Read to Learn

Main Idea **Objects that contain more matter are harder to set in motion.**

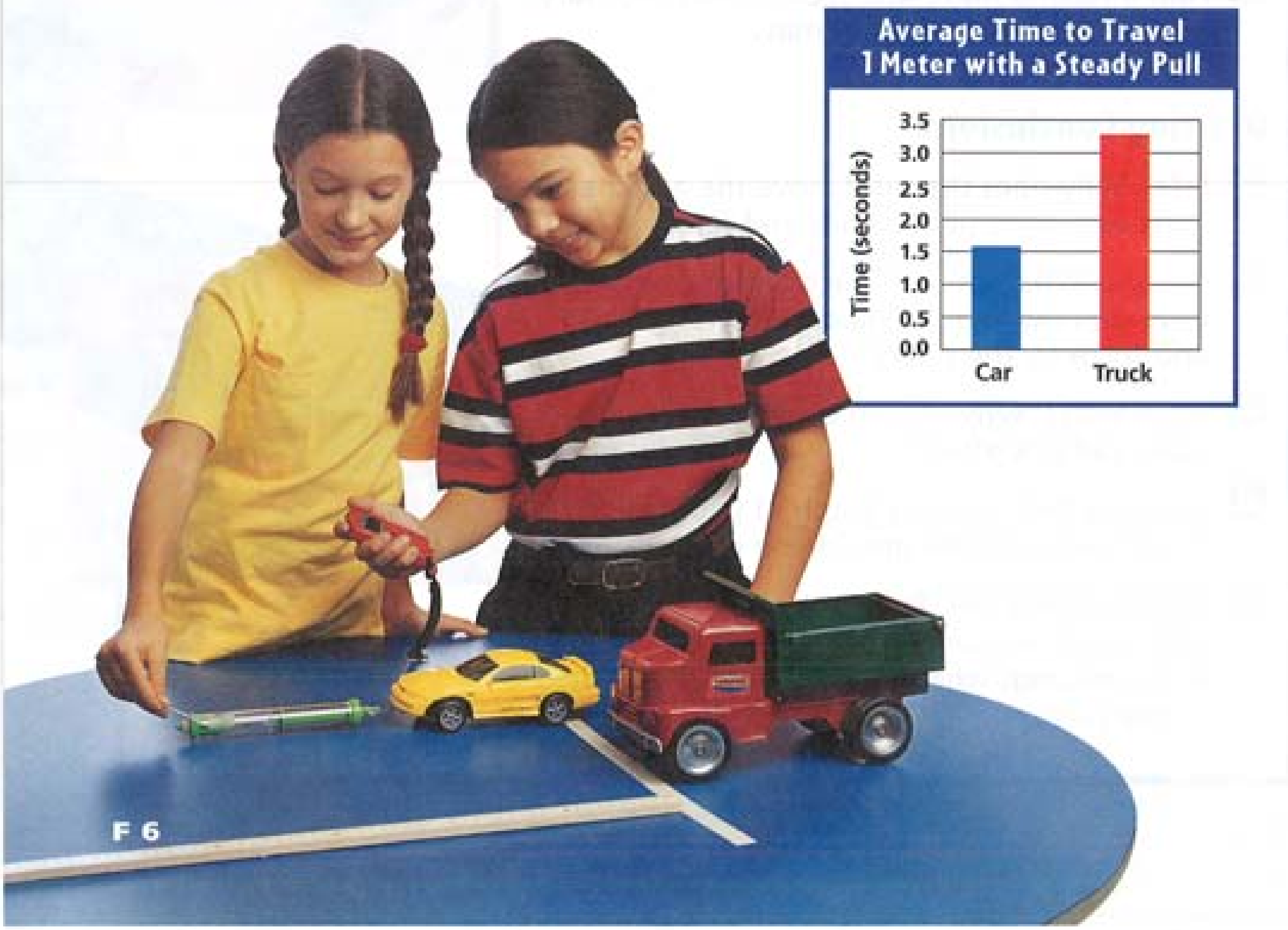
What Does it Take to Make an Object Move?

