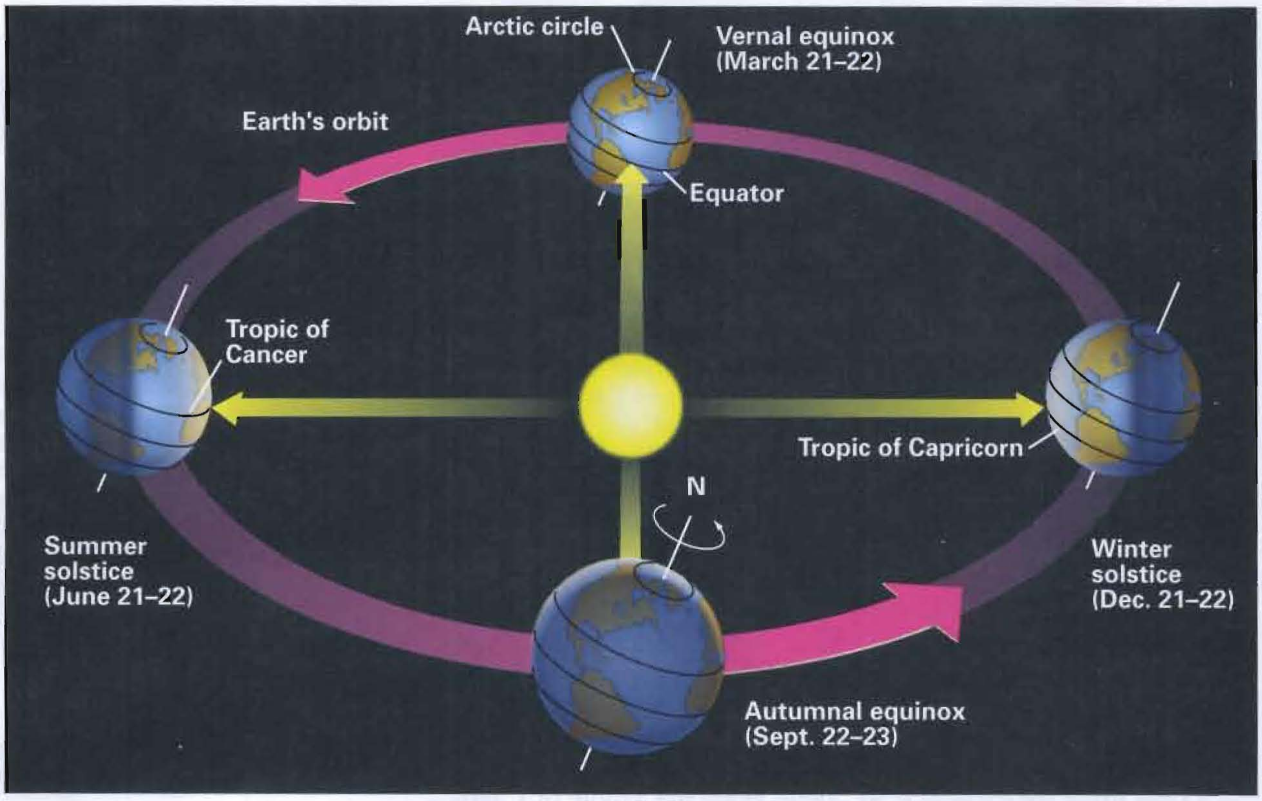


Figure 2–9. At the solstices, the sun's rays hit the Tropic of Cancer or the Tropic of Capricorn at a 90° angle. At the equinoxes, they hit the equator at a 90° angle.

that the hours of daylight and darkness are equal everywhere on the earth on that day. The hours of daylight and darkness are equal because at the equinox the North Pole tilts neither toward nor away from the sun. This position of the North Pole in relation to the sun is illustrated in Figure 2–9.

On March 21 or 22, the sun's rays again strike the earth at a 90° angle along the equator. This day is called the **vernal equinox** and marks the beginning of spring in the Northern Hemisphere. As during the autumnal equinox, the hours of daylight and darkness are equal everywhere on the earth. On this day, the North Pole tilts neither toward nor away from the sun.

