Simulate the Tides

LESSON

GRADE LEVEL:
5-8

CATEGORY:
Earth, ecosystems and ecology

TOPIC:
Tidal forces and interactions of gravitational forces between Earth, Moon, and Sun.

TIME:
20-30 minutes warm-up demonstration and experiments, 20 minutes for role play.

SETTING:
- Warm Up: Indoors for demonstration, outdoors for experiments with water
- Activity: Indoors or Outdoors

GROUP SIZE:
Small groups of 7

SKILLS:
Predicting, calculating, observing, role playing, comparing, creating, visualizing

SUBJECT AREAS:
Science: math, physics and astronomy

KEYWORDS:
Gravity, centrifugal and gravitational forces, spring and neap tides, rotation, revolution, orbits, sun, moon, earth, lunar.

Overview

Students use models, experiments and role play to help explain how gravitational and centrifugal forces cause daily changes in ocean tides. Models, experiments and role play help students visualize and understand the effects of forces that can only be seen through our experiences.

Objectives

Students will be able to:

- Explain what causes tides
- Understand how the rotation of the earth influences tides
- Understand the relationship between the moon cycle and tides
- Visualize how gravity and centrifugal forces cause ocean tides to rise and fall
- Predict monthly timing of low and high tides based on moon cycles

Materials

Warm up:

- String
- Soft balls and/or washers
- Salad spinners
- Water in buckets
- A flashlight
- Globe on an axis
- Stickers or flags for the globe (preferably glow in the dark)

Activity:

- Brightly coloured rope or string
- Masking tape to join the ends of the rope/string.

Inquiry Questions

- How do I know what activities to plan for a trip to the beach? (Based on tides, such as looking for tidepool life or going for a swim.)

- Why do high and low tides happen every day? What causes tides?
- What is the relationship between the moon cycle and the tides?

Background

Tides are the result of several influences and complex interactions between forces. These influences include the daily rotation of the Earth; the Moon's revolution around the Earth; and the Earth and Moon's revolution around the Sun. Sir Isaac Newton's Law of Universal Gravitation and his Equilibrium Theory of the Tides explains the forces at work in producing the effect of ocean tides. In simple terms, the law states that the greater the mass of the objects and the closer they are to each other, the greater the gravitational attraction between them.

Our Sun is 27 million times larger than our Moon, so one might think that the gravitational force of the Sun would be responsible for our tides. However, the Sun is 390 times further from the Earth than is our Moon. Therefore, although it is significantly smaller than the Sun, the Moon exerts about double the gravitational force and generates our tides due to its relative proximity to earth. The Sun still has a part to play and this is most evident when the Sun is in line with the Moon (at full and new Moons) and their forces combine to create spring tides. (Spring tides are named as such because the water "springs up", not named for the season). During the 27.3 day lunar month, the Sun and Moon are aligned (new Moon), opposite (full Moon) and perpendicular (half full) at the first and third quarters. The first and third quarter phases of the Moon cause neap tides which have smaller differences in height at low and high tides. Figure 1 shows the relationship between the phases of the Moon and tides.

Think of a location at the shore of an ocean. One of the tides that occurs there happens when the Earth rotates on its axis to be in line with the Moon because the gravitational force causes the ocean water to bulge up as it is pulled towards the Moon. As the Earth rotates away from direct alignment with the Moon, the tide goes out to create a low tide. As the Earth rotates it will reach a place that is directly opposite to the Moon and a second high tide is formed because some of the forces cancel each other out.

The second bulge on the opposite side of the Earth is created with the help of the centrifugal force created by the Earth's rotation that pushes objects away from its center. An example of a centrifugal force is a washing machine on spin cycle or a salad spinner pushing lettuce to the edges. Earth's stronger gravity keeps the Moon in its orbit and ensures our fluid oceans, lakes and atmosphere are not thrown off by centrifugal force or pulled off under the gravitational force of the Moon.