The students below are investigating how easily objects of different masses are set into motion. First, one student uses a spring scale to pull a toy car from rest through a distance of one meter (39.37 inches). As she pulls, she keeps the reading on the spring scale constant. Her teammate times how long it takes the toy car to travel one meter. Next, the students repeat the experiment using a toy truck that has three times the mass of the toy car.

The results of the experiment show that the toy car traveled the one-meter distance in a shorter time than the toy truck. The amount of pull was kept the same, so why did the car travel faster than the truck? The car traveled faster because objects with more mass are harder to set in motion with a certain push or pull than objects with less mass. The car has less mass, so the pull of the spring scale set it into more rapid motion.

A pull or push that acts on an object is called a **force**. The students' experiment shows you how forces are needed to set objects in motion. As you've seen, objects with more mass move more slowly when acted on by a certain force.

Average Time to Travel 1 Meter with a Steady Pull



An Object's Natural Motion

The mass of an object tends to make the object resist being set into motion. That's why objects with more mass are set into less rapid motion by a certain amount of force. The tendency of an object to resist a change in its state of motion is called the object's **inertia**.

Several centuries ago the famous Italian scientist Galileo began to understand how inertia affects the motion of objects. Galileo imagined rolling a ball down a fixed *incline* (ramp) and then back up ramps of varying steepness, as in the diagram. Galileo had observed that pendulums swing back and forth to the same height. He reasoned that the ball would roll to the same height on any ramp. He realized that if the ramp were less steep, the ball would roll a greater distance and slow down more gradually.

Thinking further, Galileo inferred that if the second ramp were flat, the ball would roll forever at a steady rate (assuming no force is acting on the ball).

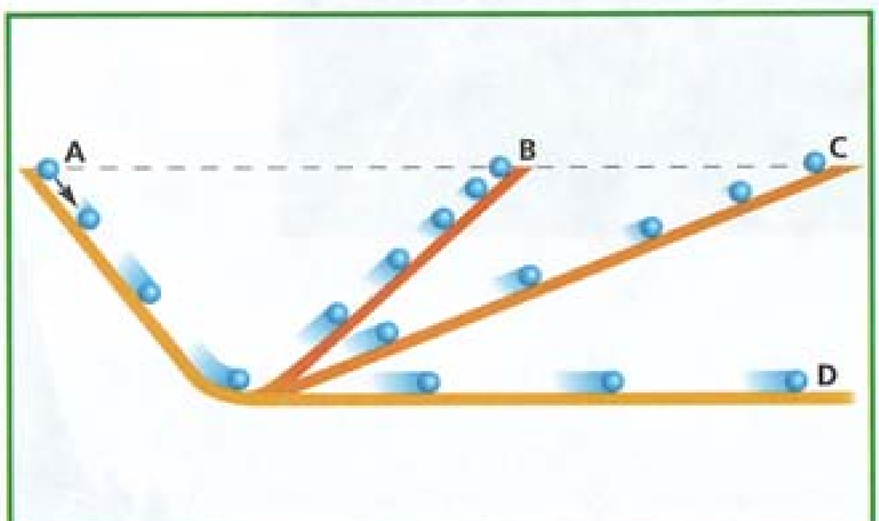
Galileo had observed that pendulums swing back and forth to the same height. He reasoned that a ball rolling down one ramp and up another would roll to the same height on any ramp.

To Galileo this meant that the ball's natural state of motion was coasting. Just as it takes a force to set an object in motion, it also takes a force to slow or stop a coasting object. Without any such force, the object will coast forever in a straight line.

What does it take to change an object's state of motion?

The ball is released from A. It rolls down the incline, then back up one of the facing inclines. If there is no force acting on the ball, it slows and comes to a stop just as it reaches the starting height.

Incline C is not as steep as incline B, so the ball takes longer to slow down. Galileo reasoned that if there were no incline for the ball to climb, it would not slow down at all—as in D.



Is Force Needed to Maintain Motion?

