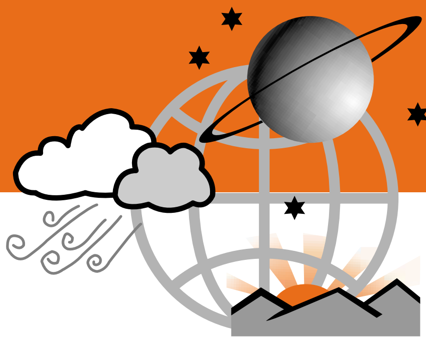


Chapter 25

Earth, Sun, and Seasons

OUR INTERNAL CLOCK

Like most other animals on Earth, people have an internal clock that works on a 24-hour cycle (the circadian rhythm). Scientists have conducted experiments in which people were voluntarily isolated. They received no natural light and no clues to tell day from night. When the subjects of the experiment established their own periods of sleep and activity, they usually settled into a cycle that was about 24 hours in length.

Scientists have learned that this cycle is influenced by brain activity that controls the release of hormones, chemicals that influence bodily functions and behavior. Furthermore, information passed to the brain by the senses, especially the sense of sight, keeps the body's cycles in line with the cycle of day and night. In this way, the cycle of Earth's rotation has become a part of our biological identity.

Our internal clock is noticeable to travelers who journey considerable distances east or west into different time zones. They experience jet lag. This includes difficulty sleeping when the people around them are going to bed, and lapses in concentration at the time that they would have been sleeping at home. After a few days, most people adjust to the new time routine, and the effects of jet lag go away.

Day and Night

Our daily cycle of night and day is so much a part of our lives that we have devised our system of clock time based on the length of the day. Most of the world's nations use the International System of Units (metric system) in which most measures are related to larger and smaller units by a factor of 10. However, the worldwide system of time is still a 24-hour day with 60 minutes to the hour and 60 seconds to the minute. Calendar time, with a year of approximately $365\frac{1}{4}$ days, is based on the cycle of seasons and Earth's revolution around the sun. These cycles are more important to us than a system of time with a base of 10. Even in nations using metric measures, clock time is still set to Earth's cycles of motion.

Two locations on Earth do not have a 24-hour cycle of night and day. The North and South Poles are on a yearly cycle of daylight and darkness. At both poles sunrise occurs on the first day of spring in that hemisphere. The sun remains continuously visible in the sky for 6 months, until the first day of autumn in that hemisphere. Night begins at that time, and continues for the next 6 months. Humans are unable to adapt their activities to a 12-month cycle of day and night.

In addition, there is no natural way to assign clock time at these two locations. Although there is no settlement at the North Pole, the United States does maintain a permanent research station at the South Pole. Clocks at the South Pole are set to the time in New Zealand, the closest inhabited area, and the place from which most people fly to the South Pole research station.

WHAT IS ASTRONOMY?

The study of objects beyond Earth and its atmosphere is known as *astronomy*. Most of our knowledge of the heavens comes through the light (electromagnetic radiation) these objects give off or reflect. In some ways astronomy is one of the oldest sciences. Historians have found written records of celestial observations that go back thousands of years. This branch of science also involves some of the most advanced technology. It has consistently yielded new insights into where we came from as well as the fundamental nature of matter and energy.

In this chapter, it will be important to distinguish between what is apparent and what is real. For example, we observe the daily path of the sun through the sky. Although we know that this cycle is caused by Earth's rotation on its axis, we conduct our lives as if it the sun actually moves around Earth. We talk about the sun rising and setting as if these were real motions of the sun. We call the motion of the sun through the sky an *apparent motion* because this movement of the sun looks real, even though we know it is Earth that is moving. Later in this chapter, you will learn how scientists proved that Earth moves. However, for the sake of describing celestial events, it is convenient to stay with the Earth-centered point of view.

HOW CAN WE DESCRIBE THE POSITION OF CELESTIAL OBJECTS?

To any observer on Earth, the sky looks like a giant dome that stretches across the sky from horizon to horizon. **Celestial objects** are the things seen in the sky that are outside of Earth's atmosphere. These objects include the sun, moon, planets, and stars. You may know that some of these objects are farther away than others. Nevertheless, many appear as if they are points of light on the surface of the sky.

In locating celestial objects, it is convenient to treat the sky as a two-dimensional surface. Two coordinates are all that are needed specify a location on a two-dimensional surface. For example, positions based on the *x*- and *y*-axes of a graph. Angles of latitude and longitude are the coordinates used to locate places on Earth's two-dimensional surface. Like Earth, the sky appears as a curved surface. Therefore, scientists also use angles to locate positions in the sky.

In the sky, you can specify a location using *azimuth* (compass direction) and angular altitude. You learned about compass directions such as North or Southwest when you read about maps in Chapter 3. For locations in the sky, the compass direction refers to the direction along the horizon directly below the position in the sky. Azimuth usually is expressed as an angle measured from North (0°), clockwise to East (90°), South (180°), West (270°) and around the horizon back to 360°. (360° is also 0°, due North.)

Using this coordinate system, altitude is the second coordiante. **Altitude** is the angle above the horizon. Altitude angles start at a level horizon (0°) and increase to 90° at the point directly overhead, sometimes called the **zenith**. The coordinates of compass direction and angular altitude allow us to locate any point in the sky. Figure 25-1 shows the angle of direction and altitude for a star that is high in the southeastern sky.

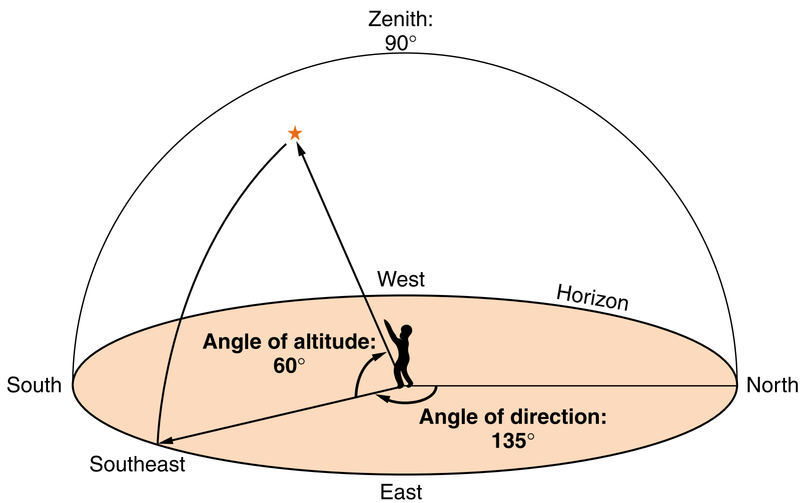


Figure 25-1 Any point in the sky can be located by two angles. The angle of direction is the clockwise angle from due north to a place on the horizon directly below the point in the sky. The angle of altitude is the angle from the horizon up to that point.

WHAT IS THE SUN'S APPARENT PATH ACROSS THE SKY?

For most observers on Earth, the sun rises in the eastern part of the sky. The sun reaches its greatest angular altitude at solar noon. It then moves down to dip below the western horizon. This apparent motion of the sun is the basis for the earliest clocks: sun dials. Figure 25-2 shows a very large sundial.

Local **solar noon** is the time at which the sun reaches its highest point in the sky. For mid-latitude locations in the Northern Hemisphere, such as New York State, the sun at solar noon reaches its highest point when it is due South. The noon sun is never directly overhead in New York State. In fact, the sun is never at the zenith except for observers located between the Tropic of Capricorn (23.5°S) and the Tropic of Cancer (23.5°N).

Figure 25-2 Solar time can be measured with a sundial. The long arm of the sundial (the gnomon) casts a shadow on the dial's horizontal face. The movement of the shadow is used to measure the passage of time. Solar noon occurs when the shadow points exactly north. This is the largest sundial in the United States, located near Phoenix, Arizona.

