BioEd℠

THE SCIENCE OF SLEEP AND DAILY RHYTHMS

Using a Sundial

by
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RESOURCES

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BCM®
Baylor College of Medicine

Printed in the United States of America, Second Edition.

ISBN-13: 978-1-888997-58-3

BioEd[SM]

Teacher Resources from the Center for Educational Outreach at Baylor College of Medicine.
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Cover: Illustrations of moon, clock, sun, world and waking female © Adobe, Inc. Illustrations of globe model with flashlight and graphs by M.S. Young; protractor by G.L. Vogt from Space Educator's Handbook, NASA Johnson Space Center. Photographs of girl with clock face, girl holding globe and sleeping student © PunchStock. Image of astronauts courtesy of NASA.

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ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of Bobby R. Alford, M.D., Jeffrey P. Sutton, M.D., Ph.D., William A. Thomson, Ph.D., Laurence R. Young, Sc.D., Jeanne L. Becker, Ph.D., and Kathy Major, B.A., as well as the contributions of the following science reviewers: Mary A. Carskadon, Ph.D., Kimberly Chang, Ph.D., Charles A. Czeisler, Ph.D., M.D., David F. Dinges, Ph.D., Hans P.A. Van Dongen, Ph.D., and Kenneth P. Wright, Jr., Ph.D.

We especially thank Siobhan Banks, Ph.D., and Daniel Mollicone, Ph.D., the science reviewers for this revised and updated version of the guide. Preparation of this guide would not have been possible without the invaluable assistance of the following field test teachers: Yolanda Adams, Jeri Alloway, Vivian Ashley, Susan Babac, Henrietta Barrera, Paula Clark, Carol Daniels, Barbara Foreman, Carolyn Hopper, Susan King-Martin, Mary Helen Kirby, Sue Klein, Jacqueline McMahon, Sandra Prill, Carol Reams, Mary Ellen Reid, Saundra Saunders, Angi Signorelli, and Marcia Wutke.

This work was supported by National Space Biomedical Research Institute through NASA NCC 9-58.

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TEAMING WITH BENEFITS

by **Jeffrey P. Sutton, M.D., Ph.D.**, Director, National Space Biomedical Research Institute (NSBRI)

Dr. Jeffrey P. Sutton

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.

The NSBRI, a unique partnership between NASA and the academic and industrial communities, is advancing biomedical research with the goal of ensuring a safe and productive long-term human presence in space. By developing new approaches and countermeasures to prevent, minimize and reverse critical risks to health, the Institute plays an essential, enabling role for NASA. The NSBRI bridges the research, technological and clinical expertise of the biomedical community with the scientific, engineering and operational expertise of NASA.

With nearly 60 science, technology and education projects, the NSBRI engages investigators at leading institutions across the nation to conduct goal-directed, peer-reviewed research in a team approach. Key working relationships have been established with end users, including astronauts and flight surgeons at Johnson Space Center, NASA scientists and engineers, other federal agencies, industry and international partners. The value of these collaborations and revolutionary research advances that result from them is enormous and unprecedented, with substantial benefits for both the space program and the American people.

Through our strategic plan, the NSBRI takes a leadership role in countermeasure development and space life sciences education. The results-oriented research and development program is integrated and implemented using focused teams, with scientific and management directives that are innovative and dynamic. An active Board of Directors, External Advisory Council, Board of Scientific Counselors, User Panel, Industry Forum and academic Consortium help guide the Institute in achieving its goals and objectives.

It will become necessary to perform more investigations in the unique environment of space. The vision of using extended exposure to microgravity as a laboratory for discovery and exploration builds upon the legacy of NASA and our quest to push the frontier of human understanding about nature and ourselves.

The NSBRI is maturing in an era of unparalleled scientific and technological advancement and opportunity. We are excited by the challenges confronting us, and by our collective ability to enhance human health and well-being in space, and on Earth.

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

The amount of blood in the body is reduced when astronauts are in microgravity. The heart grows smaller and weaker, which makes astronauts feel dizzy and weak when they return to Earth. Heart failure and diabetes, experienced by many people on Earth, lead to similar problems.

