Where's East and West?

Materials

- Pole for casting shadow (gnomon)—1 meter or more if for whole class use and/or sharpened pencils for small group use
- Marking pen—1 for whole class and/or 1 for each group of students
- Ruler, 12" (30 cm) or yard-stick (meter stick)
- Stiff board (e.g. cardboard, posterboard, tagboard, foamboard), at least 1' x 2' (30x60cm) for whole class use or 81/2 x 11" for small group use
- Sheet(s) of paper to cover the board
- Tape
- A way to secure the board to the ground: e.g. big nails if it's soil, or tape (masking tape or duct tape) if it's pavement
- 2 lengths of string, each at least a meter or two long
- A way to secure the lengths of string to the ground: e.g. big nails if it's soil, or tape (masking tape or duct tape) if it's pavement

Objectives

Students learn how to determine cardinal directions by observing changes in the shadow of a gnomon. After the activity, students will be able to:

1. Explain that the Sun moves across the sky slowly in an observable pattern.
2. Describe how a gnomon can be used to track the movement of the Sun.
3. Describe how a gnomon can be used to determine cardinal directions (East, West, North, South)

This activity supports National Science Education Standards:

- Sky objects have properties, locations, and movements that can be observed and described. [NSES K-4; D: Objects in the Sky, p. 134.]
- Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. [K-4; D: Changes in the Earth and Sky, p. 134.]
- Most objects in the solar systems are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses. [NSES 5-8; D: Earth in the Solar System, p. 160.]

Preparation

- Read the Activity section and decide if you will use the "whole class" activity method or have students work in small groups.
- Get the materials, find suitable outdoor site.
- Secure the gnomon pole either by driving it into the ground (as a stake) or securing it to a flat board so it stands straight up.

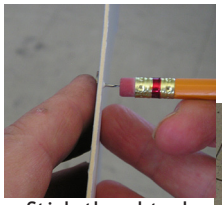

Lab pole and stand


Dowel with clamp from clip-on light


PVC pipe and fittings


Shop clamp and meterstick


Pencil with paper clamp


Stick thumbtack through cardboard and into pencil eraser


Pencil-tack-cardboard gnomon complete

Ideas for Gnomons

- Secure the stiff board north of the gnomon so that the shadow of the gnomon falls on it.
- Tape paper onto the board for marking shadow positions.
- Plan on starting the activity about a half hour before local noon.
- Make sure you have made arrangements for it to be a sunny day :-)

To determine local noon, visit http://aa.usno.navy.mil/data/docs/RS_OneDay.html, enter your location and then look for "Sun transit time" which is the same as local noon.

Activity

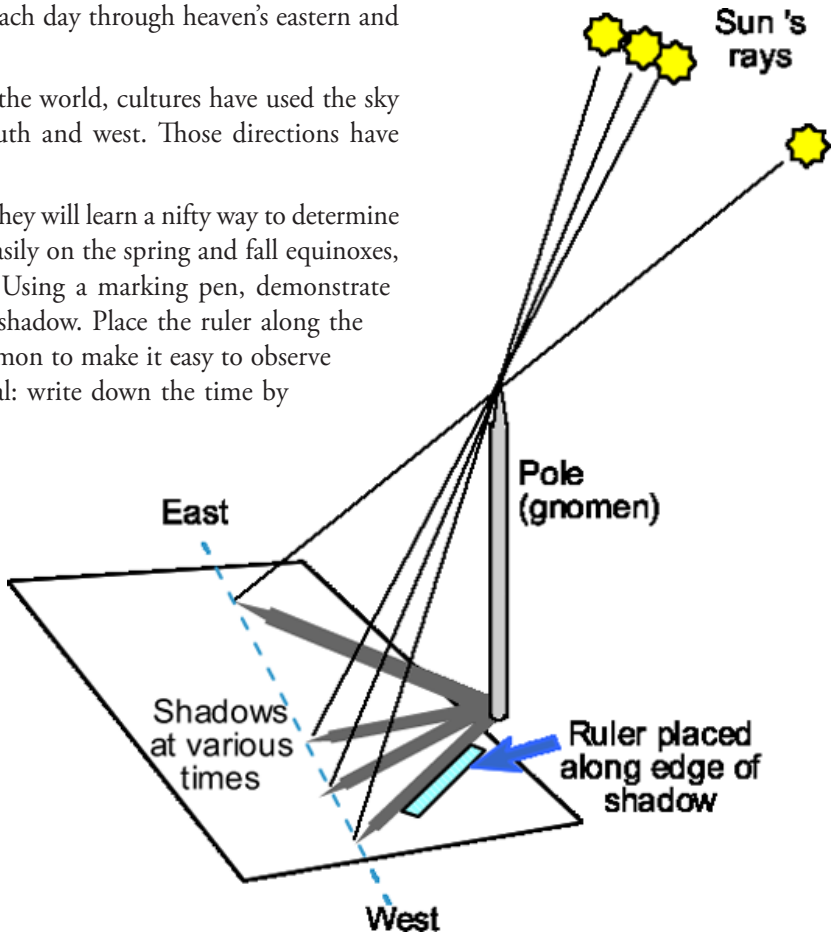
1. The four cardinal directions. Explain that in many cultures, the four directions, North, East, South and West have great meaning. For some, the Sun is a deity that visits us every day coming from the East and leaves each day in the West.

