# chapter 2 Motion

## section 3 Acceleration

### What You'll Learn

- how acceleration, time, and velocity are related
- the different ways an object can accelerate
- how to calculate acceleration
- the similarities and differences between straight line motion, projectile motion, and circular motion

## Before You Read

Describe what happens to the speed of a bicycle as it goes uphill and downhill.

## Read to Learn

### Velocity and Acceleration

A car sitting at a stoplight is not moving. When the light turns green, the driver presses the gas pedal and the car starts moving. The car moves faster and faster. Speed is the rate of change of position. **Acceleration** is the rate of change of velocity. When the velocity of an object changes, the object is accelerating.

Remember that velocity is a measure that includes both speed and direction. Because of this, a change in velocity can be either a change in how fast something is moving or a change in the direction it is moving. Acceleration means that an object changes it speed, its direction, or both.

#### How are speeding up and slowing down described?

When you think of something accelerating, you probably think of it as speeding up. But an object that is slowing down is also accelerating. Remember that acceleration is a change in speed. A car that is slowing down is decreasing its speed. It is also accelerating, because its speed is changing.

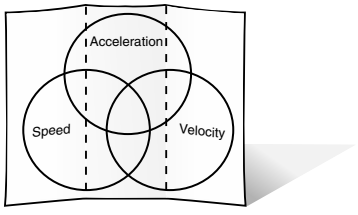
Imagine a car being driven down a road. If the speed is increasing, the car has positive acceleration. When the car slows down, the speed decreases. The decreasing speed is called negative acceleration. In both cases, the car is accelerating, but one acceleration is positive and one is negative.

**Study Coach**

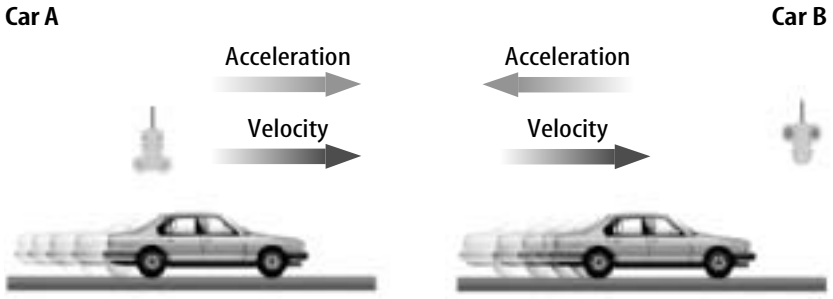
**Outlining** As you read the section, make an outline of the important information in each paragraph.

**FOLDABLES**

**Construct a Venn Diagram** Make the following trifold Foldable to compare and contrast the characteristics of acceleration, speed, and velocity.



Acceleration has direction, just like velocity. In the figure below, both cars are accelerating because their speeds are changing. When a car's acceleration and velocity are in the same direction, the speed increases and the acceleration is positive. Car A has positive acceleration. When a car is slowing down, the acceleration and velocity are in opposite directions. The acceleration is negative. Car B has negative acceleration.




## Does changing direction affect acceleration?

A change in velocity is either a change in an object's speed or its direction. When a moving object changes direction, its velocity changes and it is accelerating. The speed of a horse moving around on a carousel remains constant, but it is constantly changing direction. So, the horse is accelerating.

## How do you calculate acceleration?

Acceleration is the rate of change in velocity. To calculate acceleration, you first find the change in velocity. To find change in velocity subtract the beginning velocity of an object from the velocity at the end of its movement. Beginning velocity is called the initial velocity, or $v_i$. Velocity at the end is called the final velocity, or $v_f$.

$$\textbf{change in velocity} = \textbf{final velocity} - \textbf{initial velocity}$$
$$= v_f - v_i$$

If motion is in a straight line, the change in speed can be used to calculate the change in velocity. The change in speed is the final speed minus the initial speed.

To find acceleration, divide the change in velocity by the length of time during which the velocity changed.

$$\textbf{acceleration } (a) = \frac{\textbf{change in velocity}}{\textbf{time } (t)} \quad \text{or} \quad a = \frac{(v_f - v_i)}{t}$$

The SI unit for velocity is meters per second (m/s). To find acceleration, velocity is divided by the time in seconds (s). So, the unit for acceleration is $m/s^2$.

## Picture This

1. **Describe** the acceleration of the cars in each figure.

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**Reading Check**

2. **Use Variables** Write what $v_f$ and $v_i$ mean.

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**Applying Math**

3. **Calculate** Suppose a bird takes off from a tree and flies in a straight line. It reaches a speed of 10 m/s. What is the change in the bird's velocity?

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## How is positive acceleration calculated?

How is the acceleration of an object that is speeding up different from that of an object that is slowing down? The acceleration of an object that is speeding up is always positive. The acceleration of an object that is slowing down is always negative.

