WHAT IS DENSITY?

Mass and volume are physical properties of matter. However, using mass and volume alone are not the best way to describe an object or substance. There must be a better way to describe these differences in mass and volume when comparing substances.

Density is a way of describing the relationship between mass and volume of an object or substance. It is a mathematical expression that compares mass and volume. **Density** can be expressed as ***mass per unit volume*** or density is the ***mass of an object or substance divided by it's volume.***

$$\text{DENSITY} = \frac{\text{mass}}{\text{volume}}$$

Material	Mass (grams)	Volume (cm^3)	Density ($grams/cm^3$)
Lead 	113	10	11.3
Aluminum 	27	10	2.7
Water 	10	10	1
Wood 	5	10	.5

Calculating Density

Using the formula for density, you can calculate any one of the variables if you know any of the other two.

Calculate mass from volume and density…

1. Multiply both sides of the equation by volume.
2. Volume cancels on the right side.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{volume} \times \text{density} = \frac{\text{mass}}{\text{volume}} \times \text{volume}$$

$$\text{mass} = \text{density} \times \text{volume}$$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Calculate volume from mass and density…

1. Multiply both sides by volume.
   This removes volume from the denominator.
2. Volume cancels on the right side.
3. Divide both sides by density.
4. Density cancels on the left side.

$$\text{volume} \times \text{density} = \frac{\text{mass}}{\text{volume}} \times \text{volume}$$

$$\text{volume} \times \text{density} = \text{mass}$$

$$\text{volume} \times \frac{\text{density}}{\text{density}} = \frac{\text{mass}}{\text{density}}$$

$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

If you were to take a 10 milliliter sample of water, you would find that it weighs 10 grams. You would divide the mass by the volume and find that water has a density of 1 gram per milliliter. Any size sample of the same substance has the same density.

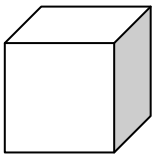
10 mL of water weighs 10 grams.

10 grams / 10 mL = 1 gram/mL

10 mL of aluminum weighs 27 grams.

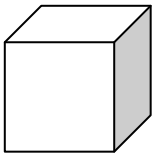
27 grams / 10 mL = 2.7 gram/mL

20 mL of water weighs 20 grams



20 grams / 20 mL = 1 gram/mL

20 mL of aluminum weighs 54 grams



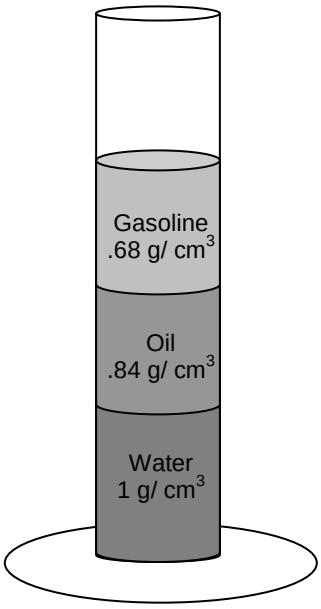
54 grams / 20 mL = 2.7 gram/mL

Since changing the size of a sample of a substance does not change the density, we can use standard values when describing substances. The following table lists the densities for some common substances. Yes gases have densities too!

Substance	**Density (grams/cm^3)**	**Substance**	**Density (grams/cm^3)**
Gold	19.3	Magnesium	1.7
Mercury	13.5	Water	1.0
Lead	11.4	Oil	.84
Copper	9.0	Gasoline	.68
Iron	7.9	Wood	0.5
Zinc	7.1	Styrofoam	0.2
Aluminum	2.8	Carbon dioxide	0.0019
Concrete	2.5	Oxygen	0.0014
Sodium Chloride	2.2	Nitrogen	0.0013

Why is density important?