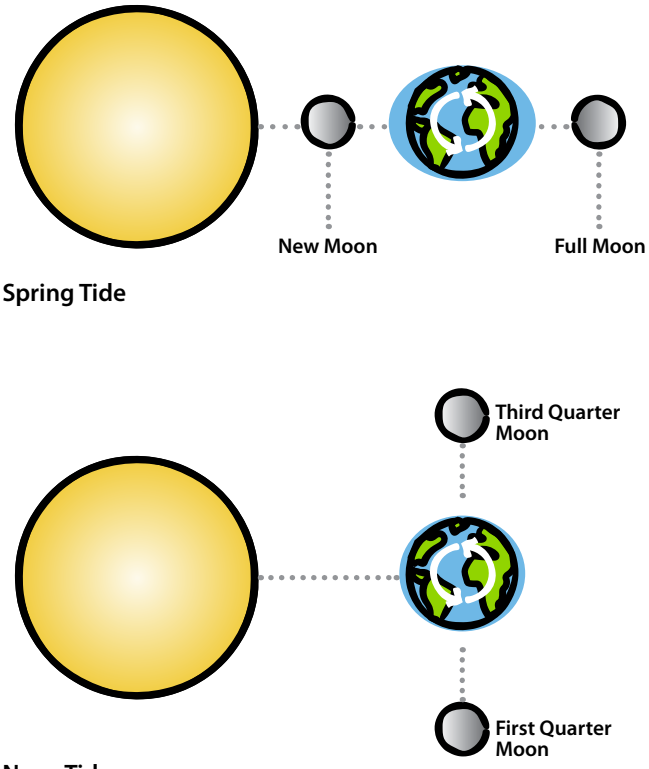

Figure 1: The relationship between the phase of the Moon and tidal heights.

The tides do not occur at the same time everyday because the Moon is also moving around the Earth. The Earth rotates a little further each day to be in the same alignment for the highest tide. This means high tide occurs 50 minutes later each day. Tides are also different across the Earth because of the shapes and depths of coastal inlets, sounds and fjords. Changes in barometic pressure, winds and waves also influence tides. This variation results in a great diversity of seashore and ocean dwelling life as they keep time by the tides.

Warm Up

1. Demo the Earth's Rotation

Demonstrate the Earth's rotation with a globe (on an axis) and flashlight. Have one student control the classroom lights and another student to hold a flashlight for a sun. Position another student as a Moon. To keep things easy, let the students know that for this demonstration we are going to use the time of year when the day and night times are equal on the equinox (March

20/21 or September 20/21). Also pick one time during the lunar month such as the full moon. See Figure 2.

Position the globe so that your location is directly in front of the Sun. Put a flag or glow-in-the-dark sticker to mark your location. This is when the Sun is at its highest point in the sky and it occurs around mid day (noon). The student Moon can stand in the position of a full Moon (directly across from the Sun) with their arms stretched out to show its gravitational pull on the Earth. Have a student come up and look at the spot while another student turns the lights out in the room. The student looking at the Earth without getting in the way of the Sun should describe what they see on the Earth.

Next, rotate the Earth on its axis counterclockwise to the opposite side and have another student come up. Repeat the procedure and describe what is occurring with the lights out. Repeat using different positions of the sticker on the globe and the Sun, such as dawn and dusk. Repeat the steps until the Earth has completed one full cycle (24 hours). Don't forget to move the Moon a little bit to show that it is also moving and repeat. Next move the Moon several days to the 1/4 or 3/4 position and repeat. Option: Discuss the illusion of the Sun moving from east to west in the sky. Why does this appear to be happening when it is really the Earth moving with us on it west to east in its rotation?

2. Centrifugal Forces

Experiment with centrifugal forces, gravity and inertia using ropes, soft balls or washers tied on them; salad spinners in sinks or spinning small buckets of water off the ground (perpendicular is preferred) without spilling. Ask students to identify what forces are at work, which are stronger at different times or explain what is happening using keywords from this activity.

Procedure

Part one

1. Choose 7 students who will take part in the first simulation (1 Earth, 1 Sun, 1 Moon, and 4 Ocean Surface). All other students will observe. Everyone will have the opportunity to take part in a simulation after observing the first one.

2. Position Earth in a central, open location and have Moon stand about 2 meters from Earth. Sun stands farther away to the side. Review how far the Earth turns in a day (rotates one full turn) and how far the Moon moves in relation to Earth (it orbits Earth every 28 days). How far do they think the Moon should move in 24 hours? Have Earth rotate in one spot four times to represent 4 days, (4 days is about 1/7th of the way around the Earth) while Moon moves approximately 1/7 of a circle around Earth. Remind Moon to always face Earth because like the Earth, the Moon also rotates on its own axis, but the rotation is synchronous with its revolution time around the Earth so we always see the same side of it. See Figure 2.

