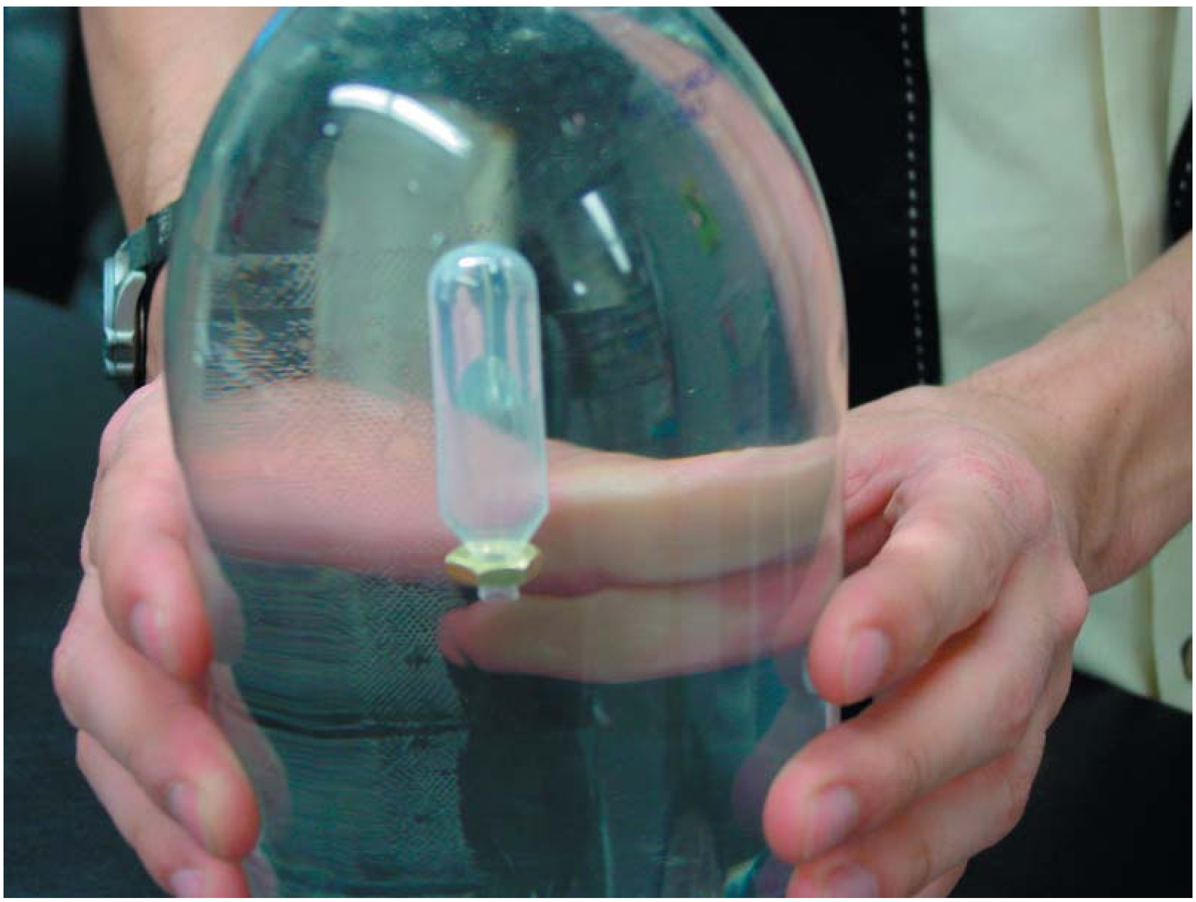
Cartesian Divers

A lesson by Byron Warner and Kevin Dilley



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BASIC DIVER

What you need:

*Pipettes
*Brass nuts
Scissors
2-liter soda bottles (with cap)
Plastic cup
Water

Step 1: Fit a brass nut over the open end of the pipette. Push and twist the nut toward the reservoir of the pipette until it is secured to the pipette.

Step 2: Cut off the remaining portion of the pipette with a pair of scissors. You have just made your diver.

Step 3: Fill the small plastic cup with water. Holding the open end of the pipette under water, squeeze out some of the air within the pipette, allowing water to be drawn into it.

*The pipettes and brass nuts can be purchased from Educational Innovations, Inc. at www.teachersource.com. The pipettes are listed as EI# PP-222 and the nuts are listed as CD-3, 12/24.

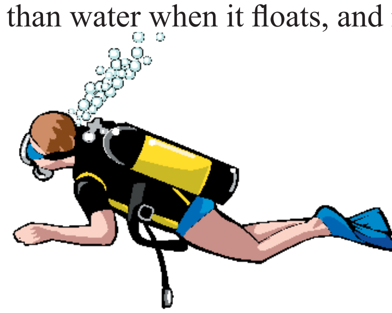
Step 4: Add or subtract water from the pipet until it just barely floats in the plastic cup.