Precession

The illustration in Figure 2–9 also shows that as the earth completes its revolution of the sun, its axis of rotation continuously points toward Polaris, the North Star. This has not always been the case, however. As the earth rotates about its axis, the direction in which the axis points slowly changes in relation to the distant stars. This change results from a circular motion of the earth's axis, called **precession.** Precession is caused by forces acting on a spinning body, in this case by the gravitational pull exerted on the rotating earth by the moon, the sun, and the other planets. Precession causes the earth's axis to move slowly in a circle, much like a top does as it spins on a table. The earth's axis, however, completes only one full circle every 26,000 years, so Polaris will continue to be our North Star for many years to come.

INVESTIGATE!

To learn more about the motion of the sun and earth, try the In-Depth Investigation on pages 40–41.

Time Zones

Using the sun as the basis for measuring time, 12:00 noon is defined as the time when the sun is highest in the sky. Because of the sun's apparent movement from east to west, the sun appears highest over different locations at different times. For example, assume the sun is highest over New York City at 12:00 noon. In Philadelphia, a short distance west of New York City, the sun would appear highest a few minutes later. In Baltimore, just west of Philadelphia, the sun would appear highest a few minutes after that. If these communities were to set their clocks precisely by the sun, the clocks in each community would mark slightly different times. To avoid problems created by different local times, the earth's surface is divided into 24 **standard time zones.** In each zone, noon is set as the time when the sun is highest over the center of that zone.

IMPACT ON SOCIETY

Biological Clocks

Our earliest ancestors lived in harmony with the cycles of the sun. They were awakened by the sun's first rays, and they ended their workday at sunset. With the development of artificial light sources, however, humans have become less dependent on the availability of sunlight to set their daily routines. Yet research reveals surprising evidence that human behavior is still closely tied to solar rhythms.

Scientists have discovered that many body processes occur in 24-hour cycles called *circadian rhythms. Circa* is Latin for "about"; *dies* is Latin for "day." No one understands exactly what controls circadian rhythms, but the human body seems to have a number of internal clocks. They regulate patterns of sleeping and waking, daily changes in body temperature, hormone secretions, heart rate, and blood pressure. Even moods, coordination, and memory have their own circadian rhythms.

Studies indicate that the cycle of darkness and light caused by the earth's rotation sets and resets the clocks of the body. It more or less keeps vital processes on a 24-hour schedule.

When the internal clocks get out of sync with the sun's cycle, problems arise. One graphic example is jet lag, the combination of exhaustion, irritability, and insomnia that travelers often suffer after a long flight across several time zones.

Based on your knowledge of time zones and circadian rhythms, explain the cause of jet lag.

Figure 2–10. The earth has been divided into 24 standard time zones. Going east, travelers must set their clocks ahead one hour for each time zone crossed. Going west, travelers must set their clocks back one hour.

Because the earth is nearly spherical, its circumference equals 360°. Dividing 360° by the 24 hours needed for one rotation, you find that the earth rotates at a rate of 15° each hour. Therefore, each of the earth's 24 standard time zones covers about 15°. The time in each zone is one hour earlier than the time in the zone to its east. Figure 2–10 shows the standard time zones in the United States. At 6 P.M. in New York City, what time is it in Los Angeles? in Denver?

There are 24 standard time zones and 24 hours in a day. But there must be some point on the earth's surface where the date changes from one day to the next. To prevent confusion, the **International Date Line** has been established. The International Date Line is a line running from north to south through the Pacific Ocean. When it is 8:00 A.M. Friday west of the International Date Line, it is 8:00 A.M. Thursday east of the line. The line is drawn so that it does not cut through islands and continents in the Pacific Ocean. Thus, the people living within one country have the same date. Note how this is done between Alaska and Siberia in Figure 2–10.

During the summer, most of the United States uses **daylight saving time.** Under this system, clocks are set one hour ahead of standard time in April, which provides an additional hour of daylight during the evening. For example, if the sun sets at 7 P.M. standard time, it would set at 8 P.M. daylight saving time. In October, clocks are set back one hour, returning to standard time.

Section 2.2 Review

1. Describe the position of the earth during the summer solstice. Where do the sun's rays strike the earth at a 90° angle?
2. What causes winter in the Northern Hemisphere?
3. What are the advantages in using daylight saving time?

