Water Density

If you are still in school, you've probably heard the statement in the box to the right a number of times:

If you're not still in school, then you probably forgot you ever even heard it. The definition of density, also known as "specific gravity", makes a lot more sense with a little bit of explanation. As long as an object is made up of molecules, and thus has size, it has a density. Density is just the weight for a chosen amount (volume) of the material.

Density

Density is the mass per unit volume of a substance. On Earth, you can assume mass is the same as weight, if that makes it easier.

Water's density varies with temperature

Growing up with an older brother was difficult, especially when he had his friends over, for their favorite activity was thinking of ways to antagonize me. I was able to use water density once to at least play a trick on them, though. One hot summer day they climbed the huge hill next to our house to dig a hole to hide their bottle-cap collection. They got thirsty and made me go back home and bring them a gallon of water. That gallon of tap water at 70°F weighed 8.329 pounds, which was a lot for a scrawny 70-pound kid to haul up a huge hill.

So, when they demanded another gallon of water, I consulted the "Internet" of that day—an encyclopaedia— and found out that a gallon of water at the boiling point only weighed 7.996 pounds! I ran up the hill carrying my gallon of water that weighed 0.333 pounds less; and ran back down even faster, their angry voices fading behind me.

Density and weight of water, at standard sea-level atmospheric pressure

Temperature	Density	Weight
°F/°C	grams/cm^3	pounds/ft^3
32°/0°	0.99987	62.416
39.2°/4.0°	1.00000	62.424
40°/4.4°	0.99999	62.423
50°/10°	0.99975	62.408
60°/15.6°	0.99907	62.366
70°/21°	0.99802	62.300
80°/26.7°	0.99669	62.217
90°/32.2°	0.99510	62.118
100°/37.8°	0.99318	61.998
120°/48.9°	0.98870	61.719
140°/60°	0.98338	61.386
160°/71.1°	0.97729	61.006
180°/82.2°	0.97056	60.586
200°/93.3°	0.96333	60.135
212°/100°	0.95865	59.843

Ice is less dense than water

If you look at this picture you can see that some of the iceberg is below the water level. This is not a surprise, but actually almost all of the volume of an iceberg is below the water line, not above it. This is due to ice's density being less than liquid water's density. Upon freezing, the density of ice decreases by about 9 percent.

The best way to visualize how water can have different densities is to look at the frozen form of water. Ice actually has a very different structure than liquid water, in that the molecules align themselves in a regular lattice rather than more randomly as in the liquid form. It happens that the lattice arrangement allows water molecules to be more spread out than in a liquid, and, thus, ice is less dense than water. Again, lucky for us, as we would not hear that delightful tingle of ice cubes against the side of a glass if the ice in our ice tea sank to the bottom. The density of ice is about 90 percent that of water, but that can vary because ice can contain air, too. That means that about 10 percent of an ice cube (or iceberg) will be above the water line.

This property of water is critical for all life on earth. Since water at about 39°F (4°C) is more dense than water at 32°F (0°C), in lakes and other water bodies the denser water sinks below less-dense water. If water was most dense at the freezing point, then in winter the very cold water at the surface of lakes would sink, the lake could freeze from the bottom up, and all life in them would be killed. And, with water being such a good insulator (due to its heat capacity), some frozen lakes might not totally thaw in summer.

The real-world explanation of water density is actually more complicated, as the density of water also varies with the amount of material that

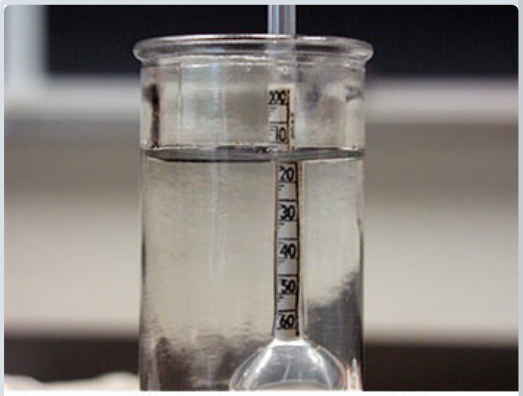
is dissolved in it. Water in nature contains minerals, gasses, salts, and even pesticides and bacteria, some of which are dissolved. As more material is dissolved in a gallon of water then that gallon will weigh more and be more dense—ocean water is denser than pure water.

We said ice floats on water, but what about "heavy ice"?


Credit: Mike Walker

We already said ice floats on water because it is less dense, but ice of a special kind can be denser than normal water. "Heavy ice" is denser than normal water because the ice is made from "heavy water". Heavy water, D_2O instead of H_2O, is water in which both hydrogen atoms have been replaced with deuterium, the isotope of hydrogen containing one proton and one neutron. Heavy water is indeed heavier than normal water (which contains a tiny amount of heavy water molecules naturally), and heavy-water ice will sink in normal water.

Measuring Density



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The instrument to measure the density of a liquid is called a hydrometer. It is one of the simplest of scientific-measuring devices, and you can even make your own out of a plastic straws (see links below). More often, though, it is made of glass and look a lot like a thermometer. It consists of a cylindrical stem and a weighted bulb at the bottom to make it float upright. The hydrometer is gently lowered into the liquid to be measured until the hydrometer floats freely. There are etched or marked lines on the device so the user can see how high or low the hydrometer is floating. In less dense liquids the hydrometer will float lower, while in more dense liquids it will float higher. Since water is the "standard" by which other liquids are measured, the mark for water is probably labeled as "1.000"; hence, the specific gravity of water at about 4°C is 1.000.

Hydrometers have many uses, not the least being to measure the salinity of water, or even urine, for science classes in schools. They are also used in the dairy industry to get estimates of the fat content of milk, as milk with higher fat content will be less dense than lower-fat milk. Hydrometers are often used by people who make beer and wine at home, as it offers an indication of how much sugar is in the liquid, and lets the brewer know how far along the fermentation process has gone.

Make your own hydrometer; Science projects:

- Make your own hydrometer
- Hydrometer science-fair project
- Making and using a hydrometer

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URL: http://water.usgs.gov/edu/density.html
Page Contact Information: Howard Perlman
Page Last Modified: Monday, 27-Jul-2015 14:42:11 EDT