As you sit in class reading this line, you are traveling at a constant speed as the Earth rotates on its axis. Your speed depends on where you are. If you are at the Equator, your speed is 1670 km/h (1040 mph). At 42° latitude, your speed is 1300 km/h (800 mph).

What do you think?

- Do you feel the rotational motion of the Earth? Why or why not?
- What evidence do you have that you are moving?

Record your ideas about these questions in your Active Physics log. Be prepared to discuss your responses with your small group and the class.
For You To Do

1. When you view a sculpture you probably move around to see the work from different sides. In this activity, you’ll look at motion from two vantage points—while standing still and while moving. Get an object with wheels that is large enough to hold one of your classmates seated as it rolls down the hall. You might use a dolly, lab cart, a wagon, or a chair with wheels.

2. Choose a student to serve as the observer in the moving system. Have the observer sit on the cart and practice pushing the cart down the hall at constant speed. (This will take a little planning. Find a way to make the cart travel at constant speed. Also, find a way of controlling that speed!)

3. Once you can move the cart at a constant speed, give the moving observer a ball. While the cart is moving at constant speed, have the moving observer throw the ball straight up, then catch it.

   a) How does the person on the cart see the ball move? Sketch its path as he or she sees it.
   b) How does a person on the ground see the ball move? Again, sketch the path of the ball as he or she sees it.
4. With the observer on the cart traveling at constant speed, let a student standing on the ground throw the ball straight up and catch it.
   a) How does the moving observer see the ball move? Sketch its path.
   b) How does a person on the ground see the ball move? Sketch its path.

5. Work in groups for the following steps of this activity, as directed by your teacher. Get a wind-up or battery-powered car, two large pieces of poster board or butcher paper, a meter stick, a marker, string, and a stopwatch from your teacher.

   Use a marker to lay out a distance scale on the poster board. Be sure to make it large enough so that a student walking beside the poster board can read it easily.

   Next, lay out an identical distance scale along the side of the classroom or in a hall.

   Attach a string to the poster board and practice moving it at a constant speed.

6. Place the toy car on the poster board and let it move along the strip. Measure the speed (distance/time) of the car along the poster board as the board remains at rest. Try the measurement several times to make sure that the motion of the car is repeatable.
   a) Record the speed.

7. Move the poster board at constant speed while the car travels on the board. Focus on the car, not on the moving platform. Measure the speed of the car relative to the poster board when the board is moving.
   a) Record the speed.
   b) Compare the speed of the car when its platform is not moving and when its platform is moving.
   c) Do your observations and measurements agree with your expectations?
8. Work with your group to make two simultaneous measurements. Measure the speed of the board relative to the fixed scale (the scale on the floor) and the speed of the car relative to the fixed scale. The second measurement can be tricky. Practice a few times. It may help to stand back from the poster board.

a) Record the measurements.

9. Next, measure the speed of the poster board and the car relative to the fixed scale while moving the board at different speeds. Make and complete a table like the one below.

<table>
<thead>
<tr>
<th>Speed of the Board Relative to Fixed Scale</th>
<th>Speed of the Car Relative to Fixed Scale</th>
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<tbody>
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a) Work with your group to state a relationship between the speed of the car relative to the fixed scale, its speed relative to the board, and the speed of the board relative to the fixed scale. Describe the relationship in your log. Also explain your thinking.

b) What do you think will happen if the car moves in the direction opposite to the direction the board is moving? Record your idea. Now try it. Do the results agree with your predictions?

c) Plan an experiment in which the car is moving along the poster board, the poster board is moving, and the car remains at the same location. Try it. Record the results.
d) What will happen if the car travels perpendicular to the direction in which the board is moving? Record your ideas. Now try it. Do the results agree with your predictions?

e) When the car travels perpendicular to the motion of the frame of reference, does the motion of the board affect your measurement of the car’s speed?

Physics Words

relativity: the study of the way in which observations from moving frames of reference affect your perceptions of the world.
to another frame of reference, as long as both are moving at constant speed in a straight line. Newton’s First Law of Motion states that an object at rest will stay at rest, and an object in motion will stay in motion unless acted on by a net outside force. Newton’s First Law holds in each frame of reference. Such a frame of reference is called an **inertial frame of reference**.

If you are in a frame of reference traveling at a constant velocity from which you cannot see any other frame of reference, there is no way to determine if you are moving or at rest. If you try any experiment, you will not be able to determine the velocity of your frame of reference. This is the first postulate in Einstein’s Theory of Relativity. Think of it this way: Any observer in an inertial frame of reference thinks that he or she is standing still!

