Educational Services

A Field Trip Guide

FOR THE PLANETARIUM SHOW
And a Star to Steer Her By

AND THE EXHIBITION
GPS: A New Constellation

Smithsonian
National Air and Space Museum
Exhibits and Public Services Department
Public Services Division

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A Field Trip Guide for the planetarium show *And a Star to Steer Her By* and the exhibition *GPS: A New Constellation*

Educational Services
National Air and Space Museum
Smithsonian Institution
Washington, DC

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The National Air and Space Museum is located at Independence Avenue between 4th and 7th Streets SW, Washington, DC. *And a Star to Steer Her By* is shown daily at the Museum's Albert Einstein Planetarium. For show times call (202) 357-1686. The companion exhibition is located on the second floor of the Museum.

This Field Trip Guide was produced to provide educators with information and activities to enhance the educational content of the planetarium show and exhibition. It was developed for Educational Services, National Air and Space Museum, by Interactive Exhibits, Inc. To schedule a group visit, contact the Reservations Office at (202) 357-1400 or visit the web site (http://www.nasm.edu). For more information about education programs at the Museum contact Educational Services, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560-0305 or visit the web site.

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The Planetarium Show and the Exhibit

And a Star to Steer Her By, a 30-minute planetarium show narrated by Sir Alec Guinness, traces the colorful history of navigation and presents the basic principles of finding position on Earth. The show demonstrates how north latitude can be measured from observations of the North Star and how longitude is obtained from further astronomical observations combined with accurate timekeeping. As an example of navigation at sea under the most challenging conditions, the show presents in vivid detail the plight of Ernest Shackleton's 1915 expedition to the South Pole. The ship became stuck in the ice near Antarctica and eventually sank. Despite terrible visibility, members of the crew found their way to an inhabited area and arranged for a rescue party. To show modern, high-tech navigation, the show closes with a description of the Global Positioning System (GPS).

The planetarium show's companion exhibit, *GPS: A New Constellation*, describes the history and operation of the Global Positioning System and the dramatic impact of GPS in thousands of applications. The system has three basic components: ground stations that control the operation, individual receivers carried by users, and a "constellation" of 24 satellites that simultaneously transmit signals all over the world. By measuring the difference in arrival time of three or four of these signals, the GPS receiver calculates the distance to the corresponding satellites and, by combining all the data, calculates the position of the receiver. GPS technology is now used in transportation, communication, public safety, and many other applications. GPS receivers are standard equipment on commercial ships, and the system is so inexpensive that it is widely used in recreational boats and in automobiles. The GPS exhibit displays the hardware and provides images that explain how the system operates.

How to Use this Guide

This guide provides pre-visit activities that will enable your students to have the best possible learning experience during their visit to *And a Star to Steer Her By* and *GPS: A New Constellation*. These activities develop the basic concepts of latitude and longitude and their connection to observing objects in the sky and measuring time. Although the concepts presented are closely related, each activity is self-contained, so that you may choose among them as you wish. The range of grade levels is nominally fifth through ninth, but older students can certainly benefit from these activities and younger ones can as well. For example, the first part of Activity 1, fastening paper continents on a basketball to make a model of Earth, works well with students in third and fourth grades. Activity 3, which presents the relationship of time and longitude, introduces concepts that are also addressed at the high school level. As you read through the activities, you may select and modify them to meet the needs of your students.

You are encouraged to visit the Museum before the field trip, to see the show and exhibit, so that you can better anticipate what your students will need to learn and understand in advance. If you have access to the Internet, you can visit the recommended web sites, which are listed in the Resources for Teachers section.

NATIONAL EDUCATION STANDARDS ADDRESSED IN THIS GUIDE

National Science Education Standards

Unifying Concepts and Processes

- Systems, Order, and Organization
- Evidence, Models, and Explanation
- Constancy, Change, and Measurement

Abilities Necessary to Do Scientific Inquiry (5-8)

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Use mathematics in all aspects of scientific inquiry.

National Council for Geography Education Standards

The World in Spatial Terms

- Maps and other geographic tools for information in a spatial perspective
- Mental maps and spatial context
- Spatial organization of Earth

Skills

- Acquiring geographic information
- Organizing geographic information

National Council for the Teaching of Mathematics (NCTM) Standards

Geometry (5-8): Geometric models provide a perspective from which students can analyze and solve problems…Many ideas about number and measurement arise from attempts to quantify real-world objects that can be viewed geometrically.

Measurement (5-8): Measurement in grades 5-8 should be an active exploration of the real world. The development of the concepts of perimeter, area, volume, angle measure, capacity, and weight is initiated in grades K-4 and applied in grades 5-8.


Colur
der
Plejaden
Algol
Kastor
Pollux
Zenith
Polarkreis
Kleiner Bär
Nördlicher
Wega
Krone
Gemma
Friedrichsehre
Herschels
Kreis
Telescop
Polarstern
Kopf des Drachen

Latitude and Polaris

Grade Level: 5 through 9

Time Required: one and a half class periods

Activity 1

OVERVIEW

How can we use the North Star (Polaris) to determine latitude? Students mount paper continents on a basketball to make a model of Earth and then predict the altitude of Polaris at various latitudes.

OBJECTIVES

- ★ Identify the shape of each continent
- ★ Make a model of Earth
- ★ Describe the relative positions of the continents
- ★ Predict the altitude of Polaris as seen from various latitudes
- ★ Identify the altitude of Polaris as the latitude

BACKGROUND INFORMATION

This activity develops the relationship between latitude and the altitude of Polaris, the North Star. Once you have identified Polaris, you can measure the angle between Polaris and the horizon, as shown in Figure 1. This angle is called the *altitude* of Polaris (sometimes called the angular altitude) and is equal to the latitude of the place where the observation is made. (The horizon is the point where the sky seems to meet the land or the sea.)

