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Overview

Shipping is one of the earliest and most important means of transportation—and until the last century, one of the most perilous. This Delta Science Module introduces students to the world of shipwrecks and marine archaeology.

Students learn where mariners sailed, the methods and tools they used to navigate, and some of the most common causes of shipwrecks. They discover how archaeologists work in the marine environment to discover, map, interpret, and preserve historic shipwrecks as precious artifacts of the past.

In Activity 1, students discover by working with maps that nearly three-quarters of the earth's surface is covered with water. Students identify the earth's oceans and continents and label the principle surface currents of the Atlantic and Pacific oceans. They learn that mariners followed the direction of these currents whenever possible.

Mapping the physical features of the ocean floor can sometimes provide clues as to the cause of the wrecks found there. In Activity 2, students probe ocean-floor models and interpret depth readings to create a series of depth profiles. From these profiles students infer the shape of their ocean-floor models.

In Activity 3, students explore the role of the oceans in the transport of goods and people around the world. Students plot major sixteenth- to nineteenth-century maritime shipping routes in the Americas and locate some historic shipwreck sites along the way.

Students learn what keeps boats afloat—and what causes them to sink—in Activity 4. They then apply what they have learned to the design of model cargo ships. Students are given the opportunity to simulate a shipwreck and to explain what happens in terms of buoyant force.

In Activity 5, students learn how early navigators used compasses to help them determine the direction of their ships. They build and calibrate a floating compass and then plot the course of a historic voyage using a modern magnetic compass. In Activity 6, students learn how navigators used a quadrant to determine their latitude at sea. Then they assemble a model quadrant and use it to determine their position as they "navigate" around the classroom.

Water pressure and its effects on divers are examined in Activities 7 and 8. In Activity 7, students discover that pressure increases with depth, and they speculate as to the effect of this pressure on an underwater diver. In Activity 8, students investigate the effect of pressure on a volume of confined gas (Boyle's law), and relate what they observe to a diver's ability to breathe under water. Students are also taught how to perform some of the same calculations (regarding air supply) SCUBA divers must make before they enter the water.

Students examine a variety of everyday objects in Activity 9 and learn to view them as artifacts of contemporary life. This exercise prepares students for the interpretation of shipwreck artifacts in Activity 10.

In Activity 10, students conduct a survey of a shipwreck site. They map the location and orientation of the artifacts as they are found on the ocean floor, and then infer the probable cause of the wreck.

Finally, in Activity 11, students examine the groups who share an interest in shipwrecks: salvagers, souvenir hunters, artifact dealers, collectors, and archaeologists. They discuss the archaeologist's code of ethics and learn to view shipwrecks as scarce, nonrenewable cultural resources that must be protected and preserved.

Materials List

Qty		Description
2		aluminum cylinders
1	c	aluminum foil, heavy-duty
16	c	Artifact Decal Sheets
1		ball, foam
1		balloon, large
1		balloon, small
1	c	beach ball, inflatable
1	c	beans, small, red, 3 lb
2		blocks, wood
16	†	bottles, plastic, 2-L
8		boxes, with perforated lids
1	c	candles, p/36
1		cap for tube, with hole
64	c	cardboard, corrugated, 10 cm x 15 cm
16	c	cardboard, corrugated, 10 cm x 20 cm
8	c	containers, paper, quart
16		compasses
3		cones, foam
2		cork stoppers
9	c	cups, foam, 16-oz
8	c	cups, paper, 8-oz
3		disks, foam
8		dowels, wooden
4		foam, squares, 10 cm x 10 cm
1	c	glue, 4 oz
32	c	grid sheets, tracing paper
3		hemispheres, foam
1		Lincoln Profile Silhouette
1		magnet, bar
1	c	matches, book
16		needles, blunt
2	c	notes, self-sticking, p/100
16		pans, aluminum
3	c	paper clips, p/100
1		paper, construction, yellow
1		poster, Spanish Galleon
1		push pins, p/12
1		Resource Sheet 1
1		Resource Sheet 2
1		Resource Sheet 3
1		Resource Sheet 4
1		Resource Sheet 5
1		Resource Sheet 6
1		Resource Sheet 7
1		Resource Sheet 8
3		rings, annular, foam
2		rubber stoppers, large
1	c	sandpaper
2		sinkers, 8-oz
8		spring scales
1	c	straws, plastic, p/50
1	c	string, roll
1	c	tape, masking
1		test tube
1	c	thread, black
1		tube, plastic
8		tubes, glass
16		tubes, plastic, long
1		tubing, plastic, 15 cm
8		tubs, plastic
1		video, *Pieces of the Past: Searching for Underwater Treasure*
16		washers
1		teacher's guide

