when an object accelerates?
- How can you calculate constant acceleration?
- How can graphs show acceleration?

How Is Acceleration Related to Velocity?

Acceleration occurs when an object changes velocity. Remember that velocity has both a speed and a direction. Therefore, acceleration also has two components: a magnitude and a direction. When the speed or the direction of an object changes, the object is accelerating.

READING TOOLBOX

Define As you read this section, underline any words you don't know. When you learn what they mean, write the words and their definitions in your notebook.

ACCELERATION AND SPEED

An object that changes speed is accelerating. An accelerating object may speed up or slow down. An object that is speeding up has a positive acceleration. An object that is slowing down has a negative acceleration. ☑

READING CHECK

1. Describe A car slows down as it comes up to a stop sign. Is its acceleration positive or negative?

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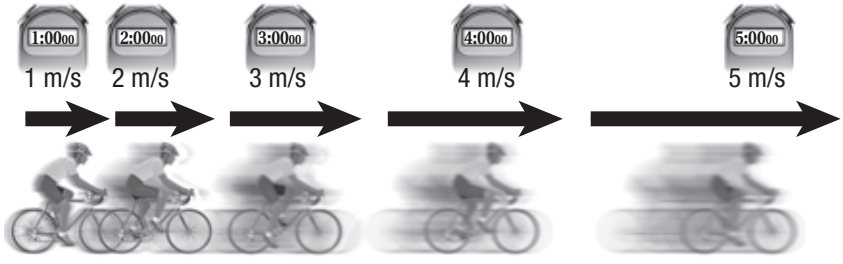
Suppose a cyclist starts peddling south and speeds up down the road. Every second, the velocity of the cyclist increases by 1 m/s. After 1 s, the cyclist's velocity is 1 m/s south. After 2 s, the cyclist's velocity is 2 m/s south. After 5 s, the cyclist's velocity is 5 m/s south.

You can describe the cyclist's acceleration by saying that his velocity is increasing by one meter per second per second (1 m/s/s or 1 m/s^2). In this case, the cyclist is speeding up. Therefore, his acceleration is +1 m/s^2 south.



This cyclist's speed increases by 1 m/s every second. Therefore, his acceleration is 1 m/s/s, or 1 m/s^2.

LOOKING CLOSER

2. Identify Relationships What happens to the cyclist's speed as time increases?

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Talk About It

Brainstorm Make a list of 10 examples of acceleration. With a partner or in a small group, identify how velocity is changing in each example.

ACCELERATION AND DIRECTION

An object that changes direction is accelerating, even if its speed is constant. For example, the skaters in the figure below are moving at a nearly constant speed. However, they must change direction to stay on the track. As they go around the curves in the track, they accelerate.

As these skaters change direction, they accelerate, even if their speed doesn't change.

LOOKING CLOSER

3. Identify Give two ways the skaters may be accelerating.

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CENTRIPETAL ACCELERATION

Imagine moving at a constant speed in a circle. At each point in the circle, your direction is changing. Therefore, you are constantly accelerating, even though your speed does not change. You are experiencing centripetal acceleration. *Centripetal acceleration* is the acceleration that occurs when an object moves in a circular path. ☑

READING CHECK

4. Explain How can an object moving in a circular path be accelerating if its speed does not change?

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You may think that centripetal acceleration is not very common. In fact, you and everything around you are experiencing centripetal acceleration right now. This is because Earth is rotating on its axis. As Earth rotates, its surface—and everything on it—travels in a circular path. Therefore, it experiences centripetal acceleration.

Earth itself also experiences centripetal acceleration as it orbits the sun. Our moon is constantly accelerating as it orbits Earth. In fact, every object that orbits another object is experiencing centripetal acceleration.

How Can You Calculate Acceleration?

For an object moving in a straight line, acceleration occurs only because of changes in speed. Therefore, you can calculate the object's acceleration if you know its speed at two different times. You can use the equation below to calculate acceleration:

$$acceleration = \frac{final\ speed - initial\ speed}{time}$$

$$a = \frac{\Delta v}{t}$$

In this equation, the symbol "delta" (Δ) means "change in." You calculate acceleration by dividing the change in speed by the time in which the change occurred.

If the acceleration is small, the velocity is changing slowly. For example, a person can accelerate at about 2 m/s^2. If the acceleration is large, the velocity is changing more quickly. A sports car can accelerate at about 7.2 m/s^2.

