Cartesian Diver Activity

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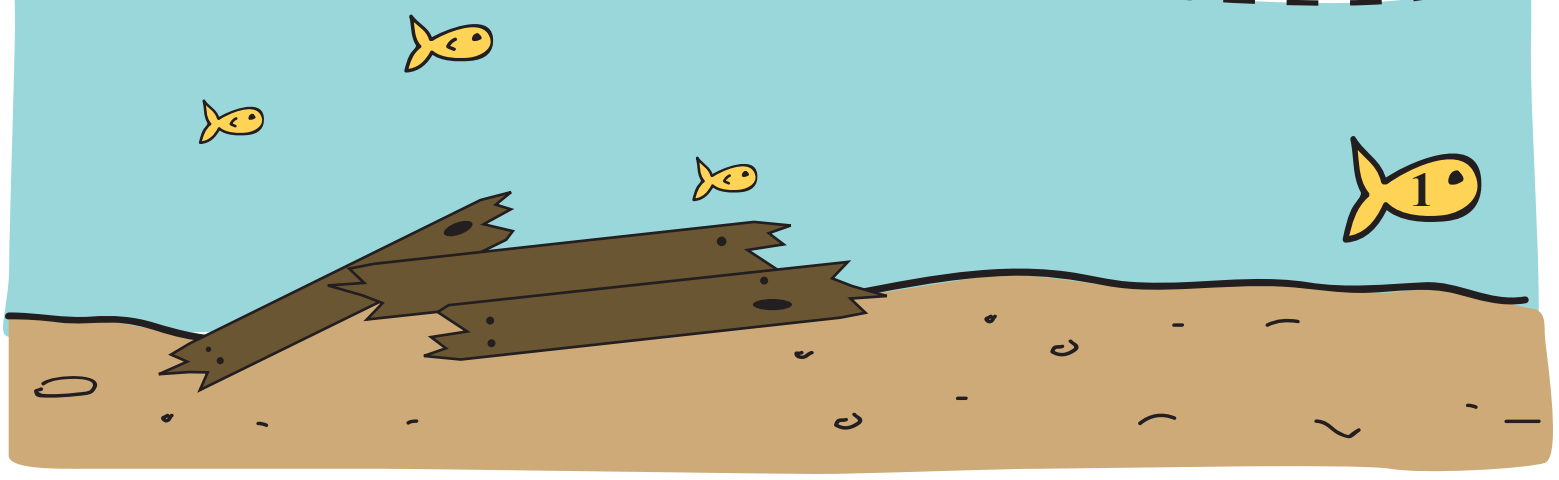
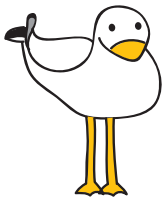


Cartesian Divers



Captain's Notes

Overview

In this activity, students will learn about pressure, density, compressibility, and buoyancy-some of the most important concepts to SCUBA diving. Students will create Cartesian divers which offer a hands-on demonstration of those ideas.

Difficulty/Grade Level

Easy-Moderate/Elementary-Middle School

Suggested Group Size

<30 students, individual or pairs

Time

Between 45-60 Minutes

One Size Fits All

Many concepts can be taught with the Cartesian diver. Concentrate on one or two simple concepts with younger students and the more complicated concepts with more advanced students.

Objectives

- *Create a physical representation of the concepts of pressure, density, compressibility, and buoyancy.*
- *Define pressure, volume, and density and describe the compressibility of air and water.*
- *Describe how a Cartesian Diver works.*
- *Describe how pressure, density, and compressibility relate to SCUBA diving.*
- *Describe Boyle's Law*

Skills and Strategies

- *Forming hypotheses*
- *Tangibly demonstrating abstract scientific concepts*
- *Exercising artistic and design creativity*

Materials (per student)

- *Small ball of modeling clay (1/4 oz, 3/4 in.)*
- *Pen cap (eye droppers and condiment packets like soy or taco sauce packets work as well with modification)*
- *Clear plastic soda/water/juice bottle*
- *Water to fill bottle*
- *Paint supplies/permanent markers*
- *How it Works handouts*
- *One fully assembled Cartesian Diver for teacher demonstration*
- *One or two small tubs of water for the class in which students can test the buoyancy of their divers*
- *Hand towels or paper towels*