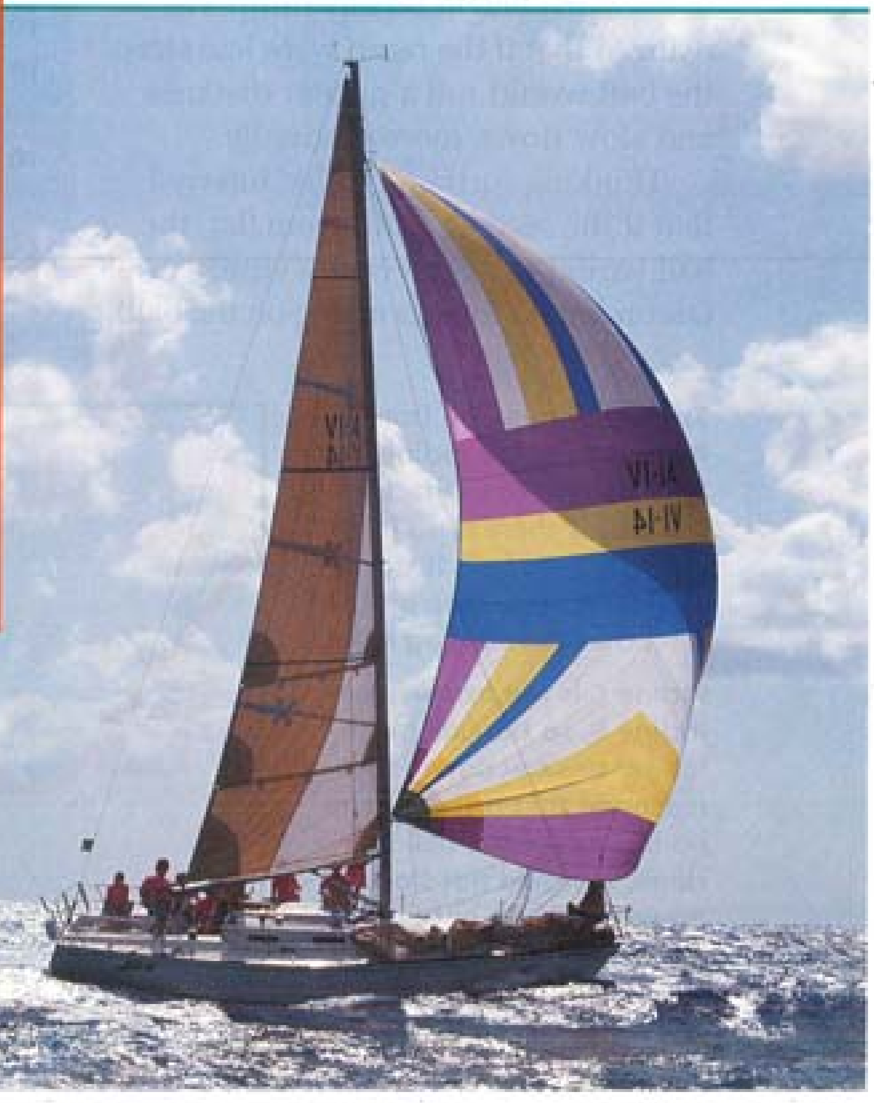
The sailboat in the picture is traveling at a steady rate in a straight line. The wind has filled its sails and is pushing the boat forward. Until just a few centuries ago, most people believed that a force was necessary to keep an object traveling at a steady rate, just like the wind pushing the boat.

Galileo realized that this idea was incorrect. He understood that a force called **friction** acts against moving objects. Friction opposes the motion of one object moving past another. If the friction is taken away, no force is needed to maintain motion at a steady rate. An object's inertia is all that is needed to keep it moving.

Forty-five years after Galileo died, Sir Isaac Newton published a complete description of the concept of inertia. This is *Newton's first law of motion*: Objects at rest remain at rest and objects traveling at a steady rate in a straight line continue that way until a force acts on them.

A spacecraft far from any star or planet can continue traveling in a straight line at a steady speed. There is no air in space, so there is no friction to slow the spacecraft down.

The sailboat needs the force of the wind to keep it moving. That is because the friction between the boat and the water tends to slow the boat down.



