Buoyancy

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Buoyancy is the upward force that makes an apple float in water and floats you when swimming. To feel this force, half fill a bucket with water and find a strong plastic milk bottle.

I used a glass cylinder so you can see the bottle inside.

Push the bottle all the way to the bottom so it's under the water.

The deeper it is the harder you have to push down. *You can see my hands in the image but you can't feel the upward force*. Pease do this <u>*yourself*</u> at least once, with a bucket and a bottle.

How much force will just sink the two-litre bottle? *What could you do to just keep it on the bottom when you take your hands away*?

Answer: fill the empty bottle that's under the water with water.

There is another way to do that. Get another bottle. Fill that with water and gently place it on top of the empty one. The two bottles will just float with the empty one just under the water.

The Buoyancy upward force is equal to the weight of water displaced. If you don't believe that: please do it yourself.

To finish this let's *measure* the buoyancy force. We need a balance calibrated in newtons (weight). A spring balance in a shop is calibrated in kilograms (mass). That can be done because on earth gravity pulls on one kilogram with a force of 10 newtons (almost). The same kilogram weighs only 1.6 newtons on the moon (gravity is weaker). The conversion from newtons to kilograms on the moon is 1.6:1 not 10:1.

This spring balance that was bought with a 0-5 kilogram scale has been recalibrated for our purpose.

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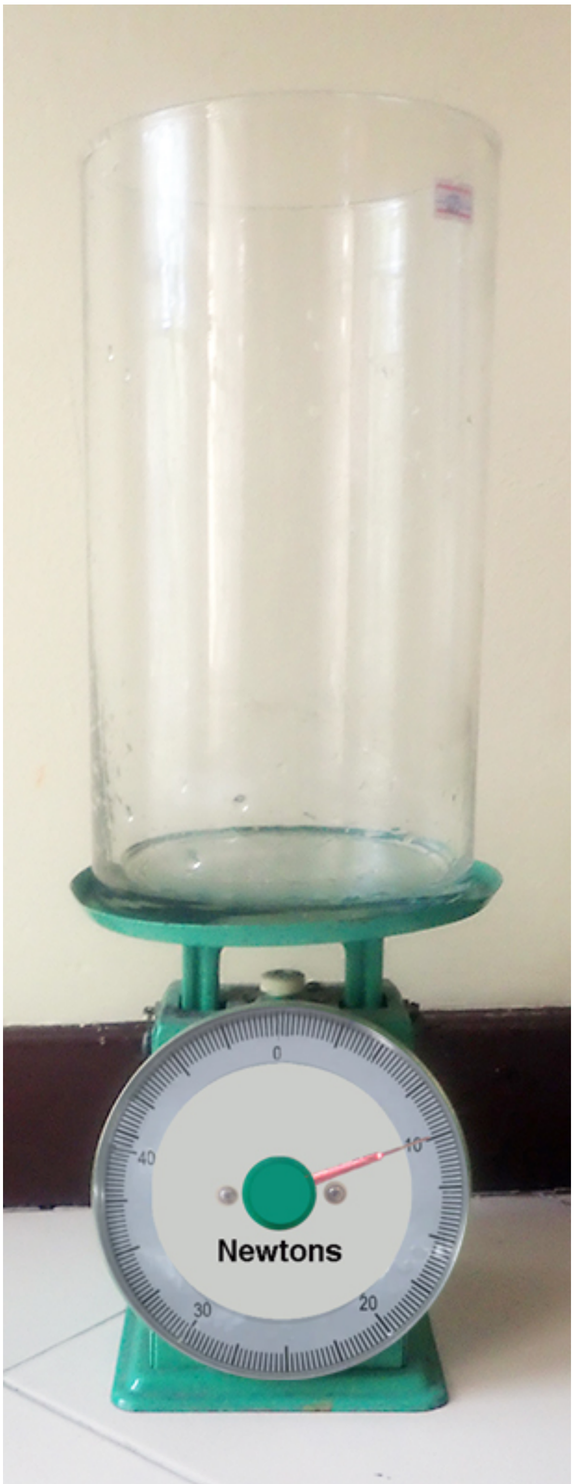
The scale on the balance is now in Newtons (force).

The 0-50 newton balance is not expected to be accurate to better than ± 0.25 N.



The pointer position has been adjusted slightly to read 10 N when the empty glass cylinder is placed on the balance.

Two litres of water have been added to the cylinder. The water is 12 cm deep and the balance reads 10 + 20 = 30 N.

Pushing the empty 2 litre bottle down with a force of 10 N half submerges the bottle and raises the water level against the glass.

Pushing the empty bottle all the way down raises the water level against the glass to 24 cm and the balance reading to 50 N.

Summary

The buoyancy force on the 2.0 litre bottle is 20 newtons, which is the weight of 2.0 litres of water. The plastic bottle will stay where it is if you fill it with water and take your hand away.

Uncertainties

This demonstration was arranged with simple numbers. Two litres of water were put in the cylinder and submerging the empty 2 li bottle doubled the depth of water against the glass. The measured values are not claimed to be accurate to better than ± 1 newton. Small discrepancies will occur for the following reasons.

The walls of the bottle are about one mm thick. The volume of the plastic bottle is a little *more* than 2 litres, which will increase the measured buoyancy force slightly. The bottle plastic is close to the density of water and the walls are strong but not perfectly rigid. Submerging the bottle will compress the sides a little reducing the displacement and also reducing the measured buoyancy force by a small, unknown amount. These effects may tend to cancel.

The net content of the bottle when sold with milk is 2 litres, when the bottle is close to, but not completely full. To take account of this informally the bottle was not quite submerged in the final figure above. The balance itself is not expected to be accurate to better than ± 0.25 N.

Questions

Buoyancy forces are often forgotten when weighing things in air. Why, for instance, is the weight of a capped plastic bottle of air exactly the same as the weight of the pieces if it is cut up? How could we find the weight of one litre of air with a balance?