# Archimedes and Ice Cubes

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Many of you are probably familiar with the story of Archimedes discovering the principle of flotation while taking a bath. Back in 212 BCE, this was cause for major celebration, prompting Archimedes to throw caution, as well as modesty, to the wind and run naked through the streets of Syracuse, Sicily shouting "Eureka" – "I have found it". He stated simply that any floating object displaces its own weight in water, which was rather profound for that time. Conversely, an object that does not displace a volume of water equal to its own weight will sink.

From a food perspective, we can apply this knowledge to the example of an apple and a potato.

A piece of potato with a volume of 100 mL weighs about 107 grams. When placed in water, it can only displace 100 mL of water, which weigh 100 grams (1 millilitre of water weighs very close to 1 gram at room temperature). Since it cannot displace its own weight in water, it sinks. On the other hand, an apple with a volume of 100 mL may weigh only about 80 grams. Dropping the apple into water will cause it to displace 80 grams of water, which has a volume of about 80 mL. The end result is that the apple will bob around on the surface with 20 mL of its volume above the water level. This is probably why the game of bobbing for apples is slightly more popular than plunging for potatoes.

Archimedes' principle of flotation also explains why ice cubes float. Interestingly, water is one of the few substances that expand when frozen, thereby reducing its density. We are fortunate that this happens, since if ice was more dense than water, it would sink to the bottom of our lakes and rivers where it would accumulate and perhaps never melt.

Here's a simple little experiment you can try with a glass of water and some ice. Make an ice cube that is long and slender in a non-breakable container. For a super-cool effect, you can add food colouring to the water before freezing. When it is totally frozen, remove the ice and place it in a tall, wide drinking glass so that there is a space all the way around between the ice and the glass.

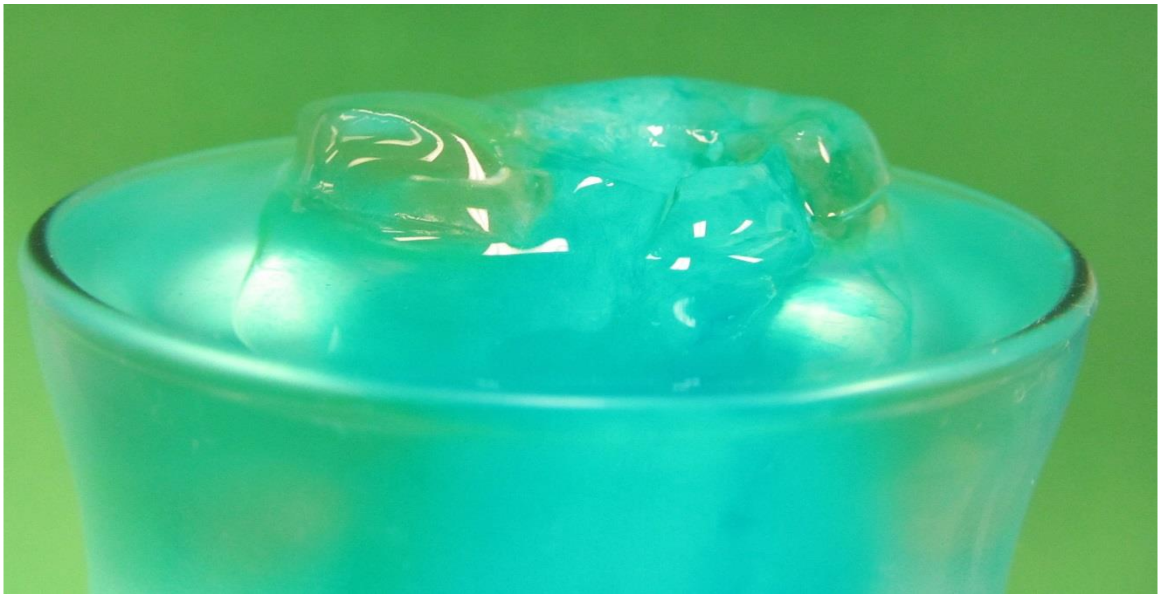
Add just enough water to bring its surface level with the rim of the glass. Be careful not to have the surface tension of the water create a rounding of the water surface above the rim of the glass. The ice cube should then protrude above the water surface as it floats freely. The big question now is, "Will the glass overflow when the ice melts?"

While the ice is melting, you contemplate the theoretical aspects of what is happening, and have some fun with the mathematics involved. Let's say you freeze exactly 100 grams of water with a volume of 100 mL. The ice cube you get should also weigh exactly 100 grams, if there are no losses. Due to expansion during freezing, it will have a volume of about 111 mL, and a corresponding density of 0.9 grams per millilitre. Initially, the ice cube will displace 100 grams of water with a volume of 100 mL. As a result, approximately 11 mL of ice will be above the surface of the water. Now you know why ice floats with about 10% of its volume above water and the remaining 90% hidden below the surface.

As it melts, the volume of the water coming from the ice will be 100 mL in total, which is exactly the same as the volume of the water displaced in the glass by the ice cube at the start. Therefore, the water level in the glass will remain the same after the ice has melted and there will be no overflow.

One thing I noticed was a puddle of water on the counter under the glass after the ice had melted. This was not due to the glass overflowing. Moisture from the humid air around the glass had condensed on the cold outside surface and had run down onto the counter. Just to prove the point, I did some tests on a sensitive laboratory balance to account for the condensation of moisture from the air. The glass with its contents weighed the same before and after the ice had melted, verifying no overflow had occurred.

Archimedes' principle of flotation has many applications in the world around us. Sometimes we just need to look at a quirky little example like this to drive the concept home.



**Ice protruding above the water surface. Will the glass overflow when it melts?**