HUMAN FACTORS AND PERFORMANCE

Many factors can impact an astronaut's ability to work well in space or on the lunar surface. NSBRI is studying ways to improve daily living and keep crewmembers healthy, productive and safe during exploration missions. Efforts focus on reducing performance errors, improving nutrition, examining ways to improve sleep and scheduling of work shifts, and studying how specific types of lighting in the craft and habitat can improve alertness and performance.

MUSCLE AND BONE LOSS

When muscles and bones do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' bones and muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth, as well as people whose work requires intense physical exertion, like firefighters and construction workers.

NEUROBEHAVIORAL AND STRESS FACTORS

To ensure astronaut readiness for space flight, preflight prevention programs are being developed to avoid as many risks as possible to individual and group behavioral health during flight and post flight. People on Earth can benefit from relevant assessment tests, monitoring and intervention.

RADIATION EFFECTS AND CANCER

Exploration missions will expose astronauts to greater levels and more varied types of radiation. Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury and changes to white blood cell counts and the immune system. Longer-term effects include damage to the eyes, gastrointestinal system, lungs and central nervous system, and increased cancer risk. Learning how to keep astronauts safe from radiation may improve cancer treatments for people on Earth.

SENSORIMOTOR AND BALANCE ISSUES

During their first days in space, astronauts can become dizzy and nauseous. Eventually they adjust, but once they return to Earth, they have a hard time walking and standing upright. Finding ways to counteract these effects could benefit millions of Americans with balance disorders.

SMART MEDICAL SYSTEMS AND TECHNOLOGY

Since astronauts on long-duration missions will not be able to return quickly to Earth, new methods of remote medical diagnosis and treatment are necessary. These systems must be small, low-power, noninvasive and versatile. Portable medical care systems that monitor, diagnose and treat major illness and trauma during flight will have immediate benefits to medical care on Earth.

For current, in-depth information on NSBRI's cutting-edge research and innovative technologies, visit www.nsbri.org.

OVERVIEW

It is possible to measure time via the relative positions of Earth and the sun. Students make a sundial (shadow clock) appropriate for their geographic location in the northern hemisphere and use it to tell time.

ACTIVITY

USING A SUNDIAL

For centuries, people relied on the position of the sun in the sky to estimate the time of day. Noon or midday was designated as the time when the sun was at its highest point in the sky. We now know, of course, that the sun does not move across the sky. Rather, Earth rotates as it revolves around the sun.

One of the earliest tools used to measure time was the movement of shadows on the ground over the course of a day. Since shadows move the same way each day, they can be used to estimate time. Simple sundials—perhaps only a stick placed vertically in the ground—used shadows to tell time in Egypt more than 3,000 years ago.

When humans first began keeping track of time, an hour was calculated as 1/12 of the period of daylight on any given day. Thus, the length of an hour varied with the seasons. Now, we divide each day into 24 equal hours, which remain unchanged regardless of the time of year. In modern society, time also is standardized from place to place. Before 1884, every town set its clocks to the highest position of the sun (noon). As a result, each town ran on a different time, and there was great confusion. Today, the world is sectioned into 24 standard, uniform time zones. Each time zone accounts for 15 degrees longitude and 60 minutes of Universal Time.

SCIENCE EDUCATION CONTENT STANDARDS*
GRADES 6-12

PHYSICAL SCIENCE
- The motion of an object can be described by its position, direction of motion and speed. That motion can be represented and measured on a graph.
- The sun is a major source of energy for changes on Earth's surface. The sun's energy arrives as light.

EARTH AND SPACE SCIENCE
- The sun, an average star, is the central and largest body in the solar system.
- Most objects in the solar system are in regular and predictable motion.

SCIENCE, HEALTH & MATH SKILLS
- Measuring
- Locating cardinal directions
- Making a model
- Observing
- Drawing conclusions

* National Research Council. 1996. National Science Education Standards. Washington, D.C., National Academies Press.

TIME

10 minutes for setup; two 30–45 minute periods to conduct activity

MATERIALS

Teacher (see Setup)
- 24 sheets of white cardstock
- Flashlight
- Globe or map with latitude markings
- Sundial template

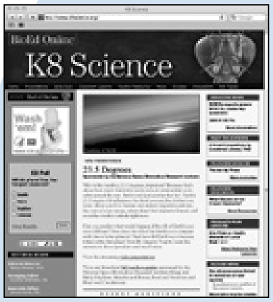
Each group of students will need:
- Flashlight
- Hole punch
- Magnetic compass

Each student will need:
- Fine-tip ballpoint pen
- Opaque drinking straw

Apparent Time

The sun's apparent position in the sky depends on your location on Earth's surface, the day of the year, and the time of day.