2.3 Artificial Satellites

Section Objectives

- **Compare two types of satellite orbits.**
- **Discuss ways in which satellites are used to study the earth.**

If you drop a ball, it will fall straight down because the force of gravity pulls objects toward the center of the earth. If you throw a ball horizontally, it will follow a curving path. The force of gravity still pulls the ball toward the earth, but the ball also moves horizontally as it falls. The greater the speed at which the ball is thrown, the farther it will travel before gravity pulls it to the earth's surface. For example, a ball thrown at about 8 km/s and not slowed down by air resistance would follow the curve of the earth. As shown in Figure 2–11, the ball would fall toward the earth but never reach the earth's curved surface. Instead the ball would become an artificial earth **satellite.** A satellite is any object in orbit around another body with a larger mass.

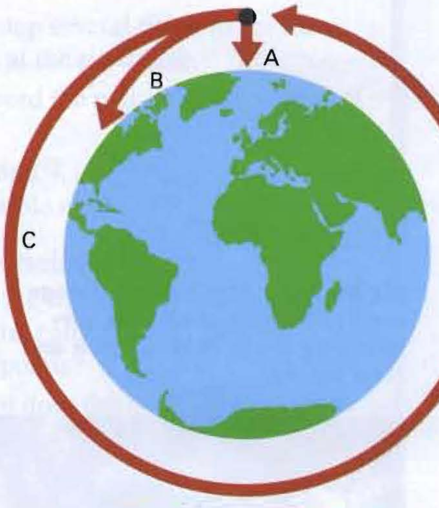


Figure 2–11. ***A*** **is the path of a ball that is dropped.** ***B*** **is the path of a ball thrown horizontally.** ***C*** **is the path of a ball moving fast enough to go into orbit.**

Satellites and Orbits

Today hundreds of artificial satellites orbit the earth. Meteorological satellites gather and transmit weather information. Communications satellites relay radio, telephone, and television signals to and from various locations on earth. Navigation satellites send out radio signals that help pilots of ships and aircraft determine their locations. Scientific satellites and orbiting telescopes are outfitted with special instruments that allow scientists to study the distant reaches of space.

Satellites are put into orbit by powerful computer-guided rockets. A rocket carries the satellite to an appropriate altitude above the earth. The rocket then aims the satellite at the angle necessary for the desired orbit. Once the satellite is in place, the rocket automatically detaches from the satellite. A smaller rocket on the satellite may provide the extra speed necessary to send the satellite orbiting around the earth. The earth's gravity holds the satellite in orbit.

The altitude of a satellite determines the speed necessary to keep it in orbit. As the distance from the earth increases, the force of earth's gravity decreases. Air resistance is also reduced in the earth's thin upper atmosphere. Therefore, the higher the orbit of a satellite, the lower will be the speed needed for it to stay in orbit.

At an altitude of 36,100 km, a satellite completes one revolution in 24 hours. At this altitude, a satellite in orbit directly above the earth's equator and moving in the direction of the earth's rotation is in **geosynchronous orbit.** A satellite in geosynchronous orbit always remains at the same point above the equator and appears to be stationary in the sky. Satellites used for communications are usually put into geosynchronous orbits. High above the earth, these satellites can act as antennas, relaying electronic signals over great distances. Some weather satellites use this high stationary orbit to continuously track hurricanes and other storms.

A satellite can also be placed in a **polar orbit.** A polar orbit carries the satellite over the earth's North and South poles. As the earth rotates beneath it, a satellite in polar orbit passes over a different portion of the earth's surface during each revolution. After a certain number of revolutions, the satellite will have surveyed the entire surface of the earth. A polar orbit is useful for mapping the earth's surface and for tracking weather. Why might a polar orbit be better than a geosynchronous orbit for some weather satellites?

Most satellites follow slightly elliptical orbits around the earth. The point closest to the earth in the orbit is called *perigee*. The point farthest from the earth in the orbit is called *apogee*. A satellite travels fastest at perigee and slowest at apogee.

To stay in orbit, a satellite must maintain a speed adequate for its altitude. If the orbit comes too close to the earth at perigee, friction with the earth's upper atmosphere will slow the satellite down. This decrease in speed means that each successive orbit will bring the satellite closer to the earth at perigee. Eventually, the increasing friction of the earth's atmosphere will generate too much heat, and the satellite will burn up.

