7.3 Movements of Earth and the Moon

Key Terms
tides
ellipse
phases of the Moon
eclipse
lunar eclipse
solar eclipse
gravitational force

An understanding of Earth and its movements is important. Understanding Earth's rhythms is critical to understanding the life cycles of all living things on Earth. The seasons are a result of Earth's revolution around the Sun, combined with Earth's tilt. The study of our closest neighbour in space, the Moon, is also important. The Moon is responsible for the tides that occur on Earth. The **tides** are the rising and falling of ocean waters. The orbit of the Moon around Earth results in the phases of the Moon, as well as eclipses.

Earth's Motion

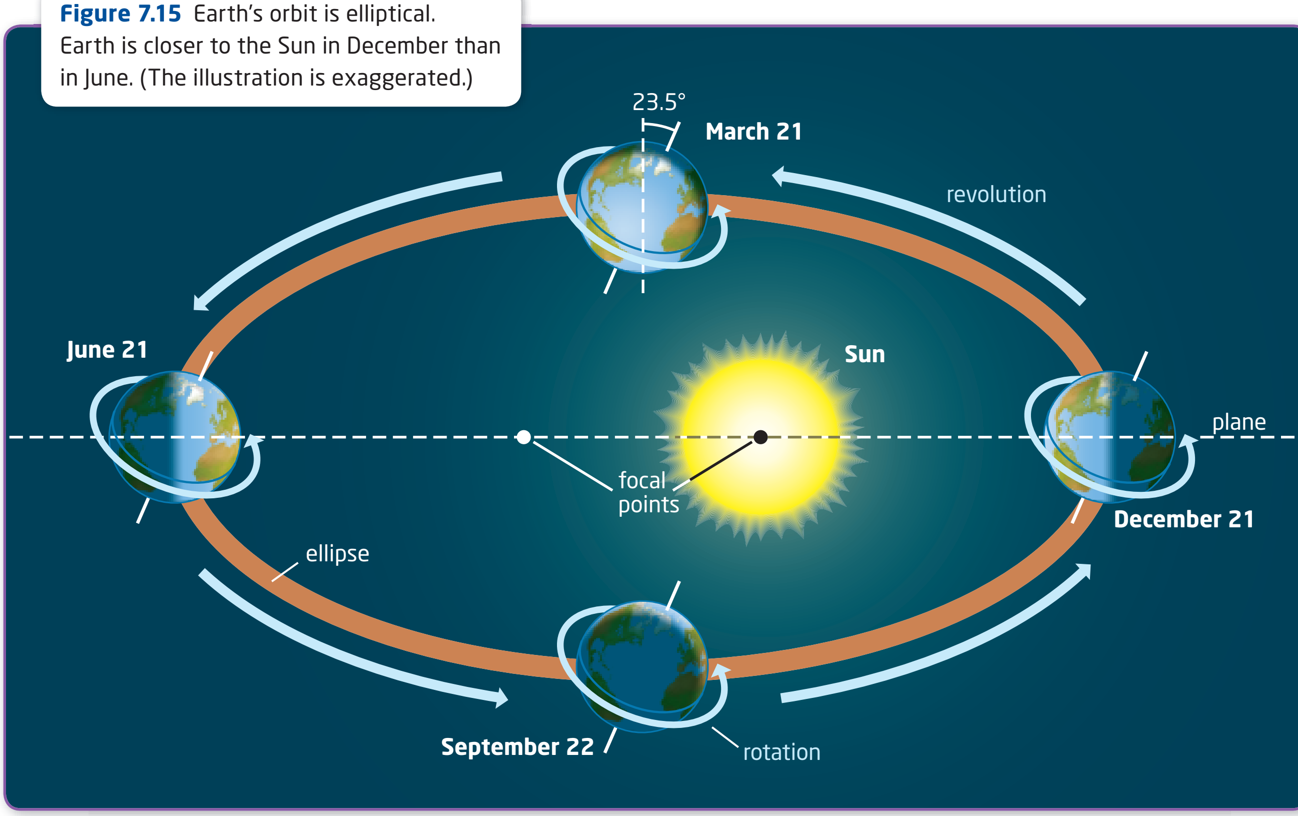
As you learned earlier, Earth undergoes two different types of motion through space: rotation and revolution. As a result of Earth's rotation, everything in the night sky appears to rise in an easterly direction and set in a westerly direction. As a result of Earth's revolution around the Sun, you see different constellations at different times of the year.

