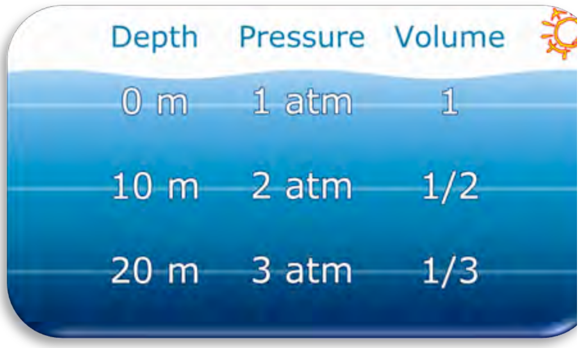
Sink or Float: A Buoyancy Experiment



Dive Science: At the surface there is 1 atmosphere of pressure, every 10 meters there is another atmosphere of pressure, which means the volume of the air in your lungs halves every 10 meters as you descend

FOCUS

Physics , dive science

GRADE LEVEL

Primary (UK); 3 -5 (US)

FOCUS QUESTION

What are density, pressure, buoyancy and volume and how do these variables change if one of them increases or decreases?

LEARNING OBJECTIVES

Students learn about the properties of density, buoyancy, pressure and volume, all variables of Boyles Law. Students will use applications of Archimedes' Principle and Boyle's Law. Additionally, students will create their own experimental models, manipulate, observe, predict and communicate results.

MATERIALS NEEDED

- Empty 2L soda bottles with caps
- Water
- Eye dropper/small disposable pipette
- Paperclips
- Balloons
- Packing peanuts
- Fishing weights
- Neoprene

AUDIOVISUAL MATERIALS NEEDED

Diving science movie Explorer 2012

TEACHING TIME

One 45-minute period

SEATING ARRANGEMENT

Groups of two students

KEY WORDS

Mass- measure of the amount of matter in an object.

Density- the mass per unit volume of an object.

Volume- The amount of space occupied by a three-dimensional object or region of space

Buoyancy- is a force exerted by a fluid that opposes an object's weight.

Pressure- *stress* that is exerted *uniformly* (or the same way) in *all directions*. Pressure is measured in units of *force* applied per unit of *area*.

Temperature- is a measurement of the amount of *heat* a substance contains. There are three major **temperature** scales: Fahrenheit, Celsius, and Kelvin.

Archimedes' Principle- Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object

Boyle's law -describes the relationship between the absolute pressure and volume of a gas, if the temperature is kept constant within a closed system. The law states that when one (volume or pressure) doubles the other halves.

Buoyancy Compensation Device- a piece of diving equipment that controls a diver's overall buoyancy, allowing a diver to achieve neutral buoyancy while remaining at a constant depth. The device, which looks like a vest, uses air from the dive cylinder (SCUBA tank) to inflate and deflate the vest for the proper amount of buoyancy.

BACKGROUND INFORMATION

Pressure and volume are key concepts required to understand many oceanographic principles. Scientists at BIOS use pressure, volume, and temperature every time they deploy the CTD off of the R/V Atlantic

Explorer, and we will use those same principles as we investigate the Cartesian Diver experiment today.

As you descend in the water, you typically feel pressure in your ears and sinuses. This is because the water at depth exerts a greater pressure on your body's air spaces than water at the surface. Now that I've repeated the most important point of a PADI Discover Scuba Diving course, let's investigate why this happens.

Pressure, volume, temperature, and number of moles of gas are all connected by an equation called Boyle's Law:

$$PV=nRT$$

Where P stands for pressure, V for volume, n for number of moles of gas, T for temperature and R is a constant. Similarly, the volume of a balloon of air at one pressure can be compared to that same balloon at a different external pressure by the equation:

$$P_1V_1=P_2V_2$$

This means that if I start with air in a balloon at pressure=1 volume=1, and bring it down to pressure=2, then volume will be ½ of the original volume. So if we raise pressure we, in turn, lower volume.

