Section 11.1

1 FOCUS

Objectives

11.1.1 **Identify** frames of reference and **describe** how they are used to measure motion.
11.1.2 **Identify** appropriate SI units for measuring distances.
11.1.3 **Distinguish** between distance and displacement.
11.1.4 **Calculate** displacement using vector addition.

Reading Focus

Build Vocabulary L2

Vocabulary Knowledge Rating Chart Before students read the section, have them rate their knowledge of the vocabulary terms for this section in a chart with the following headings: Term, Can Define or Use It, Have Heard or Seen It, Don't Know. After they have read the section, have them return to the chart and update it to reflect any increase in understanding.

Reading Strategy L2

a. Answers may vary. Sample answer: Frame of reference may mean the range of distances or area that you are considering in a problem. **b.** Frame of reference is a system of objects that are not moving with respect to one another. Frames of reference are important because they are needed to accurately describe motion.

2 INSTRUCT

Choosing a Frame of Reference

Use Visuals L1

Figure 1 Discuss Figure 1 with students after they read the section Choosing a Frame of Reference. Ask, **Describe the motion of the girl in the butterfly's frame of reference.** *(She would appear to bob up and down, exactly opposite the motion of the butterfly as seen from the girl's frame of reference.)* **Describe the motion of the butterfly in the butterfly's frame of reference.** *(The butterfly is at rest in the butterfly's frame of reference.)* **Which one is "really" moving, the butterfly or the girl?** *(It depends on the frame of reference.)*
Visual, Logical

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?

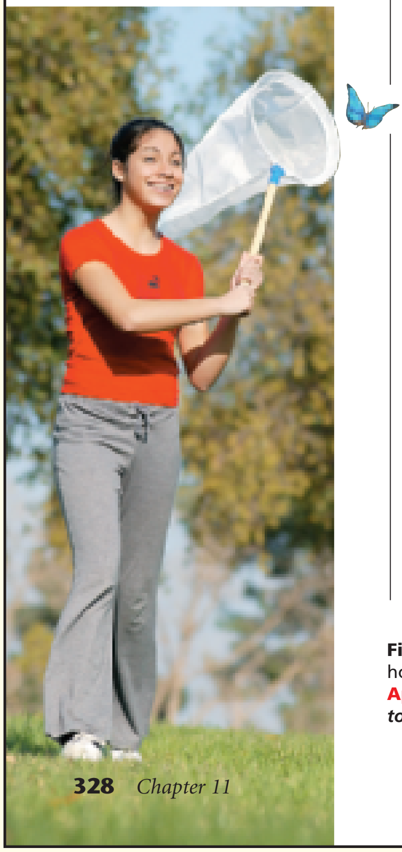

Figure 1 You must choose a frame of reference to tell how fast the butterfly is moving.
Applying Concepts ***Identify a good frame of reference to use when describing the butterfly's motion.***

Section Resources

Print

- ***Laboratory Manual,*** Investigation 11A
- ***Reading and Study Workbook With Math Support,*** Section 11.1
- ***Transparencies,*** Chapter Pretest and Section 11.1

Technology

- ***Interactive Textbook,*** Section 11.1
- ***Presentation Pro CD-ROM,*** Chapter Pretest and Section 11.1
- ***Go Online,*** NSTA SciLinks, Comparing frames of reference

328 Chapter 11

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.

Go Online NSTA SCI LINKS

For: Links on comparing frames of reference
Visit: www.SciLinks.org
Web Code: ccn-2111

Teacher Demo

Frames of Reference L2

Purpose Students observe how motion can appear differently in different frames of reference.

Materials tennis ball

Procedure Stand at the front of the room, turned sideways, and toss the tennis ball straight up and then catch it. Ask, **Describe the path of the ball.** *(The ball travels straight up and down).* Tell students that to you, the ball also appears to travel straight up and down. Now, walk slowly across the front of the room as you toss the ball up and catch it. Ask, **Describe the path of the ball.** *(The ball travels up and down in an arc.)* Tell students that to you, the ball still appears to travel straight up and down.

Expected Outcome The description of motion depends on the frame of reference. **Kinesthetic, Visual**

Measuring Distance

Build Reading Literacy L1

Monitor Your Understanding Refer to page **326D** in this chapter, which provides guidelines for monitoring your understanding.