ACTIVITY 25-1 THE LENGTH OF A SHADOW

Select a place where buildings or trees do not block the sun for an extended period. During the course of one day, take measurements of the changes in length of the shadow of a vertical object 1-meter tall (1 meter = 39.37 inches). Use these measurements to draw a graph of the change in length of the shadow from sunrise to sunset. Measurements must be made on a level surface. Think about the best times to take measurements and which values of shadow length you can determine by logical thinking. Your teacher will collect your data table and your graph.

According to your graph, what was the clock time of solar noon? As an extended activity, make the changing direction of the shadow part of your data and your graph.

ACTIVITY 25-2 CONSTRUCTING A SUNDIAL

A number of sites on the Internet as well as books contain plans for making a simple paper or cardboard sundial. All individuals or groups of students can make the same style, or each can select a different design to construct.

Sundials must be positioned carefully in an open area on a level surface with a north–south alignment. You can check your sundial by comparing its reading with a clock or watch. Solar time and clock time will differ depending on your longitude even if you account for daylight savings time.

HOW DOES THE SUN'S PATH CHANGE WITH THE SEASONS?

The previous section did not specify the exact direction of sunrise and sunset, nor did you learn how high the noon sun reaches in New York State. These observations depend upon the time of year. In fact, the seasons can be defined based on observations of the path of the sun through the sky.

For observers with a level horizon, such as anyone at sea, the sun rises exactly (due) east and sets due west on just two days of the year. People who live on land would also observe this if hills, trees, and buildings did not block a level line of sight to the horizon. These two days of the year are the **equinoxes**. Equinox can be translated as equal night. On these days, daylight and night are approximately equal in length: about 12 hours of daylight and 12 hours of night.

It is useful to remember that the complete apparent path of the sun is a circle. Part of this circle is above the horizon and part is below the horizon. The total angular distance around a circle is 360°. Furthermore, the apparent motion of the sun along that circle is constant. The rate at which the sun appears to move is determined by dividing 360° by 24 hours, which equals 15° per hour. No matter when or where you observe the sun, it always appears to move at a rate of 15° per hour. However, the length of daylight changes. This is because the portion of the circle that is above or below the horizon changes on a yearly cycle.

Spring

Consider the changing path of the sun for an observer facing south at 42° north latitude in New York State. March 21 is the *spring equinox* as shown in Figure 25-3. (This is also called the vernal equinox.) The sun rises due east at 6 A.M. It moves to the observer's right as it climbs to a noon altitude angle of 48°. In the afternoon, the sun continues to the right, setting due west at 6 P.M. Of the sun's circular path of 360°, half is in the sky and half below the horizon, so there are 12 hours of daylight.

Summer

The longest period of daylight in New York State occurs 3 months later, usually on June 21, which is called the **summer solstice**. On that date, the sun rises in the northeast at

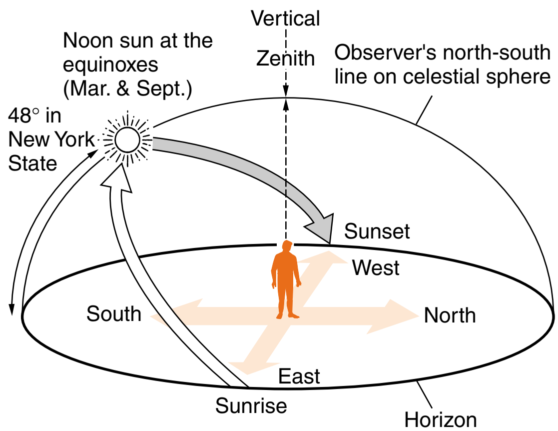


Figure 25-3 In New York State on the spring equinox, the sun rises due east at about 6 A.M. and sets due west at about 6 P.M., giving 12 hours of daylight. The sun reaches its highest point at solar noon when it is due south, 48° above the southern horizon.

about 4:30 A.M. standard time (5:30 A.M. daylight savings time) and sets at about 7:30 P.M. standard time (8:30 P.M. daylight savings time). (See Figure 25-4.)

New York has about 15 hours of daylight at the summer solstice because the sun rises well into the northeast and sets in the northwest. Therefore, more than 60 percent of the sun's circular path is above the horizon. This is also when the noon sun is highest in the sky in New York State—71.5° above the horizon (but still 18.5° below the zenith). Insolation is strongest at this time of the year. The season of summer begins on the summer solstice.

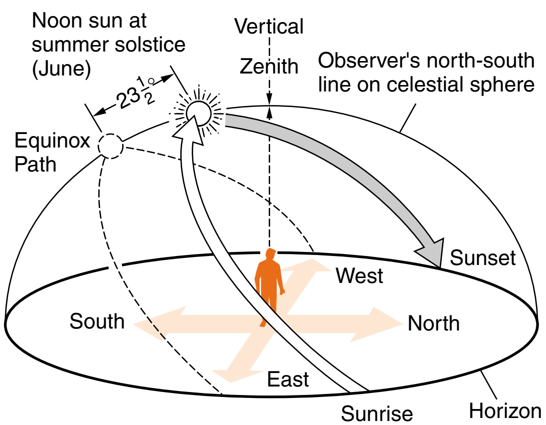


Figure 25-4 In New York State on the summer solstice, the sun rises in the southeast at about 4:30 A.M. (standard time) and sets in the southwest about 7:30 P.M., providing 15 hours of daylight. The sun reaches its highest point at noon when it is nearly 72° above the southern horizon. The sun's path in March is shown by a dotted line.

Autumn

The **autumnal equinox** occurs about September 22. On that day sunrise occurs at 6 A.M. due east, and sunset at 6 P.M. due west. The sun follows the same path it took 6 months earlier at the spring equinox. Figure 25-3 on page 635 is appropriate for both equinoxes. Because there are not exactly 365 days in a year, periodic adjustments must be made in our calendars. Therefore, the dates of the beginning of the seasons vary from year to year.

Winter

The first day of winter occurs each year between December 21 and December 23, which is called the **winter solstice**. On that day, the sun rises in the southeast a shown in Figure 25-5. Its path through the sky is relatively short and the sun sets in the southwest. Less than 40 percent of the sun's circular path is above the horizon. Sunrise does not occur until about 7:30 A.M., and the sun sets at about 4:30 P.M. The length of daylight at 42° north on the winter solstice is about 9 hours.

The maximum altitude of the sun, at solar noon, is only about 24.5° above the southern horizon. The sun is never very high in the sky, even at noon. This is why solar energy is weakest at this time of year. This pattern of change is the same for

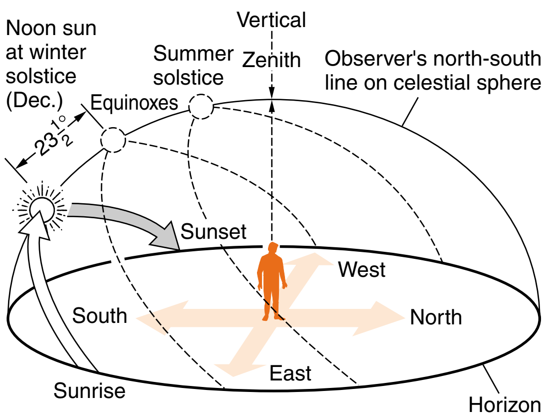


Figure 25-5 In New York State on the winter solstice, the sun rises in the southeast at about 7:30 A.M., and sets in the southwest about 4:30 P.M., giving just 9 hours of daylight. The sun reaches its highest point at noon when it is 24.5° above the southern horizon. Dotted lines show the sun path at the equinoxes and the summer solstice.

all mid-latitude locations on Earth, although the angular altitude of the noon sun does change with latitude.

