Name: ____Date: ______________________ Class: ___________________

Cartesian Diver Worksheet Answer Key

Objectives

- To demonstrate understanding of Pascal's Law and Archimedes' principle.
- To use a Cartesian diver based on understanding of density, buoyancy and pressure.

Definitions

volume A measurement of the amount of space an object occupies.

mass A measurement of the amount of matter in an object.

density A measurement of the compactness of an object.

buoyancy The ability of an object to float in a liquid.

pressure A measurement of force per unit area.

Relationship Question

What is the relationship between volume, mass and density?

($\rho = m / v$)

Materials

- 1-liter bottle with cap filled with water
- bowl of water
- Cartesian diver

Procedure

1. Fill the bottle with water.
2. Using the bowl of water, adjust the amount of water and air inside the Cartesian diver so that it barely floats.
3. Place the Cartesian diver inside the bottle, making sure the bottle is filled to the top with water.
4. Screw the cap on the bottle so it is closed securely.
5. Squeeze the bottle and observe what happens to the Cartesian diver.

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Questions

1. What happens when the bottle is squeezed?
   The Cartesian diver sinks to the bottom of the bottle.

2. What happens when the bottle is released?
   The Cartesian diver rises back up.

3. What variables affect an object's ability to float?
   Density of the object, density of the fluid, surface area, pressure, volume

4. Use the variables you listed in question 3 to explain what is happening inside the bottle.
   Volume and density are inversely proportional.
   Density and pressure are proportional.
   When pressure is increased, the volume of the air decreases, and the density of the air increases; therefore, the object becomes denser than the surrounding fluid and sinks.

5. How do Pascal's law and Archimedes' principle apply to the Cartesian diver?
   Pascal's law states that a pressure applied at any point on a confined incompressible fluid is transmitted equally throughout the fluid. When the bottle is pressurized (squeezed) the pressure within the entire bottle and Cartesian diver is increased. Archimedes' principle applies because the Cartesian diver sinks when its density is increased.

6. Use the ideal gas law to explain the relationship between volume and pressure when the bottle is pressurized and explain why the Cartesian diver sinks.
   ideal gas law: $PV = nRT$
   Where P = pressure, V = volume, n = number of moles of gas, R = universal gas constant, and T = temperature
   The pressure in the bottle is increased, therefore the volume of air trapped inside the Cartesian diver decreases. As the volume of air decreases, water is taken up into the Cartesian diver which increases the density of the Cartesian diver so it sinks.

7. BONUS: Provide a few examples of how these principles are used in real-world science, engineering and/or technology.
   The concepts of Pascal's law, Archimedes' principle, the ideal gas law and the density-buoyancy relationship are important in science, engineering and technology applications such as fish physiology, scuba diving and various submersibles. Most boney fish have a swim bladder that models a lung and enables fish to control their buoyancy, or height in the water column, without swimming. In contrast, non-boney fish such as sharks, store lipids to maintain buoyancy or employ dynamic lift, which is the use of the pectoral fins for constant swimming to maintain buoyancy. Scuba divers use special equipment such as weighting systems, diving suits and buoyancy compensators to control their buoyancy. They use a weighting system so that they are negatively buoyant and sink by default; then they can then adjust their buoyancy compensator by adjusting the volume of gas in the bladder, which is taken from the diver's air tank or mouth. Submersibles enable the exploration of depths much greater than can be reached via satellite and shipboard technologies; these creative submersible and remotely operated vehicle (ROV) inventions enable people to explore very deep ocean communities and discover new species. Additional examples include a Galileo thermometer, high-pressure systems like autoclaves (laboratory instruments that sanitize lab equipment), deep sea drilling.