CARTESIAN DIVER

OVERVIEW

Students will create a Cartesian diver, which will act in some ways like a submarine. Students will adjust the amount of air and water in an inverted test tube (the Cartesian diver/submarine) to allow it to first barely float in a water-filled plastic bottle. Then, they will squeeze the closed bottle to create higher water pressure and cause the tube to sink. They will see that releasing the bottle will allow the diver to float again.

CONCEPTS

- Swimmers know that exhaling air from the lungs will cause them to sink because their average density will be greater than that of water. Conversely, inhaling will allow most people to float since their average density will be less than that of water.
- Adding salt to the water increases the density affecting the swimmer and the Cartesian diver.

MATERIALS

- Empty 1890 ml (64 fl. oz.) plastic fruit juice bottles and the tops (bottle opening must be wide enough to place test tubes inside using your fingers).
- Glass test tubes (somewhere in the size range 16 by 100 mm to 20 by 150 mm)
- Flexible straws
- Eye Droppers (5 ml)
- Table salt
- Rubber bands
- Water
- Kitchen pans
- Metal clothes hangers or other suitable material
- Wire cutters (preparation section only)

PREPARATION

The teacher should try this beforehand. The most difficult part is adjusting the water level in the test tube. Flexible straws must be able to be bent into a J-shape and held there with a rubber band. Blowing air from the lungs through the straw may be too coarse so try squeezing air from the eye dropper into the straw. A lot of water will likely be spilled so use a pan under each bottle. Rubber stoppers can be used instead of bottle caps.

Use wire cutters and pliers on the coat hangers to form J-shaped pieces at least 5 cm (2 in) longer than the test tubes.

PROCEDURE

Engagement

Most students have dived into swimming pools and used their arms and legs to rise to the surface. They may have also floated on the surface by holding a deep breath. This happens because the average density of the human body is very close to that of water so that the buoyant force upward, equal to the weight of the water displaced, just balances the swimmer's weight. Similarly a Cartesian diver (named after the French scientist Descartes), such as the glass test tube in this experiment (density 2.5 times water), will barely float with the right amount of air added.

Activity

1. Fill the plastic bottle with water.
2. Place the bottle on the pan to catch any spills.
3. Fill the test tube with water.
4. Place a finger over the open end of the test tube, invert the tube and place in the bottle, continuing to hold the test tube so it does not sink.
5. Place the J-end of the coat hanger under the lip of the test tube to keep it from sinking.
6. Place the flexible end of the J-shaped straw under the lip of the test tube, under the water [Fig.1].
7. Force air into the tube using the straw under the lip of the test tube.
8. Test for flotation each time air is added by removing the straw and lowering the tube using the coat hanger piece.
9. Repeat steps 6-8 until only 2-3 mm (1/8 in) of the tube is above the water. Start over at step 3 if too much air is added.
10. Remove the straw and the coat hanger, fill the bottle to overflowing, and screw the top onto the bottle.
11. Firmly squeeze the sides of the bottle, the diver (test tube) should slowly sink [Fig. 2]. If not, open the bottle and return to step 3.

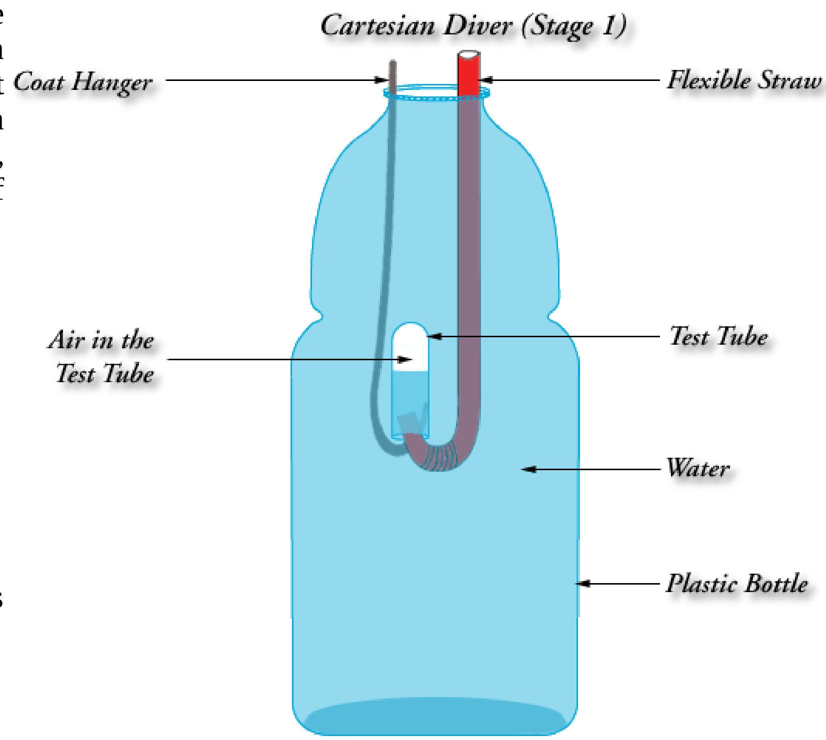

Figure 1.