For mid-latitude locations such as New York State, the seasonal changes can be summarized as follows:

1. The sun generally rises in the east and sets in the west. However, the sun rises north of east when the days are longest in spring and summer and south of east during the short days of fall and winter. The sun always sets in the west, but the pattern of change is similar. The sun sets in the northwest during the long days of spring and summer. When the days are shorter in fall and winter, the sun sets in the southwest.
2. The direction of both sunrise and sunset moves northward along the horizon as the days get longer in winter and spring. During the summer and autumn, when the days get shorter, the sunrise and sunset position moves southward from day to day.
3. The noon sun is highest at the time of the summer solstice and lowest at the time of the winter solstice. At these times, the noon sun is $23\frac{1}{2}°$ higher or lower than its equinox position.
4. When the noon sun is highest in the sky, the days are longest.

ACTIVITY 25-3 OBSERVING THE SUN

CAUTION: It is dangerous to look directly at the sun, especially for an extended time because of the potential for damage to your eyes. This danger is much greater if a person is looking through a telescope, which can concentrate the sun's energy. It is best to never look at directly at the sun through any optical device. However, there are two relatively safe ways to observe the sun.

One relatively safe method is to use a small reflecting telescope to project an image of the sun. Direct the sunlight onto a sheet of paper mounted inside a cardboard box. Focus the image

Figure 25-6 A reflecting telescope can be used to project the sun's image onto a sheet of paper mounted in a cardboard box. Dark areas known as sunspots can sometimes be seen on the sun's surface. ***Never look directly at the sun through any optical device.***

on the paper with the eyepiece. The box shields the paper screen from direct sunlight. This procedure is shown in Figure 25-6.

A second method makes use of a special kind of mirror called a front-sided mirror. Most mirrors have the silver reflective coating behind the glass to protect the coating from scratches. Front-sided mirrors can be purchased from scientific supply companies. This activity works best with a tiny piece of mirror about a quarter the size of a small coin.

Mount the small piece of front-sided mirror on a tripod so it reflects a beam of sunlight through a window. Project the reflection onto a light-colored interior wall of a darkened room. Although it can be difficult to aim this reflection, the image projected inside can be used for two purposes. This procedure will create a dim image of the sun revealing details on the solar surface. It can also be used to observe and even measure the sun's apparent motion through the sky.

DOES THE SUN'S PATH DEPEND ON THE OBSERVER'S LOCATION?

At any particular time, half of Earth is lighted and half is in shadow. Whether it is day or night depends upon where you are located. This is a consequence of living on a spherical planet.

Changes with Longitude

If you telephone someone in California, you need to take into account that the sun rises in New York 3 hours before it rises in California. This is due to Earth's rotation at 15° per hour. Local time generally changes by 1 hour for each 15° change of longitude east or west. This is why Earth is divided into time zones that generally are 1 hour apart for each 15° change in longitude.

Changes with Latitude

Although the local solar time does not change with latitude, the path of the sun through the sky does change. You have already read that observers at the North or South Pole experience 6 months of daylight followed by 6 months of night. In fact, every location on Earth has a total of 50 percent of the year when the sun is in the sky and 50 percent when it is below the horizon. However, as a result of Earth's curvature, the cycle of day and night is most changeable at the poles and most constant near the equator.

People at the equator experience approximately 12 hours of daylight every day. Although the position of sunrise along the horizon changes, as it does in the mid-latitudes such as New York, the noon sun is always high in the sky. When it is spring and summer in the Northern Hemisphere, the sun rises to the north of east at the equator. The noon sun is a little north of the zenith (the point straight overhead). From late

September through most of March the sun rises in the southeast and reaches its highest point a little south of the zenith. At the equinoxes the sun rises due east, sets due west, and the noon sun is directly overhead at the equator. Changes from season to season are hardly noticeable. This is why the tropics are sometimes called the zone of seasonless climates.

Moving out of the tropics, you would notice that the noon sun is never directly overhead. You would also notice distinct seasons and changes in the length of daylight. South of the equator, the seasons are the opposite of those in New York. When its summer here and the days are longer, it is winter south of the equator and daylight is shortest. When it is spring in New York, days are getting longer and the noon sun higher in the sky each day. At the same time, is autumn south of the equator where the opposite changes are happening.

WHAT IS REALLY MOVING, SUN OR EARTH?

This was an easy question for our ancestors to answer. They could not feel the ground moving. Their observations fit the idea that the sun circles Earth in a daily path that changes through the year.

The Geocentric Model

For most people that answer was logical and complete. This is called the **geocentric model**. (The prefix *geo-* refers to Earth, as in geology, the study of the solid Earth.) Geocentric means Earth-centered. The geocentric model assumed Earth was stationary and the real motion of celestial objects caused the motions seen in the sky.

As early as 2000 years ago, some scholars made observations that caused them to question this traditional view of Earth. These observations led some scholars to consider the idea that Earth is not a flat surface, but a huge sphere. The geocentric model was revised to include Earth as a sphere, but still at the center of the orbits of the sun, planets, and stars.

Heliocentric Model

Copernicus published his ideas about the sun-centered model in Poland in 1543. It was controversial. The well-known Italian mathematician and inventor Galileo published his own observations in the early 1600s supporting the sun-centered model. Important clues came from observations of the motions of planets in the night sky. German astronomer Johannes Kepler developed the mathematical tools needed to predict the positions of the planets among the stars. However, his theories made sense only if he assumed that the planets, including Earth, orbit the sun. This is the central idea of the **heliocentric model** of the universe. (The prefix *helio-* refers to the sun.) The heliocentric model places the sun at the center of planetary motion.

According to this model, it is mainly the motions of Earth that cause the apparent motions of celestial objects. The motion of the planets in their orbits around the sun is known as **revolution**. The heliocentric model also includes the **rotation**, or spin, of Earth on its axis.

A useful way to remember the difference between rotation and revolution is to recall that a top is a spinning toy. Rotation has two *T*s, the first letter of *top*. The American Revolution started in 1776, which is a year. A revolution is the yearly cycle of Earth's motion in its orbit around the sun. Figure 25-7 on page 642 compares the geocentric and heliocentric models.

Experimental proof of Earth's motion was not discovered until 1851. By then, most astronomers already supported the heliocentric model. Motions of the planets in the geocentric model had become too complicated to explain by the laws of physics.

Proof of Rotation

Jean Foucault invented a special pendulum that is free to rotate as it swings back and forth. The Foucault pendulum is shown in Figure 25-8 on page 642. If a Foucault pendulum were used at the North or South Pole, it would seem to rotate

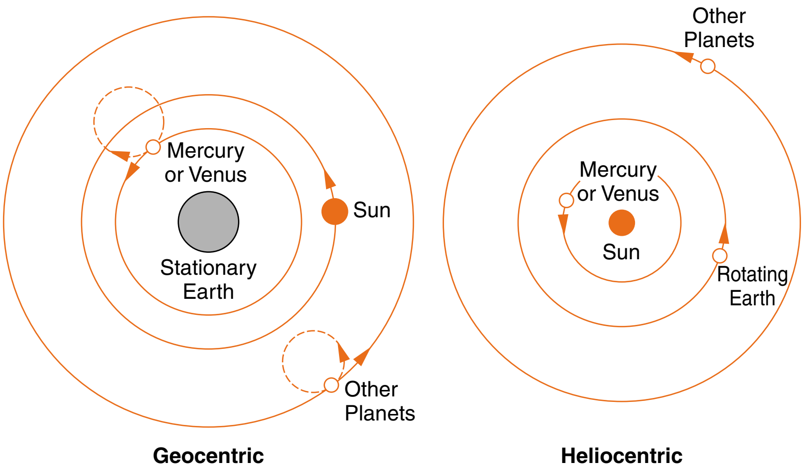


Figure 25-7 Early astronomers thought that the sun and planets orbited Earth. This is called the geocentric (Earth-centered) model. Arrows show the direction of motion in orbits. The complicated paths of the planets among the stars required astronomers to add circles to the orbits as shown by the dashed figures. A major reason that astronomers grew to prefer the heliocentric (sun-centered) model is that it is simpler.