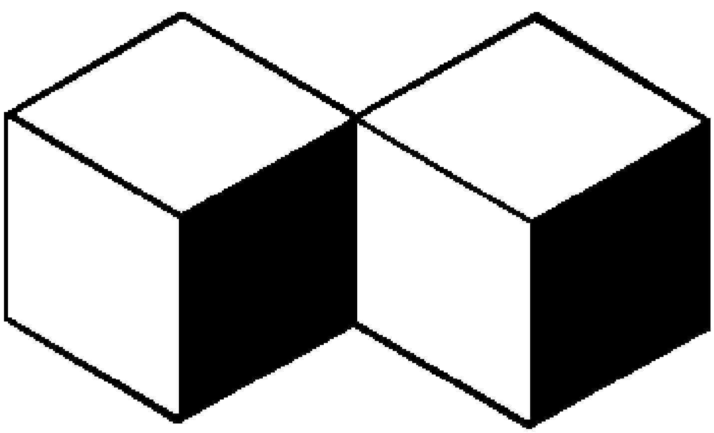
Step 5: Fill the 2-liter soda bottle with water to the very top, and drop in your diver. Screw the bottle's cap on tightly.

Step 6: Squeeze the bottle to watch your diver descend! Let go, and it will float back to the top!

DIVER DETAILS

The Cartesian diver works because of a few simple physical laws. First, all objects either float or sink because of buoyancy. The laws of buoyancy conclude that objects that are less dense than the surrounding fluid in will float to the top of that fluid. Conversely, objects that are more dense than the surrounding fluid will sink to the bottom of that fluid. Therefore, the diver is less dense than water when it floats, and more dense than water when it sinks.

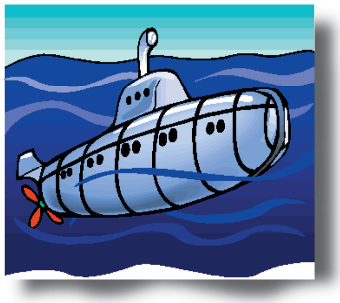




Density is mass per unit volume, or the weight of whatever is in these boxes divided by the amount of space they take up.

What exactly is density? Density is defined as mass per unit volume, or the amount of stuff you have in a given space. Helium has a low density because its atoms are small and are spread very far from one another. Lead, on the other hand, has a high density because its atoms are big and crammed in close together. In the diver, there are two different substances, water and air. As we know, Air has a very low density compared to water.

How does the diver's density change? When you squeeze on the soda bottle, you increase the pressure on the water in the bottle. This additional pressure forces more water into the diver, where the air inside it is compressed. Now, although diver is still the same shape, it has more stuff in it. Therefore, its density becomes higher than the surrounding water, and the diver sinks!



Submarines can pull water in and push it out to change its density. In order to dive under the waves, it works like a big cartesian diver!

It is often difficult to see that water is moving in and out of the diver as you squeeze and then release. If you squeeze just a little, but not enough to sink the diver, you might see the water level rise a bit. Another way to prove that the water level is changing is the following experiment:

DILUTED DIVER

What you need:

Your diver
Plastic cup
2-liter bottle with cap
Food coloring

Step 1: Add a few drops of food coloring to the small plastic cup filled with water and stir.

Step 2: Squeeze out all of the water in your diver and replace it with the colored water in the cup.

Step 3: Just as before, make sure the diver barely floats in the cup, and then add the diver to the full soda bottle. Screw on the soda bottle cap.

Step 4: Make a prediction – what will happen as you squeeze the bottle?________________________________

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Step 5: Squeeze and unsqueeze the bottle a few times and observe what has happened.

When you first put your diver into the bottle, the colored water stays within the diver. Eventually, the food coloring in the diver would spread to the rest of the bottle, but the process would take hours. By squeezing and unsqueezing the bottle, water is forced in and out of the diver, diluting the color in the diver and spreading it to the rest of the bottle. This proves that new water enters the diver every time you squeeze the bottle, which increases the diver's density, causing it to sink.

There is another way that you can make a diver's density change! Try this next experiment.

DIMPLED DIVER

What you need:

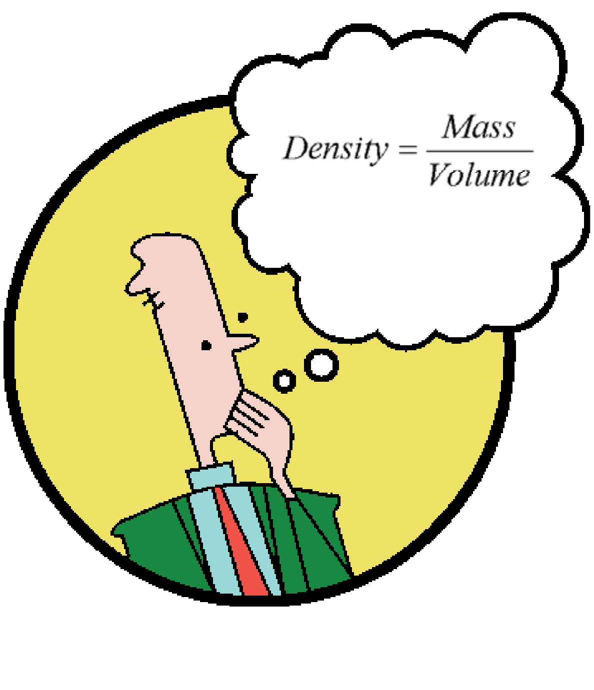
Your diver
A hot glue gun
2-liter bottle with cap

Step 1: Adjust the level of colored water within your diver so that it barely floats in the small cup.