Teacher provided items

Qty		Description
–		chalk, colored
1		container, 1-L
1		dime
1		globe
1		knife, serrated
8		marking pens
–	c	paper towels
4	c	paper, plain
–		pencils
16		rulers, metric
16		scissors
–	c	tape, transparent
1		VCR and monitor
–	c	water, tap

† = in separate box
c = consumable item

Activity 5
Navigating with a Compass

Objectives

The compass is one of the earliest navigational tools—and one of the most prevalent artifacts found at historic shipwreck sites. In this activity students learn how early navigators used floating compasses to determine direction and maintain the course of their ships.

The students

- construct and calibrate a floating compass
- use the compass to determine direction
- compare a floating compass with a modern compass
- plot the course of a historic voyage using a compass

Schedule

Session I – About 50 minutes
Session II – About 40 minutes

Vocabulary

bearing
dead reckoning
floating compass
magnetic compass
navigation

Materials

For each student

1	Activity Sheet 5, Parts A–D
1	Resource Sheet 6 (two-sided)

For each team of two

1	compass, magnetic
1	needle, blunt
8	notes, self-sticking
1	pan, aluminum
1	*ruler, metric
1 pair	*scissors

For the class

1	*container, 1-L
4	foam squares
1	magnet, bar
1	paper clip
1 roll	*paper towels
1 roll	*tape, transparent
	*water, tap

*provided by the teacher

Preparation

Session I

1. Make a copy of Activity Sheet 5, Parts A and B, for each student.
2. If the kit has not been used before, cut each of the foam squares into quarters.
3. Magnetize one needle for each team of two, as follows: Hold the needle by the eye and gently stroke the length of the needle from eye to point against the north pole of the bar magnet (see Figure 5-1). To make sure each needle is sufficiently magnetized, try to pick up or move a paper clip with it.
4. Assemble the floating compasses by taping each magnetized needle along the diagonal of a foam quarter.
5. Place a 1-liter container of tap water and a roll of paper towels at a distribution station.

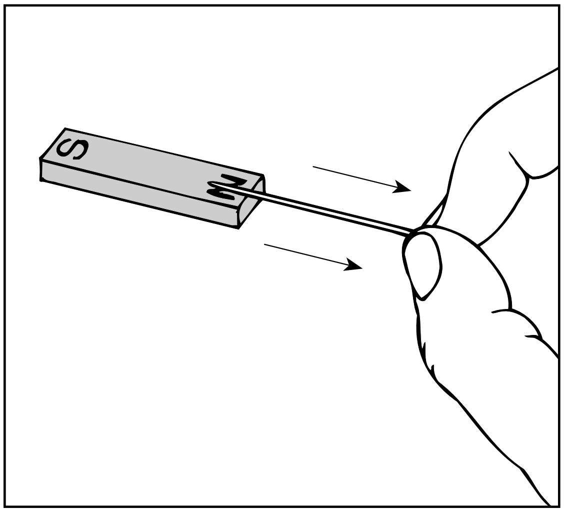


Figure 5-1. Magnetize the needle by stroking it against the north pole of a bar magnet.

6. Select eight objects around the room, the directions of which will be determined by students using both a floating compass and a modern compass. List the objects on the board.

7. Each team of two will need one aluminum pan, one foam square with a magnetized needle taped to it, eight self-sticking notes, one magnetic compass, a metric ruler, and a small amount of water.

