Single Cartesian Diver

P1-2000

BACKGROUND:

We are so accustomed to the invisible air surrounding us that we sometimes forget that air has mass and weight, occupies space, and exerts pressure. Each of these properties are directly related to the concept of air *density*. Below is a table with the densities of various gases.

Densities of Various Gases

Gas		Density (kg/m^3)*
Dry air	0°C	1.29
	10°C	1.25
	20°C	1.21
	30°C	1.16
Helium		0.178
Hydrogen		0.090
Oxygen		1.43

* At sea-level atmospheric pressure and at 0°C (unless otherwise specified) (Hewitt, 285)

(Under standard conditions, liquid water has a density of 1,000 kg/m^3.)

Let your students calculate the number of cubic meters in your classroom and multiply by 1.21 kg/m^3. They may be surprised at how much the room's air weighs. (Hewitt, 287)

Air density simply reflects the relation between its weight and the amount of space it occupies. Decrease the volume and the density goes up because the same amount of mass is being squeezed into a small area. Increase the volume and the density goes down as the mass is spread over a larger area.

Air density is also related to air pressure. A scientist named Robert Boyle discovered this relationship and it is now called *Boyle's Law*. The law simply states that if the density goes up or down, then the pressure goes up or down with it. Conversely, if you apply pressure to a gas by, say, pushing it into a smaller container, the density goes up. If you release pressure, the density goes down.

Air pressure and density can help explain the barometric property of air. When two air pressures meet, they push on each other (they are forces, after all). The two pressures will push on each other until they balance. For example, your windows don't break because the air pressure on one side is equal to the air pressure on the other. But, get caught in a tornado or hurricane and there can be great difference in air pressure shattering the window and balancing the pressure. There is another example: a classic physics demonstration in which an aluminum can is partially vacuumated by heating the air and a little water inside. When enough air has been forced out of the can, it is capped and allowed to cool. As it cools the can is crushed. By what? The pressure inside is small (due to it's low density) compared to the heavier atmospheric pressure outside. The can is crushed until the density and pressure inside equal the density and pressure outside.

Buoyancy rules are also related to density. The buoyancy law states that an object surrounded by a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object. In the case of a boat, as long as the boat weighs less than the total weight of the water that it displaces, it will float. Or, in terms of density, the boat can not be more dense than the water.

PRODUCT INFORMATION:

Buoyancy laws apply to the cartesian diver as well. As long as the combined density of the pipette, rubber cover, steel mass, and the air/water mixture inside are less than the density of the water it displaces, it will float. These cartesian divers were designed with just enough weight to bring it very close to the point of sinking, but not quite. In fact, it floats quite well. But as soon as outside pressure is exerted, the air inside compresses. The volume of the air decreases, becomes denser, and more water is pushed into the pipette. The diver now is too dense to remain buoyant - hence, it sinks.

ACTIVITIES:

1. The diver usually requires a bit of water inside the pipette to float. To find out exactly how much is mostly a trial and error game. First, try this: Fill a clear glass with water. Get water inside the diver by squeezing the pipette and releasing so that it sucks up water. Then drop the diver in the glass. Does it float or sink? If it sinks to the bottom, the diver contains too much water. If it falls over and lays on top of the water, it needs more. The water level is just right when it stands upright but is mostly submerged. After a little experience, you will be able to suspend the diver at different depths in the glass by controlling the water level.

2. Fill a 2-liter bottle all the way to the top with water. Place the diver in the bottle with the correct amount of water contained inside of it (the steps in (1) can be done by trial and error now with the 2-liter by adjusting the water level until the diver behaves properly.) Put the cap on the bottle and squeeze the middle of the bottle. The diver should sink. When you release the pressure on the bottle, the diver should rise back up to the top.

3. Try demonstrating the above phenomenon without the squid rubber cover on the pipette (be careful not to tear the rubber when taking it off and putting it back on; see the last hint below.) This way, students can see the water level inside the pipette before, during, and after squeezing the bottle. To make it more visible, try using water with coloring in it. When the bottle is squeezed, the water level in the pipette goes up. Ask your students where all of the air goes? This demonstration requires students to understand the concept of air density.

HELPFUL HINTS:

- Make sure you fill the bottle to the very top with water.
- Use room temperature water when filling your bottle. Otherwise, as the water heats up or cools, it will affect the pressure in the bottle and the water level in the diver.
- The diver may sink on its own over time due to temperature and atmospheric pressure changes and gas coming out of solution in the water. To correct, first try opening the 2-liter bottle and releasing the pressure. If this doesn't work, remove the diver and readjust the water level as in step 1.
- Try not to leave the rubber squid in the water for a long period of time because it may start to deteriorate.
- If you decide to remove the rubber squid from the pipette, put a few drops of oil on the pipette before replacing. This will allow it to slide on easily and will help make a tight seal so that water doesn't get underneath.

RELATED PRODUCTS:

Arbor Scientific also sells a **Super Diver Kit** (P1-2000-01) which contains enough material to make thirty plain Cartesian Divers.

BIBLIOGRAPHY:

Conceptual Physics by Paul G. Hewitt. Pearson Education, Inc.