Teacher Resources



Downloadable activities in PDF format, annotated slide sets for classroom use, and other resources are available free at www.BioEdOnline.org or www.k8science.org.

Universal Time

In 1972, Universal Time replaced Greenwich Mean Time as the standard reference for telling time. Universal Time, also known as International Atomic Time, is measured by an atomic clock, which uses the extremely regular vibrations that occur within atoms to measure time.

Meridians

The imaginary great circles passing through the North and South Poles are referred to as lines of longitude, or meridians.

Parallels

Circles or lines of latitude sometimes are referred to as parallels, because they are parallel to one another.

LATITUDE AND LONGITUDE

Any location on Earth can be pinpointed using the imaginary lines of latitude and longitude. Both measurements are described in degrees. Each degree is divided into 60 minutes, and each minute is divided into 60 seconds.

Image © Cartesia MapArt.

Latitude is measured with parallel imaginary lines that circle Earth, both north and south of the equator (which has a latitude of 0°). In addition to the equator, there are four key lines of latitude related to the relative positions of Earth and the sun.

- Arctic Circle: 66° 33′ 39″ N (read as 66 degrees, 33 minutes, 39 seconds)
- Tropic of Cancer: 23° 26′ 21″ N
- Tropic of Capricorn: 23° 26′ 21″ S
- Antarctic Circle: 66° 33′ 39″ S

At latitudes between the Tropics, the sun may be seen directly overhead at noon on the June solstice (in the northern hemisphere) or December solstice (in the southern hemisphere). North of the Arctic Circle and south of the Antarctic Circle, the sun is visible for 24 continuous hours at least one day per year.

Longitude describes east-west position, as measured from the prime meridian in England (which has a longitude of 0°). Lines of longitude extend between Earth's North and South Poles. Longitudes are measured from 0° to 180° east and 180° west (or -180°). Both 180-degree longitudes share the same line, in the middle of the Pacific Ocean. It takes Earth one hour to rotate 15°, which is why the 24 time zones are separated by 15° of longitude.

- Pencil
- Pair of scissors
- Ruler (12-in.)
- Several pieces of clear tape (each about 2–3 in. in length)
- Copy of student sheet
- Prepared copy of sundial on cardstock

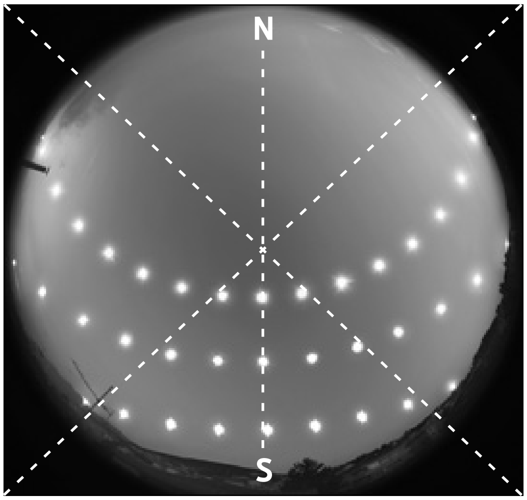
SETUP & MANAGEMENT

Make 24 copies of the sundial template on cardstock. Place materials in a central area for materials managers to collect. Students should work in groups of four to share materials, but each student should construct his/her own sundial.

PROCEDURE

1. Have students observe while you darken the room and use a flashlight to make a shadow of your hand. Then turn flashlight off, and ask, *Where is the shadow?* Students should understand that an object in front of a light source blocks the light, causing an area of darkness—a shadow. Encourage students to create different shadows using their flashlights.
2. Challenge students to envision what happens to shadows outdoors as the position of the sun changes, relative to the Earth's surface. Ask, *Are shadows always the same size? Why or why not? When are the shadows we see outside smallest? When are they largest? Can we always see shadows outside?* Ask students if there is a predictable pattern to the different sizes of shadows made by the sun (shadows are longest in the morning and evening, and shortest at midday). Using flashlights and pencils, have students make shadows of different lengths. Ask them to identify variables that affect shadow length (for example, height of pencil and angle of light).