in a complete circle every 24 hours (15° per hour) as Earth spins underneath it. At the equator, a Foucault pendulum does not seem to rotate at all because of its orientation with Earth's axis. It is important to remember that the Foucault

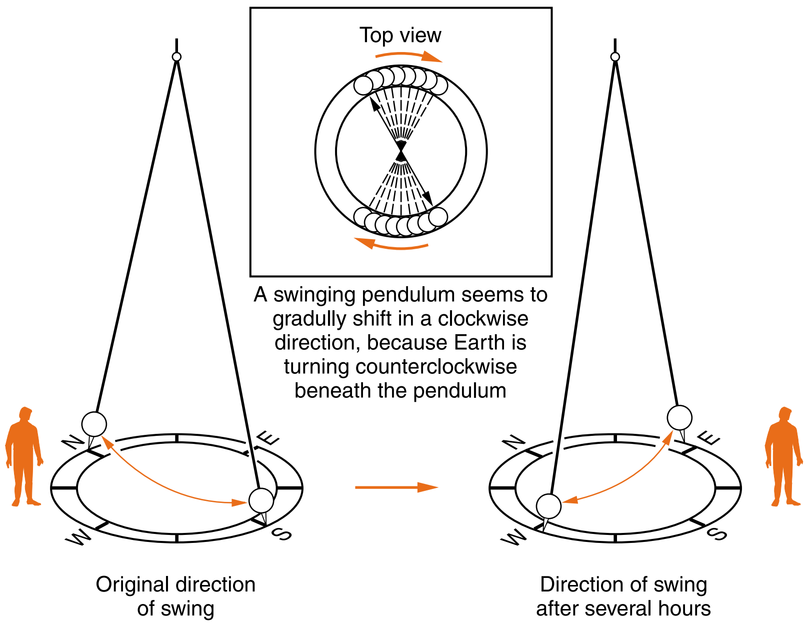


Figure 25-8 The apparent rotation of a Foucault pendulum is experimental proof that Earth rotates. One complete rotation takes 24 hours at the poles. However, the time per rotation increases if the pendulum is moved toward the equator.

pendulum swings in the same plane as the Earth rotates beneath it. A Foucault pendulum in New York State takes about 36 hours to complete one apparent rotation.

ACTIVITY 25-4 LOCATE A FOUCAULT PENDULUM

Some museums and other public places, such as the main lobby of the United Nations in New York City, have a Foucault pendulum. Locate the one nearest to where you live. If you are able to visit it, try to stay long enough to see a noticeable change in the direction of swing.

The Coriolis effect, a second proof of Earth's rotation, was discussed in Chapter 21. Due to the Coriolis effect, winds in the Northern Hemisphere curve to their right as they move out of a high-pressure system. Ocean currents in this hemisphere also curve to their right. The apparent curve to the right is actually a result of the winds and ocean currents trying to follow a straight path on a moving planet. Remember that this apparent curve is to the left in the Southern Hemisphere.

Earth's Motions as Viewed from Space

If you could view Earth from a stationary position in space beyond Earth's orbit, you might see the planet at one of the positions shown in Figure 25-9 on page 644. This diagram shows Earth's two most important motions: rotation and revolution. Note that this diagram is not drawn to a uniform scale. From outside Earth's orbit, the sun would appear as a tiny circle of light. Except in its closest position, Earth would appear as a tiny dot. In addition, at any given time Earth is at only one position in its orbit. Earth revolves around the sun in an annual cycle. With 365 days in a year and 360° in a circle, the planet revolves a little less than 1° in its orbit each day.

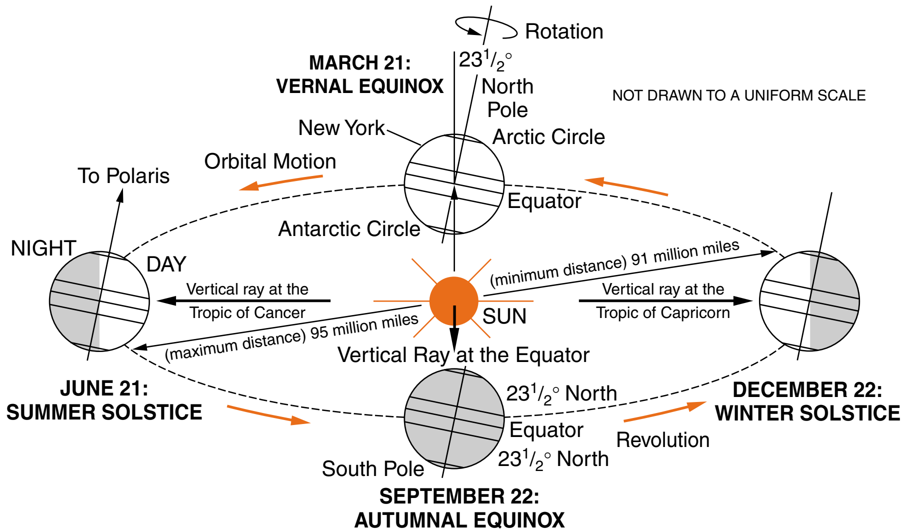


Figure 25-9 The seasons are the result of Earth's daily rotation on an axis that is tilted 23 1/2° and its annual revolution around the sun. Notice that Earth is slightly closer to the sun when it is winter in the Northern Hemisphere. The seasons labeled on this diagram apply only to the Northern Hemisphere.

Earth's Motions and the Seasons

The seasons are caused by a combination of two Earth motions. In addition to its revolution, Earth rotates on an axis that is tilted approximately 23.5° from a direction perpendicular to the plane of its orbit. The direction of Earth's axis is constant throughout the year. Polaris appears very close to the location in space directly above the North Pole. However, for half of the year, our spring and summer, the Northern Hemisphere is tilted toward the sun. For the other half of the year, our autumn and winter, the Northern Hemisphere is tilted away from the sun.

The latitude at which the vertical ray of sunlight strikes Earth determines the beginning of each season. The **vertical ray** is sunlight that strikes Earth's surface at an angle of 90°. It is sometimes called the direct ray of sunlight. This ray strikes Earth at a position where the sun is directly overhead, that is at the zenith. This ray of sunlight always hits Earth within the tropics. However, its position changes in an annual cycle

Spring The spring, or vernal, equinox, shown by the top Earth position in Figure 25-9, occurs near the end of March. At that time, the vertical ray is at the equator, and spring begins in the Northern Hemisphere (autumn in the Southern Hemisphere). Earth's axis is pointed neither toward nor away from the sun, and most of the planet receives 12 hours of daylight. The exceptions are the North and South Poles, where the sun circles very near the horizon, resulting in twilight for 24 hours.

Summer Over the next 3 months, Earth moves toward the June solstice, the beginning of summer in the Northern Hemisphere. At this time, the North Pole is tilted toward the sun and the vertical ray reaches its greatest latitude (23.5°N) north of the Equator, the **Tropic of Cancer**. In the Northern Hemisphere, this is when the noon sun is highest in the sky, the sun's path through the sky is longest, and daylight is longest.