The path of Earth's orbit around the Sun is not a perfect circle. It is an ellipse. An **ellipse** is a curve that looks like a stretched circle. A circle has one centre point and a radius, both of which define the size and shape of the circle. An ellipse has two points called focal points, which define the shape of the ellipse. The Sun is at one focal point of Earth's elliptical orbit, as shown in **Figure 7.15**. So, at one point in Earth's elliptical orbit, Earth is closest to the Sun. At another point, Earth is farthest from the Sun.

tides the rising and falling of ocean waters as a result of the Moon's gravity and Earth's gravity

ellipse a curve that is generally referred to as an oval or the shape of an egg

Figure 7.15 Earth's orbit is elliptical. Earth is closer to the Sun in December than in June. (The illustration is exaggerated.)



Why Do We Experience Seasons?

Earth does not rotate in an upright position. Rather, its axis is tilted 23.5° from the flat plane of Earth's orbit. The tilt does not change. In the summer months, the northern hemisphere is tilted toward the Sun. In the winter months, the northern hemisphere is tilted away from the Sun. The opposite happens in the southern hemisphere. Some people believe that the seasons are a result of Earth's distance from the Sun.

As a result of Earth's tilt, sunlight strikes Earth's surface at different angles. Areas that receive sunlight at larger angles receive more sunlight for longer periods of time. Look at **Figure 7.16A**, which shows the northern hemisphere in June. The solar energy reaches Earth's surface at a large angle and for longer periods of time than the solar energy that reaches the southern hemisphere. **Figure 7.16B** models the energy coverage with a flashlight. **Figure 7.16C** shows the approximate height of the Sun in Ontario around the start of each season.