- The Hopi in the American Southwest have ceremonial places called kivas. For the Hopi, each day the Sun emerges from his eastern "kiva," climbs up the ladder out of the kiva until he reaches his highest place (noon) and then descends to his western kiva. Refreshing himself with a little sleep, the Sun continues his journey under the ground until he reaches his eastern kiva once more.
- In Egypt, the Sun god Re also passed each day through heaven's eastern and western doors.

  Throughout the Americas and all over the world, cultures have used the sky to find the directions, north, east, south and west. Those directions have spiritual as well as physical meaning.

2. Marking a gnomon's shadow. Tell the class they will learn a nifty way to determine which way is east. It works especially easily on the spring and fall equinoxes, but can be used any day of the year. Using a marking pen, demonstrate how to mark the tip of the gnomon's shadow. Place the ruler along the western edge of the shadow of the gnomon to make it easy to observe the movement of the shadow. Optional: write down the time by the mark.

3. Get ready for shadow marking. To make this a whole-class activity, have students form a line in a sort of big arc around the gnomon, so they can all see the gnomon's shadow with out blocking it. Have the first student in line make a new mark at the tip of the gnomon shadow. If you prefer, have students work in small groups (2 to 6 students per group) and let them use sharpened pencils attached to cardboard with thumbtacks as shown in Preparation section.



4. One by one have each student make a new mark at the tip of the gnomon's shadow.

   You need not hurry this process, nor drag it out. If a mark is made every 30 seconds, this part of the activity takes about 15 minutes for a class of 30 students. After about 5 or 6 marks, ask the class:

   "Is there a pattern to the marks?" [They seem to be in a line.]

5. Point out the direction the shadow tip is moving. Periodically, have the whole class point with their fingers in the direction that the line of marks seems to be pointing. On the equinoxes, that's all there is to determining East.

6. Make more marks after noon [if it's not the near equinox]. At times of year other than the equinoxes, the pattern of marks is not exactly a straight line, but more of an arc. To determine the true east-west line, it's necessary to mark the tip of the shadow both before and after noonX. Return to the gnomon after local noon and have students continue marking.

7. A true East-West line. After a symmetrical pattern of marks shows on the marking sheet, ask the students:

   "How could we tell the true east west line?"

   To do this, students can measure the length of the shadow (from the gnomon base to the mark made at the tip of the gnomon shadow). A line between any two marks that are at equal distances from the base of the gnomon should be a true east-west line. Have students try drawing a series of lines between such pairs of marks (equidistant from the gnomon base) and see if the lines are all parallel.

8. A true North-South line. Stretch a string perpendicular to the East-West line. Position it so that it's touching the gnomon and then secure the ends to the ground. Ask the students:

   "When do you think the gnomon shadow falls along this north-south line?" [At local noon.]

9. What's making the shadow move? Ask the students:

   What's making the shadow move? [The Sun is slowly moving across the sky, but it's really the Earth spinning—the Sun is really in fixed position at the center of the solar system.]

10. Cultural connections. Ask the students:

    "What do you think each direction symbolizes?"