Session II

1. Make a copy of Activity Sheet 5, Parts C and D, and Resource Sheet 6 (two pages) for each student.

2. Each team of two will need one magnetic compass, one pair of scissors, one metric ruler, and several pieces of transparent tape.

Background Information

Navigation is the process of planning, tracking, and controlling the course and position of a ship or other craft. Today's ocean-going vessels are equipped with sophisticated electronic devices that measure and record the precise direction and location of the ship, as well as the ship's speed and distance traveled. Any change in the preprogrammed course of the ship—due to changes in weather or currents—is automatically detected and corrected by on-board computers that constantly monitor the progress of the ship.

But the earliest mariners had no such instruments. They navigated their ships by hugging the coast and peering through telescopes for established landmarks. With the invention of the *magnetic compass* by the Chinese in the twelfth century, mariners ventured farther from shore, employing a new method of navigation called *dead reckoning.*

Dead reckoning involves estimating the current position of the ship based on the assumed distance and direction traveled from the previous position. A form of educated guesswork, it is not particularly accurate because it does not take into account changes in the ship's speed due to ocean currents and shifting winds, nor does it allow for errors in compass readings.

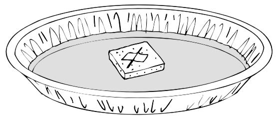
One of the earliest types of navigational tools, floating compasses were prevalent in European navigation by the fifteenth century. These compasses were made by attaching a length of lodestone, a natural magnetic material, to a piece of cork or other wood. The wood was then floated in the center of a glass container filled with water. The container, which was etched with the 32 compass points, was sealed and placed in a box that was fixed to the deck of the ship. Free of constraints, the piece of lodestone would align itself with the earth's magnetic north pole.

In this activity, students build floating compasses similar to those used by early navigators. Then they use a modern compass to plot the course of Christopher Columbus's historic voyage to the New World in 1492.

Name ______________________ Activity Sheet 5, Part A

Navigating with a Compass

1. Bring your pan and a metric ruler to the distribution station. Fill the pan with water to a depth of about 1 cm. Return to your work station and place the pan on a level surface. Carefully float the foam square (needle-side up) in the center of the pan, as shown below.



2. Observe what happens to the foam square and needle. Record your observations here.

The foam square and needle turned.

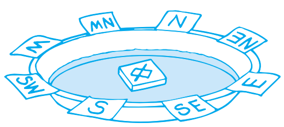
3. Gently rotate the foam square and then release it. Observe and record what happens to the foam square and needle.

The foam square and needle turned back to its original position.

Why do you think the foam square and needle moved as they did?

The needle is magnetized, so its tip always points toward the earth's north pole, regardless of how the pan is turned.

4. Label the eight self-sticking notes *N, NE, E, SE, S, SW, W,* and *NW*. Give the needle a minute or two to stabilize, then carefully position the note labeled *N* on the rim of the pan directly in line with the tip of the needle. Attach the remaining notes in their proper positions around the circumference of the pan, as shown by the drawing on the board. Sketch your floating compass in the space below.



Name ______________________ Activity Sheet 5, Part B

Navigating with a Compass

5. Use your floating compass to determine the direction of each of the eight objects listed on the board. Then use the modern compass to do the same. Record your results in the table below.

Object	Direction (Floating Compass)	Direction (Modern Compass)

Did the floating compass work as well as the modern compass? Explain.

Yes, they both indicated the same direction.

How do you think the invention of the floating compass improved navigation for ancient mariners?

With a compass, the direction of the ship could be determined at all times.

What information does the modern compass provide that your floating compass does not?

The modern compass has degrees marked on it as well as many more compass points.

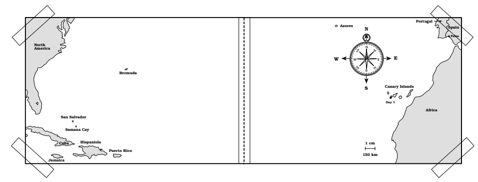
Name ______________________ Activity Sheet 5, Part C

Navigating with a Compass

6. Cut along the dashed line on the maps on Resource Sheet 6. Tape the edges of these maps together to form one large map.

