Which Way is North?

GRADE LEVEL	3rd -5th; Content Standards for 3rd and 5th
SUBJECTS	Earth & Space Science, Interpreting Data
DURATION	Preparation: 5 minutes Activity: 40 minutes (total over one day)
SETTING	Classroom

Objectives

In this activity students will:

1. Observe how the position of the sun in the sky changes during the course of the day
2. Discover the cardinal directions by tracking the motion of the sun

Materials

- One large sheet of white paper (such as easel paper)
- One pencil width wooden dowel or similar, 12-15 inches long
- A ball of clay
- Permanent marker
- Weights or adhesive tape to hold the paper in position

Scientific Terms for Students

axis: the center around which something rotates

cardinal direction: one of the four principal compass points: north, south, east and west

equinox: the two times in the year (spring and fall) when day and night are of equal length

gnomon: a vertical shaft or column used for determining the altitude of the sun by measuring the length of its shadow cast at noon; also, the part of a sundial that casts the shadow

local noon: the time when the sun crosses an imaginary north-south circle in the sky

north celestial pole: The point in the sky aligned with the earth's axis, about which all the stars seen from the northern hemisphere rotate

north star: The closest star in the sky to the north celestial pole (currently Polaris)

rotation: a single complete turn

solstice: the times in the year when the sun reaches its highest (summer) or lowest (winter) altitude in the sky above the horizon at local noon

Background for Educators

Many people know how to determine the cardinal directions by finding Polaris, the North Star, in the night sky. Polaris marks the north celestial pole and is located at the end of the Little Dipper's handle in the constellation Ursa Minor. Polaris is always above the horizon as seen from northern latitudes. During the day, however, it's too bright to see the North Star. A simple method of determining north (and therefore all of the cardinal directions) is to track the shadow of the sun as it passes through the sky in the course of a day.

From sunrise to sunset, the sun traces an arc across the sky, and reaches its highest point in the sky at local noon. For observers in northern latitudes, that point in the sky is always due south. While it is difficult (and dangerous) to measure the sun's position directly, it is easy to observe the shadows cast by objects illuminated by the sun. We can use this information to determine when the sun is highest in the sky.

As the sun moves through the sky, the shadow cast by an object is constantly changing in length. The shortest shadow occurs when the sun reaches its highest point, at local noon. By tracking the length of the shadow cast by a stationary gnomon throughout the day, it is easy to determine the point at which the shadow is shortest. A line drawn between that point and the gnomon will align directly north and south.

It is important to remember that sun time and clock time are not the same; our clocks are set to standard times for each time zone, so locally, the sun can be at its highest point many minutes before or after 12:00PM on your watch (1:00PM during daylight saving time). You should not assume that your noon measurement is the shortest, but instead do a complete sequence as described in the lesson.

While this exercise works during any season, it is possible to extend the investigation by repeating it at different times of the year. The arc that the sun traces in the sky is highest in the summer and lowest in the winter, so the shadow pattern traced by this exercise will also change: shortest in summer, longest in winter. By comparing the paths, you can easily visualize how the position of the sun in the sky changes not only during the course of the day but also from season to season.

Some elements of this activity are adapted from the Yohkoh Public Outreach Project, Montana State University: http://solar.physics.montana.edu/ypop/Classroom/Lessons/Sundials/

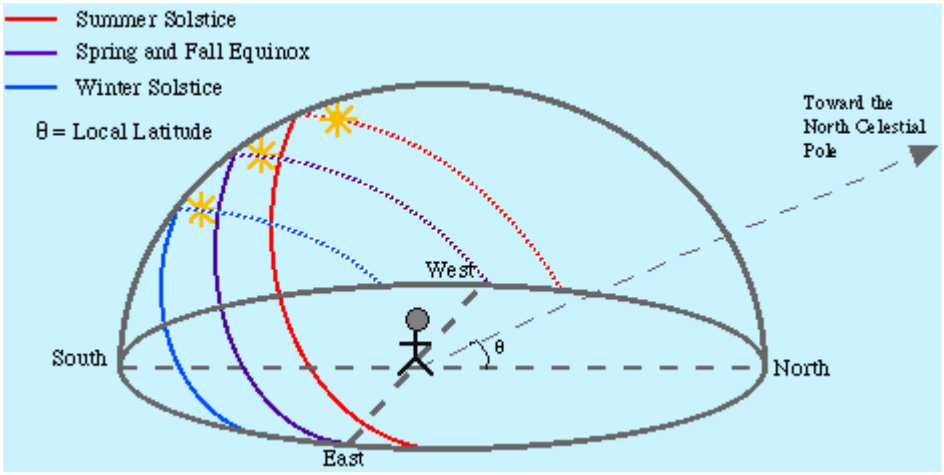

Figure 1: The picture depicts the sun's motion from a northern hemisphere perspective.