For Extension Activities

- *Tape or marker*
- *Paperclip and light wire*
- *Salt water*

Preparation

1. *Set out materials on tables over protective tablecloths. Wait for student hypotheses before handing out the How it Works page.*

For Extension Activity

1. *Set out extra materials for extension activities.*

Procedures

1. *Demonstrate a working Cartesian Diver without explaining how it works. Pretend it is a magic trick or rub your hand in your hair and act as if it is powered by static electricity, secretly squeezing the bottle with one hand while pretending to control the elevation of the diver by pointing with the other.*
2. *Ask students to try to explain what they see happening.*
3. *Next, discuss the concepts of pressure, volume, density, and the compressibility of air and water. Hand out the How it Works page and read it as a class.*
4. *Have the students cap their empty bottles and squeeze them, then fill them with water and do the same to observe that air can be compressed while water cannot be.*
5. *Discuss how these concepts relate to SCUBA diving. See the How it Works section.*
6. *Next, instruct the students to begin creating their divers. They will have to discover by trial and error how much clay to use in order to make their diver just barely float. If pen caps have slots in the top, they must be filled with clay to ensure the cap holds water. The diver is simply a pen cap with a ball of clay attached to the tab to weight the cap and to hold it upright in water. Air will fill the cap when it is put in the bottle.*
7. *Finally, students will dry their bottles and decorate the outside of them with underwater scenery and watch their divers perform!*

Boyle's Law

Named for Robert Boyle, who published his findings in the 1600's, Boyle's Law describes the relationship between pressure and volume in a gas. The law states that pressure and volume for a gas are inversely proportional at a constant temperature.

Pressure x Volume = constant

Extensions

Neutral Buoyancy

For an extension activity, mark off three different distances from the bottom of the bottle with tape or a marker. Try to make your diver descend to the first mark, hold for 3 seconds, rise or descend to the second mark, hold for three seconds, then rise or descend to the third mark and hold for three seconds. This demonstrates the concept of neutral buoyancy. Neutral bouyancy occurs when an object has equal density to the water around it and hovers at a certain depth. Notice that being neutrally buoyant at different depths requires different amounts of pressure.

Rescue Diver

For an engineering challenge have students perform "diver rescues" by attaching a paperclip, bent in a "J" shape to the bottom of their diver. Then sink a small loop or hook of something like copper wire that the diver can hook to and lift to the surface. Make sure the object is light enough so that the diver can lift it. This is hard, and should only be attempted by older students.

Fresh Water Salt Water

To help understand some of the differences between fresh and salt water, try your diver in a bottle filled with water saturated with salt. Does it take more or less pressure to make the diver sink? What does this tell you about the density of salt water as compared to fresh? It will take more pressure to sink the diver. Use this extension to demonstrate that salt water is denser, and therefore makes objects more buoyant.

Discussion

What happens to the pressure as a diver goes deeper and deeper underwater? How does this affect the solid and liquid parts of a diver's body? The air spaces like the lungs? *The pressure increases because of the added weight of the water overhead being pulled down by gravity. The solid and liquid parts are mostly unaffected but the air in spaces like the lungs is compressed.*

Do you think divers breathe air that is higher in pressure, lower in pressure, or at the same pressure as surface air when they are under water? Why? *Divers must breathe air at higher pressures underwater because the pressure in the lungs must equal the outside pressure. As the outside pressure increases with depth, pressure of the air being breathed in must also increase. The lung volume must stay the same.*

In what other ways could you make a Cartesian diver? What elements are required? *Cartesian divers can be made with a variety of materials. They need to be slightly buoyant and must contain some gas that can be compressed when the container of water is squeezed to increase the pressure.*

How do you think divers control their depth underwater? *They use air. Divers adjust the air they have in their BCD (Buoyancy Compensating Device), or inflatable vests to balance out the weight of their tanks, weights and equipment. As they change depth, the air compresses or expands and so divers need to add or let air out of their vests as they descend and ascend.*

Reeling It In

Review the concepts of pressure, density, and compressibility. Remind students that everything around them is under a variety of balanced pressures. Diving throws these pressures out of balance and therefore special skills and technology required to be safe.

