Describing Motion

Deciding if an object is moving isn't as easy as you might think. For example, you are probably sitting in a chair as you read this book. Are you moving? Well, parts of you may be. Your eyes blink and your chest moves up and down. But you would probably say that you are not moving. An object is in **motion** if its distance from another object is changing. Because your distance from your chair is not changing, you are not in motion.

Reference Points To decide if you are moving, you use your chair as a reference point. A **reference point** is a place or object used for comparison to determine if something is in motion. **An object is in motion if it changes position relative to a reference point.**

Objects that we call stationary—such as a tree, a sign, or a building—make good reference points. From the point of view of the train passenger in Figure 1, such objects are not in motion. If the passenger is moving relative to a tree, he can conclude that the train is in motion.

You probably know what happens if your reference point is moving. Have you ever been in a school bus parked next to another bus? Suddenly, you think your bus is moving backward. But, when you look out a window on the other side, you find that your bus isn't moving at all—the other bus is moving forward! Your bus seems to move backward because you used the other bus as a reference point.

Relative Motion Are you moving as you read this book? The answer to that question depends on your reference point. When your chair is your reference point, you are not moving. But if you choose another reference point, you may be moving.

Suppose you choose the sun as a reference point instead of your chair. If you compare yourself to the sun, you are moving quite rapidly. This is because you and your chair are on Earth, which moves around the sun. Earth moves about 30 kilometers every second. So you, your chair, this book, and everything else on Earth move that quickly as well. Going that fast, you could travel from New York City to Los Angeles in about 2 minutes! Relative to the sun, both you and your chair are in motion. But because you are moving with Earth, you do not seem to be moving.

Measuring Distance You can use units of measurement to describe motion precisely. You measure in units, or standard quantities of measurement, all the time. For example, you might measure 1 cup of milk for a recipe, run 2 miles after school, or buy 3 pounds of fruit at the store. Cups, miles, and pounds are all units of measurement.

Scientists all over the world use the same system of measurement so that they can communicate clearly. This system of measurement is called the **International System of Units** or, in French, *Système International* (SI).

When describing motion, scientists use SI units to describe the distance an object moves. When you measure distance, you measure length. The SI unit of length is the **meter** (m). A meter is a little longer than a yard. An Olympic-size swimming pool is 50 meters long. A football field is about 91 meters long.

The length of an object smaller than a meter often is measured in a unit called the centimeter (cm). The prefix *centi-* means "one hundredth." A centimeter is one hundredth of a meter, so there are 100 centimeters in a meter. The wingspan of the butterfly shown in Figure 3 can be measured in centimeters. For lengths smaller than a centimeter, the millimeter (mm) is used. The prefix *milli-* means "one thousandth," so there are 1,000 millimeters in a meter. Distances too long to be measured in meters often are measured in kilometers (km). The prefix *kilo-* means "one thousand." There are 1,000 meters in a kilometer.

Calculating Speed

A measurement of distance can tell you how far an object travels. A cyclist, for example, might travel 30 kilometers. An ant might travel 2 centimeters. **If you know the distance an object travels in a certain amount of time, you can calculate the speed of the object.** Speed is a type of rate. A rate tells you the amount of something that occurs or changes in one unit of time. The **speed** of an object is the distance the object travels per unit of time.

The Speed Equation

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

To calculate the speed of an object, divide the distance the object travels by the amount of time it takes to travel that distance. This relationship can be written as an equation.

The speed equation consists of a unit of distance divided by a unit of time. If you measure distance in meters and time in seconds, you express speed in meters per second, or m/s. (The slash is read as “per.”) If you measure distance in kilometers and time in hours, you express speed in kilometers per hour, or km/h. For example, a cyclist who travels 30 kilometers in 1 hour has a speed of 30 km/h. An ant that moves 2 centimeters in 1 second is moving at a speed of 2 centimeters per second, or 2 cm/s.

Average Speed The speed of most moving objects is not constant. The cyclists shown in Figure 4, for example, change their speeds many times during the race. They might ride at a constant speed along flat ground but move more slowly as they climb hills. Then they might move more quickly as they come down hills. Occasionally, they may stop to fix their bikes.

Although a cyclist does not have a constant speed, the cyclist does have an average speed throughout a race. To calculate **average speed**, divide the total distance traveled by the total time. For example, suppose a cyclist travels 32 kilometers during the first 2 hours. Then the cyclist travels 13 kilometers during the next hour. The average speed of the cyclist is the total distance divided by the total time.

Instantaneous Speed Calculating the average speed of a cyclist during a race is important. However, it is also useful to know the cyclist’s instantaneous speed. **Instantaneous speed** is the rate at which an object is moving at a given instant in time.

Describing Velocity

Knowing the speed at which something travels does not tell you everything about its motion. To describe an object’s motion completely, you need to know the direction of its motion. For example, suppose you hear that a thunderstorm is traveling at a speed of 25 km/h. Should you prepare for the storm? That depends on the direction of the storm’s motion. Because storms usually travel from west to east in the United States, you need not worry if you live to the west of the storm. But if you live to the east of the storm, take cover.

When you know both the speed and direction of an object’s motion, you know the velocity of the object. Speed in a given direction is called **velocity** **.** You know the velocity of the storm when you know that it is moving 25 km/h eastward.

At times, describing the velocity of moving objects can be very important. For example, air traffic controllers must keep close track of the velocities of the aircraft under their control. These velocities continually change as airplanes move overhead and on the runways. An error in determining a velocity, either in speed or in direction, could lead to a collision.

Velocity is also important to airplane pilots. For example, stunt pilots make spectacular use of their control over the velocity of their aircrafts. To avoid colliding with other aircraft, these skilled pilots must have precise control of both their speed and direction. Stunt pilots use this control to stay in close formation while flying graceful maneuvers at high speed.