MATERIALS

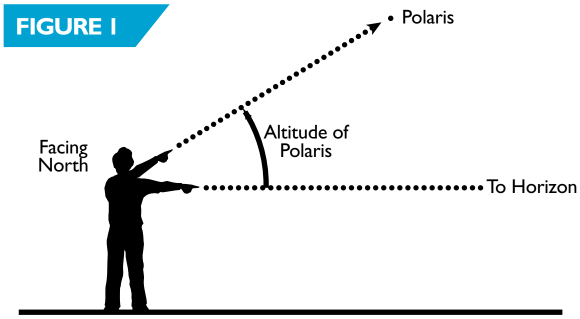
For each group:

- ★ One copy of two blackline masters: The Continents (a) and (b)
- ★ Scissors
- ★ Cellophane tape
- ★ Basketball or similar ball

For the class:

- ★ Globe or large world map (optional)

FIGURE 1



North-south position on Earth is specified by latitude, which ranges from zero to 90° north or south. Figure 2 shows Earth in cross-section, as if it were sliced right through its center. The angle gives the latitude—39° N—of Washington, DC. Notice that the arc from the equator to Washington, as defined by this angle, is also 39°. (For more information on the length of this arc, see Step 3 of this activity)

FIGURE 2

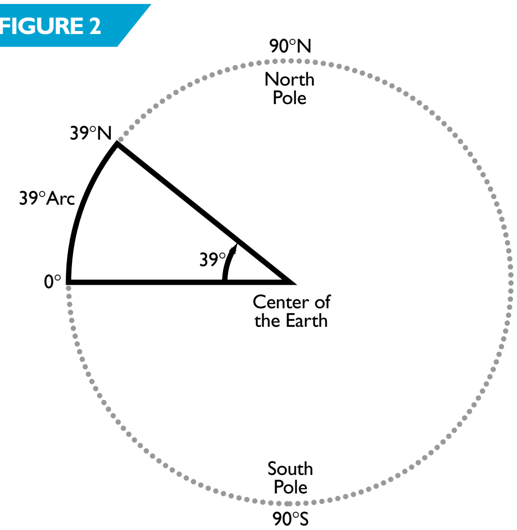


Figure 2 also shows the part of the longitude circle that this angle specifies. (The longitude circle runs from North Pole to South Pole, and is perpendicular to the equator.)

FIGURE 3

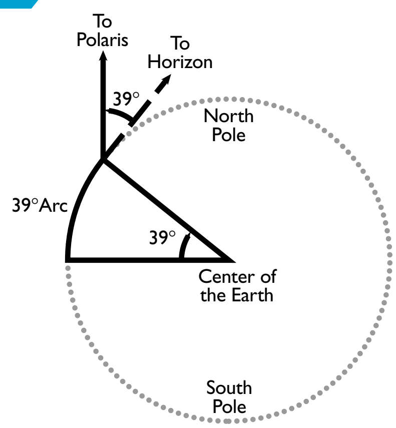
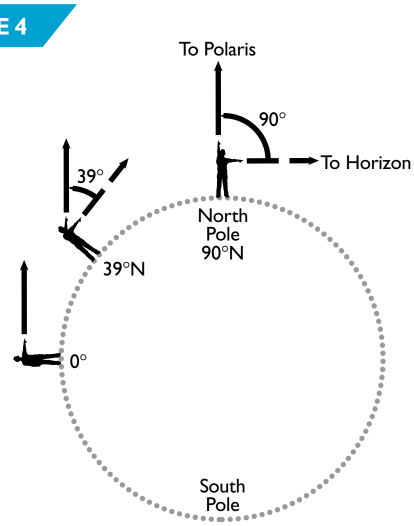


Figure 3 shows the observation of Polaris from the latitude (39°) of Washington, DC. The dashed line points to the horizon and is perpendicular to the line from the center of Earth to the point of observation. The arrow points to Polaris, which is almost directly over the North Pole. The difference in direction is only about half a degree, far too small for the students to observe in these activities. We will therefore take the altitude of Polaris to be equal to the latitude. Your students may wonder why the arrow to Polaris points straight up rather than tilting toward the North Pole. Polaris is so far away that it appears at the same place in the sky no matter where on Earth the observation is made.

FIGURE 4



Where is Polaris seen in the sky? Figure 4 shows observers at the equator, at the latitude of Washington, DC, and at the North Pole. Look at the angle made by the observer's arms in Figure 4. This angle, the altitude of Polaris, is equal to the latitude, provided the observer is in the northern hemisphere.

VOCABULARY

- ★ Polaris
- ★ model
- ★ equator
- ★ latitude
- ★ degree
- ★ angle
- ★ altitude

PREPARATION

Find one basketball for every group, or have the students bring in their own. You can also use a soccer ball, a kick ball, or a blow-up ball. If you feel your students will need help positioning the continents, set up a large world map in the classroom. Copy the two blackline masters, The Continents (a) and (b) and hand out copies to each group. Tell the students to cut out the continents, label them, and then put them aside for the activity itself. If you plan to do Extension 1, set up the overhead projector near a window.

PROCEDURE

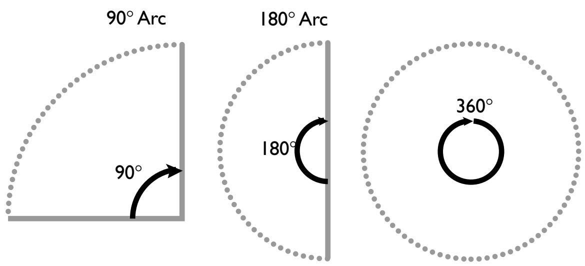
1. Hand out the basketballs. Explain that each basketball will be a model that represents Earth. You may explain that a model helps us understand how something works. Ask why a model of Earth is useful. (We can't see the whole Earth at once.)

2. Challenge the students to make a model of Earth by taping the cut-out continents in place. Hand out the cellophane tape.

   Note: If necessary, give students introductory activities to help them understand what an angle is and how it is measured. You can concentrate on angles between zero and 90°.

3. On the board, make a drawing of a quarter-circle, a semi-circle, and a complete circle, as shown in Figure 5. The parts of a circle are called arcs. For each drawing in Figure 5, ask the students how many degrees are in the angle and how many degrees are in the arc of the circle. (Degrees describe both the angle and the arc of the circle. The complete circle is 360°, the semi-circle is 180°, and the quarter-circle is 90°. The angle in the center is equal to the arc of the circle.)

FIGURE 5



4. Ask the students to hold up their Earth models so the North Pole is facing up. Ask where the equator is (right around the middle, running from east to west). Ask the latitude of the equator (zero). Ask the latitude of the North Pole (90° N).

5. Point out that the North Star, Polaris, is directly above the North Pole. Ask the students to imagine that they are at the North Pole. Ask them where in the sky they would look for Polaris (straight up). Point out that the angle from the horizon to Polaris is called the altitude of Polaris. (In the northern hemisphere, the altitude of Polaris is equal to the latitude.)

6. Point out that 90° is the size of an arc that is one quarter of a circle, which is the size of the arc from the equator to the North Pole. The latitude of the North Pole is 90°.

