Paperclip Diver

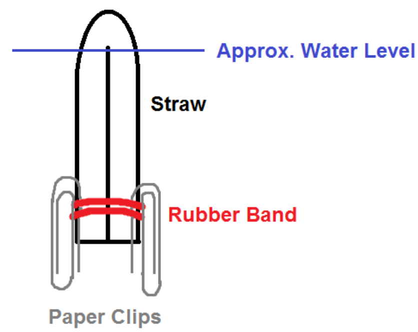
1) Trim a straw to be about 1/2 to 2/3 of its length and bend it in half.

2) Wrap the rubber band around the bottom of your diver (don’t make it too tight).

3) Attach paper clips to the rubber band to weigh your diver down. It should just barely float upright in water. Use the cups of water to test.

4) When your diver is properly weighted, place it in a plastic bottle filled with water (either a standard water bottle or a 2-liter soda bottle). Place a cap on the bottle.

5) Squeeze the bottle! Your diver will sink! When you release, it will rise again!



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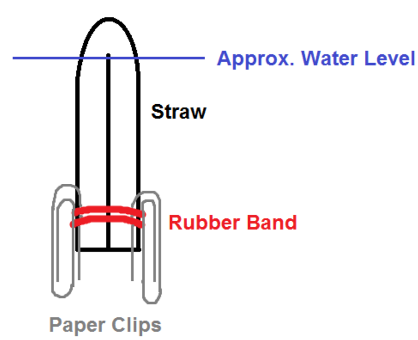

Buoyancy

The Archimedes Principle: "The buoyant force of an object is equal to the weight of the water displaced."

When we consider how something floats, there are two things to consider:

Gravity: The force that pulls things down toward the Earth.

Buoyancy: The force that makes things float.

The formulas for these two forces are:

Gravitational Force = (Mass of Object) * (9.8 meters per $seconds^2$)

Buoyant Force = (Volume of Object) * (1000 kilograms per $meter^3$)

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1) What happens to the volume of the air bubble in the paperclip diver when you squeeze the bottle?

2) What does this do to the Buoyant Force on the diver?

3) The USS *Enterprise*, the world's first nuclear-powered aircraft carrier, weighs 8.6×10^7 kilograms (= 94781 tons = 189,562,000 lbs). It is built of steel and aluminum. How does it (or any boat, for that matter) float when it weighs so much?

4) The mass of my toy boat is 1.5 kilograms. Its volume is .008 $meters^3$. Will my toy boat float?

Teacher Notes:

- The given formula for buoyancy is not quite accurate, but used for simplicity. It applies only to objects **completely submerged** in **water**. The general formula is:

Buoyancy = weight of displaced fluid = (volume displaced)*(density of fluid)

- When the bottle is squeezed, the air bubble trapped in the top of the straw will shrink due to the increase in pressure. This will reduce the volume of the bubble, shrinking the buoyancy of the diver, causing it to drop to the bottom of the bottle. When released, the bubble returns to its normal size and the diver floats once again.

- The important (and occasionally confusing) key to buoyancy is that it doesn't matter what the diver/boat/object is made out of. All that matters is the volume and the mass. If you had 2 cubes of the exact same volume and mass, one made of solid plastic, one made of hollow steel, then when placed in water, they will behave exactly the same. The buoyant force will be the same (because of the same volume), and the gravitational force will be the same (because of the same mass).

- Water is heavy (try lifting a ten gallon bucket full of water). And while steel is even heavier, the majority of a ship's volume is air. So even massive ships that weigh thousands of tons float because the sheer volume of water they displace has an equivalent weight.

- If you really want to mess with your students' minds, you can construct a reverse Cartesian diver (one that rises when the bottle is squeezed) by using a differently shaped bottle. Bottles with odd shapes (like some squeeze ketchup bottles) will **increase** in volume when squeezed (try squeezing in the wider direction instead of the "usual" way). This reduces pressure, enlarges the bubble, and therefore increases buoyancy. So just weight your diver to just barely sink and when you squeeze your bottle it will rise to the top.

- See the lesson on Density and Buoyancy on the website for more activities and science related to these phenomena.