Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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**Internal Thermal: Warming up in Space**

Lesson plan for grades 6-8
Length of lesson: 90 minutes
Adapted by: Louisa Torrance, Environmental Science Institute, 06/20/12

**SOURCES AND RESOURCES:**

- Galilean Moon animation http://upload.wikimedia.org/wikipedia/commons/8/83/Galilean_moon_Laplace_resonance_animation.gif
- Rubber Band Experiment: http://scifun.chem.wisc.edu/homeexpts/rubberband.html

**POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:**

§112.18b. Science, Grade 6 (9A, 11A)
§112.19b. Science, Grade 7 (9A)
§112.20. Science, Grade 8 (7C)

**PERFORMANCE OBJECTIVES:**
Students will be able to:

- Observe how gravity in space affects moon and planetary orbits
- Explain how tidal flexing relates to gravity and internal thermal energy
- Understand how thermal energy is transferred by convection
- Describe how the three processes above allow life to exist on earth, and how they may apply to other planets or objects within our solar system.

**MATERIALS (per group of four):**
- One sheet of white paper per student (four total)
- Scissors
- Protractor
- Pencils
- Easily removed stickers- Tape
- Small ball (rubber, foam, etc)
- Rulers
- Rubber bands
- Notebook paper

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**CONCEPTS:**

Convection - the movement caused within a fluid by the tendency of hotter and therefore less dense material to rise, and colder, denser material to sink under the influence of gravity, which consequently results in transfer of heat.

Thermal energy - An object that feels hot has more thermal energy inside it than it does after it has cooled down. Thermal energy can be transferred by conduction, convection, or radiation.

Tidal flexing - Arises from their resonant orbits, provides heat for volcanism on planetary objects within our solar system such as Io, and could result in the presence of liquid water beneath Europa's icy surface.

Resonant orbit - the driving of a dynamical system by a periodic force at a frequency which is a rational multiple of the natural frequency.

**BACKGROUND:**

Europa is an exciting moon to study because of its potential for life. Many factors contribute to this potential, including its tidal flexing and subsequent internal thermal energy. This lesson prepares students for understanding how phenomena on Earth such as gravity operate within and between other objects in our solar system, and also how thermal energy functions on small scales (rubber band stretching) and enormous scales (Europa itself)! Students will discover how the presence of gravity, thermal energy, and water can act together to provide a potential environment supporting life on a moon or planet.

**PREPARATION:**

Have all materials prepared to hand out after an initial pre-assessment. Prepare a pre-assessment with students on their understanding of celestial bodies orbiting larger planets. Check for:

- understanding that planets can have multiple satellites,
- understanding that these satellites interact and influence each other,
- comprehension that satellites can share similar geologic and chemical processes as Earth.

**ENGAGE:**

Have students work in groups of four to answer:

How are these pairs of objects and systems different?

A) Moon and B) planet
A) Moon orbits and B) Planetary orbits in our solar system

Teacher Asks: “Do other planets have moons? Is it possible to have more than one moon? No moons at all? Are any of these moons different from ours or are all moons the same?”

Give visual examples of planets with multiple moons and descriptions of their orbits.

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Mars:
http://www.edb.utexas.edu/missiontomars/pdf/ss3.pdf

Saturn:
http://www.wingmakers.co.nz/images/saturns-moons-in-orbit.jpg

Pluto:
http://www.pbs.org/wgbh/nova/space/pluto-files.html

Teacher Suggests: "One way you might define a planet is that it ought to have a moon. But, of course, Mercury and Venus don't have moons, and guess what? Tiny little Pluto does. In fact, it has three.

One of those moons, Charon, is so large compared with Pluto that they both orbit a point in space in between them, which might make you wonder which one is the planet."

Introduce Europa as one of Jupiter's moons and ask if any students are familiar with it and why it is important. Explain that Europa might have an ocean underneath a layer of ice, and that we are studying how liquid water may exist there.

Ask students where Earth gets its heat (solar and internal). Show how far Jupiter is from the sun and ask which of those two forms may be more prevalent on Europa. Then ask students how internal thermal energy is produced there and write hypothesis on the board.