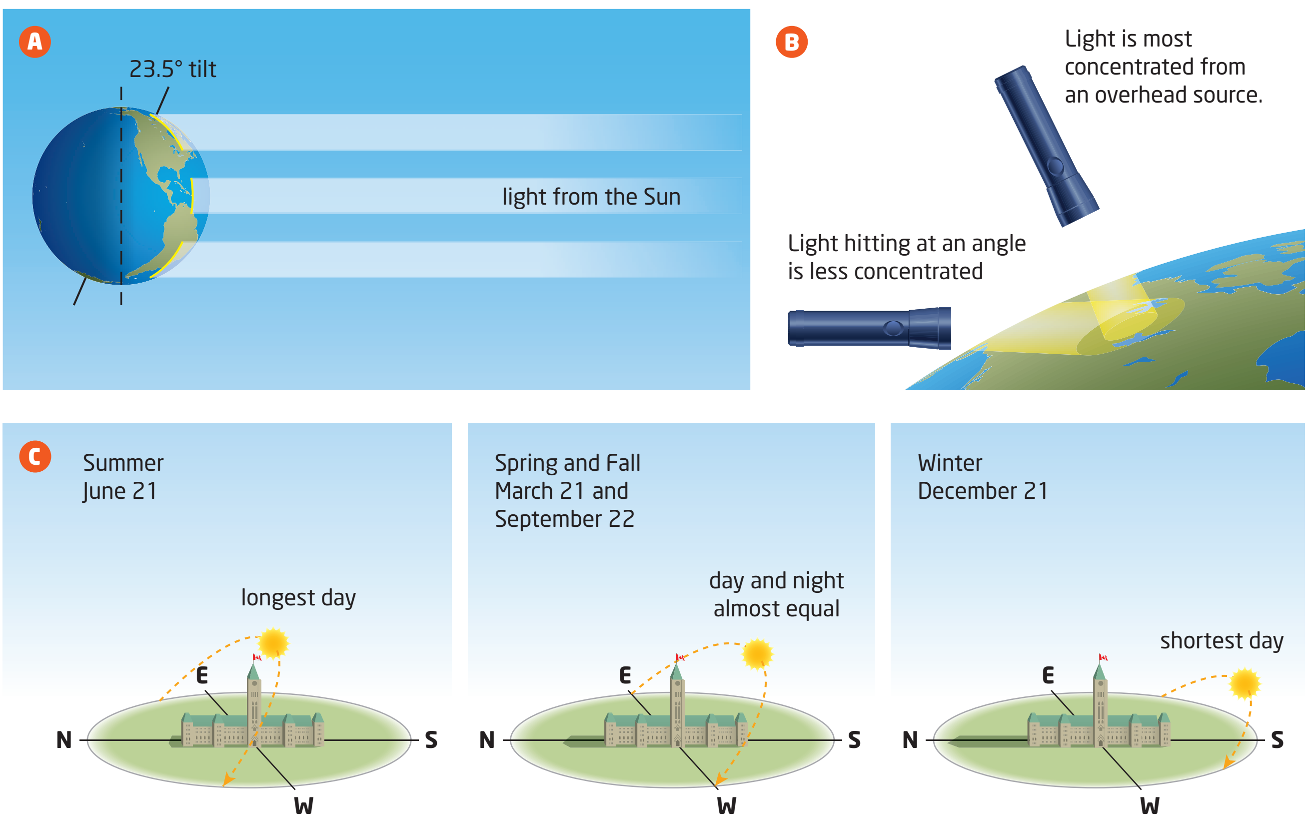


Figure 7.16 **A** During the summer in the northern hemisphere, when Earth is tilted toward the Sun, the northern hemisphere receives solar radiation at a higher angle for longer periods of time. **B** A flashlight models the Sun's energy coverage. **C** The Sun is higher in the sky for a longer period of time in the summer in the northern hemisphere.

Activity 7-2

Angle of Sunlight

In the winter in the northern hemisphere, the Sun delivers less heat to a flat patch of Earth's surface, so the temperatures are lower. How can a flashlight and a piece of paper model the amount of energy reaching Earth's surface? In this activity, you will model the Sun's effect on a patch of Earth.

Materials

- flashlight with a wide beam
- sheet of graph paper
- ruler
- protractor
- notebook

Procedure

1. Make a data table like the one below.

Data Table

Angle of Flashlight from the Vertical	Area (number of squares)
90°	
75°	
60°	
45°	
30°	
15°	

2. Your teacher will turn off the lights in the classroom.
3. While your partner shines the flashlight directly onto a sheet of graph paper, estimate the area that the flashlight beam illuminates by counting the illuminated (lit) squares on the paper.
4. Repeat step 3, but change the angle. Tilt the flashlight 15° from the vertical. Use a ruler as a marker for the vertical. Use a protractor to measure the angle. Alternate roles with your partner, so both of you have turns holding the flashlight and counting the squares.
5. Repeat step 3 until you have tried angles between 90° and 15° in increments of 15°.
6. Use your data to plot a line graph of the illuminated area (*x*-axis) against the angle of the beam (*y*-axis).

Questions

1. What angle caused the light to be spread over the largest area?
2. Why do you need to place the flashlight at a constant distance from the graph paper?
3. Which factor affects Earth's seasons—distance from the Sun or angle of sunlight?
4. How does this model demonstrate the effect of latitude on energy from the Sun?

Learning Check

1. Why do the stars appear to rise in the east and set in the west?
2. What is an ellipse, and what significance does it have regarding Earth's orbit? Review **Figure 7.15**.
3. Why are latitudes just above and below the equator always hot?
4. Why do you think it is important to understand Earth's motion through space?

The Moon's Motion

During the night, the Moon appears to move across the sky with the stars and the planets, due to Earth's rotation. The Moon also appears to move from west to east as it moves in its orbit.

The Moon makes a complete orbit around Earth in about 29.5 days. As the Moon completes one orbit around Earth, the Moon rotates only once on its axis. As a result, you always see the same side of the Moon. You never see the other side. The other side of the Moon is nicknamed "the dark side of the Moon." However, the other side does receive sunlight for about two weeks, so a better term is "far side of the Moon." It was not until 1959 that humans got their first glimpse of the far side of the Moon. At that time, the Union of Soviet Socialist Republics (most of which is present-day Russia) launched a spacecraft that passed behind the Moon and photographed the far side of the Moon.

phases of the Moon the monthly progression of changes in the appearance of the Moon, which result from different portions of the Moon's sunlit side being visible from Earth

The Moon is always half-illuminated by the Sun. But how much of the illumination you see depends on where the Moon is relative to Earth. The amount of illumination you see is classified as the **phases of the Moon**. **Figure 7.17** shows the main phases of the Moon: new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, and third quarter. *Waxing* means increasing, *waning* means decreasing, and *gibbous* means that the amount of light we see illuminating the Moon is between half-lit and fully lit.