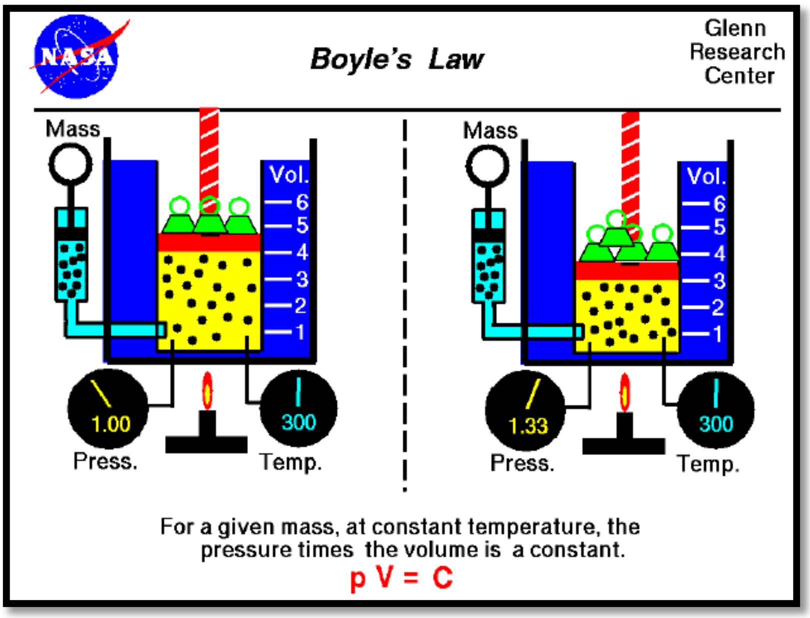
Similarly, if I were to increase the volume of a balloon filled with air, I would subsequently lower the pressure of air in that balloon.

When thinking about this experiment, consider these concepts and see if you can apply them to explaining why your structure sinks when you squeeze the bottle (and lower the volume). Make sure to remember other relevant topics such as Archimedes' Principle, which states that an object will float if it displaces a weight of water greater than a weight of itself.

As an extra trick, think about what would happen if you rose the temperature of the water in the 2L bottle with the structure floating at the top. The following equation might be helpful:

$$\frac{P1V1}{n1RT1} = \frac{P2V2}{n2RT2}$$

Now that you're a Boyle's Law expert, you know the basic principle from which much of oceanography sprouts from! Go have fun with your



Cartesian Diver!

LEARNING PROCEDURE

Prelab reading

http://www.cosmolearning.com/videos/boyles-law-demo/

http://www.grc.nasa.gov/WWW/k-12/airplane/aboyle.html

Procedure:

Demonstration:

- Before class, fill a disposable pipet with enough water such that it is just positively buoyant (so it just floats).
- When students are present, place that disposable pipet in a 2L soda bottle filled almost all the way to the top with water.
- Have students note that the pipet floats.
- Then squeeze the bottle (reducing its volume) and watch the pipet sink to the bottom of the soda bottle.
- Ask students to generate hypotheses about why this happened, and write them on the board.

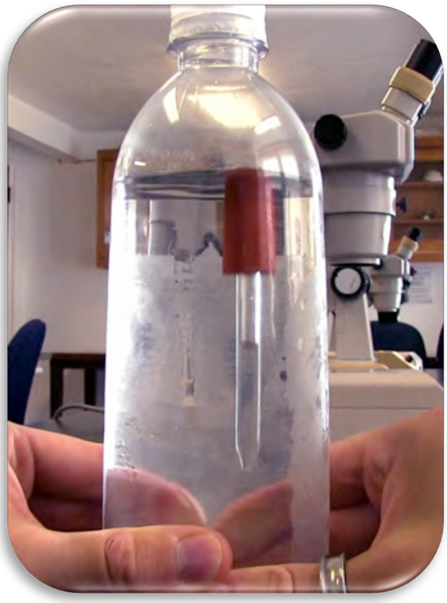


Figure 1: Pipette floats at surface (Note: you can see the airspace is a little less then half the dropper. Now, squeeze!