The rocket engines must overcome inertia. Their force moves the rocket from rest to high speeds during liftoff. The rocket's momentum is determined by the product of its mass and speed.

How Inertia Works

Newton's first law of motion—the law of inertia—tells us that the state of motion of an object does not change until a force is applied to it. That means, if an object is traveling at a steady rate in a straight line, it will continue to do so until a force is applied to it. Newton's law also means that if the object is sitting at rest, it will continue to be at rest until a force is applied to it. Each of the photographs shows an example of Newton's first law of motion.

Is a force needed to keep a moving spacecraft moving in a straight line?

These race cars could not change their direction of travel without the force of the road surface pushing sideways against the tires.

Both cars and trucks slow down when their drivers use their brakes. The force produced by the brakes slows the vehicles down. A truck has much more mass than a car, so its brakes must provide more force than the car's brakes in order to slow down or stop.

QUICK LAB

Using a Position Grid

FOLDABLES **Make a Half-Book using graph paper.** **(See p. R 41.)** **Label it as shown.**

1. **A grid has rows and columns. Each is labeled with letters or numbers. You can locate each box in the grid by its letter and number address. Make your own grid. Number the boxes from 1 to 29 across and from A to G down. Inside your Half-Book, explain why the snail didn't want to move. How is a position grid useful?**

2. **Find each box, and shade it in with a colored pencil.**

E27, B8, F24, D15, B29, C20, D5, F14, D29, B3, D11, B16, F3, D7, B27, B2, B11, F27, B20, F12, B23, D8, E17, F20, F23, C6, E2, E24, B10, B1, F10, C29, C2, F17, D24, E8, B15, E14, F1, B12, F5, D16, B21, B24, D27, C5, C10, E29, E7, B5, C14, C24, C16, E20, D2, C27, D10, C8, D17, E28, E10, D6, F25, D20, D14, F8, F29, B19, B14, F11, E5, B25, F2, B28

The snail didn't want to move because he had _______.

Where Is It?

How do you know when you are moving? You are moving when you are changing position. Position is the location of an object. Your position might be in front of, behind, to the right or to the left of some object. Cities or landmarks can be located on a map. The position of each object can be found by using a grid. The position of any object on a map is a comparison of the object's location to other things on the map. We can describe positions of things with a grid like the one covering the map. For example, the location of Atlanta can be described as box J16. You can find the number of Atlanta's position along the top or bottom and the letter along either side.

Find the city in each location.
a. K10 b. H11

Position	Distance	Time (s)
1 (B20)	0	0
2 (D16)	213 m (700 ft)	1
3 (F12)	426 m (1,400 ft)	2
4 (H8)	639 m (2,100 ft)	3

The diagram shows the shadow of the airliner moving over a town at a steady speed. The box number at each position gives the location of the center of the plane. One second passes between each position.

READING Diagrams

1. How many seconds of time pass between position 1 and position 4 for the moving shadow?
2. How far does the plane travel between position 2 and position 4?

What Speed Is

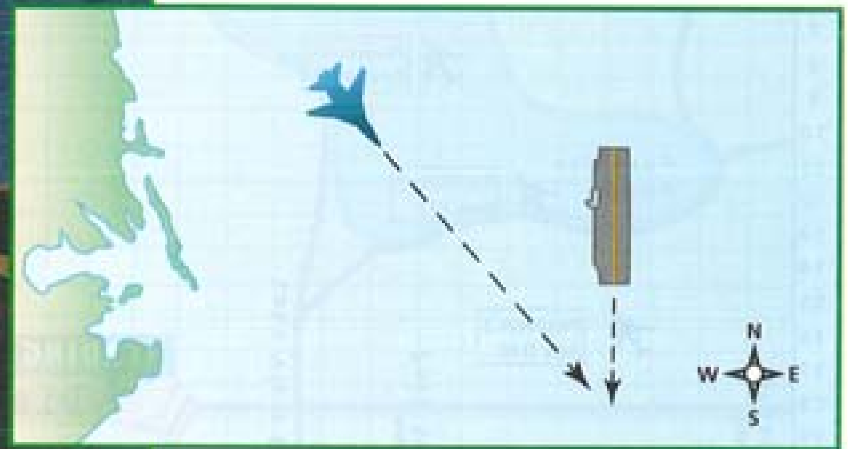
The airliner in the photo is moving rapidly through the air. How can we tell that it is moving? Think about watching the shadow of the airliner on the ground below, as in the diagram. We can see the shadow sweeping past fixed objects like ponds, homes, or streets. The change in the position of the shadow compared with the surrounding objects reveals its motion, as well as the motion of the airliner.