    For example, what would East symbolize? East, where the Sun rises, often symbolizes birth and the beginnings of cycles. West, where the Sun sets, is connected with death and the ends of cycles. Many cultures hold that each direction is associated with a color and each embodies a different aspect of life. While the meaning of each direction may differ in their interpretation in various parts of the world, here are some very general agreements:

East

East is associated with births and new beginnings because it is where each new day dawns. Spring is the season associated with this direction because Spring is also the time of new beginnings. East is the place of healing, creativity, illumination, divination, intuition, new birth and sunshine, new learning, strength of will, communication and expression of new.

West

We are born in the East, grow in the South, and it is in the West where we come to the Autumn of our lives. Thus we can see how the directions relate to the different seasons. The West is the culmination of our goals. The West is associated with death but not in the way most western societies think of it. Death is actually a vital tool in the cycle of life. Death illuminates a pivotal point, a point from which the culmination of all knowledge can be drawn. When death (in some form) is achieved, only then can there be a new beginning which utilizes, in it's new growth, the knowledge drawn from the past. West is the place of vision, dreams quests and journeys, emotions, imagination, creative arts, the feminine, higher compassion, inner spiritual renewal, and goals.

South

South is the home of the child within. While the East is where we are born. The South is where we learn to grow, nourished by the warmth of the sun. South is the place of Summer. South is the place of faith, purification, awakening inner child, overcoming obstacles, change, playfulness, protection, trust, resurrection, strength, and self sufficiency.

North

North is the place of the hereafter death. North is winter where everything lies still and dormant, where all life and knowledge exist in a state of suspended animation awaiting the hand of Great Spirit to push forward to a new beginning. North is the place of knowledge, teaching, balance, abundance, sacred wisdom, thankfulness, drawing forth inner treasures, empathic intuition, trust, and alchemy.

Ideas for this activity were developed in connection with the Cesar Chavez memorial in Berkeley, California. There, the Four Directions are associated with Four Virtues and Values of Cesar Chavez, identified as:

East

Virtue (Hope): Values (Respect for Life, Celebrating Community)

West

Virtue (Courage): Values (Sacrifice . . . or forgiveness)

North

Virtue (Non-violence): Values (Tolerance, Knowledge, Non-Violence)

South

Virtue (Determination): Values (Innovation, Service to Others, Service to the Most Needy)

Solar Snippets

The Sun's name: Egyptians called it Ra; the Greeks called it Helios; the Romans called it Sol. There are many other names—each culture is different.

Sun's Age: 4.5 billion years (happy birthday!)

Sun's Size: Diameter is about 1.4 million km (870 million mi), or 109 times Earth Diameter. In terms of volume, the Sun could contain 1.3 million Earths

Sun's Rotation Rate: At the equator the surfac-erotates once every 25.4 days; near the poles it's as much as 36 days. This odd behavior is due to the fact that the Sun is not a solid body like the Earth. Similar effects are seen in the gas planets.
Surface Temperature of the Sun: about 5,800 K (5,430 degrees C, or 9,800 degrees F)

Core Temperature of the Sun: 15,600,000 K (28,000,000 degrees F)

Temperature of the Sun's atmosphere (called the corona): Over 1,000,000 K (The fact that this is so much higher than the Sun's surface temperature was a puzzlement for a long time. We are only beginning to understand the reason for this—it has to do with activity on the surface of the Sun.

The Sun is made of about 75% hydrogen and 25% helium. This changes slowly over time as the Sun converts hydrogen to helium in its core.

Sunspots are "cool" regions, only 3800 K (they look dark only by comparison with the surrounding regions). Sunspots can be very large, as much as 50,000 km in diameter—larger than Earth! Sunspots are caused by complicated, not very well understood changes in the Sun's magnetic field.

Pressure at the Sun's core: 250 billion times Earth atmospheric pressure.

Density at the Sun's core: > 150 times that of water.

Energy output of the Sun: 386 billion billion megawatts. Each second about 700,000,000 tons of hydrogen are converted to about 695,000,000 tons of helium and 5,000,000 tons of energy in the form of gamma rays. As it travels out toward the surface, the energy is continuously absorbed and re-emitted at lower and lower temperatures so that by the time it reaches the surface, it is primarily visible light. Since its birth it has used up about half of the hydrogen in its core. It will continue to radiate "peacefully" for another 5 billion years or so (although its luminosity will approximately double in that time). But eventually it will run out of hydrogen fuel. It will then be forced into radical changes which, though commonplace by stellar standards, will result in the total destruction of the Earth (and probably the creation of a planetary nebula).