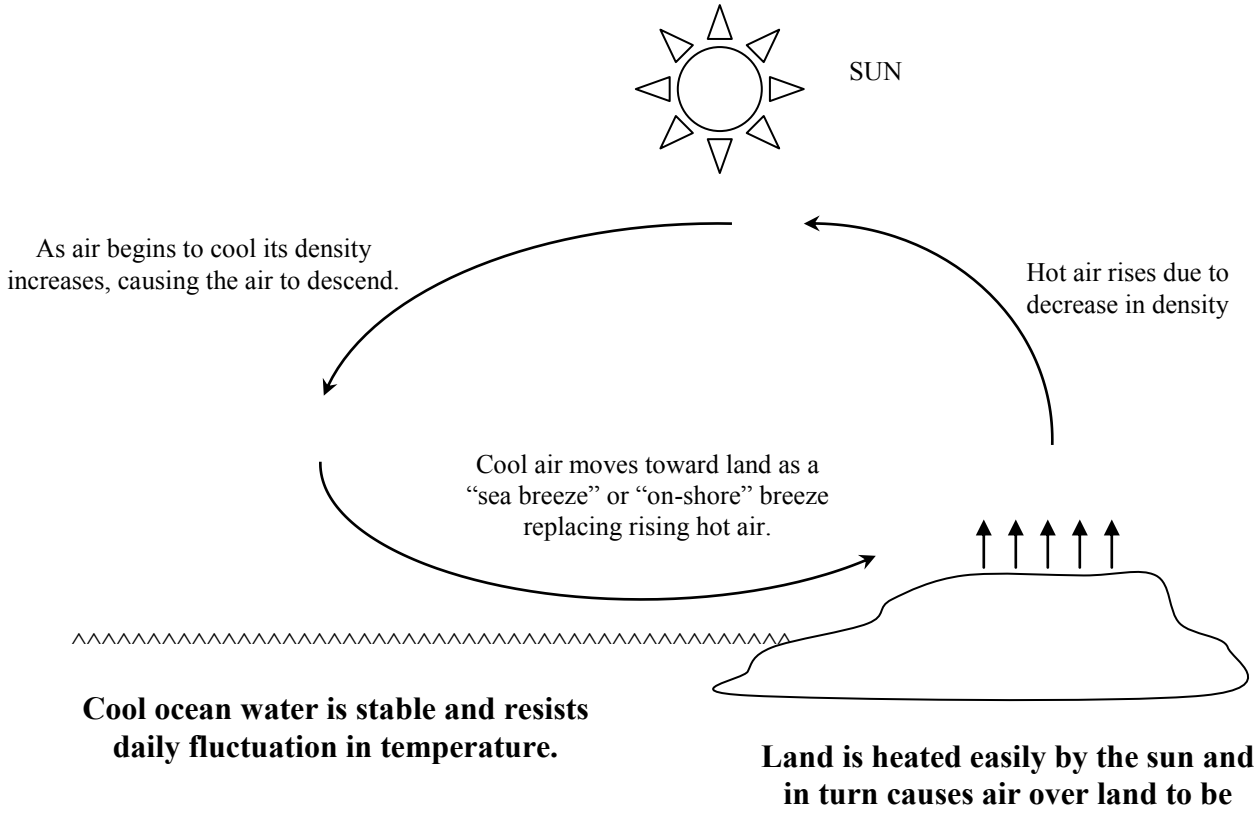
Differences in density allow some objects to float on other objects. For instance, wood is less dense than water therefore - wood floats on water. Oil is less dense than water therefore - oil floats on water. You may have noticed this if you have ever seen a bottle of salad dressing. The vinegar and water mixture settles below the less dense oil that makes up the dressing. That's why you shake the bottle before using, so you don't end up with just oil in your salad! If you could isolate oxygen and carbon dioxide in a container, you would find that oxygen gas would float on top of the carbon dioxide gas. This is because oxygen gas is less dense than carbon dioxide gas.