Figure 2: The increase in pressure decreases the volume of air in the pipette and this causes the pipette to sink

Making a neutrally buoyant pipette

- With a plastic pipette remove the end with scissor
- Insert a fishing weight into one and secure
- By adjusting the amount of air inside the pipette you should be able to make it neutrally buoyant

Students' Construction:

- With available materials, instruct the students to build their own objects that will fit in a soda bottle.
- Explain that the students should create objects that just barely float—do not tell them why though.
- See accompanying YouTube video for examples of good structures, but let the students create Cartesian Divers of their own—it's fun!
- Record exactly what objects are used, and in what configuration they've been placed (drawings can be helpful).

Deployment:

- When a student has completed his or her structure, have that student hypothesize whether or not that object will float and why.
- Then, have the student place their structure in the soda bottle.
- If the object floats, have the student hypothesize whether or not the object will sink upon squeezing the bottle and why. If the object sinks, help the student remove the object from the bottle, and discuss what alterations can be made to make the object float.
- Instruct the student to cap and squeeze the bottle.
- Record any observations.
- If the object does not sink, discuss with the student what alterations can be made to have the object a little less positively buoyant, and sink when the volume of the soda bottle is lessened.

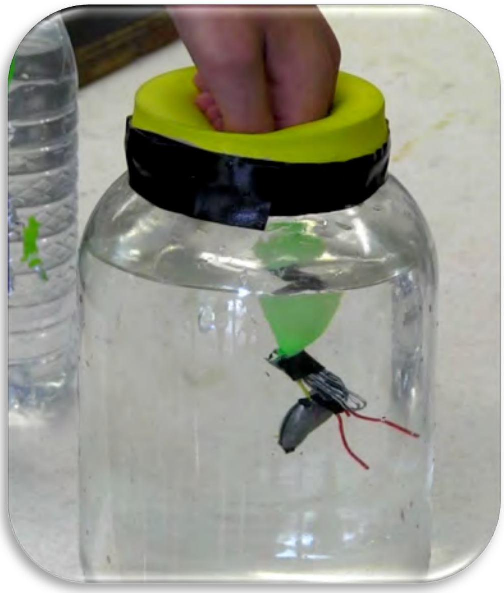


Figure 3: Cartesian diver at the surface; to make the diver sink you will need to decrease the volume of the balloon by increasing the pressure in the bottle

Figure 4: Cartesian diver; if you decrease the volume of the balloon and increase the pressure the diver will sink to the bottom. Much like a Buoyancy Compensation Device (BCD) allows a scuba diver to sink o float

Figure 5: For the diver to make it back to the surface you need to increase volume inside the balloon; this will decrease the pressure and the diver will come to the surface.

Further Discussion Questions:

1. Which one of your structures was most successful? If you had a successful attempt, explain the structure here. If you were not successful, discuss your structures and alterations that could have been made to make your structure more successful.
2. Why was it imperative that your structure be barely positively buoyant (float just a tiny bit)?
3. Upon squeezing the bottle, why did the structure sink? And then after releasing the bottle, why did the structure float again (make sure to note what the independent and dependent variables are)?
4. Explain how knowledge of 'pressure' and 'volume' are integral in full understanding of this experiment.
5. Do you think a structure that was successful in this experiment (in freshwater) would also be successful in saltwater (water with a greater density)? Why?
6. Do you think a structure that was successful in this experiment would also be successful in hot freshwater? Why?
7. Explain how the concepts explored in this lab connect to the accompanying videos.

i. Air bubble in a test tube 'shrinking' as a student descends to 33 feet (about 10 meters).
ii. Air bubble in a beaker vs. depth gauge.