ExploreLearning

Exploration Guide: Tides

Every day, tides ebb and flow along the seashore. At low tide, thousands of shorebirds flock to exposed mudflats, feasting on worms, crabs, and other delicacies. High tide brings relief to the inhabitants of tide pools. Sea anenomes, barnacles, and mussels filter the water for plankton, while snails scrape algae off the rocks. Without tides, many of these organisms would not survive.

Like many daily events, tides are often taken for granted. But coming up with a complete explanation of tides was a challenge that engaged many great scientists, including Galileo and Lord Kelvin. Even today, predicting the tides with precision is a difficult task.

Daily Tides

In the Gizmo™, Earth and the Moon are shown. An observer is standing on the equator. Although it is not visible, the Sun is considered to be far off in space to the left.

1. On the **SIMULATION** pane, notice the relative positions of the Sun, Earth, Moon and the observer. Select the **BAR CHART** tab, and click **Play** (▶). After 24 hours of simulated time, click **Pause** (⏸).
   a. As time goes by, what do you notice on the **BAR CHART** tab?
   b. Click **Reset** (↺), and then **Play**. When the water reaches its maximum depth, click **Pause**. This is **high tide**. What is the water depth at high tide?
   c. At what time did high tide occur?
   d. Press **Play**, and then **Pause** when the water is next at its minimum depth. This is **low tide**. What is the water depth at low tide?
   e. At what time did low tide occur?

2. Click **Reset**. Notice that the **BAR CHART** currently shows high tide. Click **Play**, run the Gizmo for 24 simulated hours, and then click **Pause**. Select the **GRAPH** tab.
    a. How many high tides occurred in this 24 hour period?
    b. How many low tides occurred in the same period?
    c. Suppose it was high tide. About how many hours would you have to wait for low tide to occur? Check your answer using the Gizmo.

3. Click **Reset**. On the **SIMULATION** pane, observe the elliptical bands of water representing Earth's oceans (they are not drawn to scale). Notice the depth of the ocean relative to the observer now, at high tide.
    a. At any moment on Earth, how many high tides are occurring?
    b. If you were standing at one high tide, where would you have to go to find the other high tide?
    c. At any moment, how many low tides are occurring?
    d. If you were standing at one low tide, where would you have to go to find the other low tide?
    e. How many degrees would Earth have to rotate to move you from a high tide to a low tide? Given that the Earth makes a complete rotation every 24 hours, about how long would this take?
    f. Does this agree with the observations you made in step 2c?

The Pull of the Sun and the Moon on Earth's Oceans

In this activity, you will see how the tides are related to the relative positions of the Earth, Sun and Moon.

1. Set the **Speed** slider to an intermediate value, and press **Play**. Observe the position of the bands over time. Click **Pause** after about 7 days of simulated time.
    a. How has the position of the "high tide" bulge changed in this period of time?
    b. What other object has changed position in this way? How is the

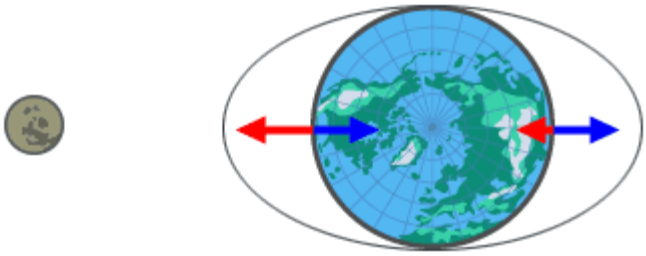
position of this object related to the alignment of the two high-tide bulges?

2. You should have seen that one of the high-tide bulges is always on the side of the Earth closest to the Moon. You may have also noticed that a second tidal bulge is always found directly opposite the Moon. The first tidal bulge is caused by the **gravitational force** exerted by the Moon. The second bulge is explained in the last section of this guide.
3. Click on the **Moon** and drag it around the Earth. Observe the shape of the tidal bulges as you do this.
    a. Do the tidal bulges stay the same size at all times? When are they largest?
    b. What are the relative positions of the Moon, Earth, and Sun when the tidal bulges are largest? Tides at this time are known as **spring tides**. At this time, high tides are higher, and low tides are lower. Click on the **camera** icon to take a snapshot of this position, and paste the image into a blank document.
    c. Experiment with the Gizmo to find a second **spring tide** position. Paste an image of this position into your document.
    d. Find the two positions where the tidal bulges are minimized. Tides at this time are known as **neap tides**. Paste the images of the neap tide positions into your blank document.
    e. Compare the positions of the Sun and Moon in the two spring tide images. What do these positions have in common?
    f. Compare the positions of the Sun and Moon in the two neap tide images. What do these positions have in common?
    g. How does the Sun influence the tides? Is the influence of the Sun's gravity as strong as the influence of the Moon's gravity? Explain your reasoning.

A Fuller Explanation of the Tides

Tides are produced by a combination of forces acting on the surface of the

ocean. The gravity of the Moon pulls oceans towards the Moon. Opposing this is the centrifugal force caused by the fact that the Earth and the Moon are both whirling around a common point in space. This force acts away from the common point around which the Earth-Moon system is moving. You can feel a similar outward force when you are spinning on an amusement park ride. The **centrifugal force** is the same all over the Earth, but the force of the Moon's gravity depends on the distance from the Moon.



In the diagram above, the force of the Moon's gravity is represented by the two red arrows, while the centrifugal force is shown by the two blue arrows. Notice that the centrifugal force is the same in both locations, but the force of the Moon's gravity is greater on the side of Earth closest to the Moon. Because the Moon's gravity is stronger than the centrifugal force there, ocean water is pulled to this side of the Earth, forming a tidal bulge. On the opposite side of the Earth the centrifugal force is stronger than the Moon's gravity, so ocean water is pulled to this side as well. The result is two equal tidal bulges on opposite sides of the Earth.

In this Gizmo, an idealized situation is described. In reality, friction and the shapes of land masses both affect the flow of water, causing tidal bulges to be variable in size and no longer perfectly aligned with the Moon. Over millions of years, friction between the solid Earth and the tidal bulges has slowed the Earth's rotation, increasing the length of a day by several hours!