7. Place the map on a table or desk. Place the magnetic compass on top of the compass points that are printed in the top right corner of the map. Once the compass needle has stabilized, calibrate the compass by turning the compass so that the N on the dial aligns with the compass needle.

8. Hold the compass steady and turn the map so that the N-S lines on the map align with the compass needle. Then tape the map to the table, as shown below.



Name ______________________ Activity Sheet 5, Part D

Navigating with a Compass

9. Begin plotting the course given in the table below by placing the center of the compass over the point marked *Day 1*. This point represents the location at which Christopher Columbus started his voyage on the dawn of September 9, 1492 (Day 1). Find the bearing of 260° on the compass. Mark a point on the map along the side of the compass at 260°.

10. Remove the compass and use a metric ruler to draw a straight line representing a distance of 900 km from point *Day 1* through the point indicating 260°. (Remember that on the map, 1.0 cm represents a distance of 150 km.) At that distance, mark point Day 6, representing Columbus' location on the morning of Day 6 of his voyage.

11. Plot the rest of the data in the same manner.

Day	Bearing	Distance (km)
1	260°	900
6	260°	1,050
14	280°	300
16	240°	450
20	260°	1,050
27	270°	750
32	250°	450

On the morning of October 12, 1492, Columbus landed after 33 days of travel.

What was the total distance Columbus sailed?

4,950 km

What was the average daily distance covered by his vessel?

4,950 km ÷ 33 days = 150 km per day

Teaching Suggestions

Additional Information

Session I

Ask students, **When you walk or ride to a friend's house, how do you know you are traveling in the right direction?**

1 Answers will vary, but students should agree that passing familiar buildings, cross-streets, and other landmarks lets them know they are going the right way.

Tell students that the earliest mariners did the same thing: They stayed close to shore and noted their progress by the passage of familiar landmarks.

Ask, **If you were traveling to someplace you had never been before, what two things would you need to know in order to reach your destination?**

Again, answers will vary, but elicit from students that they would need to know the distance—how far away the place was—and the direction in which to travel.

Write the word *navigation* on the board. Explain that the term comes from the Latin words *navis,* meaning "ship," and *agere,* meaning "to move or direct." Navigation is the process of planning, tracking, and controlling the course of a ship or other craft. Tell students that in the twelfth century, the Chinese invented a navigational tool that could be used to determine direction from any point on earth. Ask, **What is the name of a device that tells direction?**

Students may know that you are referring to a compass.

Write the term *magnetic compass* on the board, and ask a volunteer to explain how one works.

A compass consists of a magnetic needle that turns freely to align with the earth's north pole. In a modern compass, the needle pivots horizontally above a compass card which, when properly adjusted, indicates geographic direction.

Explain that the invention of the magnetic compass enabled mariners to venture farther away from the shore. By estimating the distance traveled in an exact direction, mariners could locate and plot their positions on maps. This type of navigation was called dead reckoning. Write the term *dead reckoning* on the board.

Students may be interested to know that the word *reckon* comes from the German *rechnen,* which means "to count." By the fourteenth century the word had acquired the meaning "to estimate or consider."

Tell students that in this activity they are going to build models of compasses similar to those used by early navigators. They will use them to determine the direction of several objects around the room. Then they will use a modern compass to plot the course sailed by Christopher Columbus.

2

Draw Figure 5-2 on the board and write the term *floating compass* above it.