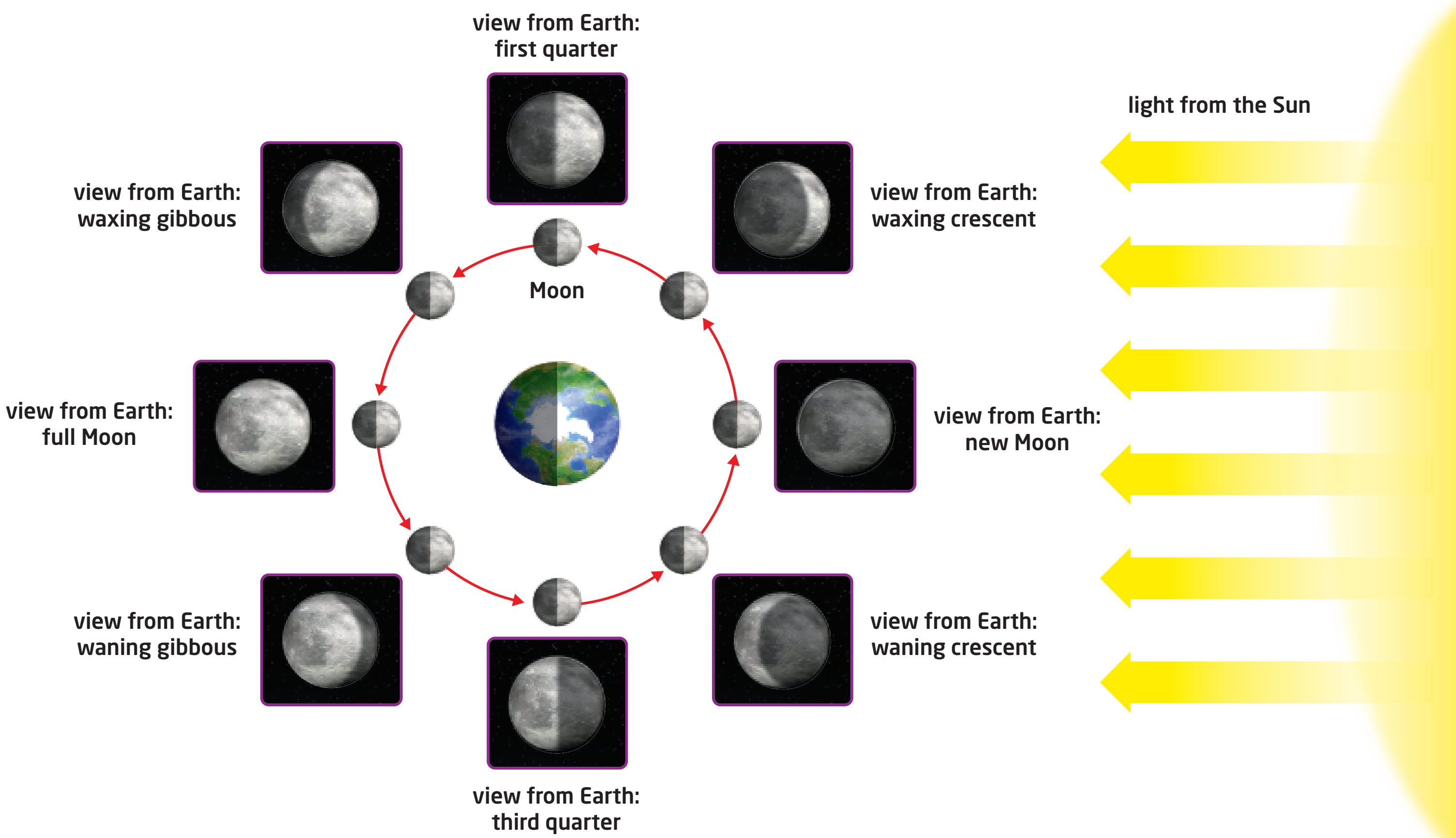


Figure 7.17 The relative positions of Earth and the Moon provide the phases of the Moon. (This diagram is not drawn to scale.)