Exploring the Earth by Satellite

Satellites have given scientists new ways of studying the earth. Some of the most fascinating information has come from a series of American scientific satellites called *Landsat*. Each Landsat orbits the earth in a polar orbit and collects information, using both television cameras and electronic sensors. The resulting images are used to identify features on the earth's surface, such as cities, vegetation regions, and even rock types.

Figure 2–12. This Landsat image shows Manhattan and the surrounding areas of New York and New Jersey.

SMALL-SCALE INVESTIGATION

Gravity and Orbits

A moving body tends to move in a straight line at constant speed unless some outside force acts on it. Gravity is the outside force that acts on satellites and keeps them in orbit around the earth. You can investigate the effect of gravity on a moving body with a simple model.

Materials

strip of flexible cardboard, 3 × 30 cm; transparent tape; sheet of white paper; a marble

Procedure

1. Form a hoop with the cardboard strip and fasten the two ends together with tape.
2. Place the hoop in the center of your paper and trace a circle along the outside edge of the hoop as shown in the photo. Mark four points at equal distances around the circle. Number the points 1, 2, 3, and 4.
3. Place a marble inside the cardboard hoop. Slowly swirl the hoop clockwise until the marble rolls smoothly around the inside edge of the hoop. Stop swirling the hoop as the marble approaches point 1; then quickly lift the hoop, allowing the marble to escape. You may have to practice this step several times to get the marble released at the right time.

4. Observe and record the path of the marble as it exits the hoop.
5. Repeat Steps 3 and 4, stopping the hoop and releasing the marble at points 2, 3, and 4.

Analysis and Conclusions

1. What path does the marble take when the hoop is removed? Is the pattern of the path the same for all four exit points?
2. In what direction does the hoop push the marble? What force does the hoop represent?
3. Compare the motion of the marble with that of a satellite around the earth. How are they alike? How are they different?

The Global Positioning System, or GPS, is a network of satellites used for accurate navigation of ships and aircraft. Even with a small hand-held receiver, the system can locate virtually any point on the earth's surface with an accuracy within several meters.

Most satellites are designed simply to receive information and to send electronic information back to earth. The space shuttle, however, is an exception. This temporary satellite is designed to carry cargo, orbit the earth, and then return to the earth's surface. While in orbit, the shuttle can release or pick up other satellites.

Section 2.3 Review

1. Compare a geosynchronous orbit with a polar orbit.
2. How are satellites used to study the earth?
3. Why is a polar orbit useful for surveying purposes?

Chapter 2 Review

Key Terms

- aphelion (29)
- autumnal equinox (31)
- axis (23)
- core (24)
- crust (24)
- daylight saving time (34)
- geosynchronous orbit (35)
- gravity (27)
- International Date Line (34)
- law of gravitation (28)
- magnetosphere (26)
- mantle (24)
- Moho (24)
- perihelion (29)
- polar orbit (35)
- precession (32)
- revolution (29)
- rotation (29)
- satellite (35)
- seismic wave (23)
- shadow zone (25)
- standard time zone (33)
- summer solstice (31)
- vernal equinox (32)
- winter solstice (31)

Key Concepts

The solid earth consists of three major zones: the crust, the mantle, and the core. **See page 24.**

Studies of seismic waves provide information about the thickness and composition of the zones of the earth's interior. **See page 24.**

The earth has magnetic properties that probably originate in the earth's core. **See page 25.**

Newton's Law of Gravitation states that the strength of the gravitational force between two objects depends on their mass and the distance between them. **See page 28.**

The earth revolves around the sun and rotates on its axis. **See page 29.**

The seasons of the year are caused by two factors. **See page 30.**

The apparent motion of the sun across the sky is the basis for measuring time. **See page 33.**

Many satellites orbit the earth in geosynchronous orbits or in polar orbits. **See page 35.**

Satellites collect information on features of the earth's surface, using equipment such as television cameras and other electronic sensors. **See page 36.**

Review

On your own paper, write the letter of the term that best completes each of the following statements.

