11.1 Distance and Displacement

Reading Focus

Key Concepts

- What is needed to describe motion completely?
- How are distance and displacement different?
- How do you add displacements ?

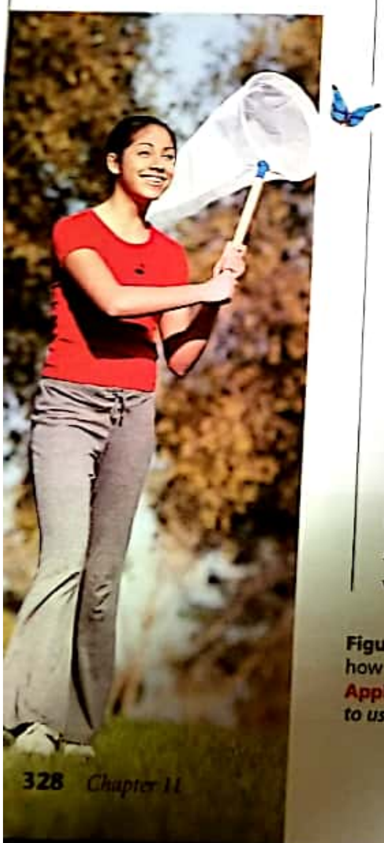
Vocabulary

- frame of reference
- relative motion
- distance
- vector
- resultant vector

Reading Strategy

Predicting Copy the table below and write a definition for *frame of reference* in your own words. After you read the section, compare your definition to the scientific definition and explain why the frame of reference is important.

Frame of reference probably means	Frame of reference actually means
a. ?	b. ?



On a spring day a butterfly flutters past. First it flies quickly, then slowly, and then it pauses to drink nectar from a flower. The butterfly's path involves a great deal of motion.

How fast is the butterfly moving? Is it flying toward the flower or away from it? These are the kinds of questions you must answer to describe the butterfly's motion. To describe motion, you must state the direction the object is moving as well as how fast the object is moving. You must also tell its location at a certain time.

Choosing a Frame of Reference

How fast is the butterfly in Figure 1 moving? Remember that the butterfly is moving on Earth, but Earth itself is moving as it spins on its axis and revolves around the sun. If you consider this motion, the butterfly is moving very, very fast!

To describe motion accurately and completely, a frame of reference is necessary. The necessary ingredient of a description of motion—a **frame of reference**—is a system of objects that are not moving with respect to one another. The answer to "How fast is the butterfly moving?" depends on which frame of reference you use to measure motion. How do you decide which frame of reference to use when describing the butterfly's movement?

Figure 1 You must choose a frame of reference to tell how fast the butterfly is moving.
Applying Concepts *Identify a good frame of reference to use when describing the butterfly's motion.*

Figure 2 To someone riding on a speeding train, others on the train don't seem to be moving.

How Fast Are You Moving? How fast are the train passengers in Figure 2 moving? There are many correct answers because their motion is relative. This means it depends on the frame of reference you choose to measure their motion. **Relative motion** is movement in relation to a frame of reference. For example, as the train moves past a platform, people standing on the platform will see those on the train speeding by. But when the people on the train look at one another, they don't seem to be moving at all.

Which Frame Should You Choose? When you sit on a train and look out a window, a treetop may help you see how fast you are moving relative to the ground. But suppose you get up and walk toward the rear of the train. Looking at a seat or the floor may tell you how fast you are walking relative to the train. However, it doesn't tell you how fast you are moving relative to the ground outside. Choosing a meaningful frame of reference allows you to describe motion in a clear and relevant manner.

Measuring Distance

Distance is the length of a path between two points. When an object moves in a straight line, the distance is the length of the line connecting the object's starting point and its ending point.

It is helpful to express distances in units that are best suited to the motion you are studying. The SI unit for measuring distance is the meter (m). For very large distances, it is more common to make measurements in kilometers (km). One kilometer equals 1000 meters. For instance, it's easier to say that the Mississippi River has a length of 3780 kilometers than 3,780,000 meters. Distances that are smaller than a meter are measured in centimeters (cm). One centimeter is one hundredth of a meter. You might describe the distance a marble rolls, for example, as 6 centimeters rather than 0.06 meter.