Step 2: Being careful not to burn yourself, use the hot glue gun to seal the end of the diver. Squeeze the diver to make sure the end is fully sealed.

Step 3: Add the diver to the full soda bottle. Screw on the soda bottle cap.

Step 4: Make a prediction – what will happen when you squeeze the bottle now? If you think that the diver will still sink, will it that the same amount of squeezing force?



If the diver has just enough water in it, squeezing the bottle will cause it to sink. But, as you can see, the end is sealed and the color in the diver is not changing. Therefore, no water is entering or exiting the diver. What is causing its density to change?

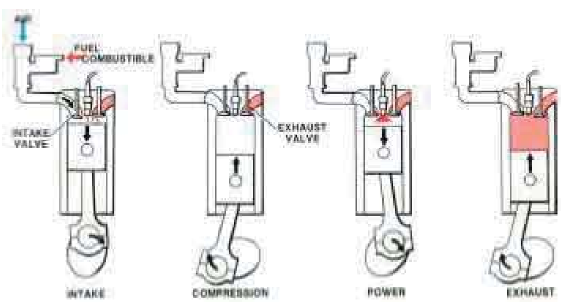
If you look closely, you might be able to see the sides of the diver caving in a bit as you squeeze. This is the key to the sinking diver now! Since density is a combination of volume and mass, we know that we can change density by changing either one of these properties. At first, we increased the mass within the diver by forcing more water into in and compressing the air inside. Now, we are decreasing the volume of the diver, but keeping the same mass. Density increases!

You might notice that the water level within the diver is rising as you squeeze and falling as you let go. This demonstrates an important concept of gases and liquids call compressibility. When you squeeze on the bottle, the water squeezes on the pipette, and its total volume is changed. However, we know that nothing is leaving the bottle, so the air and th

must be taking up less space. They are being compressed.

Compressed gases are used all around us. For example, when making helium balloons, one often uses a large bottle of compressed helium, which can fill up a volume of balloons that is much greater than the actual volume of the bottle. Compressed liquids are very useful too, but they are not as common. The gasoline in your car must be compressed to make your engine run, but it takes a lot of force to do this.

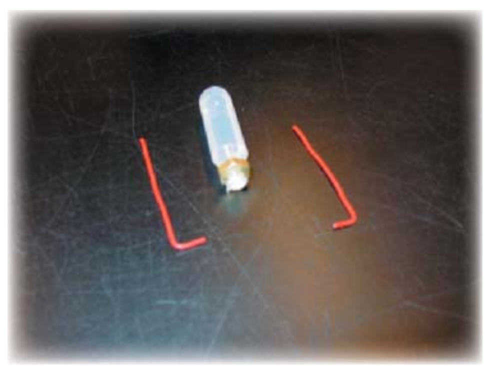
The volume of helium in the balloons is large compared to its volume in the bottle, where it is compressed.



Here is a diagram of how the engine in your car works! Between the 2nd and 3rd pictures, the fuel is compressed by the piston.

Gases, it turns out, are much easier to compress than liquids. This is why you see the water level rise in the squeezed pipette. As the water and air are compressed, the air shrinks in volume much more than the liquid, making it appear as if liquid is being added to the pipette.

DIGGING DIVER



Here’s another fun thing you can do with your divers!
What you need:

Thin electrical wire
Your diver (sealed)
Hot glue gun
Paper clip
2-liter bottle with cap

Step 1: Take the diver you made with a sealed end. When you make it sink in the soda bottle, notice where on the pipette the sides bend inward. Take the diver out and make a mark on either side of the diver where you expect the side to “cave in.”

Step 2: Cut two short lengths of wire and bend each into an “L” shape.

Step 3: Glue the tops of the “L’s” to the points at which the pipette caves in.

Step 4: Take the paper clip and bend it into an “O” shape.

Step 5: With the paper clip and the diver in the water, use the diver to snatch up the paper clip. When you squeeze the bottle, the wires should open to grab the paper clip, but when you unsqueeze, the wires come back together and the diver will pull the paper clip to the top of the bottle!

Caution: In the process of adding “claws” to the diver, you may make it too heavy to be able to pull the paper clip up from the bottom of the 2-liter bottle. In fact, the diver may sink on its own now. If this happens, you have to either remove the glue somehow and adjust the amount of water in the diver or start over with a new diver.

Another solution is to add more glue to the bottom of the diver. Why would adding more of something cause the diver to float more easily? If you guessed that it is because glue

- Inspiration for this lesson from <u>*Soda Bottle Science*</u> *by Steve Spangler*