7. Ask the students where they would look for Polaris from Washington, DC (about 39° from the horizon). Ask where they would look for Polaris from the equator (on the horizon). Ask where they would look for Polaris from the South Pole. (They wouldn't see it, because Earth is in the way.) Ask how these angles are related to the latitude of each place. (The altitude of Polaris equals the latitude.)

REFLECTION AND DISCUSSION

Ask students where in the sky to look for Polaris at different places. (The closer a place is to the North Pole, the higher Polaris is seen in the sky; in fact, the angle above the horizon equals the latitude.)

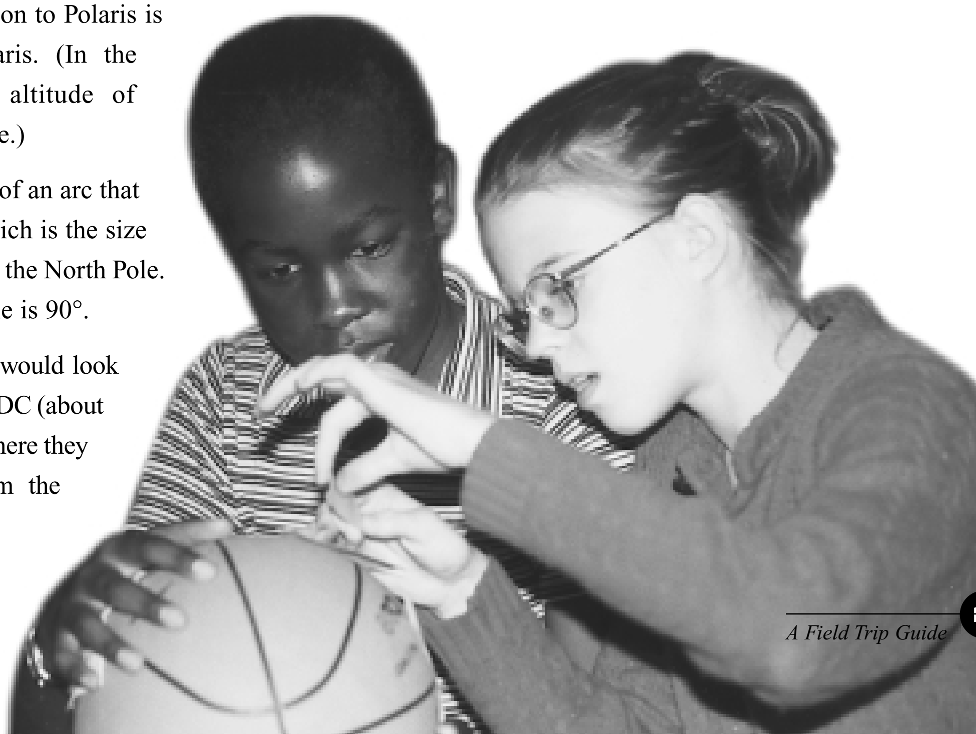
EXTENSIONS

1. Hold a basketball model in the beam of an overhead projector. Ask the students where on the model it is day and where it is night. Explore the relationship between day and night, east and west, and Earth's rotation.

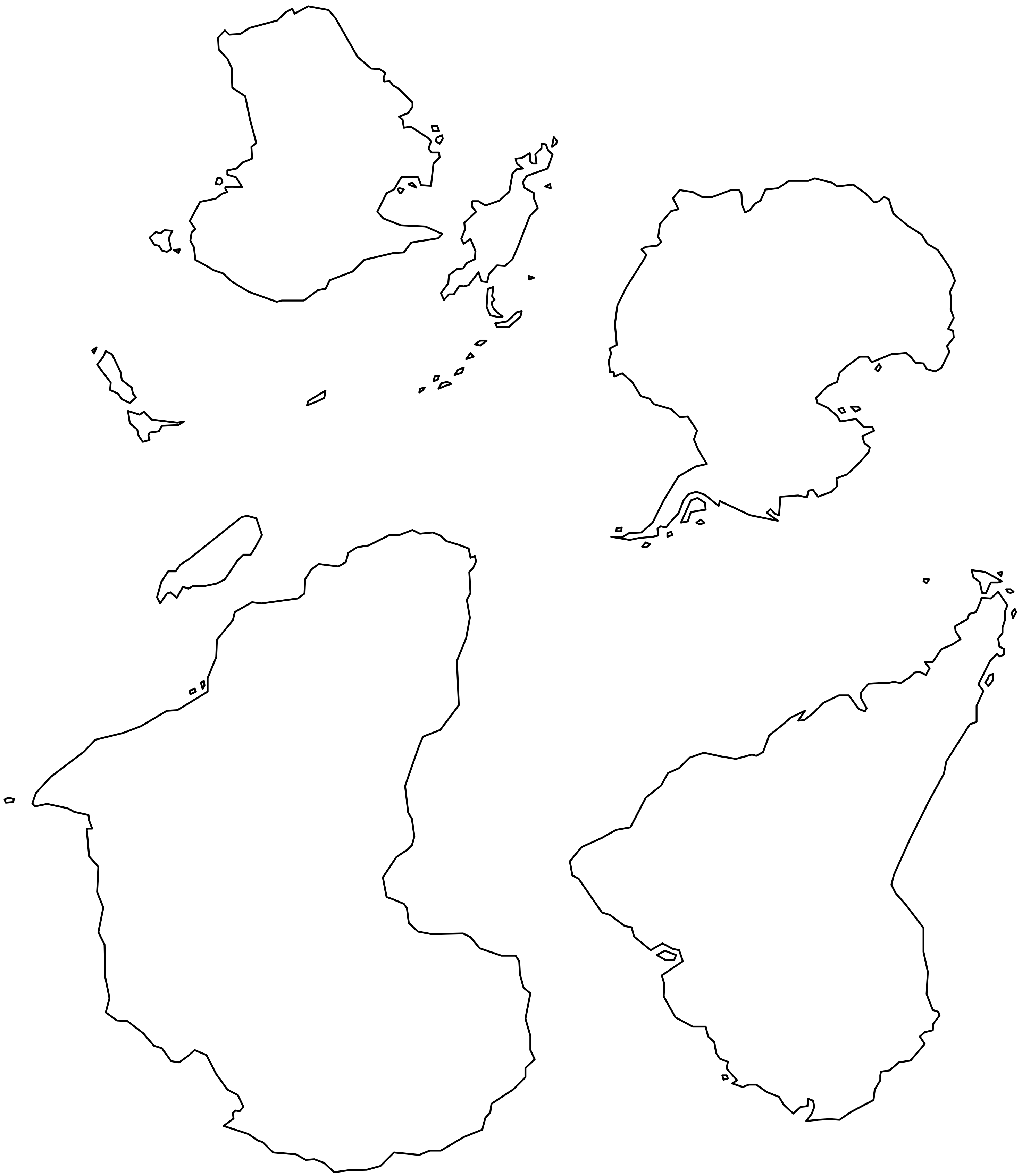
2. Have students write a story about voyagers who sailed around the world.