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Visit: www.SciLinks.org
Web Code: ccn-2111

Quick Lab

Comparing Distance and Displacement

Procedure

1. Draw a dot at the intersection of two lines near the bottom edge of a sheet of graph paper. Label the dot "Start."
2. Draw a second, similar dot near the top of the paper. Label this dot "End."
3. Draw a path from the Start dot to the End dot. Choose any path that stays on the grid lines.
4. Use a ruler to determine the distance of your path.
5. Use a ruler to determine the displacement from start to end.

Analyze and Conclude

1. **Observing** Which is shorter, the distance or the displacement?
2. **Evaluating and Revising** How could you have made the distance shorter?
3. **Inferring** If you keep the Start and End points the same, is it possible to make the displacement shorter? Explain your answer.

Measuring Displacements

To describe an object's position relative to a given point, you need to know how far away and in what direction the object is from that point. Displacement provides this information. **Distance is the length of the path between two points. Displacement is the direction from the starting point and the length of a straight line from the starting point to the ending point.**

Displacements are sometimes used when giving directions. Telling someone to "Walk 5 blocks" does not ensure they'll end up in the right place. However, saying "Walk 5 blocks north from the bus stop" will get the person to the right place. Accurate directions give the direction from a starting point as well as the distance.

Think about the motion of a roller coaster car. If you measure the path along which the car has traveled, you are describing distance. The direction from the starting point to the car and the length of the straight line from the starting point to the car describe displacement. After completing one trip around the track, the roller coaster car's displacement is zero.

Combining Displacements

Displacement is an example of a vector. A **vector is a quantity that has magnitude and direction. The magnitude can be size, length, or amount.** Arrows on a graph or map are used to represent vectors. The length of the arrow shows the magnitude of the vector. **Vector addition is the combining of vector magnitudes and directions.** **Add displacements using vector addition.**

Displacement Along a Straight Line When two displacements, represented by two vectors, have the same direction, you can add their magnitudes. In Figure 3A, the magnitudes of the car's displacements are 4 kilometers and 2 kilometers. The total magnitude of the displacement is 6 kilometers. If two displacements are in opposite directions, the magnitudes subtract from each other as shown in Figure 3B. Because the

Displacement That Isn't Along a Straight Path

When two or more displacement vectors have different directions, they may be combined by graphing. Figure 4 shows vectors representing the movement of a boy walking from his home to school. He starts by walking 1 block east. Then he turns a corner and walks 1 block north. He turns once again and walks 2 blocks east. For the last part of his trip to school, he walks 3 blocks north. The lengths of the vectors representing this path are 1 block, 1 block, 2 blocks, and 3 blocks.

The boy walked a total distance of 7 blocks. You can determine this distance by adding the magnitudes of each vector along his path.

The vector in red is called the **resultant vector,** which is the vector sum of two or more vectors. In this case, it shows the displacement. The resultant vector points directly from the starting point to the ending point. If you place a sheet of paper on the figure and mark the length of the resultant vector, you see that it equals the length of 5 blocks. Vector addition, then, shows that the boy's displacement is 5 blocks approximately northeast, while the distance he walked is 7 blocks.

Figure 4 Measuring the resultant vector (the diagonal red line) shows that the displacement from the boy's home to his school is two blocks less than the distance he actually traveled.

Section 11.1 Assessment

Reviewing Concepts

1. What is a frame of reference? How is it used to measure motion?
2. How are distance and displacement similar and different?
3. How are displacements combined?
4. A girl who is watching a plane fly tells her friend that the plane isn't moving at all. Describe a frame of reference in which the girl's description would be true.

Critical Thinking

5. **Using Analogies** Is displacement more like the length of a rope that is pulled tight or the length of a coiled rope? Explain.
6. **Making Judgments** Would you measure the height of a building in meters? Give reasons for your answer.
7. **Problem Solving** Should your directions to a friend for traveling from one city to another include displacements or distances? Explain.
8. **Inferring** The resultant vector of two particular displacement vectors does not equal the sum of the magnitudes of the individual vectors. Describe the directions of the two vectors.

Writing in Science

Compare-Contrast Paragraph Write a paragraph describing how the distance you travel from home to school is different from your displacement from home to school. (*Hint:* Make a simple sketch similar to Figure 4 and refer to it as you write.)