Continued



This all-sky composite image taken in Bursa, Turkey, shows the daily trail of the sun in three strings, sunrise-to-sunset, during the summer solstice (June, top string), the vernal equinox (March, middle string), and the winter solstice (December, bottom string). The sun's path is about the same for both the vernal equinox and autumnal equinox (September).

North is at the top of the image. The point where the "X" shaped lines intersect is Bursa's longitude projected in the sky. (Hold the picture over your head to see why.)

Download a larger version of the image from NASA's Astronomy Picture of the Day website (http://antwrp.gsfc.nasa.gov/apod/ap080922.html) for use with this activity's first Extension (below).

3. Explain to students that they will be investigating and using patterns in shadow movement to solve a practical problem: how to tell time.
4. Distribute copies of the student sheet. Students will need to know the latitude of their location to build their sundials properly. Use a globe or map, or have students find this information on the Internet.
5. Have students test their sundials by placing the dials outside on the ground, with the gnomon (part of the sundial that casts the shadow) pointed directly north. To obtain a more accurate reading, students should use a magnetic compass to orient their sundials toward the north. They also can check and correct for the magnetic declination where they live, to ensure that their sundials are pointed toward "true north," (see "Magnetic Declination, sidebar, right).
6. Once the sundial's gnomon is pointing in the correct direction, students should locate where the sun's shadow crosses the dial and estimate the time, based on their reading. Then, have students compare the time indicated by their sundials to actual "clock time." If daylight savings time is in effect, subtract one hour from the "sundial time."
7. Conduct a class discussion or have students write about the accuracy of their sundials. Ask, *How well did your sundial measure time, compared to a watch or clock? Why do you think your sundial did (or did not) measure time as accurately as other clocks do?* Also, ask students to consider if there are times a sundial might not be useful. Examples: nighttime (too dark); or when skies are cloudy (no shadows).

EXTENSIONS

- Using a copy of the image above, have students draw the lines as shown. The mid-point is Bursa's longitude line projected in the sky. Have students start from the "east," and count the number of hours of daylight for each string. Ask, *Which season does each string represent? During which season is the sun higher in the sky? Lower? What do these observations tell us about Earth's seasons?*
- Have students try using shadow length to tell the time.
- Have students think about why time zones, each of which accounts for a one-hour time difference, are separated by 15° of longitude.
- Have students figure out what time it is in other parts of the world when it is 8:00 am in their own location.