CURRICULUM CONNECTIONS

- ★ Mathematics: angles; scale; ratio and proportion
- ★ Social Studies: the continents, latitude
- ★ Language Arts: creative writing



Students in Class with Basketball:
ED LEE, INTERACTIVE EXHIBITS, INC.



Plejaden
Aldebaran
Kastor
Pollux
Herschels Telescop
Zenith Kreis
Fuhrmann
Capella
Algol
Algenib
Colur der
Friedrichsehre
Nördlicher Polarkreis
Kleiner Bär
Kopf des Drachen
Wega
Leier
Krone
Gemma

Where is Polaris?

Grade Level: 5 through 9

Time Required: one and a half class periods

OVERVIEW

How do we find the position of Polaris? Students construct a quadrant. Then they assemble a star chart to help find Polaris in the night sky, and they measure its altitude with the quadrant.

OBJECTIVES

- ★ Observe Polaris
- ★ Construct a quadrant
- ★ Measure the altitude of an object
- ★ Identify the altitude of Polaris as the latitude

BACKGROUND INFORMATION

As demonstrated in Activity 1, the altitude of Polaris is equal to the latitude for positions in the northern hemisphere. For a further discussion of latitude and altitude, see the Background Information in Activity 1. In this activity students learn to use a quadrant and a star chart to investigate latitude and altitude.

Assemble a quadrant. Notice that when you sight through the straw at the horizon, the string hangs at the 0° line. Since altitude is the angle measured up from the horizon, the horizon itself has zero altitude. Now sight through the straw straight up. The string hangs at the 90° line, because you are looking 90° from the horizon.

Next assemble a star chart. The chart will help you find the Big Dipper and Cassiopeia. Turn the dial to match the date and the time at which you are observing, and note the position of these two constellations. To begin observing, face north. If you have a compass, face in the direction that the needle points. If you have no compass, stand so the sun rises on your right and sets on your left. Polaris will be to the north, 39° above the horizon. Look in the direction indicated by the star chart to find the Big Dipper or Cassiopeia, and follow the arrows on the chart to Polaris. Alternately, face north and sight through the quadrant at an angle of 39°.

In celestial navigation the navigator observes the altitude of several objects in the sky and calculates the position from this data. (See Background Information in Activity 3) The navigator sights these objects through a device called a sextant. A clear sky is important for this observation, since both the object and the horizon must be visible.

MATERIALS

For each student:

- ★ One copy of blackline master: *The Quadrant*
- ★ One copy of blackline master: *Where is Polaris?*
- ★ Tagboard, about 15 cm square
- ★ Straw
- ★ String, about 20 cm
- ★ Nut or other small weight
- ★ Scissors
- ★ Tape, about 10 cm
- ★ Paper fastener

For the class:

- ★ White glue or gluestick
- ★ Globe

VOCABULARY

- ★ horizon
- ★ Polaris
- ★ latitude
- ★ altitude
- ★ angle

Note that "altitude," which is often called angular altitude, means the angle between the horizon and an object in the sky. In the northern hemisphere, the altitude of Polaris is equal to the latitude. For the relationship between altitude and latitude, see the Background Information of Activity 1.

PREPARATION

Make copies of the blackline masters The Quadrant and Where is Polaris? for each group.

PROCEDURE

1. Ask what the horizon is (the place where the sky appears to meet the land or the sea). Explain that navigators can find latitude by measuring the angle from the horizon to Polaris. This angle is the altitude of Polaris. Explain that a quadrant is a device that measures the angle from the horizon to an object in the sky. You can mention that the name refers to the quarter-circle (the angles from zero to 90°).

2. Hand out copies of the blackline master The Quadrant. Hand out the rest of the materials. Ask the students to assemble their quadrants by following the directions on the handout. Demonstrate the use of the quadrant before going outside. To show how they will hold the quadrant, point out the photograph on the blackline master. Add that if they find it difficult to look *through* the straw, then they can simply look *over* it.

3. After the glue has dried, have students take their quadrants outside and stand about 15 meters from a flagpole (or some other tall object). To illustrate how they will hold the quadrant, show them the photograph on the blackline master.

4. Have them measure the angle to the top of the flagpole. You might mention that they can look either through the straw or along the top of the straw. Point out that when they see the top of the flagpole through the straw, they should press the string to the quadrant so they can measure the angle. You can refer them to the photograph on the blackline master. Then have them record the angle and compare their results.

5. Ask the students where they would stand so they would all measure the same altitude to the top of the flagpole. (From any point on a circle around the base of the flagpole, they will measure the same altitude.) Point out that an altitude measurement on a single object specifies the position only to some point on a circle. For example, the observation of Polaris in Activity 2 specified the position only to a circle of latitude at 39° N.

6. Ask students how they could use their quadrant to measure the angle to a star. (They look at the star through the straw and measure the angle as they did in Step 4.)

7. Back in the classroom, hand out scissors, cardboard, and copies of the blackline master Where is Polaris? to each student. Have them follow the assembly directions printed on each copy. Review how to adjust the chart for the time. (Turn the dial to line up the time and the date.)

8. Ask the students to try to find Polaris in the night sky and then measure its angle above the horizon with the quadrant. Caution them to be sure to take an adult with them and to go out only if they have a safe place to observe. Explain that they may need an adult to help them find north. Then they will look up from the horizon and follow the directions provided in Where Is Polaris?

9. Have the students report what they observed. Compare their measurements to the latitude of Washington, DC (39° N). Ask if, during the time they were observing, any of the stars changed position. (If students made observations over several hours, they might observe the circular motion of stars around Polaris.)