1. The zone that makes up nearly two-thirds of the earth's mass is the
   a. crust. b. mantle. c. core. d. lithosphere.
2. The boundary between the earth's crust and mantle is called the
   a. shadow zone. b. asthenosphere.
   c. Moho. d. magnetosphere.
3. Both P waves and S waves can travel through
   a. liquids and solids. b. solids.
   c. liquids. d. gases.
4. The possible source of the earth's magnetism is the earth's
   a. crust. b. mantle. c. core. d. lithosphere.
5. The amount of matter in an object is the object's
   a. mass. b. weight.
   c. gravity. d. plasticity.
6. As the distance from the center of the earth increases, the force of gravity
   a. decreases. b. increases.
   c. stays the same. d. doubles.

7. The measured weight of an object is slightly less at the equator than it is at the poles because of the earth's
a. orbit. b. axis. c. shape. d. tilt.

8. The point closest to the sun in the earth's orbit is called
a. apogee. b. perigee. c. aphelion. d. perihelion.

9. At noon on the winter solstice, the sun's vertical rays strike the earth along the
a. Tropic of Cancer. b. Tropic of Capricorn.
c. equator. d. North Pole.

10. At noon on the vernal equinox, the sun's vertical rays strike the earth along the
a. Tropic of Cancer. b. Tropic of Capricorn.
c. equator. d. North Pole.

11. When the sun's rays reach their highest angle in the Northern Hemisphere, the season there is
a. spring. b. summer. c. fall. d. winter.

12. The wobbling motion made by the earth's axis as it turns in space is called
a. precession. b. gravity.
c. plasticity. d. equinox.

13. A person crossing the International Date Line gains or loses
a. 2 hours. b. 8 hours.
c. 12 hours. d. 24 hours.

14. A satellite in geosynchronous orbit is always directly above the
a. equator. b. North Pole.
c. South Pole. d. International Date Line.

15. Landsat provides information about the
a. earth's surface. b. moon's surface.
c. sun's surface. d. stars.

Critical Thinking

On your own paper, write answers to the following questions.

1. Is a hard-boiled egg a good model of the earth's different zones? Why or why not?
2. Explain why the weight of an object might increase when the object moves from point *A* to point *B* on the earth's surface.
3. Although the earth's orbit brings it closest to the sun in January, the Northern Hemisphere is having winter at that time of the year. Explain.
4. If the earth ceased rotating as it revolved around the sun, how would periods of daylight and surface temperatures on the earth be affected?
5. Suppose the earth's rotation slowed to one rotation every 48 hours. How might that change affect timekeeping systems?

Application

1. A scientist proposes the hypothesis that the moon has a liquid core. How might this hypothesis be tested?
2. If scientists discovered that the earth's magnetic field had weakened substantially, what might they suspect to be the cause of this change?
3. A group of scientists is planning to launch a satellite into orbit around the earth. The satellite will be used to survey the entire earth's surface in search of oil deposits. Which type of orbit would you recommend for such a satellite? Why?

Extension

1. Scientists made recent discoveries about the earth's core using seismic tomography. Research seismic tomography and write a report on its uses.
2. Find out how the Lapps and the Eskimos have adapted to periods of continuous daylight and continuous darkness.
3. Draw a simple map of the world. Label Washington, D.C., with the time and date 1:00 p.m., January 1. Label the correct time and date for five other cities.

In-Depth Investigation

Earth-Sun Motion

Materials

- magnetic compass
- clock or watch
- metric ruler
- wooden board (9" × 12")
- pencil
- wooden dowel (about 12" long and 1/4" diameter)
- masking tape

Introduction

During the course of a day, the sun seems to move across the sky. This apparent motion is due to the earth's rotation. In ancient times, one of the earliest devices used by people to study the sun's motion was the shadow stick. The shadow stick is a primitive form of a sundial. Before clocks were invented, sundials were the only means of telling time.