The table describes the motion of the airliner by giving the position of the airliner's shadow at various times. The position can be measured as the box number of the center of the shadow. The position can also be measured as the distance traveled past position 1.

As for any moving object, the **speed** of the airliner is how fast its position is changing with time at any moment. When the distance traveled by an object in a given time is known, the speed is found by dividing the distance by the time. The airliner, for example, travels 213 meters (700 feet) in 1 second. Therefore, the airliner's speed is 213 meters per second (700 feet per second) or 213 meters/second (700 feet/second).

What tells you how fast the plane is moving?

A pilot returning to her aircraft carrier must know the position and velocity of the ship. She must also know her location and velocity.



What Is Velocity?

The pilot of the navy jet is out on a mission. She needs to return to her aircraft carrier before she runs low on fuel. Her position and the position of the aircraft carrier are shown on the map. To get back safely, what information must she obtain from the ship to know in what direction to fly her plane?

First, she must know the position of the ship. She will also need to know the speed and the direction in which the ship is traveling. With this information, plus a knowledge of her own speed, the pilot can decide which direction she must travel in to meet up with the carrier, as shown by the dotted lines.

The speed of a moving object taken together with its direction of travel gives the **velocity** of the object. For example, the velocity of the aircraft carrier might be 40 kilometers/hour (40 km/h) due south, or the velocity of the plane might be 600 km/h to the southeast.

How can you tell the velocity of a car you are riding in? You need to know your speed. The car's speedometer will give you that information. You also need to know the direction you are traveling in. For that, you may need to use a map or road signs.

Two objects can have the same speed but different velocities if they are traveling in different directions. They may also have different velocities if they are traveling in the same direction but with different speeds. The only way two objects can have the same velocity is for the objects to both be traveling in the same direction at the same speed.

How is velocity different from speed?

What Is Acceleration?