CALCULATING ACCELERATION FROM VELOCITY

Let's look at an example. A cyclist slows along a straight line from 5.5 m/s to 1.0 m/s in 3.0 s. What is the average acceleration of the cyclist?

Step 1: List the given and unknown values.	**Given:** initial speed, $v_i = 5.5$ m/s final speed, $v_f = 1.0$ m/s time, $t = 3.0$ s	**Unknown:** acceleration, a
Step 2: Write the equation.	$a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t}$	
Step 3: Insert the known values and solve for the unknown value.	$a = \frac{1.0\ \text{m/s} - 5.5\ \text{m/s}}{3.0\ \text{s}}$ $a = \frac{-4.5\ \text{m/s}}{3.0\ \text{s}}$ $a = -1.5\ \text{m/s}^2$	

So, the cyclist accelerated at –1.5 m/s^2. The acceleration was negative because the cyclist was slowing down. Her initial, or starting, speed was higher than her final speed.

Critical Thinking

5. Infer Can you use the equation to the left to calculate centripetal acceleration? Explain your answer.

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Math Skills

6. Calculate A turtle swimming in a straight line toward shore has a speed of 0.50 m/s. After 4.0 s, its speed is 0.80 m/s. What is its average acceleration? Show your work.

How Can You Graph Accelerated Motion?

Remember that you can determine the speed of an object by examining a graph of distance versus time. Similarly, you can determine an object's acceleration by examining a graph of speed versus time.

A straight line on a graph of speed versus time indicates a constant acceleration. *Constant acceleration* is acceleration that does not change with time. The slope of a straight line on a graph of speed versus time is equal to an object's acceleration. A line with a positive slope indicates that the object is speeding up. A line with a negative slope indicates that the object is slowing down. Let's look at an example of how to graph accelerated motion. ☑

READING CHECK

7. Define What is constant acceleration?

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Imagine a bus traveling on a straight road at 20 m/s. For the first 20 s, the bus slows to a stop at a constant rate. The bus stays stopped for 20 s. For the next 10 s, the bus accelerates at 1.5 m/s^2. For the last 10 s, the bus continues at a constant speed. Graph the speed of the bus versus time from 0 s to 60 s. What is the bus's acceleration from 0 s to 20 s? What is its final speed?

Step 1: Determine the x-axis and y-axis of the graph. Here, the x-axis is time (t) in seconds and the y-axis is speed (v) in meters per second.

Step 2: Starting from the origin, graph each part of the motion. (The graph is shown at the top of the next page.)

A. The bus began at t = 0 s and v = 20 m/s. It slowed with a constant acceleration to t = 20 s and v = 0 m/s. Draw a straight line connecting these two points.

B. From 20 s to 40 s, the bus's speed was 0 m/s. Draw a horizontal line at v = 0 m/s from t = 20 s to t = 40 s.

C. From 40 s to 50 s, the bus accelerated at 1.5 m/s^2. Draw a line from t = 40 s and v = 0 m/s with a slope of 1.5 m/s^2. End the line at t = 50 s.

D. From 50 s to 60 s, the bus's speed was constant. Draw a horizontal line from t = 50 s to t = 60 s at v = 15 m/s.

Graphing Skills

8. Explain Why should you use a horizontal line to indicate where the bus is not accelerating?

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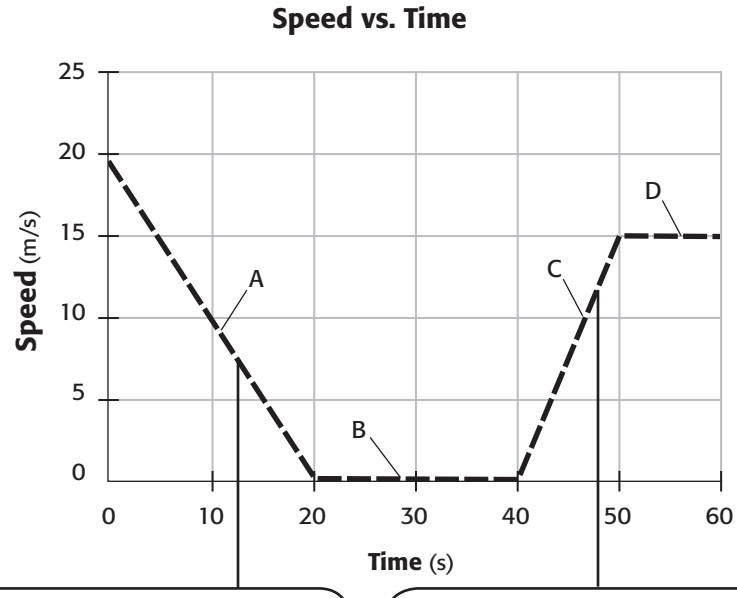
Step 3: Read the graph to determine the bus's acceleration and final speed. The acceleration between 0 s and 20 s is equal to the slope of the line between these two points. Therefore, the acceleration was –1 m/s^2. From the graph, you know that the bus was traveling 15 m/s at t = 50 s. Therefore, the bus's final speed was 15 m/s.