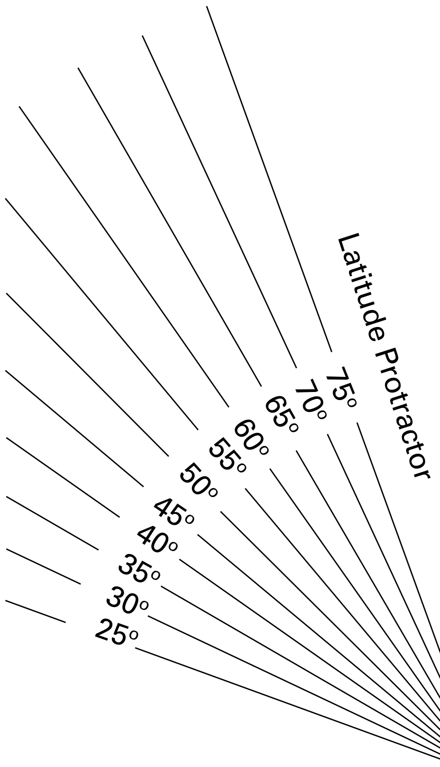
Finding Latitude and Longitude

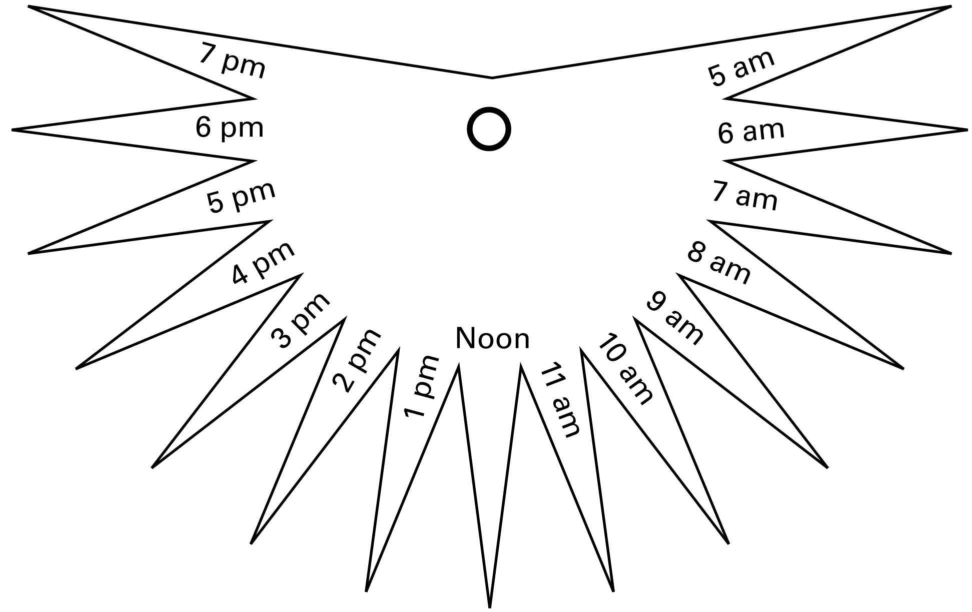
The Internet is a good resource to find latitude and longitude calculators. One such website, iTouchMap.com, will provide coordinates of any street address in degrees, minutes and seconds. To find the latitude and longitude of any given address, or to access other features, go to http://itouchmap.com/.

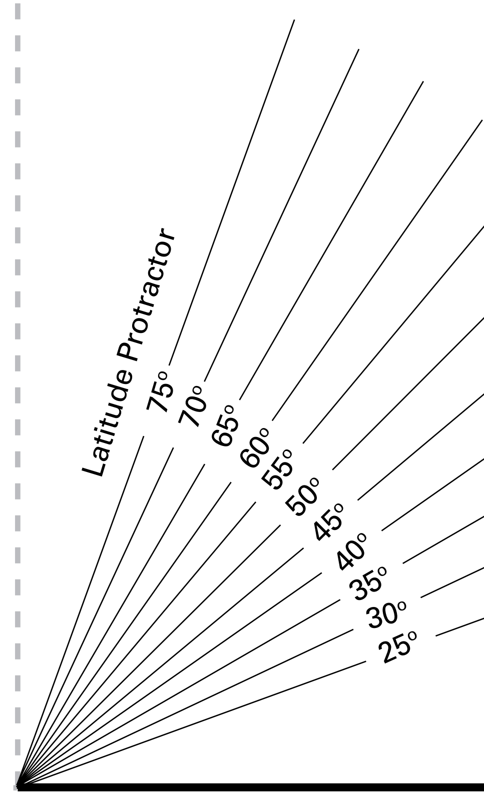
Magnetic Declination

Magnetic declination is the angle between the local magnetic field—the direction pointed by the north end of a compass—and geographic north. You can find your magnetic declination at the National Geophysical Data Center's (NGDC) website, www.ngdc.noaa.gov/geomag-models/Declination.jsp. To correct the reading given by the magnetic compass, add or subtract the appropriate number of degrees from your reading. The NGDC website displays a map with the appropriate correction.

Cut along the thick line to remove this edge of the paper.







Cut *only* on the thick line.

DO NOT CUT THE DASHED LINES.

After cutting along the thick, solid lines, fold the paper along the dashed lines.

Cut *only* on the thick line.

Base

Adapted by G.L. Vogt from the *Space Educator's Handbook*, NASA Johnson Space Center.

ACTIVITY

Making and Using a Sundial

Your teacher will give you a piece of cardstock with a sundial pattern printed on it. You also will need a 12-inch ruler, a pair of scissors, a fine-tip ballpoint pen, a hole punch, one opaque drinking straw, clear tape and a magnetic compass.

Instructions

1. Cut the pattern on the solid lines, as indicated. Extend the cuts to the edges of the paper. *Do not cut the dashed lines.*

2. Using a ruler and a fine-tip ballpoint pen, score the dashed "fold lines." (Press the pen point into the paper while tracing along the edge of the ruler. This forms a groove that enables a straight fold.)

