CARTESIAN DIVER

GRADE: Middle to upper elementary as a demonstration. Middle school and up if students are construction it themselves.

GROUP SIZE: Can be done as a demonstration to launch discussion or can be made by students, individually or in pairs.

TIME: As a demonstration, it depends on the length of the discussion you would like to hold with your class. If students are to make them in pairs or by themselves, allow about 15 to 20 minutes (depending on which diver you have them construct) or so for construction and some time after for discussion or have your students do one of the extensions.

OVERVIEW: Construct a Cartesian diver to investigate and discuss the concepts of buoyancy, density, gravity, volume, and transmitted pressures. The concepts of speed and velocity can be incorporated.

MATERIALS:
For your tank:
- 1 clear empty two liter soda or half liter water bottle with cap

For your diver:
- 1 eye dropper
- 1 hex nut
- scissors
- water – enough to fill all of the soda or water bottles
- glass of water or other container to test out the initial buoyancy of diver
- paper towels – for wiping up spills
- tweezers – helpful for removing unsuccessful divers from bottles so that they can be readjusted
- waterproof trays (litter box, dish pan, cafeteria tray)– **optional** – one per diver being constructed, so that work can be performed over the tray and help keep water contained.

BASIC DESIGN:
Your tank:
- fill your bottle with water about 2 or 3 cm below the top so that there is a air space
- screw cap on tightly after inserting diver

Your diver:
- use the eye dropper as the primary component of your diver
- cut off most of the long, skinny tip of the pipet so that between ¼ to ½ inches is left below the dropper bulb

- use various objects (paper clip, hex nut, or brass fasteners) to weigh the opening of the pipet so that the dropper floats upright with the tip down.
- you will need to add some water to the pipet so that it just barely floats at the water surface

Alternate divers:
1. Unopened condiment packet such as a ketchup, mustard, soy sauce, or taco sauce packet. These usually contain a small amount of air (try to choose ones with at least one side that is clear so that you can see the air bubble inside). Each packet will have to be tested to see if it will work. If none of them work as divers as is, they can be weighed down a bit by adding staples to the bottom of the packet being careful not to make the packet leak.

2. Pen cap without a breathing hole. Straighten a paperclip, cut it in half, bend half into a U shape, add a small nut, tape the U to the pen cap to weigh it so it stands upright in the water.

3. Bulb of a glass eye dropper. This can be weighed down as in #2.

4. Half a drinking straw bent in half. This can be weighed down as in #2.

5. Cartesian Divers are available commercially from places such as:
Boreal Laboratories Science Kit - http://www.sciencekit.com/
Squidy Cartesian Diver -
http://www.physlink.com/estore/cart/SquidyCartesianDiver.cfm
Educational Innovations - www.teachersource.com

DISCUSSION:
The Cartesian Diver works because the pressure you impose on the closed system compresses the air in the bottle (water does not compress), including the air in the diver (whether it be in a condiment packet or in a modified eye dropper). The compression of the air makes it more dense because you are forcing the amount of air in the bottle (and diver) into a smaller space. In order for your diver to sink, the density of the diver needs to become greater than the density of water. The more dense the air becomes, the further the diver will sink.

EXTENSIONS/ADD-ONS:
1. Diver Relays
Calculate the average rate in cm/sec with which your diver rises and sinks
- Perform 16 'laps' (8 up and 8 down) with your diver.
- Record the time that each lap takes.
- With the diver resting at the top of the tank, measure the distance from the bottom of the diver to the bottom of the tank to determine the distance traveled per lap.

- Measure the distance traveled per lap, calculate the total distance traveled in 16 laps, total time for 16 laps, average time per lap, and average rate in cm/sec.
- Have various people perform these laps and compare average rates.

2. High Water, Low Water

How does the amount of water in your bottle affect the pressure needed to make the diver rise and sink?

- Change the amount of water in your bottle to see what volumes of water require more squeezing.

3. Holding Pattern

How well can you control your diver?

- From the bottom of the bottle, mark off each centimeter with a permanent pen.
- Randomly choose 3 numbers (this can be done by drawing numbers from a hat), try to make your diver descend to the first number and hold for 3 seconds, then rise or descend to the next number and hold for 3 seconds, then rise or descend to your last number and hold for 3 seconds.

4. Hot or Cold

How does temperature affect your set up?

- Either:
    set up a bottle with cold (ice) water and one with hot water OR
    set up one bottle and try it with warm water, then put the set up in the fridge

to see if/how temperature affects the amount of pressure needed to make your diver sink.

The following activities requires you to modify your diver or make a different diver

1. Sunken Treasure or Diver Rescue

Use your diver to pick something up from the bottom of the bottle

- Add an L shaped “hook” to the bottom of the diver. This can be made from a paperclip, brass brad, or twist tie.
- Add another dropper or other small object that sits on the bottom of the bottle that has a loop that can be hooked by the Cartesian diver. Brass fasteners with the ends bent into loops or hooks work well.
- Your goal is to sink the diver, hook the object on the bottom, and have your diver return to the surface.

2. Delayed Divers

Two divers in one bottle so that on command one dives and then the other in succession.

Make a second diver and add it to your bottle. They will need to be slightly different so that a different amount of pressure is required to make each diver sink.

3. Modified Diver
Seal the diver with a little bit of hot glue, super glue, or tape. Place the diver back into the bottle. What happens now when you squeeze the bottle?

RESOURCES:

Cartesian Diver Lesson Plans

1. NASA
http://media.nasaexplores.com/lessons/01-080/5-8_2.pdf

2. American Chemical Society
http://www.chemistry.org/portal/resources/ACS/ACSContent/education/wande/resourcechem/density/density15.pdf
Also on page 5 of the ACS's "Celebrating Chemistry"
http://acswebcontent.acs.org/celebrate_chemistry%5Ccelebrate_chem_05.pdf

3. University of Arizona
http://ag.arizona.edu/extension/water_wagon/pdf-files/cartesiandiverwaterwagon.pdf

4. Union College, NY – nice, simple instructions and explanation
http://www.union.edu/PUBLIC/KIDS/fsnCartesianDivers.htm

5. Physics – Internet Aided Physics Teaching (Italian)
http://www.iapht.unito.it/giocattoli/en/cartesian.html

Watch a Cartesian Diver Online

Movie/video of a working Cartesian Diver
http://physics.about.com/library/audiovisual/cartesiandiver.mov

Idealized/computer simulated - Cartesian Diver Applet
http://lectureonline.cl.msu.edu/~mmp/applist/f/f.htm

Websources for Chemistry/Physics Concepts

Boyle's Law: $P_1V_1=P_2V_2$
relationship of pressure and volume of an ideal gas (constant temperature and quantity)
Chemistry Department of Davidson College – Applet
Experiment with Graphing Volume vs Pressure
http://www.chm.davidson.edu/ChemistryApplets/GasLaws/BoylesLaw.html

Archimedes Principle, Displacement, Buoyancy
NOVA Online: Buoyancy Basics
http://www.pbs.org/wgbh/nova/lasalle/buoybasics.html
NOVA Online: Buoyancy Brainteasers
http://www.pbs.org/wgbh/nova/lasalle/buoyancy.html

Volume, Mass, and Density Exercise Online
http://www.nyu.edu/pages/mathmol/modules/water/density_intro.html

Pascal's Principle, Transmitted Pressure (Water does not compress, air does)
Physics Department of Davidson College – Applet
http://webphysics.davidson.edu/physlet_resources/bu_semester1/c23_pressure_pascal.html