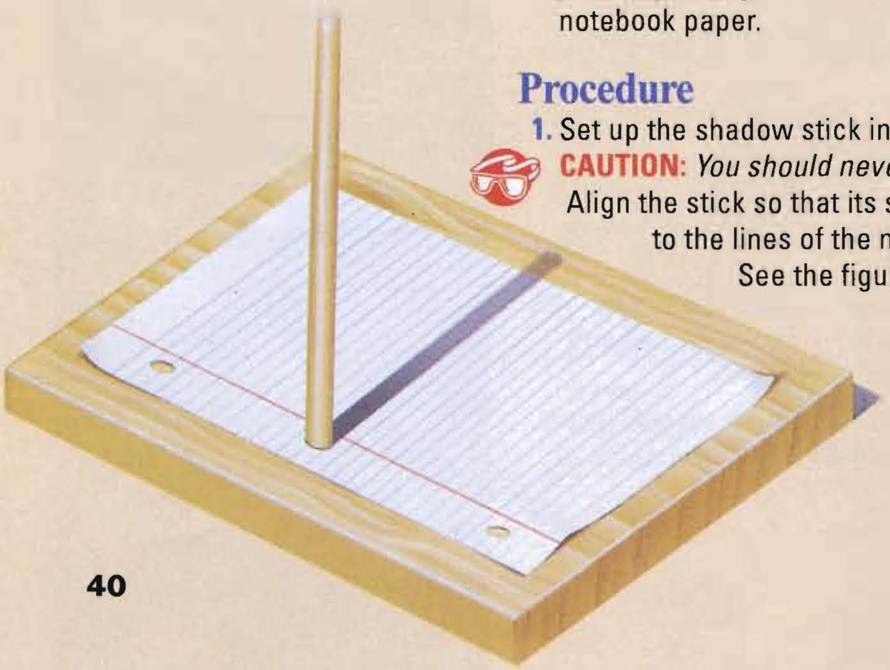
In this investigation, you will construct a shadow stick in order to identify how changes in a shadow are related to the earth's rotation. You will also determine how a shadow stick can be used to measure time.

Prelab Preparation

1. Review Section 2.2, pages 29–32.
2. Constructing a shadow stick: Using a hand or power drill, make a hole in the board at the location shown in the illustration below, just large enough to hold the wooden dowel. **CAUTION:** *If you are using hand or power tools, it is best to allow your parents or another adult skilled in the tool's operation to help you.* Place the dowel in the hole. Place a sheet of three-hole notebook paper on the base of the shadow stick. Slip the middle hole of the paper over the stick, and slide the paper down so that it rests on the base. Fasten the paper securely to the base with tape. The shadow stick should be just long enough to cast a shadow nearly across the piece of notebook paper.

Procedure

1. Set up the shadow stick in a sunny spot outdoors. **CAUTION:** *You should never look directly at the sun.* Align the stick so that its shadow is parallel to the lines of the notebook paper. See the figure to the left.



2. Place the compass on the paper above the shadow. In one corner of the paper indicate north with an arrow. Label the arrow with a capital N. Why is it necessary to indicate the direction north on the paper?

3. Make a pencil dot at the end of the shadow cast by the wooden dowel. Write the time above the dot. Do this two more times at five-minute intervals. *Note: Do not move the base after you begin to make measurements.*

4. After your last five-minute measurement, wait 10 minutes. Make another dot to show the position of the end of the shadow. Do this two more times at five-minute intervals. Be sure to record the time above each dot. Then return the shadow stick to your classroom.

5. Remove the notebook paper from the base of the shadow stick. Connect the dots with a thin pencil line. Is the line connecting the dots on the paper a straight line?

6. Draw an arrowhead on the end of the line to show the direction in which the shadow moved. In what direction did the shadow move?

7. Make two measurements of the shadow's length in centimeters. The first measurement should be from the center of the paper hole to the first dot. The second measurement should be from the paper hole to the last dot. Record the two lengths.

8. Measure and record the length, in centimeters, of the line connecting the dots. This is the distance the shadow moved in 30 minutes.

Analysis and Conclusions

1. In what direction did the sun appear to move in the 30-minute period?
2. In what direction does the earth rotate?
3. If you made your shadow stick half as long, would its shadow move the same distance in 30 minutes? Explain.
4. How might a shadow stick be used for telling time?

Extension

Repeat this investigation at different hours of the day. Do it early in the morning, early in the afternoon, and early in the evening. Record the results and any differences that you observe. Explain how shadow sticks can be used to tell direction.