3. Determine the latitude of your location by searching for your city name and latitude on the Internet, or by checking a map or globe.

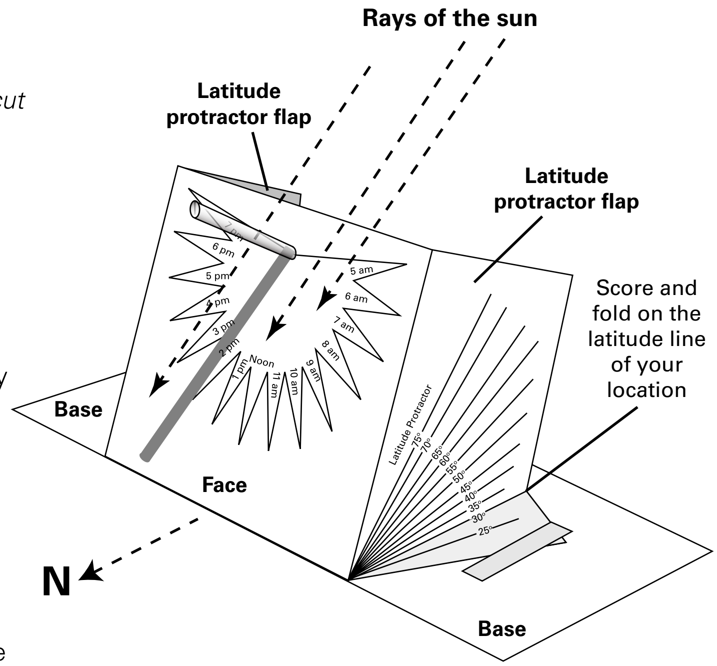
4. Score the lines on each latitude protractor that are nearest the latitude of your location.

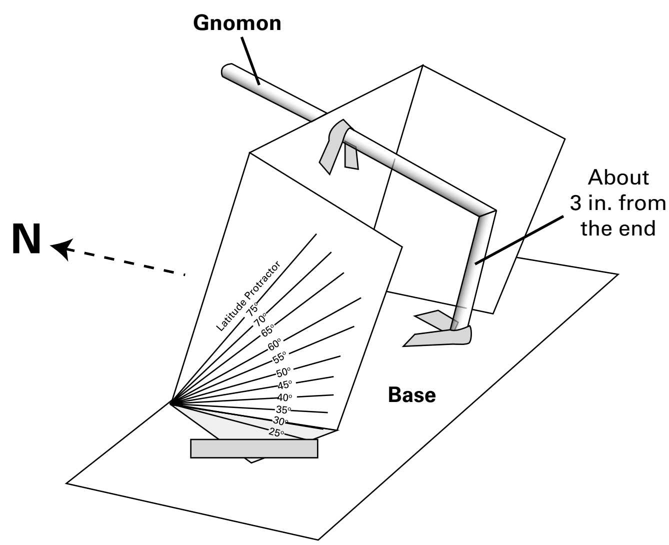
5. Fold the paper along all the scored lines. Fold the sundial rectangle and the latitude protractor flaps backward. Fold the lower corner of the latitude protractors upward along the angle line for your latitude (the latitude shown in the example is 30°).

6. Tape the corners of the latitude flaps to the base.

7. Use a hole punch to make a hole in the circle on the face of the sundial.

8. Slip a straw through the hole and bend the straw about three inches from the inside end, as shown to the right. The end of the straw sticking out from the face of the sundial is called a gnomon (noh-mon). Tilt the gnomon so that it is perpendicular (at a 90° angle) to the face of the sundial. Use tape to anchor the folded end of the straw to the base. Also, tape the straw to the back of the sundial so that the gnomon can't slip.





Using the Sundial

1. Place the dial on the ground and point the gnomon directly north. If you use a magnetic compass to determine north, be sure to check and correct for the magnetic declination where you live. Magnetic declination is the difference between magnetic north and true north for your location. You can find your magnetic declination at the following site: http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp.

2. Once your sundial's gnomon is pointing in the correct direction, locate where the sun's shadow crosses the dial and estimate the time. If daylight savings time is in effect, subtract one hour from your sundial's time.

Adapted by M.S. Young and G.L. Vogt from the *Space Educator's Handbook*, NASA Johnson Space Center.