Dance of the Moon and Oceans

http://www.lpi.usra.edu/education/explore/marvelMoon/activities/whatIf/dance/

Modified for classroom teachers from the Explore activity, which was adapted from "Tides,"Scientific Explorations with Paul Doherty © 2003, rev. 18 November 2003, the Exploratorium.

Overview

In part A, students grades 6 and up discover how the Moon's gravitational pull causes the level of the ocean to rise and fall twice a day along most coastlines. Six children represent the oceans, solid Earth, Moon, and Sun and move their bodies to show the interactions of these elements. In part B, they model the tides that would be produced by the Sun and Moon, to explore spring and neap tides. Allow 30 minutes for this activity.

Note that this activity is appropriate for older students who are able to explore the geometry of Sun-Earth-Moon relationships in three dimensions. Many children under 10 are not able to fully conceptualize the Earth's spherical nature and their relationship to it, and so they are unable to create an accurate mental model.

What's the Point?

- The Moon's motion in orbit around the Earth and its gravitational pull results in an observable phenomenon at Earth's surface: tides.
- Tides are the daily rise and fall of ocean waters along coastlines. They reach a maximum height known as high tide and a minimum height known as low tide.
- Tides have important effects on marine life and ocean currents.
- The Sun also pulls on the Earth and oceans, contributing less than half of the total height of the tides.
- Without the Moon, Earth would have smaller tides generated only by the Sun's gravitational pull.

Materials

For the group:

- Images of high and low tide in the Bay of Fundy, preferably printed in color
- Optional: Images of high and low tide at a local ocean beach photographed from the same location, preferably printed in color
- 4 blue scarves or strips of fabric

Preparation

- Print images of high and low tide. You may choose to present images of the Bay of Fundy, or you may wish to provide your own photographs of a local coastline or from a beach vacation. Be sure to photograph high and low tide from the same location for easier comparison.

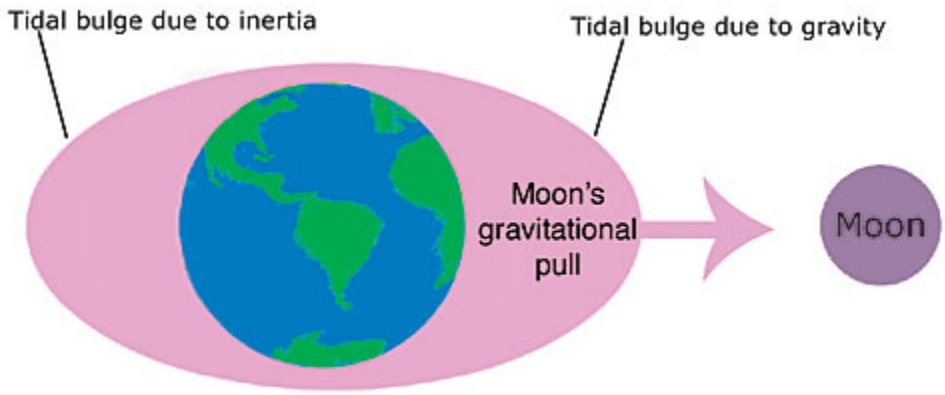
Facilitator's Note: This activity builds upon the fact that the Moon has gravity, but the children may have false ideas about the concept of gravity. You may wish to first undertake the activity *Heavyweight Champion: Jupiter*, where children ages 9–13 can discover whether other planets and the Moon have gravity and what causes this natural force.

Advanced learners may wish to explore the complex relationship between the Moon (and its phase), the Sun, and Earth. Older children may create their own tide wheels.

Background Information

The Moon's gravitational pull tugs on Earth — especially the portion that is nearest to it as it travels in orbit around Earth. Earth's crust rises slightly (several centimeters) due to this force. Ponds and lakes — such as the Great Lakes — experience small tides, as well. Earth's oceans, however, are free to lift many feet in response this tug. As the Moon orbits the Earth, it drags along behind it a "bulge" in the oceans.