It is just after this time that Earth reaches its greatest distance from the sun. However, the change in the Earth-sun distance is very small. In fact, it is too small to affect the seasons. If Earth's distance from the sun caused the seasons, you would observe two major differences from the present seasons. First, summer and winter would be reversed. Our warmest weather would be in January. Second, summer in the Northern Hemisphere would be summer in the Southern Hemisphere instead of the present 6-month difference.

Autumn and Winter Over the next 3 months as Earth moves to its September position, the vertical ray moves back to the Equator. This is the autumnal equinox. Our winter begins after another 3 months, near the end of December, when the North Pole is tilted away from the sun. At this time, the vertical ray reaches its most southerly latitude (23.5°S), the **Tropic of Capricorn**.

Two other latitude positions are important. The **Arctic Circle** (66.5°N) is the latitude north of which the sun does not rise on our December solstice. North of this latitude, the sun is in the sky for 24 hours at the June solstice. The **Antarctic Circle** (66.5°S) is the corresponding latitude in the Southern Hemisphere. On the December solstice (summer solstice in

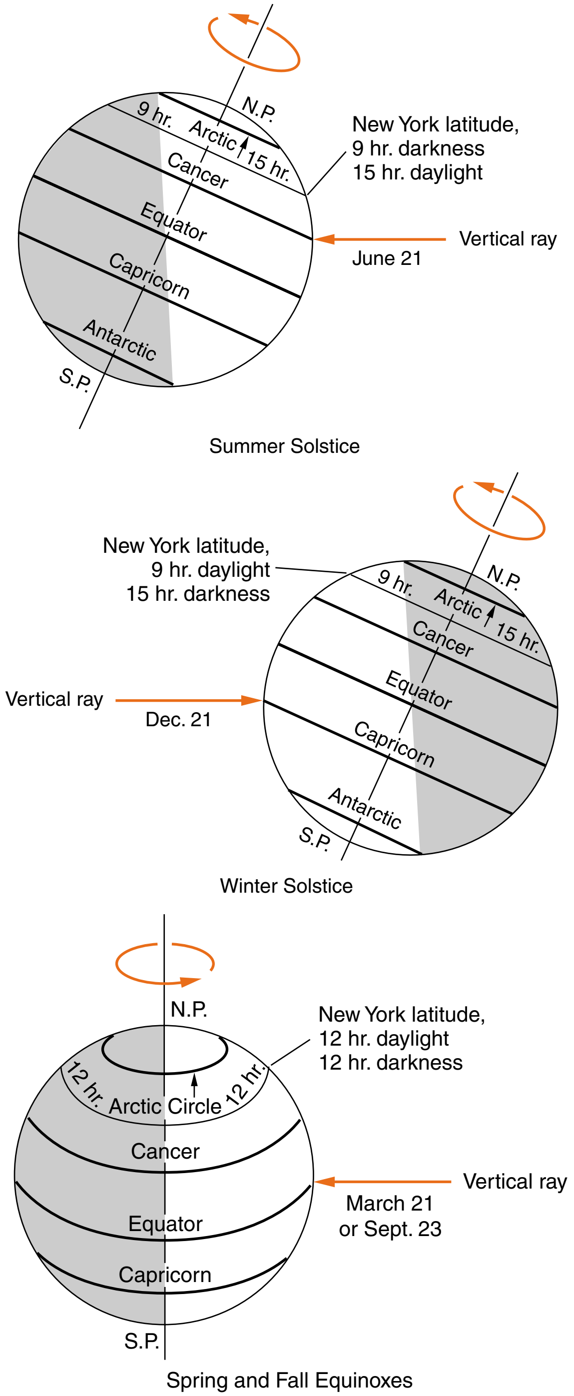


Figure 25-10 Notice how the position of the vertical ray and the daily hours of sunlight change with the seasons.

the Southern Hemisphere), the sun is in the sky for 24 hours. On the June solstice (winter solstice in the Southern Hemisphere), the sun does not rise. Figure 25-9 on page 644 should help you understand the seasonal changes in the path of the sun through the sky and why the seasons are reversed north and south of the equator.

Figure 25-10 shows Earth at the solstice and equinox positions. Notice how the latitude at which the vertical ray of sunlight strikes Earth changes as does the length of daylight in New York State.

ACTIVITY 25-5 MODELING EARTH MOTIONS

Position a single bright light, representing the sun, at the center of a darkened classroom. With a globe, illustrate Earth's motions of rotation on its axis tilted 23.5° and revolution around the sun. Notice how the height of the sun in New York State and the length of daylight change as Earth orbits the sun. In what ways is this model unlike the real Earth and sun?

If Earth's axis were perpendicular to the plane of its orbit, there would be no seasons. In places like New York State, there would be no annual cycle of temperature and changes in the sun's path. On the other hand, if Earth's axis were tilted more than 23.5°, New York State would experience greater changes in temperature from winter to summer. More extremes in the path of the sun in its annual cycle would also be observed. The sun's path would be longer and higher in summer, but lower and shorter in winter.

HOW DO EARTH'S MOTIONS AFFECT THE APPEARANCE OF OTHER CELESTIAL OBJECTS?

The night sky was familiar to our ancestors who had no electric lights, television, or computers. Although the stars are randomly distributed throughout the sky, ancient people imagined patterns in the stars.

Constellations

Certain patterns of stars are designated as constellations. Orion the hunter is a constellation prominent in New York's winter sky. Near Orion is a group of stars that represent his dog Sirius and Lepus the rabbit. Others patterns represent objects such as Lyra the harp.

Constellations were often associated with traditions and legends that became a part of the cultural heritage. The constellation called Cassiopeia was named for an Ethiopian queen who proclaimed that she was more beautiful than other women were. Two bright stars Castor and Pollux dominate the constellation Gemini. In mythology, Castor and Pollux were twins.

Different cultures imagined different things about the same group of stars. For example, the group of stars we call The Big Dipper is known as The Plow in Britain. To the ancient Greeks, this was a part of the Great Bear, which we call by its Latin name, Ursa Major. Figure 25-11 shows this constellation with a drawing of a bear superimposed on the star pattern. For many constellations, it takes a good deal of imagination to see in the pattern of stars the objects they represent.

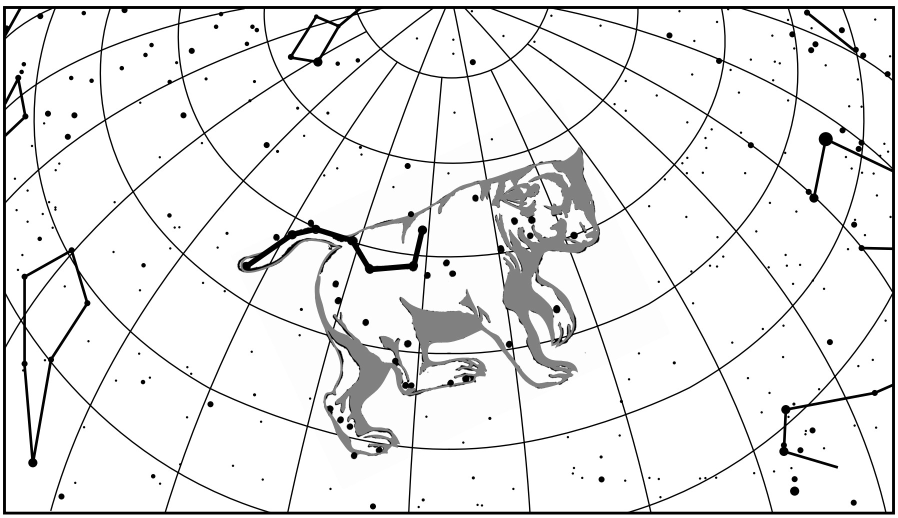


Figure 25-11 The group of stars called The Big Dipper is a part of the constellation Ursa Major (The Great Bear). For observers in New York State, this group of stars is always visible in the northern sky.