Eclipses

When one celestial object passes directly in front of another celestial object, as seen from Earth, there is an **eclipse**. There are two main types of eclipses that you can see from Earth: lunar eclipses and solar eclipses.

eclipse the phenomenon in which one celestial object moves directly in front of another celestial object

lunar eclipse the phenomenon in which the full Moon passes into Earth's shadow

Lunar Eclipses

Earth's shadow is divided into two parts: the umbra and the penumbra. As shown in **Figure 7.18**, the umbra is the inner shadow, and the penumbra is the outer shadow. During a total **lunar eclipse**, the full Moon passes through the umbra portion of Earth's shadow, so Earth is between the Sun and the Moon. On average, there are two lunar eclipses every year. If a lunar eclipse is occurring, you can watch it from anywhere on Earth where you can see the Moon. A lunar eclipse is perfectly safe to watch.

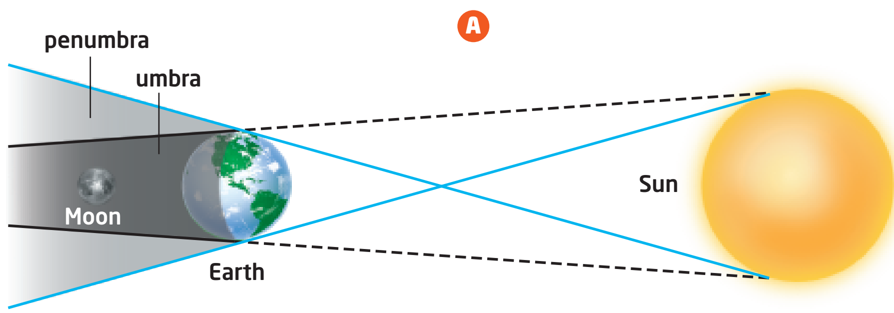


Figure 7.18 **A** If the Moon passes through Earth's umbra, a total lunar eclipse occurs. If the Moon passes through only the penumbra or part of the umbra, a partial lunar eclipse occurs. **B** During a total lunar eclipse, the Moon sometimes looks reddish.

As you have learned, the Moon orbits Earth once a month. So, why is there not a lunar eclipse every full Moon? The answer is that the orbit of the Moon is tilted, or inclined, approximately 5° to Earth's orbit about the Sun, as shown in **Figure 7.19**. The full Moon usually passes above or below Earth's shadow.

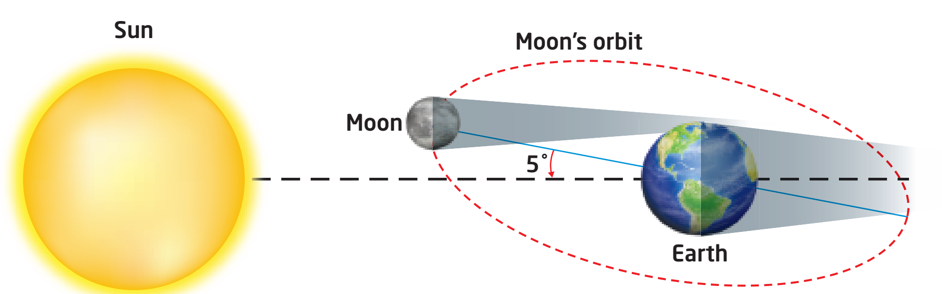


Figure 7.19 The Moon's orbit is tilted approximately 5° to Earth's orbit. Note that the angle is exaggerated in this diagram to help you see the tilt of the Moon's orbit relative to Earth and the Sun. Also, the sizes of the Sun, the Moon, and Earth are not drawn to scale.

Solar Eclipses

solar eclipse the phenomenon in which the shadow of the Moon falls on Earth's surface

A **solar eclipse** occurs whenever the shadow of the Moon falls on Earth's surface. During a solar eclipse, the Moon is between the Sun and Earth. This can only happen during a new Moon. **Figure 7.20** shows the positions of the Sun, the Moon, and Earth during a solar eclipse. Like lunar eclipses, solar eclipses occur, on average, twice a year. But unlike lunar eclipses, the shadow of the Moon on Earth is quite small. To see a solar eclipse, you have to be in a very specific, and often very remote, place on Earth's surface. For this reason, solar eclipses seem to be quite rare.