If you've ever tried to push a stalled car in neutral from a dead stop, you've experienced the same force that counteracts the Moon's gravitational pull: inertia. On the side of Earth opposite the Moon, the universal tendency for objects to resist a change in its movement wins out over the gravitational pull. The ocean here can keep going in its original direction. Near the Moon, the oceans are pulled upward and along. Opposite the Moon, the oceans are "left behind."



In this very, very exaggerated image of Earth's oceans from space, water bulges upward from the surface in two opposite locations on Earth's surface. Earth continues to spin, bringing different coastlines under the bulge throughout the course of a day. Most coastlines experience two tides each day as they pass through the two bulges. Credit: National Oceanic and Atmospheric Administration.

The Moon's contribution to Earth's tides is significant because it is so close. The Sun, of course, also exerts a gravitational pull on Earth — that's what keeps Earth in a steady orbit. Earth's oceans are pulled toward the Sun, but the Sun's gravitational pull contributes only about a third of the tides' height.

Early in Earth's history, the Moon was even closer to Earth. Billions of years ago, the Moon was 10 times closer and tides were 1000 times higher. Scientists believe that these extreme tides occurred once every three hours because the Earth was spinning more rapidly. The tides eroded the coastal areas, adding minerals to the oceans. These minerals may have been essential for life to evolve as quickly as it did.

Activity

Part A: The Moon's Gravity Creates Ocean Tides

1. Ask the students to consider the reason behind the difference between images of high and low tide. Show the images to the children and have them describe the differences between them. Guide their discussions toward identifying them as tides, and finally, toward relating the Moon as the main cause of that pattern.

- What do you notice about these pictures? *There are four images of the Bay of Fundy (on the east coast of Canada) Two are satellite images, taken several months apart. Two were taken on the ground at different times on the same day. Each pair shows the water level at a different height, which in one image, left the boats grounded!*
- Have you ever been to the coast and seen the ocean? Have you ever explored tide pools?
- What happens to the level of the ocean water over the course of a day? *They rise and fall. In some places, this occurs once a day. In others, in occurs twice a day.*
- What do we call this daily rise and fall of ocean waters along coastlines? *Tides.*
- What causes tides? *The children may know that the Moon's gravitational pull causes tides.*

Add that the Sun's gravitational pull also helps create tides. However, the Moon's gravitational pull gives the tides their height and regular, daily pattern. An area's geographic location and the shape of the sea floor also affect the tide.

> ***Facilitator's Note:*** *There is a tricky distinction between waves and tides. The waves we like to watch breaking along the beach are caused by wind and are independent of tides. Tides cause the water level to be really high up on the beach, or really far out (often leaving clams and other sea life exposed), and everything in between.*
> *A tidal wave, or tsunami, is caused by a sudden disturbance — such as an earthquake — and is unrelated to tides. If the conversation turns to tidal waves, gently clarify this distinction.*

2. Explain that six students will model how the Moon's gravitational pull creates tides. Because the Moon and Earth are in motion together as they orbit the Sun, this model will be similar to a dance. Have one student represent the solid Earth. Have four other students stand in a circle around the "Earth": one behind, two on each side, and one directly in front of "Earth." These students represent Earth's oceans. The oceans may be linked by four scarves or strips of fabric that they are holding in their hands. Have all five students stand to face the sixth student, who represents the Moon.

- What's a model?

We use models to help us represent objects and systems so that we can study and understand them more easily. Scientists use computers to create models to study the complex interactions between the Sun, Earth, and Moon.

- Is this model showing the correct sizes of the Moon, Earth, or oceans relative to each other? *No.*
- Are their distances from each other correct? *No.*
- How can the Moon influence Earth? *Its gravity pulls on Earth.*

Explain that while a pair of dancers has to actually touch each other in order to move together, moons and planets can influence each other's spins and tilts from a distance. All objects that have mass have their own gravity, but only large objects — like planets — have enough gravity to influence each other from afar.