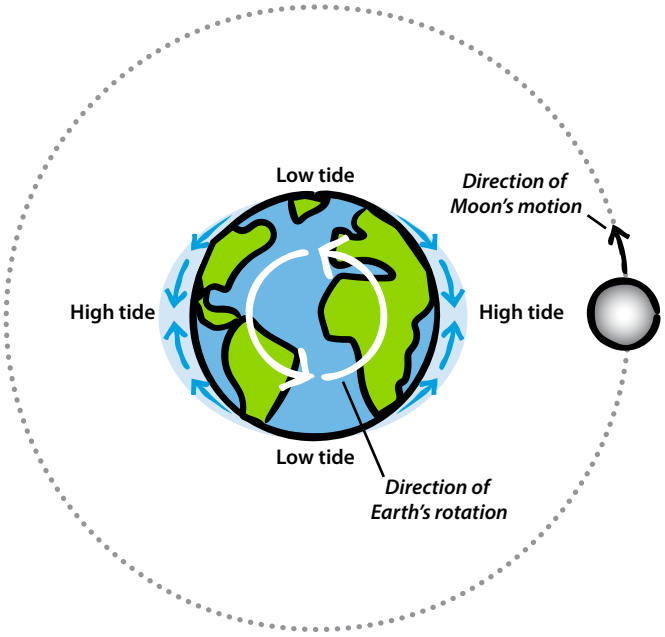

Figure 2: Where the high and low tides occur on Earth changes over the course of the day as the Earth rotates and as the Moon revolves around the Earth.

3. Position 4 Ocean students evenly around the Earth, spaced apart and facing sideways with their left arm held outwards (but not fully extended) towards the Earth and left hand touching the Earth at its shoulders (this is like gravity and without gravity, oceans would fly off the Earth into space). Have the Earth and its Ocean rotate for one day with its ocean remaining attached to the same place on the Earth (they move together one full turn). This could also be done using a pole for the Earth with ropes tied to the top (like a maypole). The Earth will rotate on the spot and the Ocean students will walk around with the Earth without letting go of their connection spot to Earth (gravity). Next, connect the water by having the Ocean students hold onto a string or rope with their right hand to represent the ocean surface. Make sure the rope is loose and slack, but long enough to be a complete circle. Join the ends of the rope with some masking or duct tape.

4. Ask students to recall the demonstrations done in the Warm Up and discuss the role that the gravitational forces play between the Moon and the Earth. Make sure that everyone is clear that the Moon is close enough to Earth to cause a gravitational pull on the surface layer of the ocean. As the Earth and its Ocean Surface rotate in a day, the Ocean student closest to the Moon extends their right arm and hand holding the rope out towards the Moon, creating a bulge. This bulge represents a high tide. Remind the students why there is a less pronounced high tide at the opposite side of the earth (see Background section for details). The student in this position indicates this by their right arm and hand holding the rope extended partway out. If the rope is the right size, and students positioned at an appropriate distance from the Earth, the students on either side of the high tides will be forced to be at low tide, indicated by their right hand and arm held close to their torso and left arm bent towards the Earth to give the slack towards the bulging high tides.

5. Have the Earth and its Ocean Surface rotate once (representing a 24-hour day) with the students raising and lower their right arms in relation to their position with the Moon. Try a few times to demonstrate what happens. Ideally, what will happen is it will look like "The Wave" in a stadium (in this case "The Tide"). As one part of the Ocean Surface approaches Moon, the student starts to reach out, the closest has their right arm fully extended, and the student who just passed by Moon begins to bring their right arm in towards their body. Once smooth, pause the demo and make sure that everyone is clear that for many locations on earth, including British Columbia, in one day there are two high tides and two low tides.

6. Now have the student representing Moon to resume slowly circling Earth (remember, it takes a month!) while Earth and Ocean Surface also go through several days. Advanced: the movement of the Moon around the Earth results in the timing of the tides being 50 minutes later each day because the Earth moves a little more reach the point where the Moon's gravitational pull is the strongest.

7. Now bring in Sun. Ask the class if Sun also has a gravitational pull on Earth's ocean surface and how it compares to the pull from the Moon. Position Sun to stand several meters away from Moon and Earth. Ask students how Earth and Moon move in relation to Sun. Students should understand that as Moon orbits Earth, together they both revolve around the Sun.