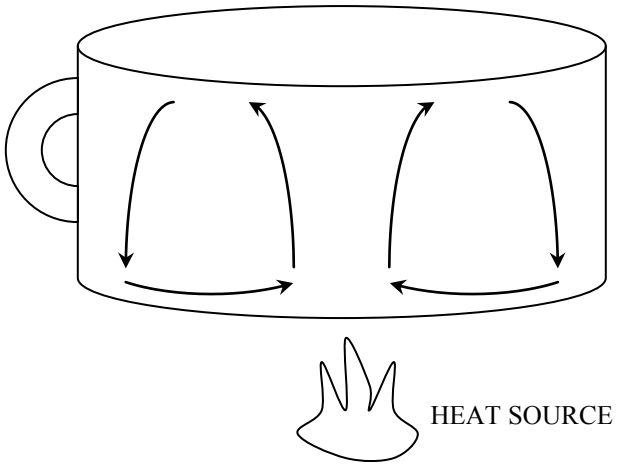
HOW DOES TEMPERATURE AFFECT DENSITY?

Increasing the temperature of a substance increases the volume. Since heat does not have mass, it does not affect the mass of the object. Increasing the volume of a substance while keeping the mass constant lowers the density of that material.

Heating a sample of air causes the volume of air to increase while the mass stays the same. This increase in volume causes the density to decrease. Conversely, decreasing the temperature of a sample of air causes the volume of air to decrease while the mass stays the same. This decrease in volume causes the density to increase. This is the reason hot air rises and cold air descends. The following diagram illustrates the heating and cooling of air and the resulting wind that develops from the rising hot air and descending cooler air. The currents of air that develop are commonly referred to as convective or convection currents.



Heating a liquid can also cause the same convective currents as just explained in air. Again, heating or cooling a liquid causes a change in density and results in the movement of the liquid.



HOW DOES ADDING SALT TO WATER AFFECT THE DENSITY OF WATER?

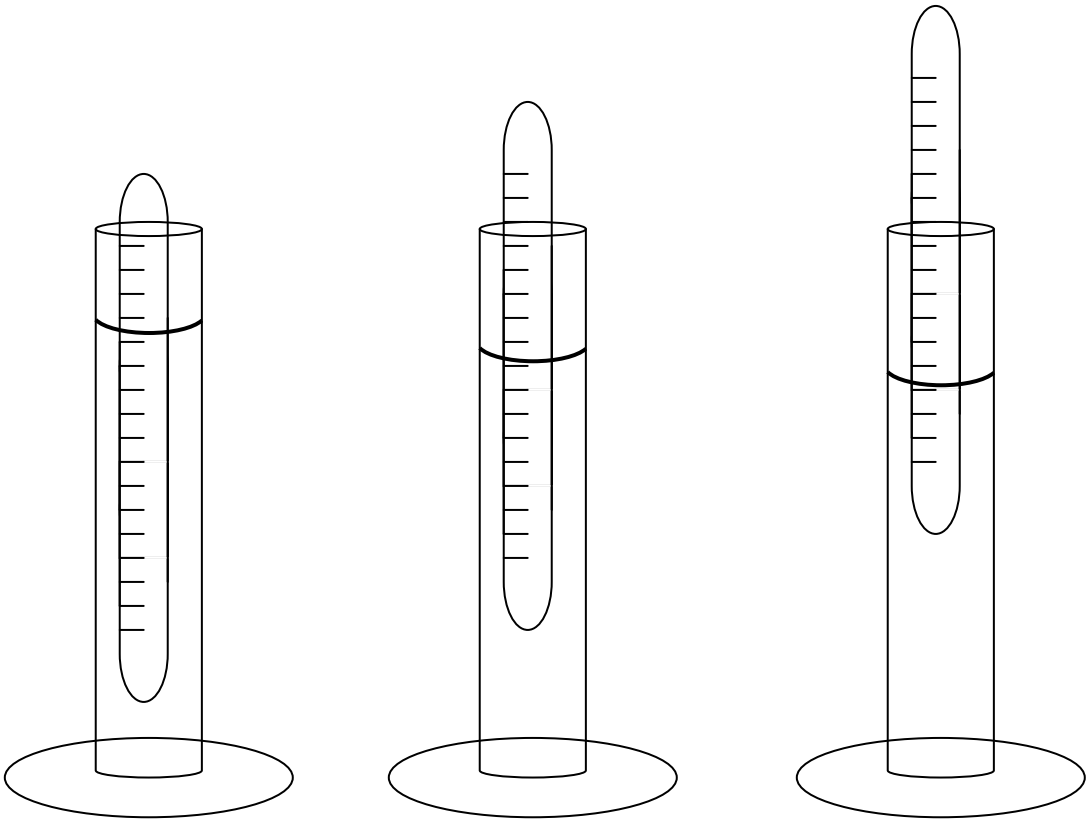
Adding salt to water increases the mass while doing very little if at all to the volume. Such an increase in mass will increase the density of water. A measure of the amount of salt in water is called **salinity**. The higher the salinity, the higher the salt content of the water and consequently the higher the density.