REFLECTION AND DISCUSSION

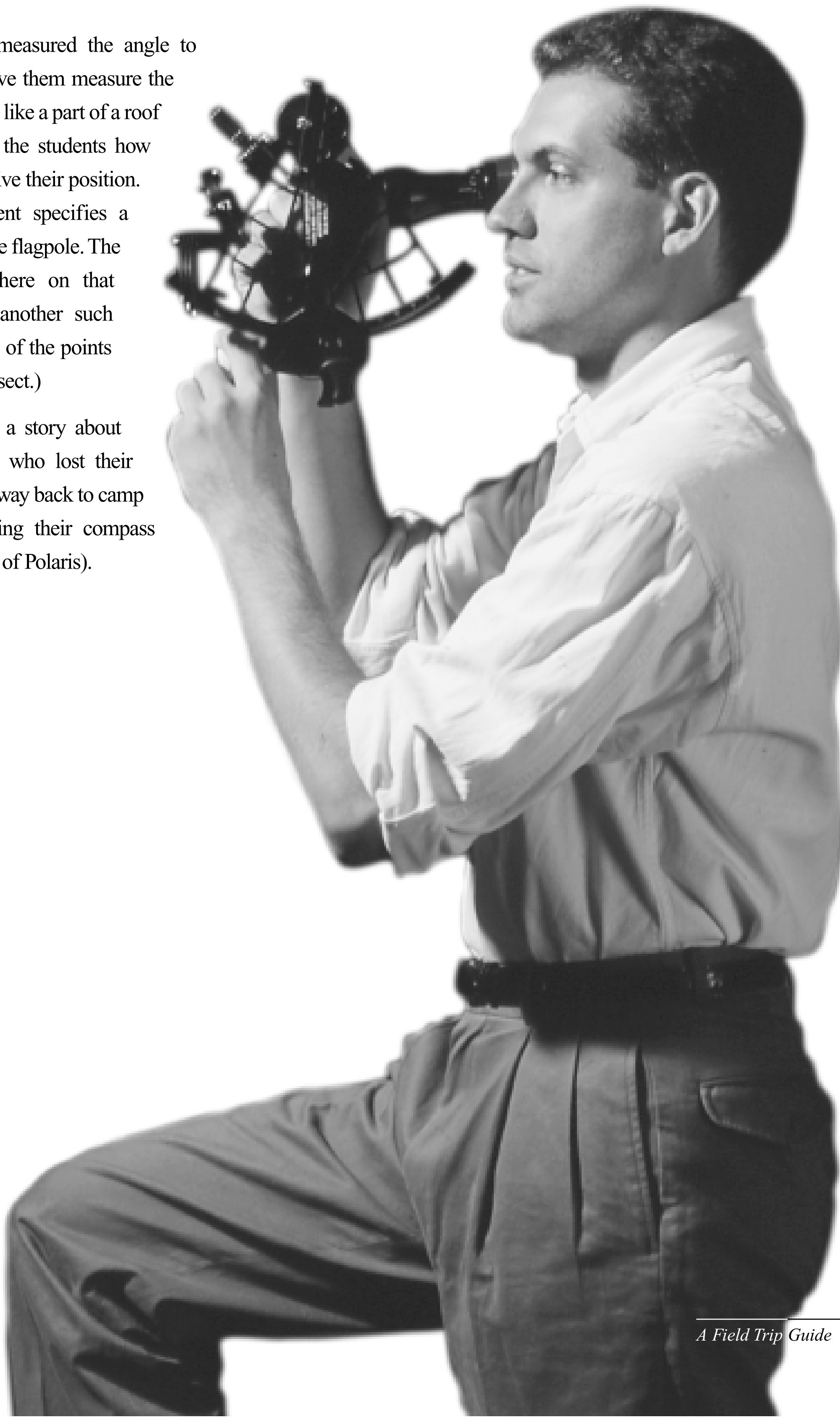
Ask students to summarize what they have learned about Polaris. (They can find it with the star chart; the other stars seem to move around it in circles. Polaris' angle with the horizon is the same as the latitude.)

CURRICULUM CONNECTIONS

- ★ Mathematics: angle
- ★ Social Studies: latitude
- ★ Language Arts: creative writing

