INQUIRY APPLY IT!

Q: *Where is the world's largest tidal range?*

A: The world's largest tidal range is found in the northern end of Nova Scotia's 258-kilometer-long Bay of Fundy. During maximum spring tide conditions, the tidal range at the mouth of the bay is only about 2 meters. However, the tidal range progressively increases from the mouth of the bay inward because the natural geometry of the bay concentrates tidal energy. In the eastern end of the bay, the maximum spring tidal range is about 17 meters. This extreme tidal range leaves boats high and dry during low tide.

Tides

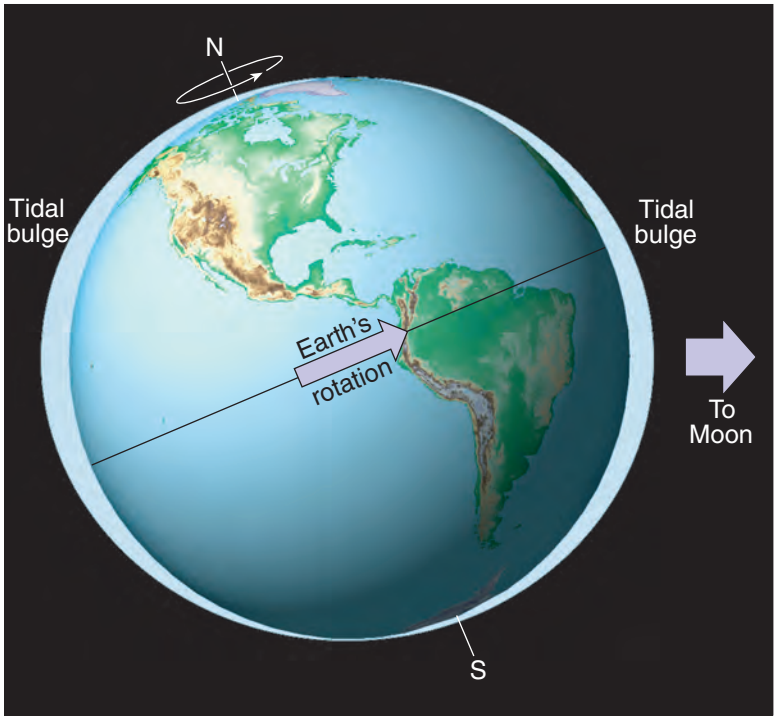
Tides are regular changes in the elevation of the ocean surface. Their rhythmic rise and fall along coastlines has been noted throughout history. But the cause of tides was not well understood until Sir Isaac Newton applied the law of universal gravitation to them. Newton showed that there is a mutually attractive force—gravity—between any two bodies, such as between Earth and the moon. The strength of gravity between two objects decreases as the distance between the objects increases. At any given time, different areas of Earth's surface are different distances from the moon. The pull of the moon's gravity is greater at parts of Earth's surface that are closer to the moon and less at parts that are farther from the moon.

The Cause of Tides

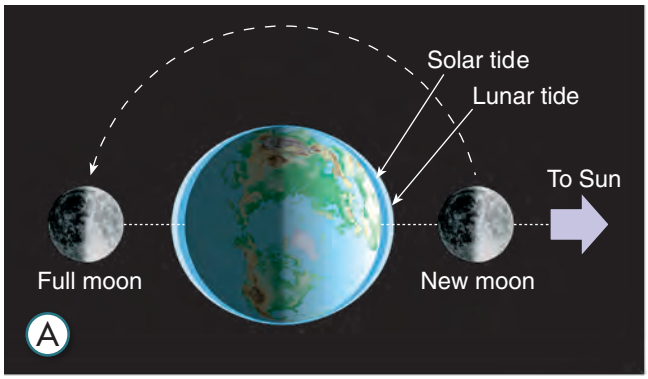
Ocean tides result from differences in the gravitational attraction exerted upon different parts of Earth's surface by the moon and, to a lesser extent, by the sun. The primary body that influences the tides is the moon, which makes one complete revolution around Earth every 29 and a half days. The sun, however, also influences the tides. It is far larger than the moon, but because it is much farther away, its effect is considerably less. In fact, the sun's tide-generating effect is only about 46 percent that of the moon's.

Think about the gravitational forces between the moon and Earth. This gravitational pull is strongest on the side of Earth closest to the moon and weakest on the far side of Earth from the moon. This difference causes Earth to be stretched slightly. The shape of the solid Earth is not affected much by this pull. However, the world ocean is much more mobile than the solid portions of Earth and a *tidal bulge* is produced as water is pulled toward the moon, as shown in **Figure 13.** A second tidal bulge is produced on the other side of Earth due to inertia—the tendency of an object, in this case water, to move in a straight line.

FIGURE 13 Tidal Bulges on Earth Caused by the Moon
Interpret Visuals *When Earth is in this position, is North America experiencing low tide or high tide?*



Because the position of the moon in relation to Earth changes only moderately in a single day, the tidal bulges remain in place while Earth rotates "through" them. For this reason, if you stand on a seashore for 24 hours, Earth will rotate you through alternating areas of higher and lower water. As you are carried into each tidal bulge, the tide rises. As you are carried into the troughs between the tidal bulges, the tide falls. Most coastal locations experience two high tides and two low tides each day.