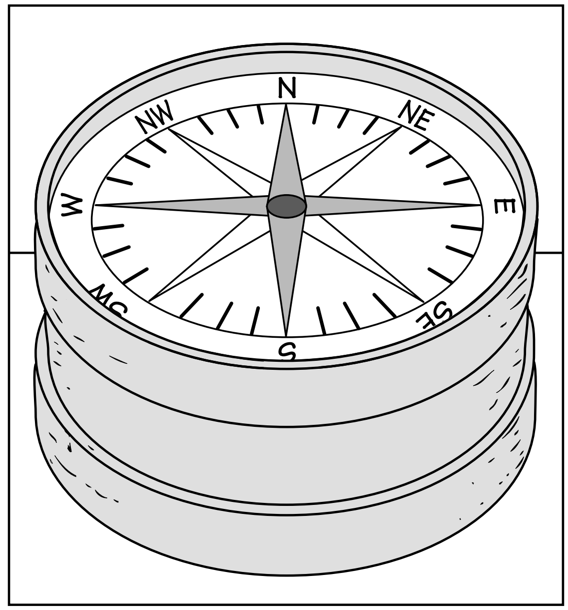


Figure 5-2. A floating compass.

Briefly explain that a floating compass was a type of magnetic compass used by early navigators. It consisted of a long piece of lodestone attached to a piece of cork or other wood and placed in a glass container. The container was then sealed and affixed to the deck of the ship. The glass was etched with the points of the compass. Because it is a natural magnetic material, the lodestone would align itself with the earth's north pole. By turning the etched glass so that the mark for north aligned with the lodestone, a navigator could tell the direction in which he was traveling.

Students may wonder what is meant by the term *compass point*. Tell them that there are four main points on a compass: north, south, east, and west, and seven more points in between each main point, for a total of 32 compass points. For example, between north and east there are: north, north by east, north northeast, northeast by north, northeast, northeast by east, east northeast, east by north, and east.

Distribute one copy of Activity Sheet 5, Parts A and B, to each student. Divide the class into teams of two and distribute one aluminum pan, one foam square with a magnetized needle taped to it, eight self-sticking notes, and a metric ruler to each team. Point out the 1-liter container of water at the distribution station.

Draw a large circle on the board to represent the face of a compass. Label the points of the compass as follows: *N, NE, E,* *SE, S, SW, W,* and *NW.* Label the diagram *Points of the Compass.* Then have students complete Part A of the activity sheet.

Tell students to try to keep their foam squares in the center of the pan at all times. They can do this by carefully tilting the pan; they should not touch the foam squares.

3

Next, distribute one magnetic compass to each team and ask students to compare it with the floating compass. Ask, **What similarities do you see between these two types of compasses?**

Students should note that both compasses have a "needle" that points north and both have at least eight identifiable compass points.

Explain that a modern compass works the same as a floating compass except that it is smaller and more portable.

Call students' attention to the eight objects listed on the board, and point out their locations around the room. Tell students to complete Part B of the activity sheet.

If necessary, review the use of a modern compass. Make sure students understand that the *N* on the compass dial should align with the needle at all times. The dial can be adjusted simply by turning it.

In addition, remind students to keep the floating compass and modern compass separated so they do not influence each other.

4

Have students discuss their observations of Steps 2–4 (in Part A of the activity sheet). Then ask students to compare the results they obtained from using the floating compass with those obtained using the modern compass (Part B).

Have students remove the foam squares from the water, dry them with paper towels, and remove the needles from the squares. Ask students to discard the self-sticking notes and empty and set aside the aluminum pans to air-dry. Return the foam squares, needles, compasses, and bar magnet to the kit.

Session II

5

Have students recall the principles of navigation. Ask, **What two measurements must you know in order to find your way?**

direction and distance

Distribute one magnetic compass to each team of two. Write the term *bearing* on the board and explain that it means "direction of travel." Add that instead of using the terms *north, south, east,* and *west* to indicate direction of travel, navigators often refer to their ship's bearing in degrees.

Tell students to look at their magnetic compasses and notice that the circular face of the compass is divided into 360°. Ask, **What is the bearing of a point that is northeast on your compass? South? Northwest?**

The bearings are 45°, 180°, and 315°, respectively.