You can measure the density of water using a device called a hydrometer. It is simply a glass tube with weight added so that it floats vertically in various liquids. A scale is added to compare the density of various liquids to that of the pure water.

EFFECT OF SALINITY ON DENSITY

Increasing salinity →

Increasing density →



EFFECT OF TEMPERATURE ON DENSITY

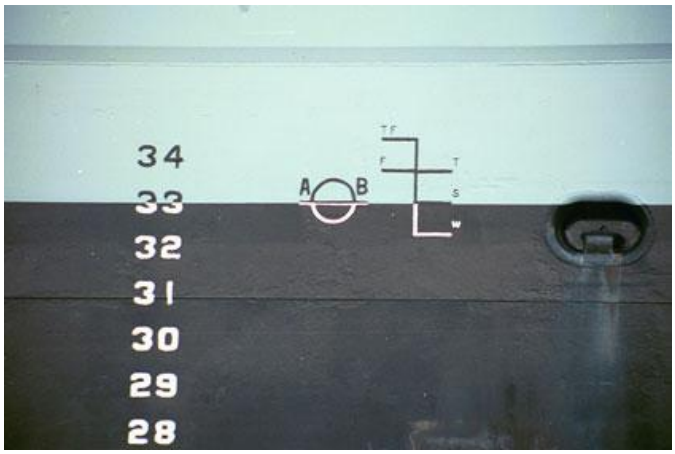
< -- Increasing temperature

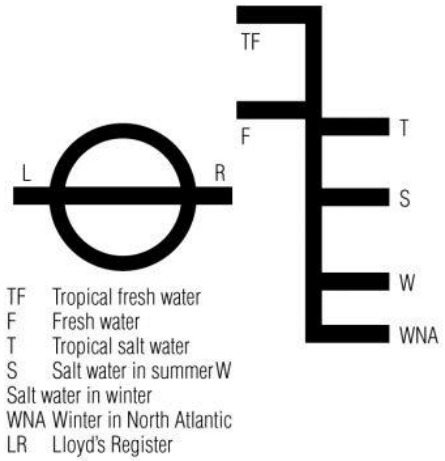
< -- Decreasing density

Plimsoll lines or ***load lines*** are used on merchant ships to show the depth to which a vessel may be safely and legally loaded. You might be wondering how some steel ships are able to float on water when the density of steel (containing iron) is much greater than the density of water. When we calculate the density of the ship, we consider the average density of the entire ship – including the hollow empty spaces in the ships hull. The empty spaces cause an increase in the volume of the ship without changing the mass of the ship. This increase in volume causes a decrease in the density of the ship!

Once a ship is built – it's volume becomes fixed. Changing the mass by adding cargo to the empty spaces can change the density of the ship. Sailing into bodies of water that vary in temperature and salinity can affect how high or low a ship will ride in the water. This can cause problems when the depth of the water becomes shallow. Ships may have to remove cargo to safely and legally navigate certain bodies of water.

The following marking(s) are placed on the hull of merchant ships to aid in determining the safe load limit. Notice how the least dense water is marked the highest, while the most dense water is marked the lowest. Also note how the season changes the depth to which the ship can be loaded. Summer ocean temperatures are on average higher than winter temperatures. Higher temperatures result in lower densities while lower temperatures result in higher densities.





The following diagram shows the variation in the worlds oceans sea-surface salinity. Notice, how the North Atlantic has some of, if not the highest salinity among the world's oceans. Now look back at the plimsoll markings and note that WNA or Winter in North Atlantic earns the lowest marking due to the decrease in temperature over the summer season and consequently an increase in density.