Suppose an airplane is sitting at the end of a runway. The plane takes off and moves down the runway. It takes 20 s for the plane to travel from one end of the runway to the other. When the airplane reaches the end of the runway, it is traveling 80 m/s. The airplane is traveling in a straight line. The initial velocity of the plane is 0 m/s and the final velocity of the plane is 80 m/s. The time is 20 seconds. The acceleration for the plane can be calculated as follows:

$$a = \frac{(v_f - v_i)}{t} = \frac{(80 \text{ m/s} - 0 \text{ m/s})}{20 \text{ s}} = 4 \text{ m/s}^2$$

The airplane is speeding up as it goes down the runway. The final speed is greater than the initial speed. The acceleration is positive.

**Applying Math**

**4. Explain** Why is the acceleration of an object moving at a constant velocity always 0?

## How is negative acceleration calculated?

Now imagine a skateboarder moving in a straight line. The skateboarder is moving at a speed of 3 m/s. It takes the person 2 s to come to a stop. The initial velocity is 3 m/s and the final velocity is 0 m/s. The total time is 2 seconds. The calculation for the skateboarder's acceleration is as follows:

$$a = \frac{(v_f - v_i)}{t} = \frac{(0 \text{ m/s} - 3 \text{ m/s})}{2 \text{ s}} = -1.5 \text{ m/s}^2$$

The skateboarder is slowing down. The final speed is less than the initial speed. The acceleration has a negative value.

**Think it Over**

**5. Think Critically** A car that is slowing down is still moving forward. Why is this considered negative acceleration?

## Amusement Park Acceleration

Roller coasters are exciting rides. People who design roller coasters use the laws of physics. The steep drops and loops of steel roller coasters give the rider large accelerations. When riders move down a steep hill, gravity will cause them to accelerate toward the ground. When riders go around a sharp turn, they are also accelerated. This acceleration makes them feel as if a force were pushing them toward the side of the car.

# After You Read

## Mini Glossary

**acceleration:** the rate of change in velocity

**centripetal acceleration:** acceleration toward the center of a curved or circular path

**1.** Review the term and its definition in the Mini Glossary. Explain why a change in velocity affects acceleration.

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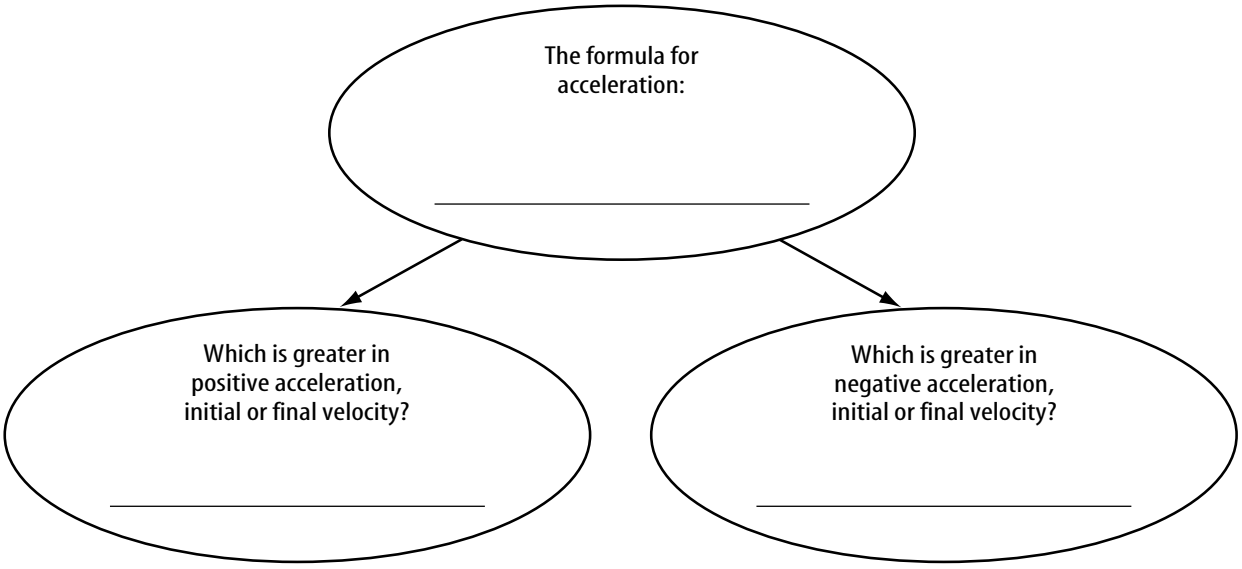
**2.** Complete the chart to organize information about how acceleration is calculated.




**3.** Study Coach As you read the section, you made an outline describing the points covered in each paragraph. How did you decide what to write as the major points in your outline?

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End of Section