LESSON 14: SPINNING BALL OF WATER IN SPACE

Astronauts on board the Space Station set a glob of water that was hanging in the air there to spinning. Then they blew some air bubbles into it. You may find a video of the activity in either of these two places:

http://www.youtube.com/watch?feature=endscreen&v=BxyfiBGCwhQ&NR=1

http://wn.com/water_sphere_in_microgravity

GRADES K-2

Because things do not "feel" gravity in space*, there is no gravity to make the water fall down and so it floats in the air. The surface tension of the water causes it to form itself into a ball. This can make eating and drinking very difficult if people are not careful.

Surface tension is a force on the surface of a drop of water that tends to pull it together. On the earth, one can see surface tension at work when using a water fountain or when pouring water slowly out of a pitcher; it is the surface tension that causes the stream of water to break up into individual drops.

The amount of surface tension on the surface of a body of water depends, among other things, on how clean the water is and what impurities it contains. For example, soap in water reduces the surface tension significantly. You can illustrate this in a classroom rather easily. You begin by pouring some water into a clean glass or pan. Let it settle for a few minutes and then sprinkle a tiny amount of powder (baby powder will work) onto the surface of the water. The surface tension on the surface of the water at any given particle of powder pulls equally hard in each direction, causing the powder to sit still. Now put a small droplet of dish soap on the tip end of a spoon (or a fork tine, eyedropper, toothpick, or anything handy) and just barely touch the tip end onto the surface of the water. The surface tension in the direction towards the spoon is suddenly much lower because of the soap and so the particles of powder will move away from the spoon.

If the astronauts were to add some soap to the spinning ball of water on the Space Station, it would still hold together; soapy water still has some surface tension. It would be much flatter, though, than the ball of water shown in the video.

GRADES K-2 (CONTINUED)

PLEASE NOTE that things not “feeling” gravity in space is not the same thing as there being no gravity there. The earth's gravity does extend into the space around the earth where the Space Station is orbiting.

As the Space Station orbits the earth, it is always “falling” down toward the center of the earth; it manages to stay in orbit because it is moving sideways so quickly that the earth's curvature makes the surface of the earth “fall” away from the Space Station just as quickly as the Space Station falls down towards the earth. And because the Space Station (and everything aboard it) is always “falling” down, it does not “feel” any effects of the gravity there. This point will probably be lost on the children, but I would like to make sure that the teachers understand the difference.

GRADES 3-5

In addition to the Grades K-2 notes, we see in the video that there are air bubbles in the middle of the water bubble. The air is a gas; the water around the bubbles is a liquid. (Can you see any solid things in the video? There are a few--starting with the objects in the background, although you cannot see them clearly. Other solid objects are the tea leaves and the fragments of the antacid tablets in the spinning ball later in the video.)

The difference between a liquid and a solid is that a solid object has a definite shape while a liquid will change its shape to fit whatever container you pour it into. In space, a liquid will pull itself into a ball, but it is still very easy to make waves along the surface of the liquid.

The difference between a liquid and a gas is that a gas will expand to fill any size of container while a liquid has a definite size, but this is harder to explain and may be left out.

GRADES 6-8

In addition to the earlier grades' lesson, we can see that the ball of water is spinning around an axis. Because it is spinning, the water in the ball “feels” a centrifugal force. The surface tension of the water provides the centripetal force that counters this centrifugal force, just as the tension in a string counters the centrifugal force of a rock in a sling as one swings it around.

Injecting air bubbles into the rotating sphere of water causes them to “float upwards” towards the axis of rotation. The force on the bubbles is their buoyancy as the centrifugal force pushes the denser water away from the axis. (The commentary in the video says that it is the angular acceleration that pushes the bubbles toward the axis of rotation; this is incorrect.)

GRADES 6-8 (CONTINUED)

One can relate what is happening to the possibly familiar question of what happens to a helium balloon in a moving car when the car goes around a turn.

The helium balloon is lighter than the air that it displaces and so floats at the ceiling of the car; as the car goes around the bend, the buoyancy of the helium balloon causes it to move towards the inside of the turn. The same phenomenon is pushing the lighter air bubbles towards the axis of the rotating sphere of liquid in the video.

GRADES 9-12

In addition to lessons from the earlier grades, we note that a glob of water that is not spinning will form itself into a sphere because of surface tension. In fact, people used to make ball bearings by creating drops of molten metal at the top of a tower and letting them solidify as they fell. If the sphere rotates, the centrifugal force on the water makes the shape of the sphere extend into an ellipsoid. (This is much like rotation of the earth deforming the shape of the earth to be an ellipsoid, but with the difference that the overriding force is caused by the surface tension instead of gravity.) One can draw a cross section of the sphere (or ellipsoid) and draw contours of constant pressure as being a constant distance from the axis of rotation. If the cross section is "through the poles," the contours will be straight lines parallel to the axis; if the cross section is "through the equator," the contours will be circles around the axis. The final configuration of the air bubbles forming a cylinder around the axis of rotation confirms this.

Very advanced students can draw a diagram of a cross-section of the rotating ellipsoid and set up a force balance diagram that will give the equation for the ellipsoid. It would be interesting to confirm that the shape of the rotating ball is in fact an ellipsoid; I have not done this myself but I am sure a sufficiently-interested and -advanced student would be able to do this. If anybody is sufficiently interested, please have him or her contact us. There is probably a technical paper available for the first person to derive this and write it up for a conference.