Part two

1. Show the forces of the Sun and Moon when they combine (in spring tides) or when they are in opposition (in neap tides; see Figure 3). Inform the class that when the Earth, Moon and Sun are aligned at the new and full phases of the Moon, it causes the highest tides in the lunar month: spring tides. To demonstrate this, ask one or two of the students to position Earth, Moon and Sun to indicate a full Moon. Once in place, request Ocean Surface to indicate the two high tides (the two Ocean Surface students who are closest to Moon and Sun fully extend their right arm and lean to the right as far as they can without letting go of Earth). Reposition Moon so they are now alongside Earth, indicating a quarter Moon; inform the class this is neap tide. To demonstrate lower tides, the Ocean Surface students close and opposite Moon extend their right arm only part way, the other two Ocean Surface students indicate low tide as usual, with right arms and hands pulled up against their body.

2. Whole Class challenge: Form 3 to 4 groups with the whole class, with a minimum of 7 students in each group. Challenge everyone to re-enact the demonstration. Afterwards reconvene as a group to discuss.

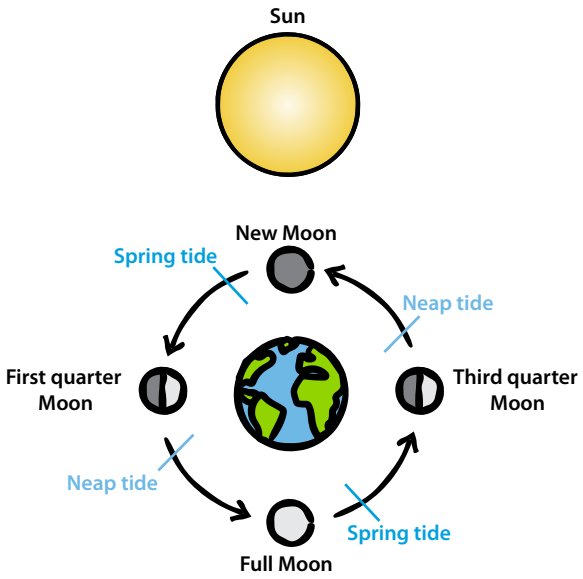

Figure 3: The combined forces of the Sun and Moon on the tides.

Assessment

1. Students can create a tide graph for a local location with the help of a tide chart. Look up the dates of the next new, first quarter, full, and third quarter phases of the Moon. Look up the predicted low and high tides for 24 hours. On each of those dates and write them down in a chart. Then make four graphs, one for each phase of the Moon. On the horizontal (x-axis) put time (hours, from 0 to 24, representing one day). The vertical (y-axis) is tidal height in meters. Make sure that all four graphs have the same scale.

   On their graphs students should be able to determine or investigate things like:

   - How much does the tidal height change over the course of the day?
   - The tidal heights and their fluctuations at the different phases of the Moon.
   - Identify and label the spring and the neap tides.
   - What day and phase of the Moon have the greatest difference between low and high tide? And the smallest difference? Are there some locations where the tide doesn't change much?
   - Draw activities that might happen at the beach during different tides and times of the day. Include animals like crabs, barnacles, birds, as well as people and your own activities at the beach.

2. Predict when and where it would be a good time to do activities at the beach, such as go swimming, have a sandcastle competition, do intertidal studies, make a bonfire, launch a boat, or set up a campsite. Use a tide chart to confirm their predictions. Can they explain any differences from their predictions?

3. Using their understanding of tides, explain the choices you make for marine recreation like hiking or camping near oceans.

4. Concepts of gravitational and centrifugal forces can be evaluated by the students' ability to identify these forces at work in carnival rides at fairs or the spin action of washing machines and dryers.

5. Write a short story about creatures that live under the influence of the tides. What is a day in the life of one of these creatures like. Some, like barnacles, live between the land and the ocean; others, like birds, come to the seashore to feed at certain tidal levels. How might their day be different from a human's conception of a day?

Extensions

1. Hypothesize whether or not lakes have tides.

2. Explain and explore tides around the world using tide data. Create a tide graph of the local area and then choose three locations in different parts of the world. Consider including a site on the Bay of Fundy, in NS and NB, which has the highest tides in the world. Graph the tidal heights at the three locations over a 24-hour period on the chosen date. Are the tides the same at all three locations? How do they compare? Do they all have two high and two low tides? Which place has the highest and lowest? What other factors might affect tidal levels? (Latitude, shoreline shape and depth).

3. Explore and experiment with gardening by the Moon phases. Waning phases (from full to new Moon) are thought to be good for seeds and planting sprouted root crops while waxing phases (from new to full Moon) are thought to be good for planting sprouted leaf vegetables (like lettuce or swiss chard).