The slope of this part of the graph is –1 m/s². Therefore, the bus's acceleration during this time period was –1 m/s². Because the bus's acceleration was constant, this part of the graph is a straight line.

From 40 s to 50 s, the bus accelerated at 1.5 m/s². Therefore, its speed increased by (1.5 m/s²) × (10 s) = 15 m/s. Since its starting speed was 0 m/s, its final speed was 15 m/s.

Graphing Skills

9. Apply Concepts Suppose the bus accelerated at 1.0 m/s² from 40 s to 50 s. Draw a line showing this acceleration.

10. Calculate What would be the bus's speed at 50 s if the bus accelerated at 1.0 m/s² from 40 s to 50 s?

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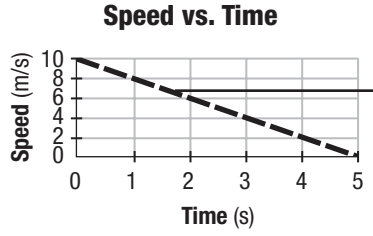
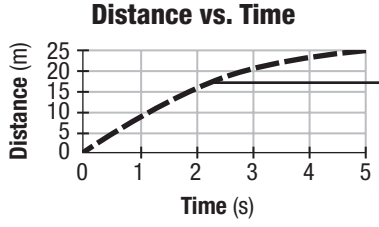
DETERMINING ACCELERATION FROM DISTANCE VERSUS TIME GRAPHS

You've just seen that you can determine whether an object is accelerating by examining a graph of speed versus time. You can also identify acceleration by examining a graph of distance versus time. On a graph of distance versus time, a curved line indicates acceleration. For example, compare the two graphs in the figure below. They show the motion of a bicyclist in a race.



On a speed versus time graph, the bicyclist's motion is a straight line with a negative slope. Therefore, the bicyclist was slowing down with a constant acceleration.



On a distance versus time graph, the bicyclist's motion is a curved line. The curve of the line indicates that the bicyclist was accelerating.

LOOKING CLOSER

11. Explain Is the bicyclist speeding up or slowing down? Explain your answer.

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Name _____ Class _____ Date _____

Section 2 Review

SECTION VOCABULARY

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

1. Explain Why is a fan blade spinning at a constant speed constantly accelerating?

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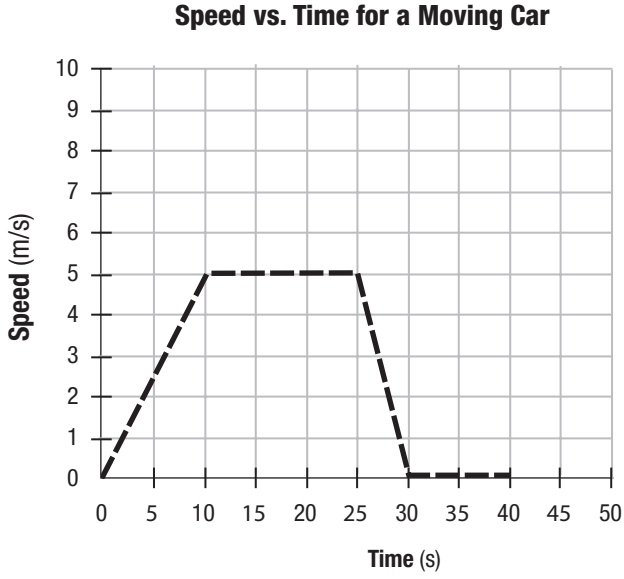
2. Graph The graph below shows speed versus time for a car traveling in a straight line. From 40 s to 50 s, the car accelerated at a constant rate of 1 m/s^2. Complete the graph to show this information.



3. Interpret Based on the graph above, what is the car's acceleration between 25 s and 30 s? Explain your answer.

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4. Calculate Based on the graph above, what is the car's acceleration between 10 s and 25 s? Explain your answer.

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