Figure credits: the Yohkoh Public Outreach Project, Montana State University

Introduction

Begin your discussion with an exploration of the cardinal directions, using a map or a globe. Ask the class if they can identify the direction of north from their current positions. Ask how they determined their answer (maps, stars, compasses are possible answers). Ask them how they would determine directions if they were in an unfamiliar daytime location and did not have any devices or information to assist them.

Activity Procedure

It's best to set up your shadow plot in the morning, around 9:00AM. An indoor location can be used if it will receive sunlight throughout the school day (south facing), or use an unshaded outdoor location that will allow the setup to remain undisturbed.

1. Push the ball of clay onto a flat level surface or the ground.

2. Insert the wooden dowel into the ball of clay so that it stands vertically. This will act as a gnomon. It will need to stand in this exact location for the entire length of the investigation, so be certain it is secure and will remain vertical.

3. Once the gnomon is in position, look for its shadow. If it is morning, the shadow should be pointing west.

4. Place the piece of paper flat on the surface on the north side of the gnomon, centered against its base (see figure 2).

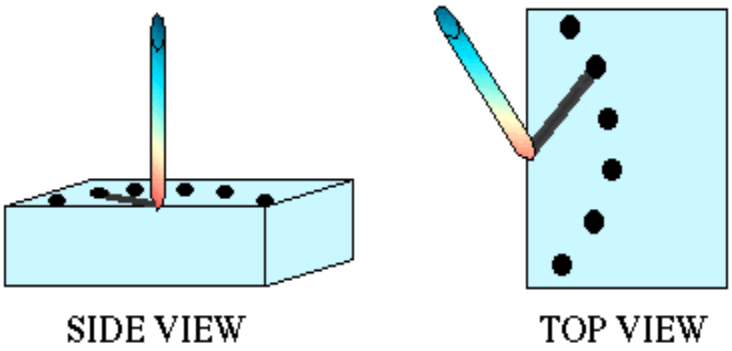

Figure 2

5. Secure your paper with weights or tape around the edge of the paper.

6. The shadow of the gnomon should be on your paper – if not, wait about an hour and return once the shadow is cast onto the paper. When you have the shadow on the paper, use your permanent marker to make a mark at the very end of the shadow.

7. Return to your shadow plot about once every half hour and make a mark at the end of the shadow each time. If you begin your plot at 9:00 a.m. you should have enough markings by 3:00 p.m. When you are finished with one day of measurements you plot should look like the one above.

8. After one day of shadow measurements you are ready to draw the North-South line. On your completed shadow plot draw a smooth curve through all of the marks that you have made, without moving the paper. The more often you have taken your measurements, the easier it will be to draw this curve accurately.

9. Once you have drawn a smooth curve through the markings, you want to find the shortest distance between the gnomon and this curve. To do this place a measuring stick so that one end is at the gnomon base and the other end crosses the curve you have drawn. Pivot the measuring stick about the end at the gnomon base until you identify the location on the curve that is the shortest distance from the gnomon. Mark this point.

10. Draw a line from the gnomon to the point you have just marked. This is a north-south line, with the gnomon at the south.

11. Draw a line perpendicular to the north-south line to indicate east and west.

12. Mark the ends of your two lines with the cardinal directions you have identified.

Extensions

You can repeat this exercise at other times of the year to observe how the sun's height in the sky changes over the course of the year, casting longer or shorter shadows that result in different arcs on the paper.

If you have a secure location, you leave your setup in place and mark the date of each observation on the same sheet of paper. If you need to reset the experiment each time, make sure you use the same gnomon for each observation. It is not essential to start or finish at the same time; once you have established your north-south line, you can compare the length and distances to the shadow paths using that line and the gnomon as a reference.

California Science Content Standards

Grade Three

Physical Science

2a. Students know sunlight can be blocked to create shadows.

Earth Science

4e. Students know the position of the Sun in the sky changes during the course of the day and from season to season.

Next Generation Science Standards

Fifth Grade

5-ESS1-2: Represent data in graphical display to reveals patterns of daily changes in length and direction of shadow, day and night, and seasonal appearance of some stars in the night sky.