3) Cartesian Divers: Experimenting with Pressure and Density

Background and Key Concepts
Density is the ratio of an object's mass to its volume. In other words, a dense object is heavy for its size. Water has a density of 1 gram per milliliter (1 g/ml). Objects that are less dense than 1 g/ml float in water, while denser objects sink. A Cartesian diver is an object whose density changes with pressure. A Cartesian diver floats in water at atmospheric pressure, and sinks when the pressure is increased.

Hawai'i Content & Performance Standards (HCPS III)
The following standards and benchmarks can be addressed using this lesson:

Science Standard 1: The Scientific Process: SCIENTIFIC INVESTIGATION: Discover, invent, and investigate using the skills necessary to engage in the scientific process.

Grade 3 Benchmarks for Science:
Benchmark SC.3.1.1 Pose a question and develop a hypothesis based on observations.
Benchmark SC.3.1.2 Safely collect and analyze data to answer a question.

Science Standard 6: Physical, Earth, and Space Sciences: NATURE OF MATTER AND ENERGY: Understand the nature of matter and energy, forms of energy (including waves) and energy transformations, and their significance in understanding the structure of the universe.

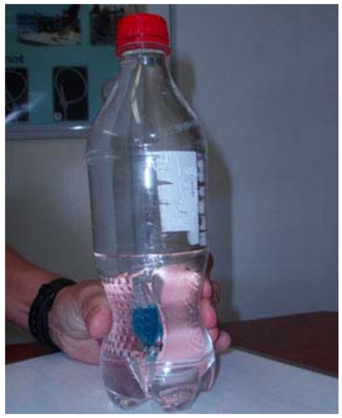
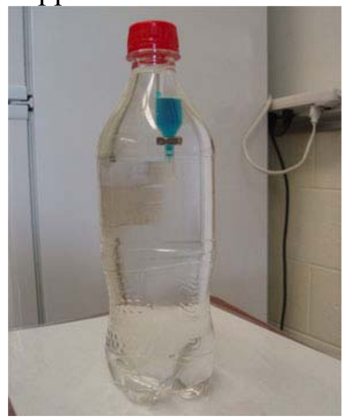
Grade 6 Benchmarks for Science:
Benchmark SC.6.6.6 Describe and compare the physical and chemical properties of different substances.

Materials
- 1 soda bottle (approx. 16 oz.) filled to the top with water
- 1 "Cartesian diver". You can purchase materials to make Cartesian divers through **http://www.teachersource.com**, but the "low-tech" option of using an unopened condiment packet works very well.


A Cartesian diver

Procedure
1) What do you think will happen when you put your Cartesian diver into a water-filled bottle? Write your hypothesis here.

2) Find out what happens by following these three easy steps:

Step 1: Place the diver in a water-filled soda bottle. Does it float or sink? 	Step 2: Squeeze the soda bottle. What does this cause the diver to do? 	Step 3: Release the bottle, and observe what happens. 

Explanation
At atmospheric pressure, the density of the Cartesian diver is approximately 0.8 g/ml, so it floats in water (because 0.8g/ml is less than 1g/ml). However, the Cartesian diver contains air. When you squeeze the bottle containing the diver, the air inside the diver gets compressed. (If you look closely, you can see this in the photo above illustrating Step 2.) This compression causes the diver to become more dense (say, 1.2 g/ml). Since the diver's density is now greater than 1g/ml, it sinks. Releasing the bottle returns the diver to its original density, so it floats again.

Extensions

1. Diver Relays -- Calculate the average rate at which your diver rises and sinks.
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?
3. Holding Pattern -- Try to make your diver descend to a given depth (mark it on the bottle) and hold there for 3 seconds.
4. Hot or Cold -- How does temperature affect the experiment?

Additional References:
Detailed description of the Cartesian diver activity and extensions:
http://www.usc.edu/org/cosee-west/MidwaterRealm/11CartesianDiver.pdf