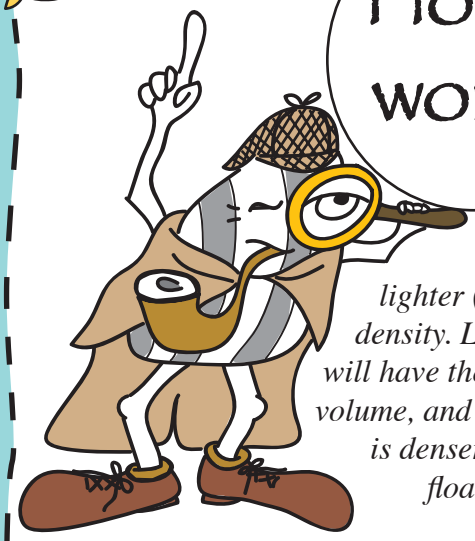
Vocabulary

***Pressure**: a force pushing on a surface*
***Volume**: how much space an object takes up*
***Density**: a measurement that puts together mass and volume in units of mass per volume.*
***Compressibility**: the capacity of a substance to be reduced in volume with increased pressure.*

Resources

1. Cartesian Diver: Lesson Plan. *Center for Ocean Sciences Education Excellence West. University of Southern California <http://www.usc.edu/org/cosee-west/MidwaterRealm/11CartesianDiver.pdf>.*
2. *Warner, Byron; Dilley, Kevin.* Cartesian Divers: Lesson Plan. *Cornell Center for Materials Research. <http://www.ccmr.cornell.edu/education/modules/documents/CartesianDiver.pdf>.*

Cartesian Divers



How it works

Whether an object floats or sinks depends on its density and the density of the liquid around it. Density is a measurement that puts together how much something weighs (mass) and how much spaceit takes up (volume; Density=mass/volume). For instance, if you inflate a balloon to the same size as a bowling ball, they both take up the same amount of space (have the same volume) but the balloon is much lighter (has less mass) than the bowling ball. The balloon therefore has a lower density. Looking at it the other way, if you fill a bag with ten pounds of leaves it will have the same mass as a ten pound bowling ball but it will have a much larger volume, and therefore a lower density. Water also has a specific density. If an object is denser than the same volume of water, it will sink. If it is less dense, it will float. A Cartesian diver is made so that extra pressure created by squeezing the bottle will change the density of the diver to make it sink. A concept necessary for understanding this is compressibility. Compressibility is the degree to which something can be squeezed to make it smaller. Everything is made up of tiny pieces of matter called molecules. Think of your classroom filled with your classmates. The people are like molecues. Compressibility has to do with how far the molecules are apart from each other. In a gas, the molecules are far apart, and therefore the gas can be squeezed into a smaller space by adding pressure. If there were only five people in your room, there would probably be a lot of room for them to move around in. They could be squeezed easily into a smaller space. Air compressors for filling balls or tires do exactly that. SCUBA air tanks are filled with a lot of air compressed into a small space so divers can breathe for a long time underwater. In a liquid or solid, though, the molecules are very close together and so compression is practically impossible. If your classroom was filled with 100 people, there proabably woudn't be much room to move around. If you can squeeze something that is solid or liquid into a smaller space, like a pillow for instance, it is because you are actually squeezing out the air inside it. The pen cap holds air inside, keeping the diver less dense than water making it float. When you squeeze the bottle, the extra pressure you create inside the bottle compresses the air in the cap, filling part of it with water. Since water is denser than air, the diver becomes denser overall, making it sink. The relationship between pressure and volume in a gas is described in Boyle's Law. This law states that pressure and volume are inversely proportional. In simpler terms, increasing pressure on a gas compresses it into a smaller space (as long as the temperature remains constant). The same gas under less pressure will take up more space.