ACTIVITY 25-6 THE BIG DIPPER AND POLARIS

On a clear night, find the group of stars called the Big Dipper. Follow the pointer stars to Polaris. Sketch the Big Dipper and Polaris showing their orientation with respect to the Northern Horizon. You may wish to repeat this activity several hours later or in a few months at the same hour to see if their orientation changes.

ACTIVITY 25-7 ADOPT A CONSTELLATION

Find a list of the major constellations in an astronomy book or another source. Select one constellation for which you will do the following:

1. Draw your constellation in white or other light-colored ink on a sheet of black paper.
2. Write a brief summary of the mythology traditionally associated with your constellation and draw the appropriate person or object on the star pattern of your constellation.
3. Tell when and where your constellation can be observed in the sky.

Star Maps

Modern astronomers use the constellations to designate 88 regions of the night sky. This is a convenient way to establish a map of the stars. The stars always occupy the same position with respect to other stars. When a star is part of particular constellation, that association helps observers locate the star in the night sky. Figure 25-12 on page 650 is a map of the evening sky in the month of April.

To use the map, hold a copy of it upside down so that the compass directions printed on the map line up with the true compass directions. If you find the Big Dipper high in the sky, you can use it to locate other stars and constellations as shown by the arrows on the chart. The two stars at the end

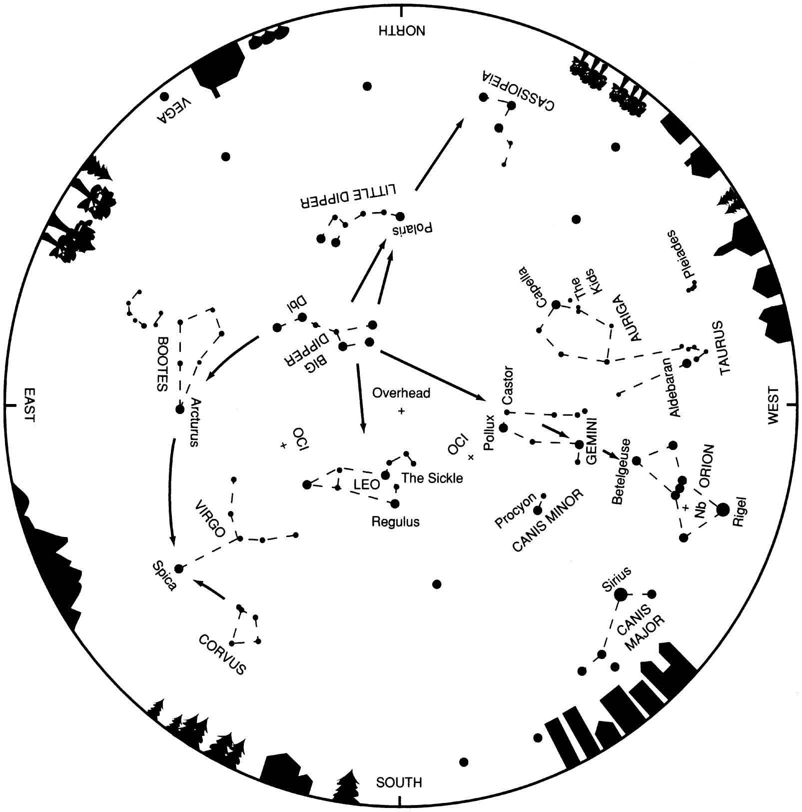


Figure 25-12 This star map shows constellations visible at about 40° North latitude at about 10 P.M. in March and about 8 P.M. to 9 P.M. in April.

of the bowl of the Big Dipper point to Polaris. Binoculars or a small telescope will help you observe objects labeled OCl (open clusters), Dbl (double stars), and Nb (nebulae). The planets wander among the stars, so they are not shown on this chart. Current information from a newspaper or the Internet can help you locate the visible planets.

ACTIVITY 25-8 LOCATING MAJOR CONSTELLATIONS

Use a copy of Figure 25-12 or a similar star map to locate constellations in the night sky. Try to observe on a clear night from a location that is far from artificial lights. The sky should not be obstructed by nearby buildings or trees. Make a list of the constellations you are able to find. Number them according to how easy they were for you to locate in the night sky.

WHY DO THE STARS SEEM TO CHANGE THEIR POSITIONS?

We do not usually see stars shift their positions relative to each other. For that, they are sometimes called the fixed field of stars. However, the cycles of daily rotation and yearly revolution of Earth influence our observations of stars .

Daily Apparent Motions

Earth's rotation makes stars appear to move through the sky just as the sun appears to move. In New York State, most stars rise in the east, travel to the right across the southern sky, and set in the west. Like the sun, their path depends on where they rise. Stars that rise in the northeast travel high in the sky and set in the northwest. Those that rise in the southeast move lower in the sky to set in the southwest.

A different kind of motion can be observed in the northern part of the sky, where the sun is never found. In earlier chapters, you read about Polaris, the North Star. Polaris is not one of the brightest stars, but it appears to be located almost directly above Earth's North Pole near a point in the sky called the celestial north pole. Consequently, Polaris is the only star that does not seem to move. Actually, Polaris is not exactly above the North Pole; therefore, it does make a very small counterclockwise circle in 24 hours.

Other stars that are not as close to the celestial pole make larger circles, all at a rate of 15° per hour, Earth's rate of rotation. Figure 25-13 on page 652 shows the apparent motion of stars in the night sky. The planets and comets also show this apparent motion, although they slowly shift their positions among the stars from night to night.

Figure 25-14 on page 652 illustrates the trails of stars that would be observed in each of the four compass directions by an observer in New York State. These diagrams show the stars rising in the east, moving through the southern sky and setting in the west. Only stars in the northern sky do not seem to rise and set; they appear to circle counterclockwise around Polaris.

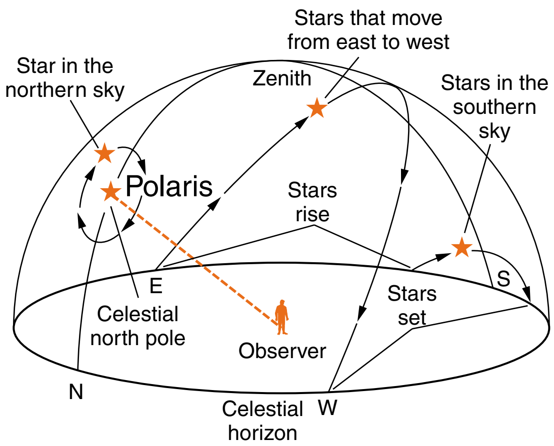


Figure 25-13 Due to Earth's rotation, the stars appear to rotate counterclockwise around Polaris, including those that rise in the east and set in the west. In fact, all star paths can be thought of as circles around the north and south celestial poles.

