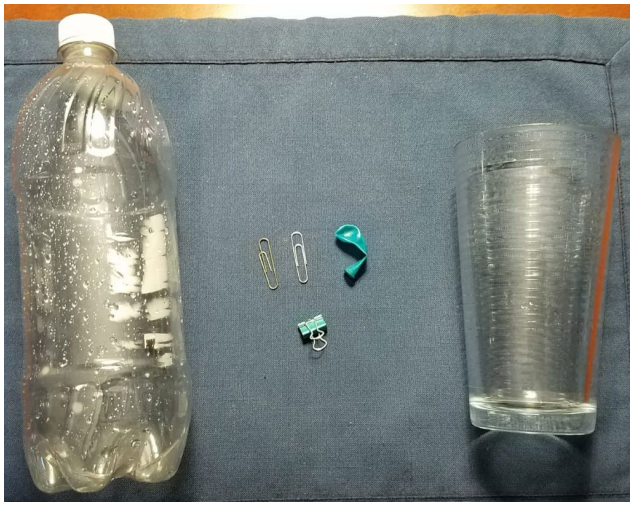
Build Your Own Cartesian Diver from a Balloon

A Cartesian Diver is a toy based on scientific principles—a toy you can make yourself using things found around the house. The Cartesian Diver sinks or floats when gas pressure (and volume) change inside the diver. A Cartesian Diver can be made using any object that contains air, can be compressed to reduce the volume of air, and can have ballast attached. (Ballast is weight in addition to the weight of the object itself.) Items from which a diver can be made include an eye dropper, an unopened ketchup, mustard, or mayo pack that floats in water, a balloon minimally filled with air, a pen with the ink cartridge removed, and a bent soda straw with bobby-pin or paperclip as ballast.

This Cartesian-Diver activity provides directions for making a diver from a small balloon. Balloons are made of latex. The ICE Virtual Chem Camp website has alternative, latex-free Cartesian-Diver activities if you don't have or can't use the materials for this one.

Materials



- A 1-L (quart-sized) or 2-L (half gallon) plastic bottle. You want to be able to see the diver inside this bottle, so try to find one that is clear and colorless and remove the labels.
- A small balloon or a light vinyl plastic protective glove. (Water balloons are the best because they most easily fit through the neck of the plastic bottle.)
- Paper clips and clamp, to be used as ballast weights.
- A clear plastic cup that is tall enough to contain the balloon (which will become the diver). (A glass will work but be careful not to break it.)
- Water. (It is a good idea to do this in the kitchen because the water might be spilled.)

This activity is courtesy of ICE, the Institute for Chemical Education at UW-Madison's Chemistry Department. This activity was adapted from the ACS Celebrating Chemistry Cartesian Diver Activity found here:
https://www.acs.org/content/dam/acsorg/education/resources/k-8/science-activities/solidsliquidsgases/gases/cartesian-diver-science-for-kids.pdf

Construct the Cartesian Diver

1. Fill a clear cup with water. This is your test site for the diver before you put it into the 1-L or 2-L plastic bottle.
2. Put a little bit of air into a small balloon and tie off the end to trap the air. The partly filled balloon must still be small enough to fit through the neck of the bottle.

   Alternatively, you can cut off a finger from a light vinyl plastic protective glove to substitute for the balloon. Make sure there is some air in the finger and then tie the open end tightly shut with string. From here on, what we say about a balloon also applies to the tied-off glove finger.


Steps 1, 2, and 3. *Step 4.*



A finger cut from a lightweight plastic glove can make a diver. The plastic is light so lots of ballast is needed.

3. Test the balloon (glove finger) in the cup of water to make sure that it floats.
4. Add paperclip ballast to the neck of the balloon and re-test it in the cup of water. For the plastic-glove diver you will need heavier ballast because the glove finger is very light. Add ballast until the top of the balloon is barely above the surface of the water.
5. Make sure the labels have been removed from the 1-L or 2-L plastic bottle. Then fill the bottle with water.
6. Add your Cartesian Diver to the bottle and then close the cap tightly. The bottle should be full enough that water runs down the side of the bottle as the cap is being tightened.
7. Squeeze the bottle. The Cartesian Diver should sink when the bottle is squeezed and rise when you let go! (See Troubleshooting on the next page if it doesn't.)


Steps 5 and 6. *Step 7.*

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Troubleshooting

- *The balloon keeps sinking with weights added…*

Test many combinations of ballast (weights). Depending on the quantity of air added to the balloon, it might not be necessary to add ballast. Other balloons may require many paper clips.

- *The balloon does not dive when the bottle is squeezed…*

This is the most difficult part of the activity to troubleshoot. Check to make sure your bottle is filled completely and that the cap is on tightly. If these two suggestions do not solve the setback, add additional ballast to the balloon. Try squeezing harder. Some bottles are made of stronger plastic than others and therefore are harder to squeeze enough. A 2L bottle is usually the easiest to squeeze.

What Happened? What Are the Scientific Principles?

- *Why does the Cartesian Diver sink when the bottle is squeezed?*
  Carefully observe the balloon when it is floating in the water. How big is the balloon when it is floating? Now squeeze the bottle and observe the size of the balloon as it sinks. Can you see a difference in volume of the balloon?

  Initially, the density of the balloon, ballast, and the air inside is less than the density of the water, so the diver floats. When you squeeze the bottle, water compresses the air inside the balloon. This decreases the volume of balloon + ballast + air, but the mass stays the same. Thus, the density of the balloon + ballast + air increases and the diver sinks.
- *What kinds of experiments were needed to get the Cartesian Diver to work?*
  Trial and error is a major part of what researchers do! Researchers learn from both successes and failures in the laboratory. Even if your initial attempt to make a Cartesian Diver sinks directly to the bottom of the glass of water, you can learn something and make a better, more informed decision about how to design a diver that works. The activity is all about testing different combinations of weights and quantities of air in the balloon. Which work, which don't, and why? You are on your way to becoming a researcher!

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