chapter 2 Motion

section 2 Velocity and Momentum

What You'll Learn

- the difference between speed and velocity
- how to describe the motion of two objects relative to each other
- how to calculate an object's momentum

Before You Read

If an object is moving at 2 m/s towards a porcelain vase, do you think it will have enough momentum to break the vase? Explain.

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Read to Learn

Study Coach

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

Velocity

Suppose you hear that there is a storm nearby. The storm is traveling at a speed of 20 km/h and is 100 km east of your location. Do you have enough information to know whether the storm will reach you?

Knowing only the speed of the storm is not enough to find the answer. The speed tells you how fast the storm is moving. To find the answer, you also need to know the direction the storm is moving. In other words, you need to know the velocity of the storm. **Velocity** is the speed of an object and the direction it is moving.

How do speed and direction affect velocity?

To help you understand velocity, think about two escalators. Some escalators go up and others go down. One escalator is moving upward at the same speed that another escalator is moving downward. The two escalators are going the same speed, but they are going in different directions. They each have a different velocity. If the second escalator were moving upward, both elevators would have the same velocity.

Think it Over

1. **Describe** how the velocity of an escalator that is going up is different from the velocity of one that is going down at the same speed.

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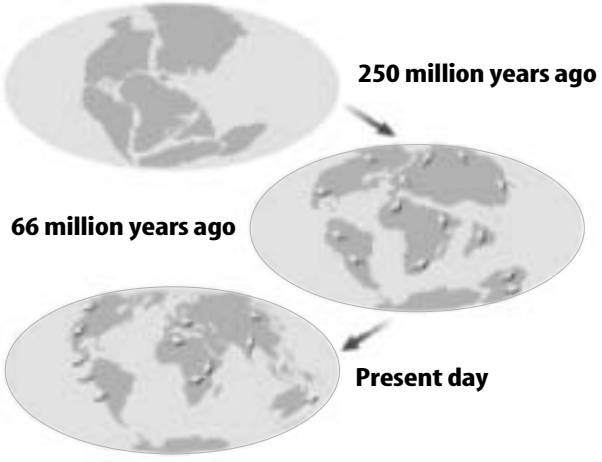
Velocity depends on both speed and direction. Because of this, an object moving at a constant speed will have a changing velocity if it changes direction. A race car on an oval track has a constant speed. But, as the race car goes around the track, the direction in which the car is moving changes. This means that the velocity of the car is changing. An object has constant velocity if neither the speed nor direction it is moving changes. The light from a laser beam travels at a constant velocity.

Motion of Earth's Crust

Some motion is so slow that it is hard to see. The surface of Earth doesn't seem to change from year to year. But if you look at geological evidence of Earth over 250 million years, you will see that large changes have occurred.

According to the theory of plate tectonics, the continents are moving constantly over Earth's surface. The movement is shown in the figure below. The changes are so slow that we do not notice them.



How do continents move?

Earth is made of layers. The top layer is the crust. The layer below the crust is the upper mantle. Together, the crust and the top part of the upper mantle are the lithosphere. The lithosphere is broken into huge sections, called plates.

Below the lithosphere, the layers are like putty. The plates slide slowly on these soft layers. The moving plates cause geological changes on Earth. These changes include the formation of mountain ranges, earthquakes, and volcanic eruptions.

The plates move very slowly. The speed of the plates is measured in centimeters per year. In California, two plates are sliding past each other along the San Andreas Fault. The average relative speed of the two plates is about 1 cm per year.

Picture This

2. **Describe** the movement of the continents over the past 250 million years.

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Think it Over

3. **Explain** Why is the speed of the movement of Earth's plates measured in centimeters per year instead of in meters per second?

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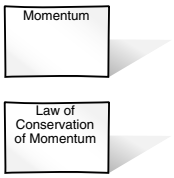
FOLDABLES™

C Finding Main Ideas
Use two quarter-sheets of notepaper to organize notes on momentum and the law of conservation of momentum.



Think it Over

4. Compare Which has more momentum, a car traveling at 12 km/h or a bicycle traveling at the same speed? Explain why.

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Applying Math

5. Apply What is the momentum of a bicycle with a mass of 18 kg traveling at 20 m/s?

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Relative motion

Not all motion is as obvious as the mail truck's motion. When you are sitting still in a desk, you appear not to be moving. However, you are moving. You are not moving in relation to your desk or school building. You are moving in relation to the Sun because you are sitting on Earth.

Relative motion means that one thing moves in relation to another thing. Earth is moving in space in relation to the Sun. The Sun is the reference point for Earth's motion.

Momentum

A moving object has a property called momentum. Momentum is related to how much force is needed to change an object's motion. The **momentum** of an object is the product of its mass and its velocity. Momentum can be found using the following equation. The symbol p represents momentum. The unit for momentum is kg•m/s.

$$\textbf{momentum}\ (\text{kg•m/s}) = \textbf{mass}\ (\text{kg}) \times \textbf{velocity}\ (\text{m/s})$$
$$p = mv$$

Two cars can have the same velocity. But the bigger car has more momentum, because it has more mass. An archer's arrow can have a large momentum because of its high velocity, even though its mass is small. A walking elephant may have a low velocity, but because of its large mass, it has a large momentum.

Suppose a sprinter with a mass of 80 kg has a speed of 10 m/s. What is the sprinter's momentum? Substitute the known values into the momentum equation.

$$\begin{aligned} p &= mv \\ &= (80\ \text{kg})(10\ \text{m/s}) \\ &= 800\ \text{kg•m/s} \end{aligned}$$

The sprinter's momentum is 800 kg•m/s.

How are force and momentum related?

Recall that acceleration is the difference between final and initial velocity, divided by the time. Also recall that the net force on an object is its mass times its acceleration. When you combine these two relationships, you get the following equation.

$$F = \frac{(mv_f - mv_i)}{t}$$

After You Read

Mini Glossary

momentum: the product of an object's mass and velocity, represented by the formula $p = mv$

velocity: the speed of an object and the direction of its motion

1. Review the terms and their definitions in the Mini Glossary. Explain how speed is related to an object's momentum.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to the question.

Question:

Answer:

3. Study Coach Think about what you have learned in this section. How did identifying the main point and supporting details of each paragraph help you learn the new material?

End of Section