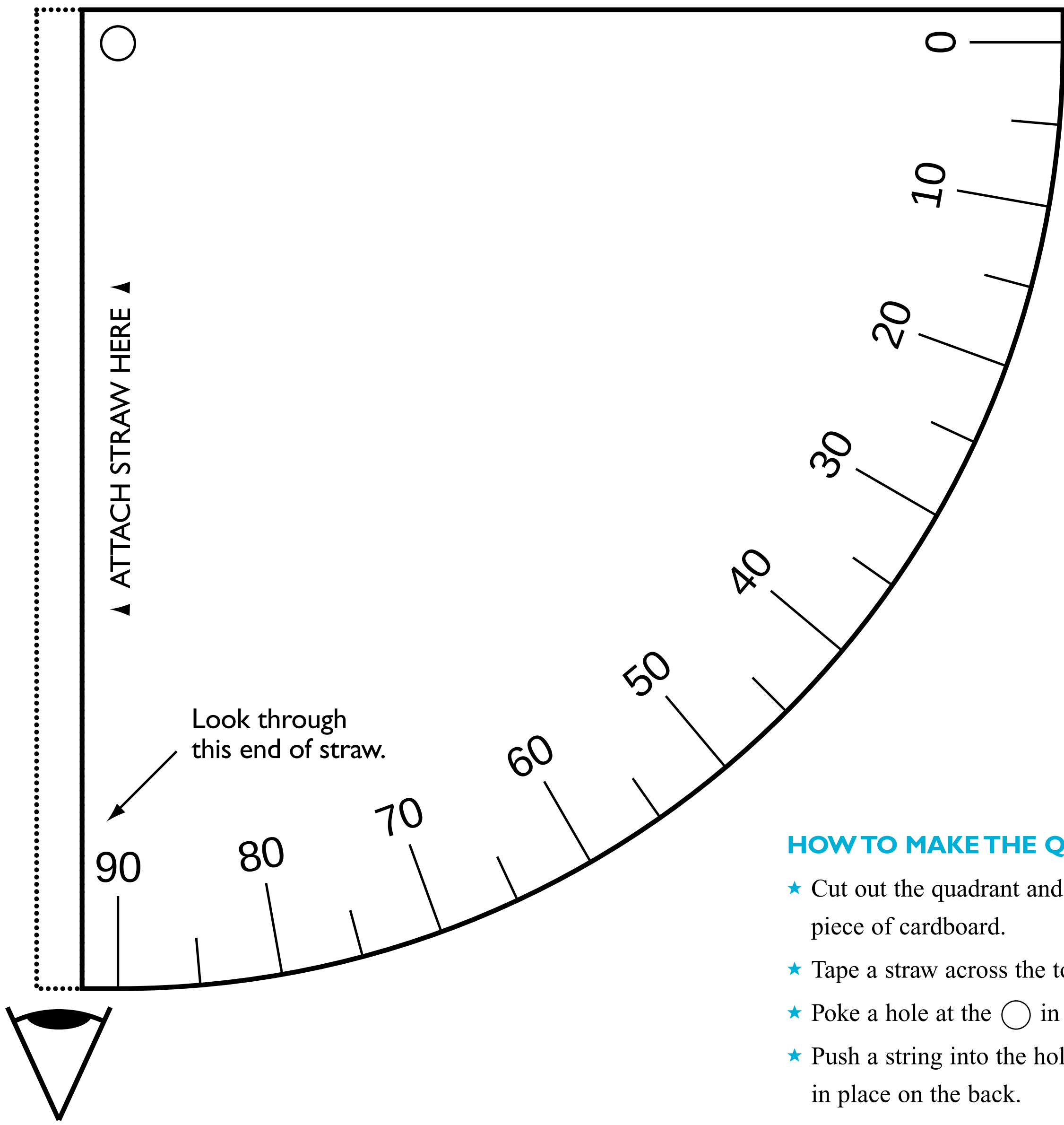
EXTENSIONS

1. After the students have measured the angle to the top of the flagpole, have them measure the angle to another tall object, like a part of a roof or the top of a tree. Ask the students how these two measurements give their position. (The flagpole measurement specifies a circle around the base of the flagpole. The students could be anywhere on that circle. But if they find another such circle, they must be at one of the points where the two circles intersect.)
2. Ask the students to write a story about how a group of campers who lost their compass tried to find their way back to camp on a clear night (by taking their compass direction from the position of Polaris).



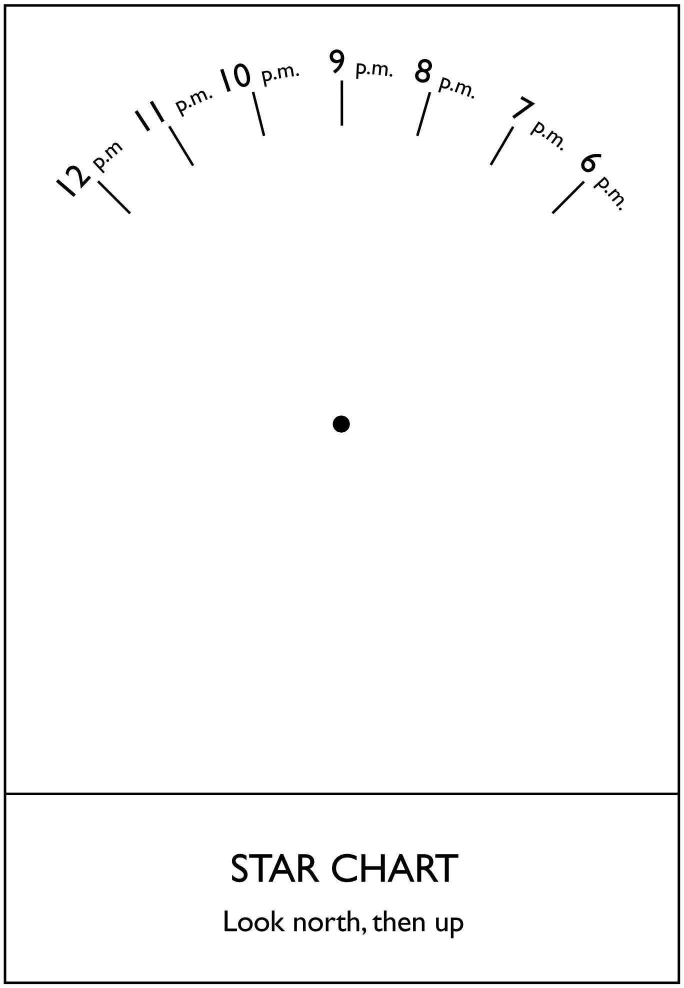
Sextant Photo: CAROLYN RUSSO, SMITHSONIAN INSTITUTION

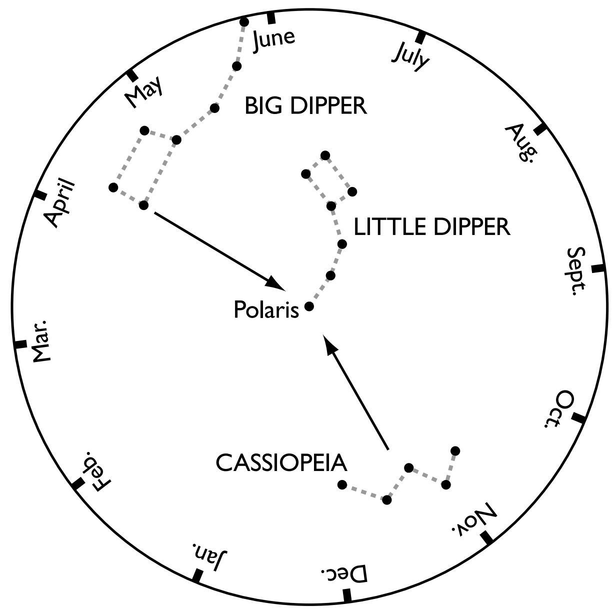
ACTIVITY 2 BLACKLINE MASTER: THE QUADRANT



HOW TO MAKE THE QUADRANT:

- ★ Cut out the quadrant and glue it to a piece of cardboard.
- ★ Tape a straw across the top.
- ★ Poke a hole at the ◯ in the corner.
- ★ Push a string into the hole and tape it in place on the back.
- ★ Tie the weight to the string. Be sure the weight hangs below the angle marks.





Star Trails: GEOFF CHESTER, McMATH SOLAR TELESCOPE, KIT PEAK NATIONAL OBSERVATORY

This photo was taken by pointing the camera at Polaris and leaving the shutter open for one hour. The trail of Polaris is the bright spot at the center.

HOW TO MAKE THE STAR CHART:

- ★ Cut out the two pieces and glue them onto tagboard.
- ★ Punch holes in the middle of each one.
- ★ To hold them together, push a paper fastener through the holes.

HOW TO FIND POLARIS:

- ★ Line up the month and the time. The chart tells you where to look to find the Big Dipper or Cassiopeia.
- ★ The arrows point toward Polaris.