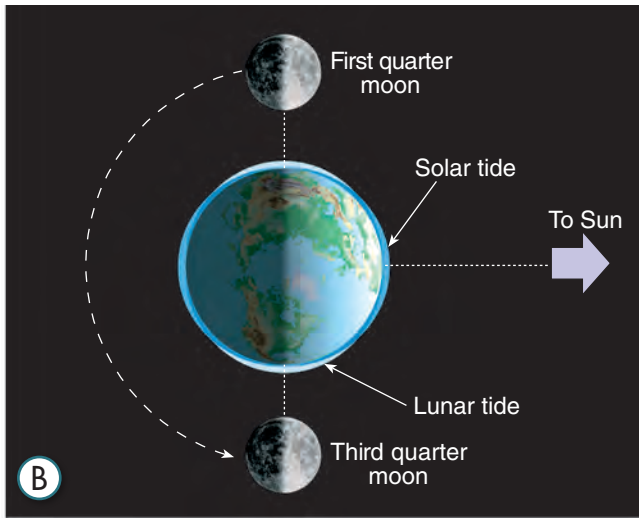


FIGURE 14 Earth-Moon-Sun Positions and the Tides
A When Earth, moon, and sun are aligned, spring tides are experienced. **B** When Earth, moon, and sun are at right angles to each other, neap tides are experienced.
Describe *How does the sun influence the formation of spring and neap tides?*

Tidal Cycle Although the sun is farther away from Earth than the moon, the gravitational attraction between the sun and Earth does play a role in producing tides. The sun's influence produces smaller tidal bulges. These tidal bulges are the result of the same forces involved in the bulges created by the moon. The influence of the sun on tides is most noticeable near the times of new and full moons. During these times, the sun and moon are aligned, and their forces are combined, as shown in **Figure 14A.** The combined gravity of these two tide-producing bodies causes larger tidal bulges (higher high tides) and larger tidal troughs (lower low tides). The result is a larger than normal **tidal range,** which is the difference in height between successive high and low tides.

Spring tides are tides that have the greatest tidal range due to the alignment of Earth, the moon, and the sun. They are experienced during new and full moons. Conversely, at about the time of the first and third quarters of the moon, the gravitational forces of the moon and sun act on Earth at a right angle, as shown in **Figure 14B.** The sun and moon partially offset the influence of the other. As a result, the daily tidal range is less. These tides are called **neap tides.** Each month there are two spring tides and two neap tides, each about one week apart.

Reading Checkpoint *What is the tidal range?*

FIGURE 15 High Tide and Low Tide in a Village in Nova Scotia

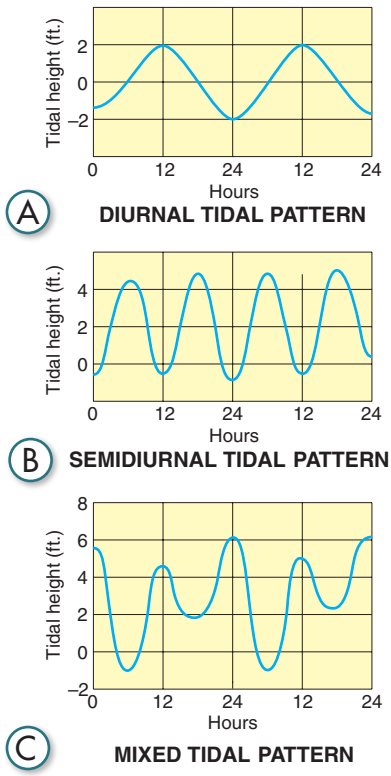


FIGURE 16 Tidal Patterns
The high points in these graphs represent high tides and the low points represent low tides.

Tidal Patterns You now know the basic causes and types of tides. However, many factors—including the shape of the coastline, the confi uration of ocean basins, and water depth—greatly influence the tides. Consequently, tides at various locations respond differently to the tide-producing forces. This being the case, the nature of the tide at any coastal location can be determined most accurately by actual observation. The predictions in tidal tables and tidal data on nautical charts are based on such observations.

Th ee main tidal patterns exist worldwide: diurnal tides, semidiurnal tides, and mixed tides. A *diurnal* tidal pattern is characterized by a single high tide and a single low tide each tidal day, as shown in the graph in **Figure 16A.** Tides of this type occur along the northern shore of the Gulf of Mexico.

A *semidiurnal* tidal pattern exhibits two high tides and two low tides each tidal day. The two highs are about the same height, and the two lows are about the same height. **Figure 16B** shows a semidiurnal tide pattern. This type of tidal pattern is common along the Atlantic Coast of the United States.

A *mixed* tidal pattern, shown in **Figure 16C,** is similar to a semidiurnal pattern except that it is characterized by a large inequality in high water heights, low water heights, or both. There are usually two high and two low tides each day. However, the high tides are of different heights, and the low tides are of different heights. Such tides are found along the Pacific Coast of the United States and in many other parts of the world.

16.2 Assessment

Review Key Concepts

1. From where do ocean waves obtain their energy?
2. What three factors determine the height, length, and period of a wave?
3. How does energy move by means of a wave?
4. What changes occur in a wave as it approaches shore?
5. Which celestial bodies influence Earth tides?
6. What force produces tides?
7. What are the three types of tidal patterns?

Think Critically

8. **Infer** Two waves have the same fetch and were created by winds of equal speed. Why might one wave be higher than the other?
9. **Relate Cause and Effect** Explain how gravity leads to tides in Earth's oceans.
10. **Compare and Contrast** Compare and contrast spring tides and neap tides.

MATH PRACTICE

11. **Calculate** Wavelength, wave period, and wave speed can be related to each other in the equation:

$$\frac{\text{wavelength}}{\text{wave period}} = \text{wave speed}$$

If wavelength = 187 meters, and wave speed = 16.8 meters per second, what is the period of this wave?