Facilitator's Note: *Does the Moon's gravity pull on humans, too? The Moon's gravity affects humans, as well. The tug of the Moon's gravity decreases a person's weight by a few grams. These tides are inconsequential, however, compared to the much stronger pull of the Earth beneath our feet.*

2. Ask the students to demonstrate how the Moon's gravitational pull creates two tides in most coastal locations on Earth each day.

- Which part of the Earth and ocean is being pulled the most by the Moon? *The student closest to the Moon (one of the "oceans").*
- Which part of the Earth and oceans is being pulled the least by the Moon? *The student farthest from the Moon (another "ocean.")*

Have the "ocean" student nearest the "Moon" take three large steps toward him or her. "Earth" and the two "oceans" standing beside Earth take two large steps toward the "Moon." The "ocean" student furthest from the "Moon" takes one large step toward the Moon.

- Why did the oceans move toward the Moon? *The Moon's gravity pulled on them.*
- What happened to the oceans? *They moved apart around the "Earth" to form an oval rather than a circle shape.*

Explain that the water from the oceans has "piled up" under the Moon and directly opposite the Moon. The two children standing beside "Earth" represent parts of the ocean where there is less water.

- Where are the oceans at the highest levels? *The "oceans" nearest and furthest from the "Moon."* Are the coastal areas next to those "oceans" seeing a high or low tide? *High.*
- How many sides of the Earth experience high tide at the same time? *Two (in general).* Which part of "solid Earth" is experiencing high tide right now? *The part that is under the "piled up" oceans.*
- Where is low tide? *Near the "oceans" standing closest to "Earth."*

Note which body parts — the arms or front and back — are experiencing "high tide" and which are experiencing "low tide."

- Why did the "ocean" furthest from the Moon move the least? *It was "left behind."*

Facilitator's Note: *The formation of the second ocean bulge is simplified in this model and ignores subtle motions of the Earth. A more accurate and complete description is presented in the following sources. Note that the science content level of these sources is intended for an adult audience.*

"Our Restless Tides," National Oceanographic and Atmospheric Administration (NOAA)

Bad Astronomy: Misconceptions and Misuses Revealed, from Astrology to the Moon Landing "Hoax" *Philip Plait, John Wiley & Sons, Inc., 2002, ISBN 0471409766*

Explain that the model demonstrates how the Moon produces two high tides and two low tides at the same time. The ocean furthest from the Moon is far enough away that it "feels less" of the Moon's gravitational pull.

- Is the solid Earth standing still, like in this model? *No*, *it's spinning.*

Invite "solid Earth" to spin about once on his or her axis (the line straight up from the floor to his or her head) a few times to demonstrate about one day. Explain that the Moon is also moving — orbiting around the Earth over about 27 days — and that the oceans are dragged along with the solid Earth as it spins. Have Earth stop spinning in a new position. Note again which body parts

— the arms or front and back — are experiencing "high tide" and which are experiencing "low tide."

- Is high tide still near the same place (i.e. is "high tide" still near the arms or front and back), or is it in a new place? Is low tide still in the same place? *No, high and low tide are on different parts of the solid Earth now.*

Summarize that the Moon's gravitational pull creates two high and low tides for most coastal areas on Earth each day. As the Earth spins, the tide flows in and out.

Part B: Spring and Neap tide

3. Ask the students to consider how the Sun might affect the Earth's tides. Have the "oceans" stand in their original positions around the "Earth" so that the scarves or strips of fabric are linked in a circle. Have a new volunteer join the model as the "Sun."

- Would the Earth still have tides? *Accept all answers.*
- Besides the Moon, what pulls on the Earth? *The Sun.*
- Does the Sun pull on Earth's oceans?

Explain that the Sun does pull on Earth and its oceans (and keeps them in orbit). Since it is so far away, the Sun's pull gives the tides only a third of their height.

