Ocean Tides

Arriving at a sandy ocean beach early in the day, you set up a blanket and chairs within a few meters of the water. After a swim in the surf, you decide to go off the beach to a refreshment stand for a snack and to an amusement park to ride the rollercoaster. You return to the beach later, only to discover the ocean has flooded your chairs and soaked your blanket. What force has moved the ocean water level up the beach? What force will later move the ocean water level back down?

Gravity in the Sun-Earth-Moon System
Throughout the day, water levels in oceans and lakes around the planet rise and fall. These regular movements, or tides, are produced by the motions and positions of three objects in space. These objects are Earth, Earth’s Moon, and the Sun.

Each day, Earth makes one rotation about its axis. (Earth’s axis is an imaginary line that runs through the planet’s center, between its north and south geographic poles.) The Moon revolves, or moves, around Earth. One revolution of the Moon around Earth takes about 28 days, or one month. Meanwhile, Earth revolves around the Sun. One revolution of Earth around the Sun takes about 365 days, or one year.

As they move through space, the Moon, Earth, and the Sun exert gravitational forces on one another. The force of gravity is affected by two variables: the masses of the objects and the distance between them. Although the Moon is much less massive than the Sun, the Moon is much closer to Earth than Earth is to the Sun. As a result, the force of the Moon’s gravity on Earth is more than double the force of the Sun’s gravity on Earth. Substances that are free to move on Earth’s surface, such as ocean water, are more greatly affected by the Moon’s gravity than by the Sun’s. This is particularly important for Earth’s tides. As the Moon revolves around Earth, it pulls water in oceans and lakes toward it. This causes water levels to rise in some places and to fall in others.
Ocean Tides

All things in the universe that have mass have gravity and pull on each other. We can see the effect of the Moon’s gravity as tides rise and fall. As the Moon’s gravity pulls on Earth, Earth pulls back on the Moon. If the Moon had any oceans or lakes, the water in those bodies would also experience tides.

Gravity and Ocean Tides

Each day, tides on Earth rise and fall between two extremes. A high tide is the highest point on a shore that water will reach, mainly due to the gravitational attraction of the Moon. At any given time of day, high tides are produced on whichever shores are facing the position of the Moon relative to Earth. At the same time, high tides are also produced on the shores opposite the position of the Moon relative to Earth. In other words, at any given time on Earth, one tidal bulge faces the Moon, and one tidal bulge faces the opposite direction.

What causes this second tidal bulge? A combination of gravity and inertia. Inertia is the tendency for something to remain at rest or in motion unless acted on by an unbalanced force. Water on Earth has inertia: It tends to stay in place unless acted on by an unbalanced force. For example, forces from winds cause waves as air moves across the surfaces of oceans and lakes. Another force that overcomes water’s inertia is gravity.

Look at the diagram on the right. On the side of Earth facing the Moon, the pull of the Moon’s gravity is greater than the water’s inertia—its tendency to stay in place. So, the water on that shore bulges toward the Moon. At the same time, the Moon’s gravity pulls Earth slightly toward the Moon. The Moon’s gravity doesn’t affect water on the side of Earth opposite the Moon. Therefore, as the planet is pulled in one direction toward the Moon, the water on the opposite side of the planet remains in place. The result is a second tidal bulge due to inertia. As Earth rotates under the Moon, the bulges move around the planet. However, they are always opposite each other.

A low tide is the lowest point on a shore that water will reach. Low tides always happen at places on Earth that are at right angles to the tidal bulges. Like high tides, two low tides occur at the same time on opposite sides of Earth.

At any given place on Earth, high tides occur twice most days and low tides occur twice most days. For example, suppose a beach in New Jersey faces the Moon at noon. That beach will experience a high tide at noon (as will a beach on the opposite side of the planet). Approximately twelve hours later, that beach will face away from the Moon. This will produce another high tide around midnight. Low tides on the same beach will occur at approximately 6:00 p.m. and 6:00 a.m.
Ocean Tides

Look Out!

Tides don’t occur at the same times every day. At any beach, high tides are separate by approximately 12 hours and 25 minutes. The same is true of low tides. Therefore, each day high tides and low tides happen slightly later than they happened the previous day.

What Do You Think?

Find the Gulf Coast of Texas on a globe of Earth. (If you do not have a physical globe, you can find many globes online. Enter the term “virtual globe” in a search engine.) When it is high tide in Texas, where on Earth is also experiencing a high tide? Where is it low tide? Choose one other location on another part of the globe. When it is high tide in this location, where on Earth is it also high tide? Where is it low tide?

Tidal Variations

If you measured high and low tides every day for a month, you would discover that some high tides are higher than others. You would also discover that some low tides are lower than others. If you did the same thing over the course of a year, you would discover that the range between high and low tides is greatest around January 2. You would also discover that the range between high and low tides is least around July 2.