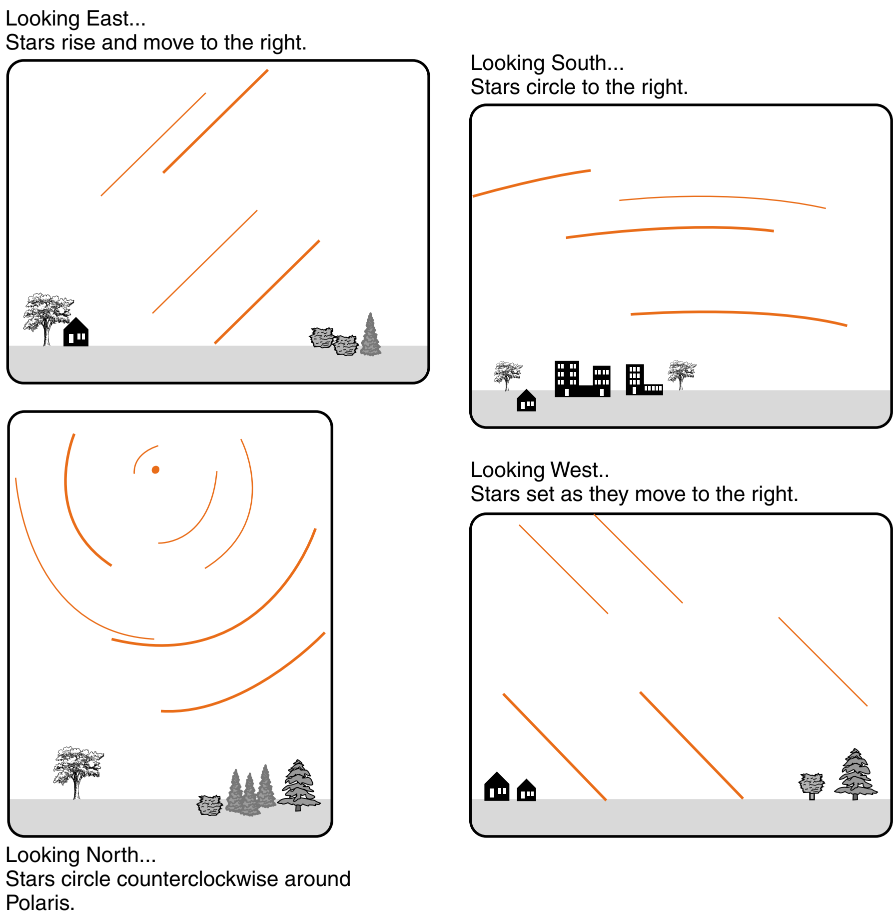


Figure 25-14 These drawings represent time exposure photographs of the night sky. True photographs would show light star trails moving through a dark sky.

ACTIVITY 25-9 PHOTOGRAPHING STAR TRAILS

You can use an adjustable camera that allows you to take very long exposures to take photographs of star trails. The camera must be mounted on a tripod or other object(s) to hold it steady while the shutter is open. A clear, dark sky away from artificial lights is essential. Exposures 15–30 seconds in length show star patterns in constellations. Exposures of 5 minutes to an hour will yield patterns like those in Figure 25-14. For best results, try a few star photographs and have them developed. After viewing your photographs, you can plan changes to improve your pictures in later attempts. If color photography is used, these trails may be of different colors, indicating the surface temperature of the stars.

Yearly Apparent Motions

In addition to the apparent daily cycle of motion of stars through the sky, the stars in the evening sky also change in a yearly cycle. In the summer, Scorpio, the scorpion, with its red star, Antares, is prominent in the southern sky. At this time, the stars of Scorpio are located on the opposite side of Earth from the sun. This is why they are visible in the night sky at that time of year.

By winter, 6 months later, Earth has revolved half way around its orbit. Orion, the hunter, is now visible in the southern sky in the evening. Scorpio is still in the sky, but it is now located in the direction of the sun. During the day, the sky is too bright for most stars to be visible. Figure 25-15 on page 654 shows Earth's orbit and some of the brighter constellations visible in the evening at different times of the year. Because Earth moves about 1° in its orbit each day, changes in the evening sky are not noticeable from night to night. However, over a period of months this change is obvious.

Not all the constellations are seasonal. Stars and constellations in the northern sky, such as Polaris in Ursa Minor (the Little Bear), Ursa Major (including the Big Dipper), and Cassiopeia, are visible throughout the year. However, the

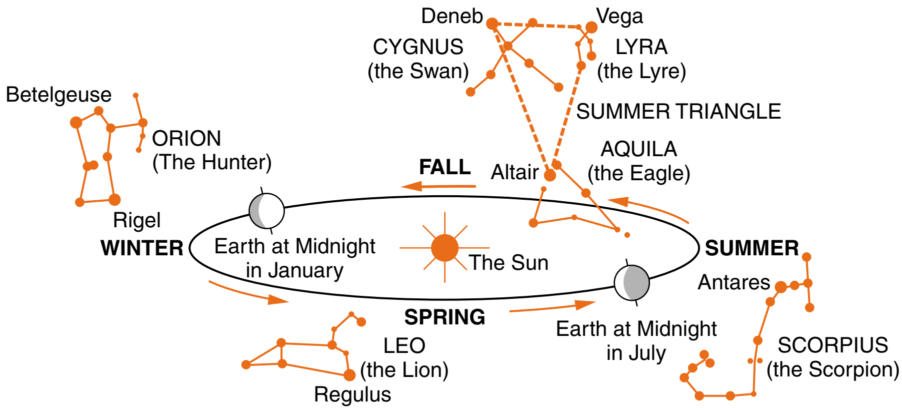


Figure 25-15 As Earth revolves around the sun, the night side of Earth faces different directions in space. Only constellations opposite the sun are visible because the light of the sun hides stars during the day.

polar constellations that are below Polaris at one time of year are high in the sky, above Polaris, 6 months later.

ACTIVITY 25-10 CELESTIAL OBSERVATIONS

This chapter has introduced a number of changes that you can observe and/or measure quite easily. For example, you can measure the rate at which the sun moves through the sky or the apparent motions of stars.

The topics in this chapter relate to a number of long-range projects that are not difficult to perform. You might use a digital camera to a photograph the horizon, recording changes in the position of sunset or sunrise over a period of weeks. The changing angular altitude of the noon sun can also be documented. Changes in the moon and the stars can also be observed and documented.

TERMS TO KNOW

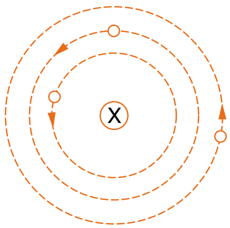
altitude	**equinox**	**solar noon**	**vertical ray**
Antarctic Circle	**revolution**	**solar time**	**winter solstice**
Arctic Circle	**rotation**	**summer solstice**	**zenith**
celestial object			

CHAPTER REVIEW QUESTIONS

1. In which direction on the horizon does the sun appear to rise on July 4 in New York State?

(1) due north
(2) due south
(3) north of due east
(4) south of due east

2. The diagram below represents a simple geocentric model. Which object does letter X represent?



(Not drawn to scale)

(1) Earth
(2) the sun
(3) the moon
(4) Polaris

3. Which observation provides the best evidence that Earth rotates?

(1) The position of the sun changes during the year.
(2) The location of the constellations in relationship to Polaris changes from month to month.
(3) The length of the shadow cast by a flagpole at noon changes from season to season.
(4) The direction of swing of a freely swinging pendulum changes during the day.

4. The apparent rising and setting of the sun, as viewed from Earth, is caused by

(1) Earth's rotation.
(2) Earth's revolution.
(3) the sun's rotation.
(4) the sun's revolution.

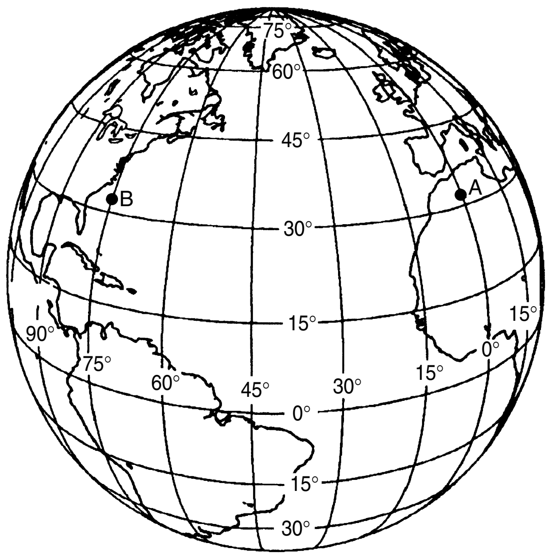
5. The length of an Earth day is determined by the time required for approximately one

(1) Earth rotation.
(2) Earth revolution.
(3) sun rotation.
(4) sun revolution.