- The "Moon" pulled the nearest "ocean" three steps forward. How many steps forward does the "Sun" alone pull him or her? *One-third as many steps, or one step forward.*

4. Have the students model the tides with the Sun and the Moon to pull on the oceans, positioning the Moon to stand between the Earth and Sun. Have the student nearest the Sun and Moon take 3 steps plus one *large* step toward the Moon. "Earth" and the two standing beside him or her take 2 steps plus one *normal* step toward the Sun and Moon. The student furthest from the Sun and Moon takes one normal step plus one small step forward.

- What happened to the oceans? *The high tides became even higher, and the low tides became even lower.* This is called spring tide.
- What Moon phase do we have modeled here, with the Moon between the Earth and Sun? *New Moon.*

5. Have the students model the tides with the Sun and the Moon to pull on the oceans, positioning the Moon to move ¼ of the way around the Earth (counter-clockwise—to the left), so that it's 90 degrees from the Sun. Have the "ocean" student nearest the "Moon" take three large steps toward him or her. "Earth" and the two "oceans" standing beside Earth take two large steps toward the "Moon." The "ocean" student furthest from the "Moon" takes one large step toward the Moon.

Now have the student nearest the Sun take an additional large step towards the Sun. "Earth" and the two standing beside him or her take one additional *normal* step toward the Sun. The student furthest from the Sun takes one s*mall* step toward the Sun.

- What happened to the oceans? *The high tides are not as high, and the low tides are a bit higher.* This is called neap tide.
- What Moon phase do we have modeled here, with the Moon a quarter of the way around the Earth? *First quarter.*

6. Have the students model the tides with the Sun and the Moon to pull on the oceans, positioning the Moon to move ½ of the way around the Earth, so that it's 180 degrees from the Sun. Have the "ocean" student nearest the "Moon" take three large steps toward him or her. "Earth" and the two "oceans" standing beside Earth take two large steps toward the "Moon." The "ocean" student furthest from the "Moon" takes one large step toward the Moon.

Now have the student nearest the Sun take an additional large step towards the Sun. “Earth” and the two standing beside him or her take one additional *normal* step toward the Sun. The student furthest from the Sun takes one s*mall* step toward the Sun.

- What happened to the oceans? *The high tides are higher, and the low tides are lower.* What is this called? *Spring tide.*
- What Moon phase do we have modeled here, with the Moon on the opposite side of the Earth from the Sun? *Full Moon.*

7. Have the students model the tides with the Sun and the Moon to pull on the oceans, positioning the Moon to move ¾ of the way around the Earth. Have the "ocean" student nearest the "Moon" take three large steps toward him or her. "Earth" and the two "oceans" standing beside Earth take two large steps toward the "Moon." The "ocean" student furthest from the "Moon" takes one large step toward the Moon.
Now have the student nearest the Sun take an additional large step towards the Sun. “Earth” and the two standing beside him or her take one additional *normal* step toward the Sun. The student furthest from the Sun takes one s*mall* step toward the Sun.

- What happened to the oceans? *The high tides are not as high, and the low tides are not as low.* What is this called? *Neap tide.*
- What Moon phase do we have modeled here, with the Moon ¾ of the way around the Earth? *Third or Last Quarter Moon.*

Conclusion

Regroup the students and discuss Earth’s tides — and how different it would be without the Moon's gravitational pull adding significantly to the height of the tides. Explain some of the effects of tides on marine life: Tides create tide pools along rocky shores and where many creatures breed, feed, and hunt. Other creatures thrive in places like harbors, bays, and mangroves where the tide exposes mud flats or tree roots. Tides create currents that mix the ocean, spreading nutrients and removing waste.

Studying the motions and gravitational pull of the Moon today helps scientists understand its influence on Earth today — and long ago. Scientists use computer models to help them understand the relationship between the Sun, Earth and Moon — just like the students used their own bodies! They want to know more about how the Moon's gravity has affected the Earth over their long history together. They use mathematics to describe how the masses, speeds, and directions of the Sun, Earth, and Moon interact in space; and the computer combines all of the factors together to show the overall effect. Mathematics and computers are tools for looking at the past, into the future, and considering what might have been!