Colur
Plejaden
Kastor
Pollux
Herschels Telescop
Zenith
Algol
Nördlicher Polarkreis
Polarstern
Kleiner Bär
Quadrant
Krone
Gemma
Wega
Leier
Friedrichsehre
Messier
Kopf des Drachen

Longitude and Time

Grade Level: 7 through 9

Time Required: one class period

OVERVIEW

How can we determine longitude? Students calculate time for different longitudes and record the results on a map of the world. Then they predict the longitude by comparing local time to Greenwich time.

BACKGROUND INFORMATION

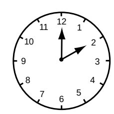
In Activity 2, the students found that latitude specifies the position to somewhere on a latitude circle. To specify the position to a point on this circle requires that longitude be determined. Longitude is measured in degrees east and west from the prime meridian, the north-south line running through Greenwich, England.

Due to Earth's rotation, a measurement of time is necessary to specify longitude. Since Earth turns through a complete revolution, 360° every 24 hours, in one hour Earth turns 15° (15° = 360°/24) Consequently, local time on the surface of Earth changes by one hour with every 15° change in longitude. (See the blackline master Longitude and Time.) Of course, time zones modify the relationship between time and longitude, but Los Angeles and New York differ in longitude by about 45°, which corresponds to their three hour time difference.

Suppose a navigator had an accurate clock that kept the time at Greenwich, England, on the prime meridian. Further, suppose the navigator determined local noon by noting when the sun reached its highest point in the sky. Then the navigator could find the longitude from the *difference* between local time and prime meridian time, through the 1 hour = 15° relationship. (Again, see the blackline master.) For instance, if local time were two hours behind prime meridian time, the ship would be at 30° W longitude.

Please note that "local time," as used here, means local time as found from the observation of objects in the sky rather than the time determined by time zones. The example in Table 1 is the special case of an observation made at local noon.

TABLE I

Local Time	Prime Meridian Time	Longitude
Noon	 p.m.	30°W

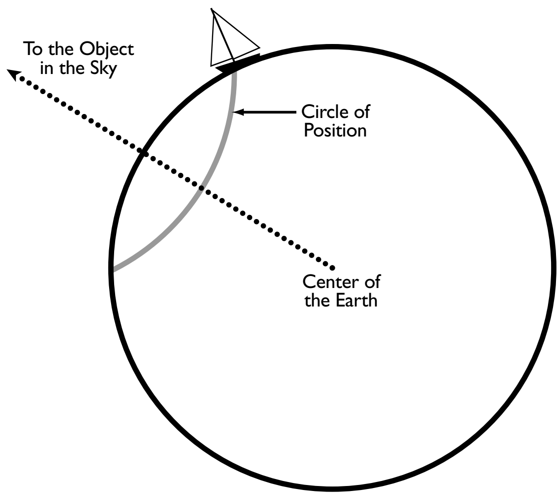
In general, navigators measure the altitude of several objects in the sky. Figure 1 (page 22) shows how each altitude determines a circle of position on Earth, like the circle around the flagpole in Activity 2, Step 5. The navigator consults astronomical tables to specify the orientation of Earth in space at the time of the observation. With this information, the navigator locates each circle on the surface of Earth. The intersection of these circles gives the position of the navigator.

MATERIALS

For each student:

- ★ One copy of blackline master: Longitude and Time

FIGURE 1



Historically, position-finding was essential for seafaring nations such as England, but the accurate measurement of time was a daunting challenge. To maintain a standard reference time, sailors departed England with clocks set to Greenwich time. Unfortunately, eighteenth century clocks could not keep time in the harsh marine environment, with wide temperature ranges, irregular motions, and water and humidity everywhere. Finally, after three and a half decades of intensive effort in England, John Harrison produced a clock—the chronometer—that kept time to within a tenth of a second per day. With the chronometer, navigators could determine position accurately and set courses to bring a ship to its destination safely.

VOCABULARY

- ★ longitude
- ★ prime meridian

OBJECTIVES

- ★ Describe the relationship between longitude and time
- ★ Calculate the time at various longitudes
- ★ Find longitude by comparing local time to Greenwich time

PROCEDURE

1. Ask students to give an example of two places with different times. (California time is three hours behind Washington, DC time.)
2. Hand out to each student a copy of the blackline master Longitude and Time. Ask what time it is at the prime meridian (3:00 p.m.).
3. Ask how the time changes if they go east (as they move further east, time moves further ahead) and if they go west (as they go further west, time moves further behind; for example, California is three hours behind Washington, DC).
4. Ask the students what time it is at 15° W longitude (2:00 p.m.). Point out the one hour per 15° of rotation relationship and discuss where it comes from. (See text at bottom of blackline master.)
5. Ask the students what time it is at 60° W (11:00 a.m.). Have them write in the time. Ask if it's still the same day (yes).
6. If the students are ready to work on their own, have them fill in the times, including "a.m." or "p.m.," for all the remaining boxes. Table 2 shows the answers.

TABLE 2

Longitude	Time
180°	3:00 a.m.
105° W	8:00 a.m.
45° E	6:00 p.m.
90° E	9:00 p.m.

7. Now suggest that the students imagine that they are going on an ocean voyage from England in the eighteenth century. The navigator takes along some clocks set to Greenwich time (on the prime meridian). After sailing west for a few days, the navigator observes the Sun to find out when it is noon. Ask the students how the navigator can tell when it is noon (when the Sun is highest in the sky).

8. At noon on the ship, the Greenwich clocks read 3:00 p.m. Ask the students where the ship is (this is a difficult question). Ask the students to find the time on the handout that is three hours behind prime meridian time (45° W). Point out that this measurement gives only the longitude.

9. If the students could follow the example in Step 8, give them this data. For each set of times in Table 3, ask the ship's longitude.

TABLE 3

Ship Time	Prime Meridian Time	Longitude
noon	9:00 p.m.	135° W
noon	6:00 a.m.	90° E
noon	midnight	180°

REFLECTION AND DISCUSSION

Ask if a student can sum up the relationship between time and longitude. (Earth rotates on its axis every 24 hours. There are 360° of longitude going around Earth. Every 24 hours, Earth turns through 360° of longitude, so Earth turns 15° per hour. If you know the time at the prime meridian and the local time, you can determine the local longitude.)