**Reflecting on the Activity and the Challenge**

Different observers make different observations. As you sit on a train and drop a ball, you see it fall straight down—its path is a straight line. Someone outside the train observing the same ball sees the ball follow a curved path, a parabola, as it moves down and horizontally at the same time. However, a logical relation exists between different observations. If you know what one observer measures, you can determine what the other observer measures. This relation works for any two observers. It is repeatable and measurable. Pseudoscience requires special observers with special skills. No relation or pattern exists between them. Different explanations can be accepted for the same phenomenon and it’s still science. Your **Chapter Challenge** is to distinguish between different explanations that are science and different explanations that have no basis and are pseudoscience.

**Physics To Go**

1. A person walking forward on the train says that he is moving at 2 miles per hour. A person on the platform says that the man in the train is moving at 72 miles per hour.
   a) Which person is correct?
   b) How could you get the two men to agree?
2. If you throw a baseball at 50 miles per hour north from a train moving at 40 miles per hour north, how fast would the ball be moving as measured by a person on the ground?

3. You walk toward the rear of an airplane in flight. Describe in your own words how you would find your speed relative to the ground. Explain your thinking.

4. A jet fighter plane fires a missile forward at 1000 km/h relative to the plane.
   a) If the plane is moving at 1200 km/h relative to the ground, what is the velocity of the missile relative to the ground?
   b) What is the velocity of the missile relative to a plane moving in the same direction at 800 km/h?
   c) What is the velocity of the missile relative to a target moving at 800 km/h toward the missile?

5. A pilot is making an emergency air drop to a disaster site. When should he drop the emergency pack: before he is over the target, when he is over the target, or after he has passed the target?

6. Each day you see the Sun rise in the east, travel across the sky, and set in the west.
   a) Explain this observation in terms of your frame of reference.
   b) Compare the observation to the actual motions of the Sun and Earth.
FOR YOU TO READ

A Social Frame of Reference

Physics is sometimes a metaphor for life. Just as physicists speak of judging things from a frame of reference, a frame of reference is also used in viewing social issues. For example, a Black American*, one of the authors of this chapter, shared the following story about choosing a career, because his frame of reference conflicted with that of his father.

“I was born in Mississippi in 1942, the place where my parents had spent their entire lives. My father lived most of his life during a period of “separate-but-equal,” or legal segregation. He believed that the United States would always remain segregated. So when I was choosing a career, all of his advice was from that frame of reference.

“On the other hand, my frame of reference was changing. To me, the United States could not stay segregated and remain a world power. The time was 1962, about 10 years after the Supreme Court had made its landmark Brown vs. Topeka School Board decision. I reasoned that the opportunities for black people would be greatly expanded.

“Both my parents had encouraged me to get as much education as possible. My mother always said that “the only way to guarantee survival is through good education.” I had a master’s degree and was teaching in a segregated college. I thought I would need a Ph.D. to stay in my profession, and decided to quit my job and go back to school. That decision brought on an encounter with my father that I shall never forget.

“My father did not say good-bye on the day I left home for graduate school. Our frames of reference had moved very far apart. The possibility of becoming a professor at a white college or university, particularly in the South, was not very high. My father could not understand why I needed a Ph.D. After all, I could have a good life in our segregated system without quitting my prestigious job to return to graduate school.

“As was usual for him, my father eventually supported my decision. At his death in 1989, however, he still had not fully accepted my frame of reference.”

* The author uses the term Black American instead of African-American because the use of that term also shows social changes in frames of reference.

7. How would you explain relativity to a friend who is not in this course. Outline what you would say. Then try it. Record whether or not you were successful.

8. Explain this event based on frame of reference. You are seated in a parked car in a parking lot. The car next to you begins to back out of its space. For a moment you think your car is rolling forward.

Coordinated Science for the 21st Century
Patterns and Predictions

**Stretching Exercise**

1. The famous scientist Albert Einstein is noted for his Theory of Relativity. Research Einstein’s life. What kind of a student was he? What was his career path? When did he make his breakthrough discoveries? What were his political beliefs as an adult? What role did he play in American political history? Report your findings to the class.

2. A Social Frame of Reference tells the story of one man’s encounter with different ideas about society, or social frames of reference. Write a short story that illustrates what happens when two people operate from different frames of reference. Your story can be based on your own experience, or it can be fiction.