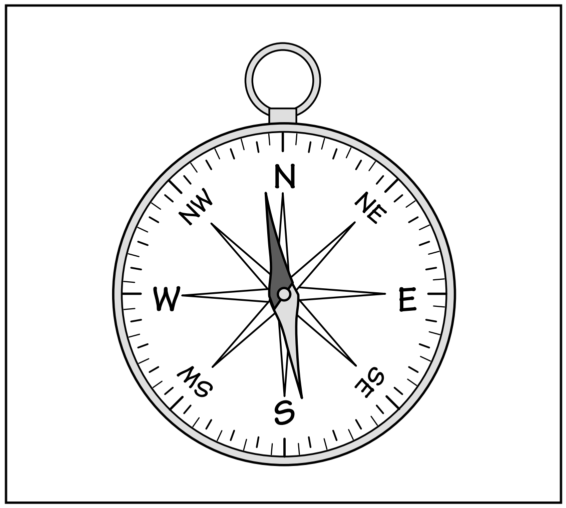


Figure 5-3. A magnetic compass.

Congratulate students on their compass-reading abilities. Tell them that they have just been commissioned to plot the compass bearings and chart the distance traveled by Christopher Columbus on his most famous fifteenth-century voyage to the New World.

6

Distribute one copy of Activity Sheet 5, Parts C and D, to each student. Distribute one copy of Resource Sheet 6 (two pages), one pair of scissors, one metric ruler, and several pieces of tape to each team of two. Have students complete the activity sheets.

If students are having difficulty plotting distance on the map, remind them that the scale of the map is 1 cm = 150 km. Tell them to divide the distance given in the table by 150. The resulting value will be the length of the line they need to draw in centimeters.

7

Have students compare their plotted voyages and discuss any differences. Ask, **According to your charts, where did Columbus land?**

San Salvador

Explain that it was traditionally thought that Columbus landed on Watling Island (renamed San Salvador in 1926). Modern replotting of Columbus' course indicates it is more likely that he landed on the island of Samana Cay at a latitude almost 1° south of San Salvador.

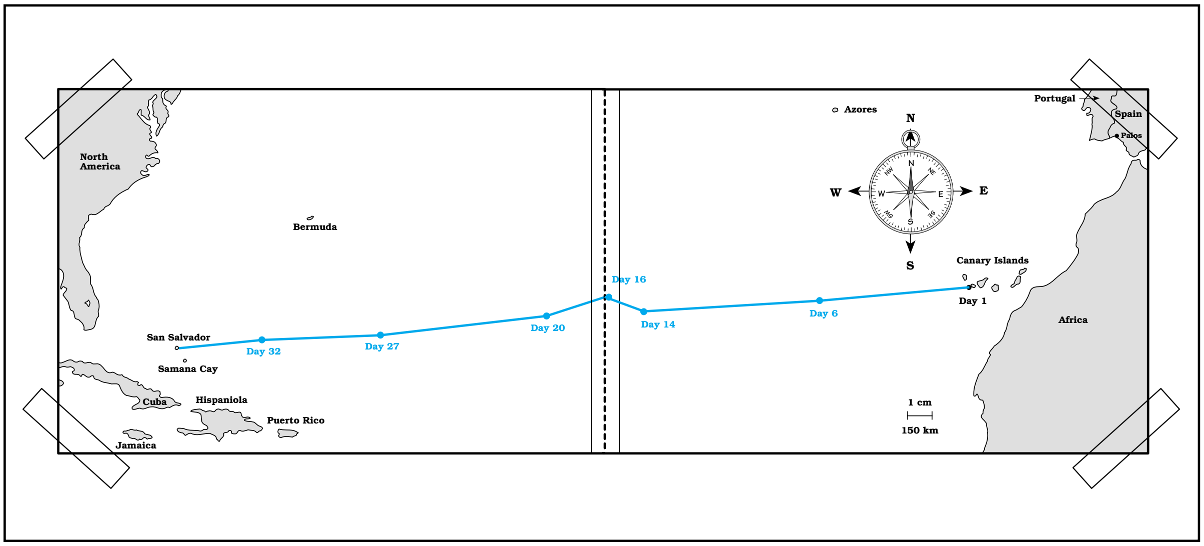


Figure 5-4. Completed student maps tracking Columbus' journey to the Americas.