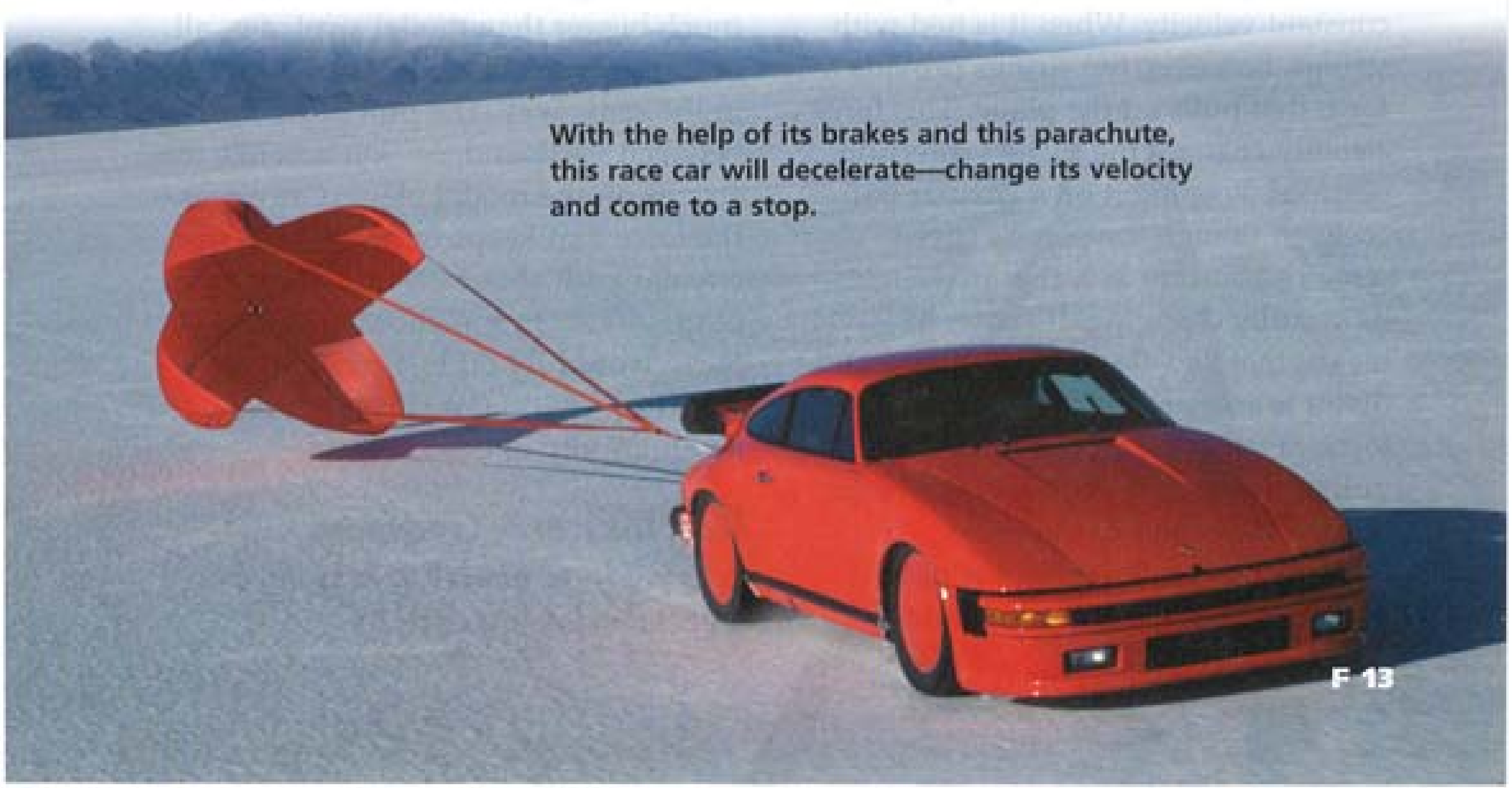
As long as an object travels in a straight line at a steady speed, its velocity is constant. Newton's first law tells us that an object's velocity will remain constant unless a force is applied to it. What if such a force is applied? How could the force affect the velocity of a moving object?

Both of the photographs on this page show how the velocity of an object can change when a force is applied. The force may change the object's speed, its direction of travel, or both. Any of these changes will change the velocity.

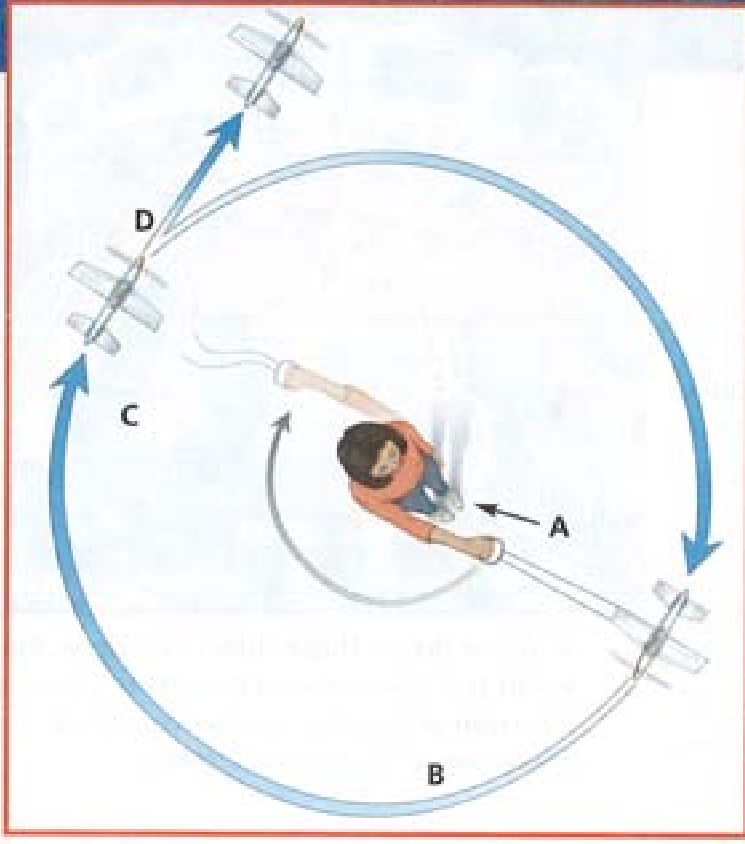
A change in velocity is called **acceleration**. Isaac Newton realized that applying a force to an object would overcome its inertia and change its velocity, causing it to accelerate. A special case of acceleration—*deceleration*—occurs when a force causes the speed of an object to decrease. Look at the photographs. Each photograph shows acceleration due to changing velocity. Which photograph shows a change in direction? Which photograph shows a deceleration?