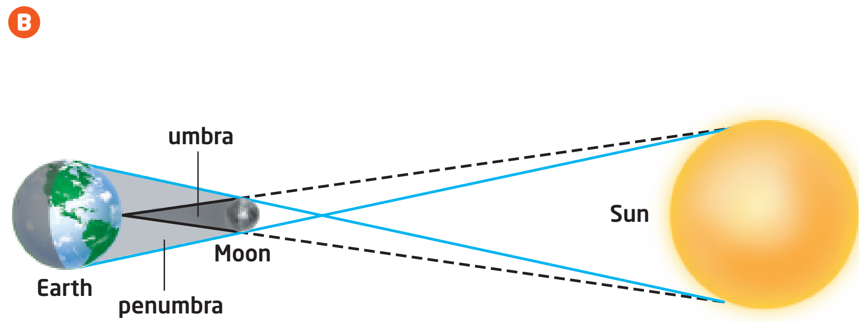


Figure 7.20 **A** This total solar eclipse happened on March 29, 2006. **B** If you are in a location where the umbra touches Earth's surface, you will see a total solar eclipse. If you are in a location where the penumbra touches Earth's surface, you will see a partial solar eclipse. (This diagram is not drawn to scale.)

The diameter of the Sun is about 400 times larger than the diameter of the Moon. But during a total solar eclipse, the Moon can cover the Sun completely. The reason this is possible is that the Sun is about 400 times farther from Earth than the Moon is. As a result, the Sun and the Moon appear to be about the same size in the sky.

It is never safe to look at the Sun with the unaided eye. The radiation from the Sun can burn your retina and blind you. (You will learn more about the Sun in Chapter 8.) During a solar eclipse, as the Moon starts to cover the Sun, the Sun is still visible and still dangerous. It is not safe to watch a solar eclipse when any portion of the Sun is still visible. Experienced astronomers project the image of the Sun onto a light-coloured surface. Some use binoculars to focus the image of the Sun onto a sidewalk or a sheet of paper.

Suggested Investigation

Inquiry Investigation 7-A, Modelling the Moon's Movement, on page 307

Learning Check

5. Define the terms *umbra* and *penumbra*. Explain how they relate to solar eclipses or lunar eclipses.
6. Why does a lunar eclipse only happen when the Moon is full?
7. In your notebook, make a simple diagram that shows how a total solar eclipse happens. Review **Figure 7.20** if necessary.
8. Why do you always see the same side of the Moon?

Tides

The Moon's motion is also responsible for tides. Tides in the open ocean are about half a metre to a metre high. Tides along coastal areas, however, can vary greatly. The Bay of Fundy, which lies between New Brunswick and Nova Scotia, is a good example of this. Tides in the Bay of Fundy can reach 16 m. **Figure 7.21** shows high and low tide at a location in the Bay of Fundy. The Bay of Fundy is one of only a few places in the world with a range in tide heights that is great enough to harness tidal energy.

Sense of scale

Approximately 4.4 billion years ago, the Moon was much closer to Earth. Ocean tides would have been hundreds of metres high at that time, instead of the current one half to one metre.

What Causes Tides?

Tides are caused by the force of gravity. The amount of the force of gravity, or **gravitational force**, between two objects depends on the masses of the objects and the distance between them. The larger the masses, the greater the gravitational force is. But the farther the objects are from each other, the less the gravitational force is. The Moon is held in orbit around Earth by gravity. The Moon's gravity pulls on Earth, and Earth's gravity pulls on the Moon, resulting in tides.

gravitational force the force of attraction between all masses in the universe

Note that it is not the direct pull of the Moon's gravity that causes the tides. Rather, it is the *difference* between the force of gravity on the side of Earth nearest the Moon and the force of gravity on the side of Earth *farthest* from the Moon. The result is a stretching effect on Earth. This stretching effect is called a *tidal force*. See **Figure 7.22**.