**EXPLORE:**

1. Have each student take one sheet of white paper and measure its center using a ruler. Mark the center with a dot.
2. Measure out 1 ¾ inches from the center and use a protractor to create an orbit. This will be labeled "Io". Measure out 3 ½ inches from the center. This will be labeled "Europa". Measure out 7 inches from the center. This will be labeled "Ganymede". Explain that these are three of Jupiter's moons. Ask students if they think these moons interact, and how.
3. Have students cut the paper into a circle around the outer orbit. Using stickers, have students place the moons on their orbits in any position, EXCEPT for in a line.
4. Cut a direct line from the outside of the paper round to the center hole. Now fold the paper so that the round becomes a cone. Tape the cut sides shut.
5. Put the small ball at the bottom of the cone.
6. Show video from the Elegant Universe:
   http://www.youtube.com/watch?v=4yyb_RNJWUM
   From 6:30 to 7:23
   Invite students to to think about objects in space sitting on a plane, or blanket. The more mass an object has, the more it "pulls" down on the blanket. This in turn creates a stronger gravity force on objects around it.

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7. Have students look at the orbits in their cone from above and describe what shape the orbits are in. [circles]
8. Now have the students peel off the stickers and place all the moons in a straight line. Have the students slightly push in on one side of the cone. Teacher asks: “What do you notice happening to the shape of the orbits?” [ovals]
9. Explain how when the planets are in a straight line, they have an orbital resonance. The other moons are also having a "pull" on the blanket and change the orbit just slightly.
   Show the animation and have students look for when the moons are in the line.
   http://upload.wikimedia.org/wikipedia/commons/8/83/Galilean_moon_Laplace_resonance_animation.gif
   Show lined orbits and how they become slightly oval shaped.
   Lined up: http://www.physast.uga.edu/%7Ejss/1010/ch11/11-19b.jpg
   Oval shaped: http://www.physast.uga.edu/%7Ejss/1010/ch11/12-22a.jpg

Have students write down on the outside of their cone "resonant orbits" and keep the stickers in a line. Also have them write that this happens ~7 days.

Return to the image of the moon in the oval form, normal and then stretched. Ask students why they think this could be important and predict what this is doing to the moon.
Now hand have students make a graph on a sheet of notebook paper labeled "Tidal Flexing and Thermal Energy". The graph should include an X axis that says "Condition" and a Y axis that says "Temperature".

1. Hand out a rubber band to each student. Have them write down under Condition "normal".
2. Have each student hold the rubber band as minimally as possible, and WITHOUT STRETCHING, and place it on their forehead. Repeat multiple times until student has a confirmed answer as one of the following: cooler, same, warmer than forehead. NOTE: Students may need fresh rubber bands for each time they playce it on their forehead because their skin will warm the rubber bands up when they place them there.
3. Students will then stretch the rubber band and quickly place on forehead. For Condition, write "stretched". Repeat multiple times until student has a confirmed answer as one of the following: cooler, same, warmer than forehead.
4. Afterwards, have students compare their results. The consensus should come to a warmer temperature when the rubber band is stretched. Explain tidal flexing as the phenomena of stretching and returning to normal shape. The teacher may need to re-illustrate this point using the images listed under Step 9.

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**EXPLAIN :**

- What happened to the rubber band when it was stretched?
- What was the temperature of the rubber band when it was "normal"?
- Could this explain what is happening on Europa?
- What causes Europa to be stretched like the rubber band?
- What would happen if Europa wasn't being stretched?
- Why is internal thermal energy important for a planet with ice?

**ELABORATE**:

- Show video of Earth's internal convection: http://www.youtube.com/watch?v=ryrXAGY1dmE
- Explain how internal thermal heat produces hot mantle to interact with the surface. If Europa is covered in ice, could internal thermal energy be acting the same way? Why is this internal thermal energy important for creating a livable environment?
- Show video of Dr. Britney Schmidt: http://www.youtube.com/watch?v=rN3oLVGht0o&feature=relmfu

**EVALUATE**:

Have students:

- Draw out Europa's orbit when it is in resonant orbit. Show Europa in four different positions around Jupiter and label it's respective temperature and shape.
- Hypothesize what is happening under the ice of Europa's surface and draw how the internal thermal energy is interacting with the ice. Write a short paragraph explaining how tidal flexing is important.