A motor drives these riders in a circle. Even when the riders' speed is constant, their direction of travel is always changing. Therefore, they are accelerating.

How is acceleration related to velocity?



With the help of its brakes and this parachute, this race car will decelerate—change its velocity and come to a stop.



The inward force of the strings (A) keeps the plane on a circular path (B). If the strings were to break (C), the plane would fly off in a straight line (D) at a constant speed due to inertia.

What Keeps Things Moving in a Circle?

A gas-powered model airplane can be tied to a handle with strings. This allows the plane to be flown in a circle. Without strings, the plane tends to fly in a straight line at constant speed—a constant velocity. When it is tied with strings, however, the strings provide a force that pulls on the plane. This force steadily changes the plane's direction of travel, keeping it on a circular path.

Even though the plane's speed remains constant as it flies in a circle, its steadily changing direction of travel means that its velocity is changing and that it is accelerating. Note how the force causing the acceleration—the pull of the strings—is always directed toward the center of the circle.

If the strings tethering the plane were to break suddenly, it would fly off in a straight line at a constant speed. There would no longer be any force to overcome its inertia, and it would travel with constant velocity.

Although Earth and the Sun are much bigger than model airplanes, all of these objects obey the laws of motion in the same way. The pull of *gravity* between Earth and the Sun acts like the strings on the model plane. Gravity is the force that keeps Earth moving in a circular path about the Sun. If the force of gravity were somehow to disappear, Earth would fly off in a straight line into deep space! (You'll learn more about gravity in Lesson 3.)

READING **Draw Conclusions**

Why is a force needed to keep an object moving in a circle?

Lesson Review

Why It Matters

In outer space, spacecraft are not slowed by air resistance. When a pilot tries to dock one spacecraft with another, she sets her craft in motion with a burst of gas. To slow her craft, she applies a burst of gas in the opposite direction. With too little force, her craft may strike the other. With too much force, she may start going backward. It takes great skill to guide a spacecraft.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on force and mass.

Think and Write

1. A boat's motor dies when it is traveling at high speed. The boat slows to a stop. Why?
2. On a wet road, a car drives at high speed. At a sharp turn, the car slides straight out into a field. Why?
3. What do you need to know to find a car's velocity?
4. What is happening when a mass on a spring swings back and forth?
5. **Critical Thinking** If you tie a thread to the middle of a water-filled plastic bottle and pull slowly, the bottle moves. If you pull very rapidly, the thread breaks before the bottle can move. Why?

L•I•N•K•S

MATH LINK

Solve a problem. Absolute motion or rest is misleading. You are speeding faster than most airliners as you read this. Why don't you feel it? Where is the evidence that Earth rotates once every 24 hours? Its circumference is about 40,000 km (25,000 mi). Calculate how fast you and Earth are moving.

WRITING LINK

Expository Writing On a trip to the Moon and back, when would the astronauts be accelerating? When would they be traveling at a constant velocity? What forces would they experience? Research this topic and write a report.

ART LINK

Make a poster. A weather satellite circles Earth at a steady speed. Make a poster that shows its orbit and illustrates why it is accelerating.

TECHNOLOGY LINK

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