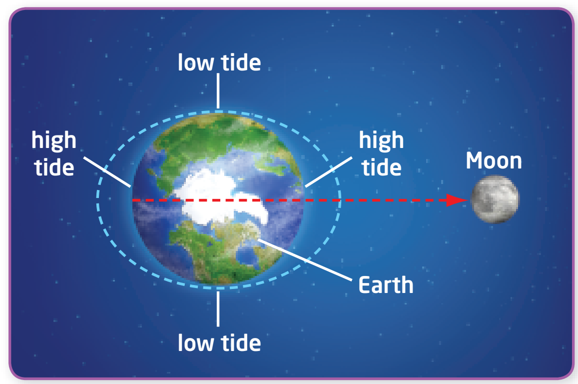


Figure 7.22 The Moon's gravitational pull on the side of Earth nearest the Moon is stronger than on the side of Earth farthest from the Moon.

To understand how this effect results, imagine three people holding hands and running as fast as they can to catch a bus. If the person in the middle is between the slowest person and the fastest person, he or she will experience a very large stretching force. How does this analogy relate to the tides? The side of Earth that is closest to the Moon experiences the largest gravitational pull. The centre of Earth feels less gravitational pull because it is farther from the Moon. The side of Earth farthest from the Moon experiences the least gravitational pull.

Figure 7.21 High tide is shown in **A**, and low tide is shown in **B**.

Section 7.3 Review

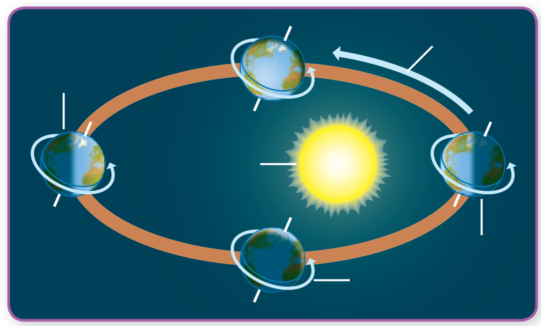
Section Summary

- The tilt of Earth's axis, combined with Earth's motion around the Sun, gives rise to the seasons.
- We see different phases of the Moon, depending on where the Moon is in relation to Earth.
- During a lunar eclipse, the Moon passes through Earth's shadow.
- During a solar eclipse, the Moon passes in front of the Sun.
- The tides are a result of the difference between the force of gravity on the side of Earth nearest the Moon and the force of gravity on the side of Earth farthest from the Moon.

Review Questions

K/U **1.** Create a Venn diagram to compare the terms *rotation* and *revolution*.

C **2.** Draw the illustration at the right. Add the following labels: Sun, rotation, revolution, December, June.



Earth's orbit around the Sun

K/U **3.** Earth is farthest from the Sun in its orbit in June, but the northern hemisphere is warmer in the summer than in the winter. Explain why.

C **4.** In a diagram, indicate at which Moon location Earth would experience the following.

a. a new Moon phase
b. a full Moon phase
c. a solar eclipse
d. a lunar eclipse

C **5.** Describe why tides occur. Include tidal force in your description, as well as a diagram.

A **6.** Why is it safe to watch an eclipse of the Moon but not an eclipse of the Sun?

K/U **7.** Why is there not a lunar eclipse every month?

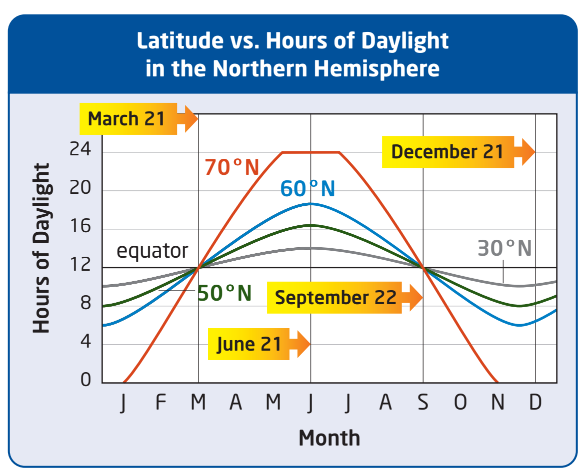
T/I **8.** The graph shows the hours of daylight for five different latitudes in the northern hemisphere:

a. For all latitudes, which date has the greatest number of hours of daylight?

b. On which two dates are day and night always equal in length for all latitudes?

c. For latitude 70°N, does the Sun set between June 1 and July 15? Explain your answer.

d. Based on the graph, infer the date on which there is the least amount of daylight for all latitudes in the southern hemisphere.



The latitudes 0° (equator), 30°N, 50°N, 60°N, and 70°N are shown.