All of these variations are caused by three factors:

• How the Moon, Earth, and the Sun are aligned with each other
• Where the Moon is positioned relative to Earth
• Where Earth is positioned relative to the Sun

Let’s examine these in order. As the Moon revolves around Earth, it reaches a point between Earth and the Sun. This happens once each month, during the new moon phase of the lunar cycle, when the side of the Moon facing Earth is dark. When Earth, the Moon, and the Sun are aligned like this, the effect of the Sun’s gravity combines with the Moon’s gravity.

The same thing happens about two weeks later when Earth is between the Moon and the Sun. (In this alignment, the side of the Moon facing Earth is completely bright. This is the full moon phase.) These two alignments produce higher-than-average high tides and lower-than-average low tides. We call these tides spring tides.

lunar cycle: the pattern that describes how the Moon’s appearance in the sky changes over the course of a month
About one week after a new moon or a full moon, the Moon and the Sun form a right angle relative to Earth. In this position, the Sun’s gravity works against the Moon’s gravity. High tides are lower than average, and low tides are higher than average. We call these tides **neap tides**.

Why is the range between high and low tides greatest in early January and least in early July?

Earth follows an **elliptical**, or oval-shaped, path around the Sun. Earth’s path takes it closest to the Sun around January 2 of each year. On that date, called **perihelion**, the gravitational force between Earth and the Sun is strongest. This produces a greater-than-average range of tides. Earth’s path takes it farthest from the Sun around July 2 of each year. On that date, called **aphelion**, the gravitational force between Earth and the Sun is weakest. This produces a lower-than-average range of tides.

**Looking to the Future: Harnessing the Energy of Tides**

To reduce our dependence on fossil fuels such as oil, coal, and natural gas, many countries have turned to alternative sources of energy. These include wind energy, solar energy, geothermal energy, and the energy of moving water. Another benefit of these alternative resources is they create less pollution than do fossil fuels.

Until recently, the energy of moving water has mainly been harnessed by damming rivers to produce electricity. Since the 1960s, some countries, such as France, have built tidal power plants. Other countries, including Canada and the United States, are investigating ways to transform the movements of tides into electrical energy.
Here’s how a tidal power plant works. As tides rise and fall, they have kinetic energy: the energy of motion. This kinetic energy is used to turn the blades of a machine called a turbine. Gears and other devices transmit this motion to an electric generator. This machine transforms the tidal energy into electrical energy. The electrical energy is transmitted through cables to homes, factories, and communities. The photo on the right shows a tidal power plant in Nova Scotia, Canada.

**What do you know?**
The relative positions of the Moon, Earth, and the Sun produce different kinds of tides. In the spaces below, draw the positions of the Moon, Earth, and the Sun that produce each kind of tide or condition.

NOTE: The same kind of tide may be produced by more than one set of positions of the Moon, Earth, and the Sun. In such cases, draw all sets of positions that produce the tide.

<table>
<thead>
<tr>
<th>Tide or Condition</th>
<th>Relative Positions of the Moon, Earth, and the Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring tide (above-average range of tides)</td>
<td></td>
</tr>
<tr>
<td>Neap tide (below-average range of tides)</td>
<td></td>
</tr>
<tr>
<td>Earth at perihelion (above-average range of tides)</td>
<td></td>
</tr>
<tr>
<td>Earth at aphelion (below-average range of tides)</td>
<td></td>
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</tbody>
</table>
Charting the Tides
You can relate the discussion of tides to the phase and position of the Moon in the night sky. Find a tide table for a nearby location (or a distant location of your choice, if you do not live near an ocean or a large lake). You can find this information online or in some newspapers. Have your child review the data for several months, noting when high and low tides happen and how great or small the tidal range is each day. Your child should be able to locate spring and neap tides and, based on these data, infer when during each month the Moon and the Sun are aligned with Earth and when they form a right angle relative to each other.

If your child has already learned about the lunar cycle and the Moon’s phases, you may combine your study of tides with observations of the Moon. Take your child outdoors in the evening, bringing with you a pad or notebook of unlined paper and a pencil. Have your child sketch the Moon each night and identify its phase (e.g., new moon, waxing crescent, first-quarter moon, etc.), then connect this information to what they have learned about tides. For example, when the Moon is full or new, spring tides will occur. (Your child should be able to explain the reason: because the Moon, Earth, and the Sun are aligned.) When the Moon is in its first-quarter or last-quarter phases, neap tides will occur. (Your child should be able to explain the reason: because the Moon, Earth, and the Sun form a right angle relative to each other.)

Here are some questions to discuss with your child:
• When are the spring tides during this month? When are the neap tides?
• How do these tidal patterns relate to the positions of the Moon and the Sun relative to Earth?
• How do the positions of the Moon and the Sun relative to Earth affect their gravitational pulls on Earth? What does this have to do with tides?