Have students read the passages Measuring Distance and Measuring Displacements (pp. 329–330). When they reach the bottom of p. 329, have them stop and write down the main ideas in the passage. Have them ask themselves, "Did I have any trouble reading this passage? If so, why?" Then, have them come up with their own strategies to improve their understanding. Have them use this strategy as they continue reading. **Intrapersonal, Verbal**

Go Online NSTA SCI LINKS

Download a worksheet on comparing frames of reference for students to complete, and find additional teacher support from NSTA SciLinks.

Answer to . . .

Figure 1 *The ground would make a good frame of reference.*

Customize for English Language Learners

Use Narrative
English language learners can better understand science content when it is framed in the context of a personal narrative. Have students use narrative to better understand displacement that isn't along a straight path. Pair ELL students and encourage them to narrate the route they take from the science classroom to the cafeteria, or another room in the school. As one student narrates, the other student may sketch a simple map, similar to the one on p. 331. Challenge students to mark the resultant vector on the map.

Measuring Displacements Combining Displacements

Quick Lab

Comparing Distance and Displacement L2

Objective
After completing this activity, students will be able to
- distinguish between distance and displacement.

Address Misconceptions

This activity helps address the misconception that the distance an object travels and its displacement are the same. Challenge this misconception by discussing the answers to the Analyze and Conclude questions.

Skills Focus **Measuring**

Prep Time 10 minutes

Materials graph paper, metric ruler

Class Time 15 minutes

Teaching Tips
- Make sure that students read the metric side of the ruler if their rulers have both metric and English units.

Expected Outcome Students will be able to distinguish between distance, the length traveled between two points, and displacement, the length of the line between two points.

Analyze and Conclude
1. Displacement is always shorter than or equal to the distance because it is a straight line between two points, not always the actual path of motion.
2. The distance would be shorter if the path were more direct. The shortest path would be a diagonal line connecting Start and End, and it would be the same length as the displacement.
3. No, the displacement could not be shorter because it will always be the straight-line distance between the Start and End points.

Visual, Logical

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 car's displacements (4 kilometers and 2 kilometers) are in opposite directions, the magnitude of the total displacement is 2 kilometers.

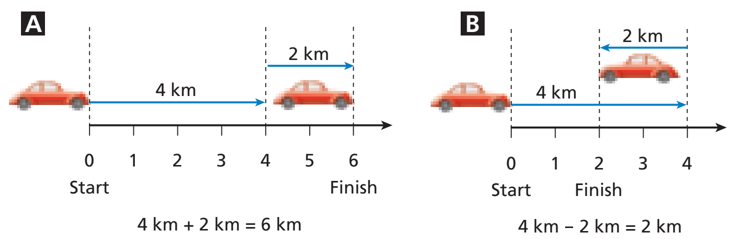

Figure 3 When motion is in a straight line, vectors add and subtract easily. **A** Add the magnitudes of two displacement vectors that have the same direction. **B** Two displacement vectors with opposite directions are subtracted from each other.

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.)

Build Science Skills L2

Measuring Have students use a map of the city or area to measure the straight-line distance from their homes to the school. They will have to use the scale information on the map to convert from distances on the map to actual distances. Then, have them determine the distances they travel from their home to school by observing the odometer of a car or bus. To get the distances traveled, they should subtract the odometer readings at their start points from the odometer readings when they arrive at the school. Have them compare the distances. In almost every case, the distance traveled should be greater than the straight-line distance on the map. **Logical**

3 ASSESS

Evaluate Understanding L2

Ask students to write a paragraph describing a situation in which the same motion appears differently from different frames of reference.

Reteach L1

Use Figure 4 to reteach the difference between displacement and distance traveled.

Writing in Science

Students' paragraphs should generally describe distances and directions they travel on the way to school. They should understand that displacement is determined by a straight-line distance from home to school. The total distance they travel will almost always be greater than the magnitude of the displacement, unless they travel in a single direction the whole time.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 11.1.

Section 11.1 Assessment

1. A frame of reference is a set of objects that are not moving with respect to one another. Motion can only be described in comparison to a frame of reference.
2. Distance is the length of an object's actual path from a starting point to an ending point. Displacement is the length of a straight line from the starting point to the ending point.
3. Displacements are combined using vector addition.
4. If the plane is far away and flying directly toward or away from the girl, the plane would appear not to be moving. Also, the plane would not be moving in the frame of reference of the people on the plane.
5. Displacement is more like the length of a rope that is pulled tight; it measures the shortest distance between two points.
6. It makes sense to measure the height of a building in meters. Kilometers are too large and centimeters are too small.
7. You should use displacements. Displacements will tell your friend how far and which direction to go. Distances will only tell how far to go.
8. The vectors are at an angle to each other.