CURRICULUM CONNECTIONS

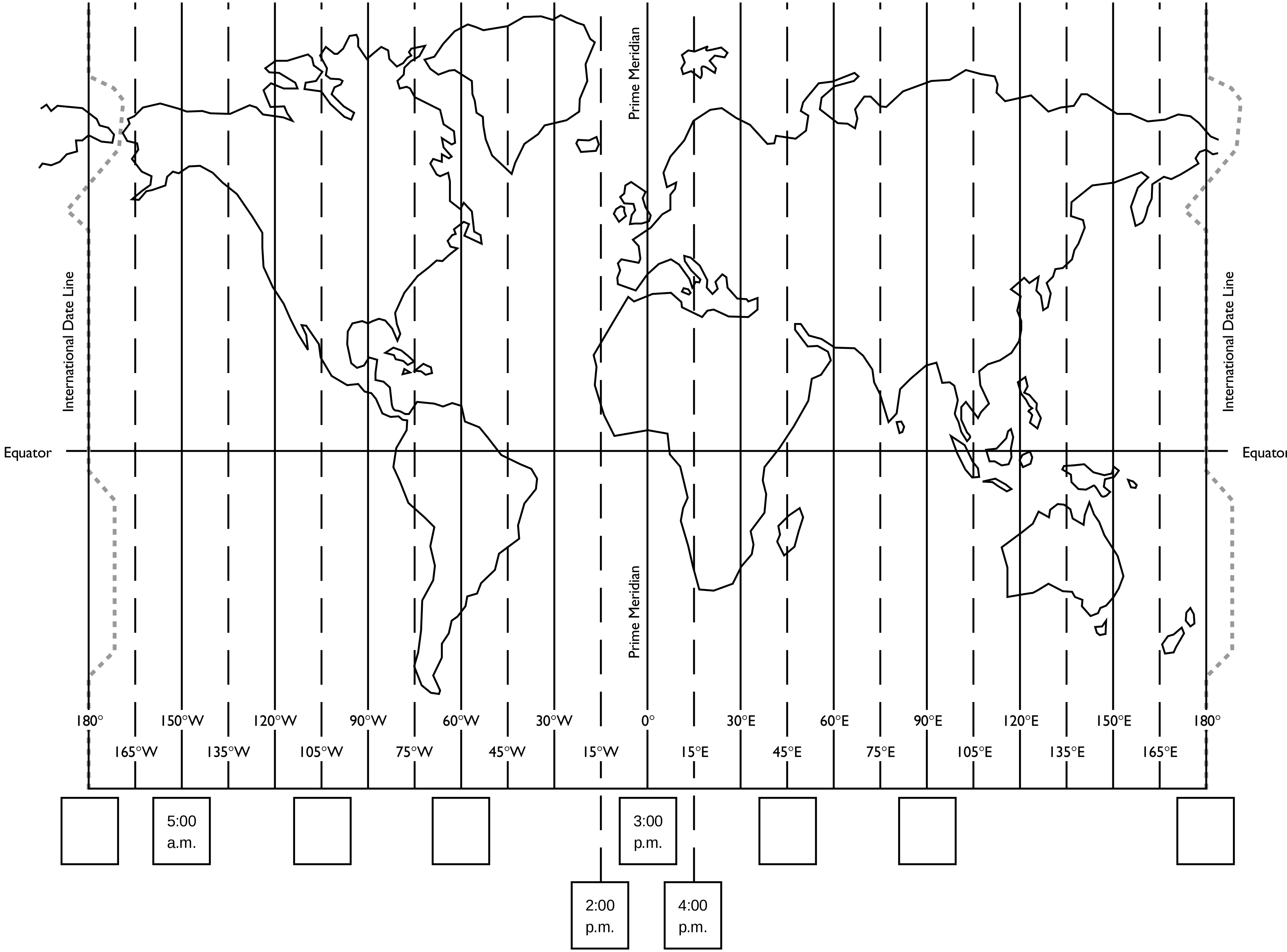
- Mathematics: angles
- Social Studies: longitude
- Language Arts: descriptive writing

EXTENSIONS

1. To help students better understand latitude and longitude, have them mark the equator and the prime meridian on a balloon. Then have them add latitude and longitude scales and roughly sketch in the continents. Ask for a representative latitude and longitude for each continent.

2. As a demonstration, fasten suction-cup darts onto a basketball model of Earth. Explain that the darts represent flagpoles on the surface of Earth. Ask the students what information could be found from measurements of the altitude of the tops of the darts. With a piece of chalk, draw position circles, large enough to intersect, on the basketball. Discuss with the students how these circles could be used to find position.

3. Have the students write a description of what people in various lands around the world are doing at one particular time (getting up in Europe, working in Asia, sleeping in South America, etc.).



Earth turns 360° in 24 hours (all the way around in one day). Earth turns 15° in one hour (15° = 360°/24)

Resources for Teachers

BOOKS

Davidson, N. *Sky Phenomena: A Guide to Naked-Eye Observation of the Stars*. New York: Lindisfarne Press, 1993.

Fraknoi, A., ed. *The Universe At Your Fingertips*. San Francisco: Astronomy Society of the Pacific, 1995.

Levy, D. *Sharing the Sky: A Parent's and Teacher's Guide to Astronomy*. New York: Plenum Trade, 1997.

Rey, H. *The Stars: A New Way to See Them*. Boston: Houghton Mifflin Company, 1976.

Sorbel, D. *Longitude*. New York: Walker and Company, 1995.

Van Cleave, J. *Geography for Every Kid: Easy Activities that Make Learning Geography Fun.* New York: John Wiley & Sons, Inc., 1993.

MAGAZINES

Kirschner, S. "Wired Wheels". *Popular Science*, March, 1998, 54-55.

Wildstrom, S. "Let Your Laptop Do the Navigating". *Business Week*, October 6, 1997, 23.

WEB SITES

For current information about the night sky, see the Smithsonian's Weekly Skywatcher's Report at *www.si.edu/resource/faq/skywatch.htm*

For information about time zones, see the Naval Observatory's site at *www.aa.usno.navy.mil*

For a clear, concise description of the Global Positioning System, see "All About GPS" on the Trimble site at *http://www.trimble.com/gps/index.htm*

For a visualization of GPS satellite orbits, see *http://liftoff.msfc.nasa.gov/realtime/jtrack/3d/JTrack3d.html*

For more information about Shackleton's expedition to the South Pole, see *http://www.blast.net/features/shackleton.html* and *http://tierradelfuega.ml.org/antartida/shackletoneng.htm*

A Field Trip Guide

FOR THE PLANETARIUM SHOW
And a Star to Steer Her By

AND THE EXHIBITION
GPS: A New Constellation

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