8

Point out that the invention of the compass and the use of dead reckoning was an important advancement in navigational science. However, dead reckoning is really just a form of educated guesswork. Ask students, **Why was dead reckoning not a particularly reliable form of navigation for early mariners?**

While the compass enabled mariners to determine the direction in which they were traveling, they still had no means of accurately measuring the distance traveled.

Lead students to realize that dead reckoning does not take into account changes in ocean currents and winds nor does it allow for errors in compass readings. As a result, early navigators could not determine accurately the distance that had been traveled using that method of navigation alone. As a result, many ships were literally lost at sea.

Add that shortcomings of this method of navigation are not always to blame, and that the even the best navigators could get lost if the maps they were using to chart their course were incomplete or inaccurate.

Students may be interested to know, for example, that Christopher Columbus was searching for a westward trade route to India when he reached the Bahamas. According to the maps available at the time, the Asian continent appeared to be only about 4,000 km (about 2,500 mi) west of Portugal. When he dropped anchor he was convinced he had reached Asia when, in fact, he had never left the Atlantic Ocean!

Conclude the activity by telling students that it was the development of another tool in the 1700s that enabled mariners to determine more precisely their location at sea. This device improved not only the accuracy of navigation but of mapmaking in general. Activity 6 examines the role of the quadrant in navigation.

Reinforcement

R

Have students plot a course for a fictitious return journey by Columbus to Palos, Spain, via Bermuda Island and the Azores. Students should indicate the position each fifth day (Days 1, 5, 10, and so forth), using an average distance of 150 km traveled per day.

Cleanup

C

Have students return the magnetic compasses to the kit.

Connections

Science Challenge

Have students position a compass on a desk so that *N* is aligned with the north-pointing end of the compass needle. Students should then tie a string to a bar magnet, suspend it above the compass, and turn it slowly. What happens to the compass needle? (It turns to follow the magnet.) Ask students to suggest a reason for this. (The attraction of the magnet so close to the compass is stronger than the attraction of the earth, so the needle follows the magnet.) Ask students what this observation would lead them to suggest as a precaution when using a compass. (Make sure there are no magnetized objects nearby.)

Science Extension

Students might like to try orienteering—using a compass and written instructions to find their way from a starting point to an end point. Set up an orienteering course in a large open area—outdoors, preferably, or in a gym or cafeteria. With flags, boxes, or some other marking devices, indicate a starting point at one end of the area and three or more possible end points elsewhere in the area. Prepare a set of written instructions that will lead students from the starting point to only one of the end points. Instructions should combine measurements and compass directions ("Walk 4 meters east," for example). Give each team a metric measuring tape and a copy of the instructions. Have teams start the course a few minutes apart and work their way to an end point. When all teams have completed the course, identify the correct end point by walking the course yourself as students read the instructions aloud. Have students who did not complete the course correctly repeat it.

Science and the Arts

A compass rose is a drawing, sometimes highly decorative, of compass points for reference on a map. Early map-makers often decorated the compass rose with illustrations showing what they believed to be true about the world—for example, sea dragons waiting for unwary ships. Compass roses frequently included symbols of wind, clouds, and ships. Ask students to look for various types of compass roses in encyclopedias, atlases, and other reference books. Encourage them to design compass roses of their own.

Science and Careers

Invite a professional navigator or a recreational sailor to visit the class to explain how he or she navigates while sailing. Tell the visitor beforehand that you are particularly interested in the use of the compass as a navigational tool. Perhaps the visitor has a story to share about a difficult or dangerous situation in which he or she depended on the compass.

Science and Math

Students may be interested to learn that the traditional nautical measure of water depth is the *fathom.* Have students convert fathoms to meters (and feet, if you wish), and vice versa, using the following equivalent:

1 fathom = 1.83 meters (6 ft)

Science, Technology, and Society

Tell students that another type of compass frequently used today is the gyrocompass. Obtain a gyroscope and show students how it works. Challenge students to think about how it could possibly be used to determine directions.