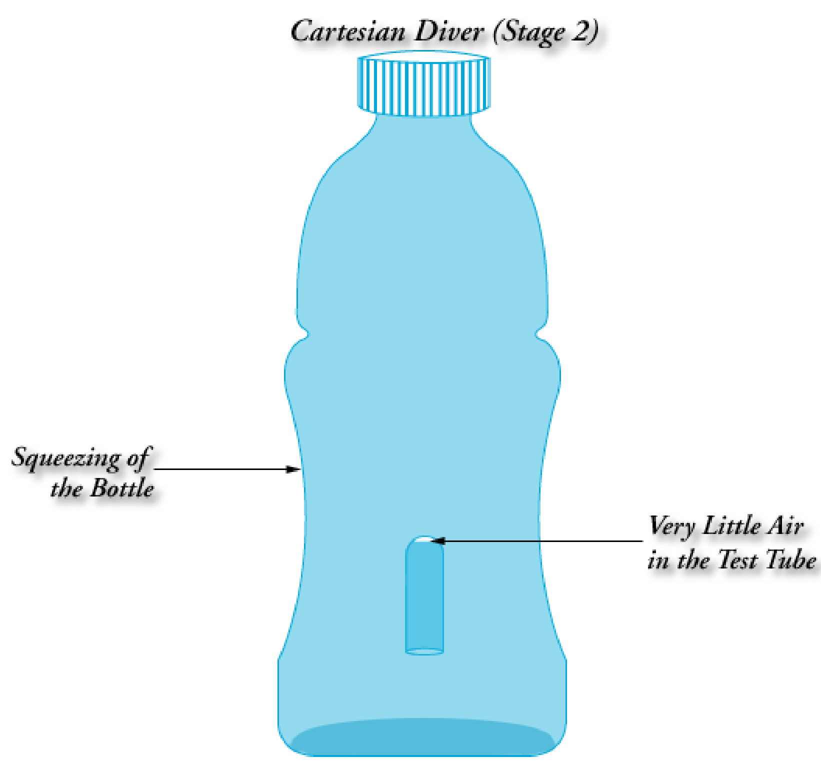

Figure 2.

12. Stop squeezing the bottle (the Cartesian Diver tube should return to the top of the bottle). Strike the bottom of the bottle lightly if the diver stays down.
13. Try to position the diver halfway between the top and bottom by varying your pressure on the sides of the bottle.
14. Repeat steps 11, 12, and 13, this time noticing what happens to the air in the test tube again as you squeeze the sides of the bottle. Does the air take up more room at the top or the bottom of the bottle? (It may be difficult to tell because the change will be small. If you cannot tell for sure, speculate on which should be true. Why?)
15. Carefully remove the bottle top and add up to 20 ml (4 tsp.) of table salt to increase the water density.
16. Replace the lid and squeeze the sides of the bottle. Can you get the diver to go to the bottom? Is it easier or more difficult now?

Explanation

Squeezing the closed bottle increases the water pressure throughout the bottle, forcing more water into the test tube and compressing the air in the test tube. These effects increase the average density of the tube and cause it to sink. The pressure at the bottom of the bottle is about 1% higher than at the top.

Adding salt to the water increases the density of the water. This makes it more difficult for the diver to go down.

Submarines are a large scale example of a variable density aquatic object. Submarine ballast tubes use compressed air to take in or expel water as needed. When in motion, adjusting horizontal planes at the front and rear will force the submarine up or down.

Extension

This experiment can also be done using a 2 liter plastic bottle and condiment packets. You will probably need to test a variety of condiment packets to find one that will float when you aren't squeezing the bottle and will sink when you do. There is a small air bubble inside each condiment packet that will compress in size when the plastic bottle is squeezed. This will cause the packet to sink.

Source

San Juan Institute Activity Series,
Little Shop of Physics (Colorado State University)