6. The length of Earth's year is based on Earth's

(1) rotation of 15°/h.
(2) revolution of 15°/h.
(3) rotation of approximately 1°/day.
(4) revolution of approximately 1°/day.

7. The diagram below shows the latitude-longitude grid on an Earth model. Points A and B are locations on the surface.



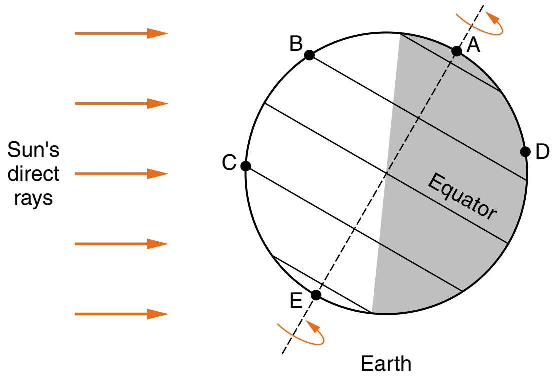
On Earth, the solar time difference between point A and point B would be

(1) 1 hour.
(2) 5 hours.
(3) 12 hours.
(4) 24 hours.

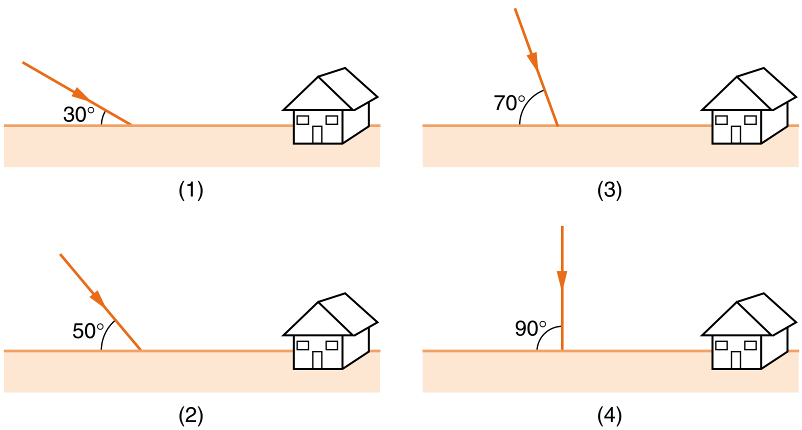
8. Summer days in New York State are likely to be hotter than winter days because in summer

(1) Earth is closer to the sun.
(2) the number of sunspots increases.
(3) Earth's northern axis is tilted toward the sun.
(4) the sun gives off more energy.

Base your answers to the questions 9–11 on the diagram below, which shows the tilt of Earth's axis and the pattern of day and night on a particular day of the year. Positions A through E are along Earth's surface. Point D is located in New York State.



9. Which diagram best represents the angle of the sun's rays at location C at noon on this day?



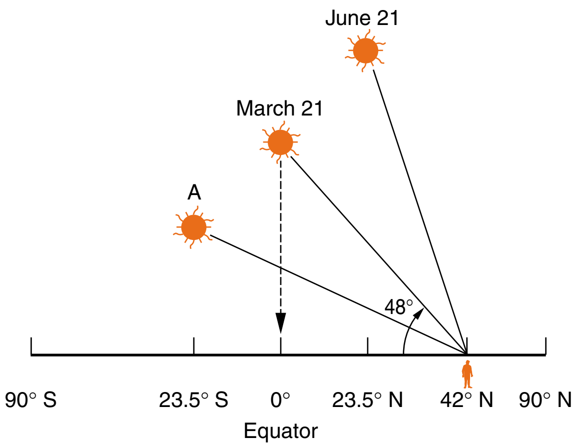
10. On this day, which location had the greatest number or hours of daylight?

(1) B
(2) C
(3) D
(4) E

11. What date is illustrated on the diagram of Earth above?

(1) March 21
(2) June 21
(3) September 22
(4) December 22

Base your answers to questions 12 and 13 on the diagram below, which represents the position of the sun with respect to Earth's surface on certain dates. The latitude of six locations on the same line of longitude is shown.



12. When the sun is at position A, which latitude receives the most direct rays of sunlight?

(1) Tropic of Cancer (23.5°N)
(2) Equator (0°)
(3) Tropic of Capricorn (23.5°S)
(4) Antarctic Circle (66.5°S)

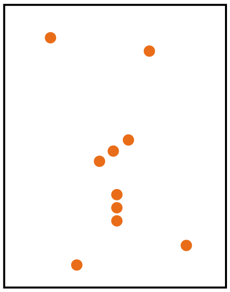
13. When the sun is at the March 21 position, New York State will usually have

(1) longer days than nights.
(2) 12 hours of daylight and 12 hours when the sun is below the horizon.
(3) the lowest altitude of the sun at solar noon for the whole year.
(4) the highest altitude of the sun at solar noon for the whole year.

14. As observed in New York State, in which part of the sky do the stars seem to move in small circles?

(1) north
(2) east
(3) south
(4) west

15. The diagram below represents the major stars of the constellation Orion, as viewed by an observer in New York State.



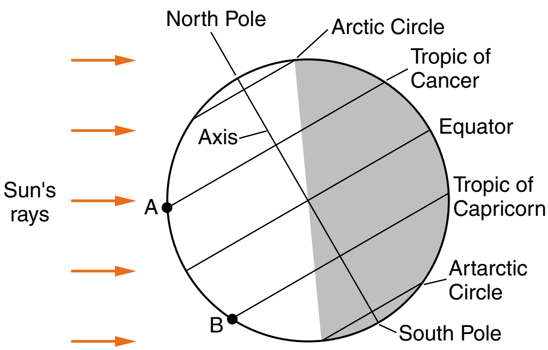
Which statement best explains why Orion can be observed from New York State on December 21, but not on June 21?

(1) Orion has an eccentric orbit around Earth.
(2) Orion has an eccentric orbit around the sun.
(3) Earth revolves around the sun
(4) Earth rotates on its axis.

Open-Ended Questions

16. State two factors that combine to cause Earth's seasons.

Base your answers to questions 17–19 on the diagram below that represents Earth at a specific position in its orbit as viewed from space. The shaded area represents nighttime.

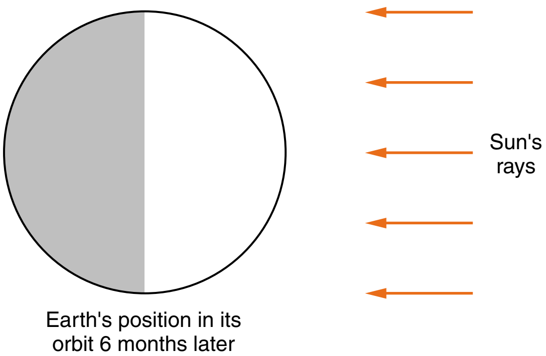


17. *a*. State the month represented by the diagram.

b. Name the area that receives the most intense radiation from the sun when Earth is at this position in its orbit.

18. Describe the length of daylight at point A compared with the length of daylight at point B on the day represented by the diagram.

19. The diagram below represents the position of Earth in its orbit *6 months later*. Make a copy of this diagram. (Please do not write in this book.)



a. Draw the position of Earth's axis and label the axis.
b. Label the North Pole.
c. Draw the position of Earth's equator and label the equator.

20. What would happen to the average summer and winter temperature in New York State if the tilt of Earth's axis were to decrease from 23.5° to 20°?