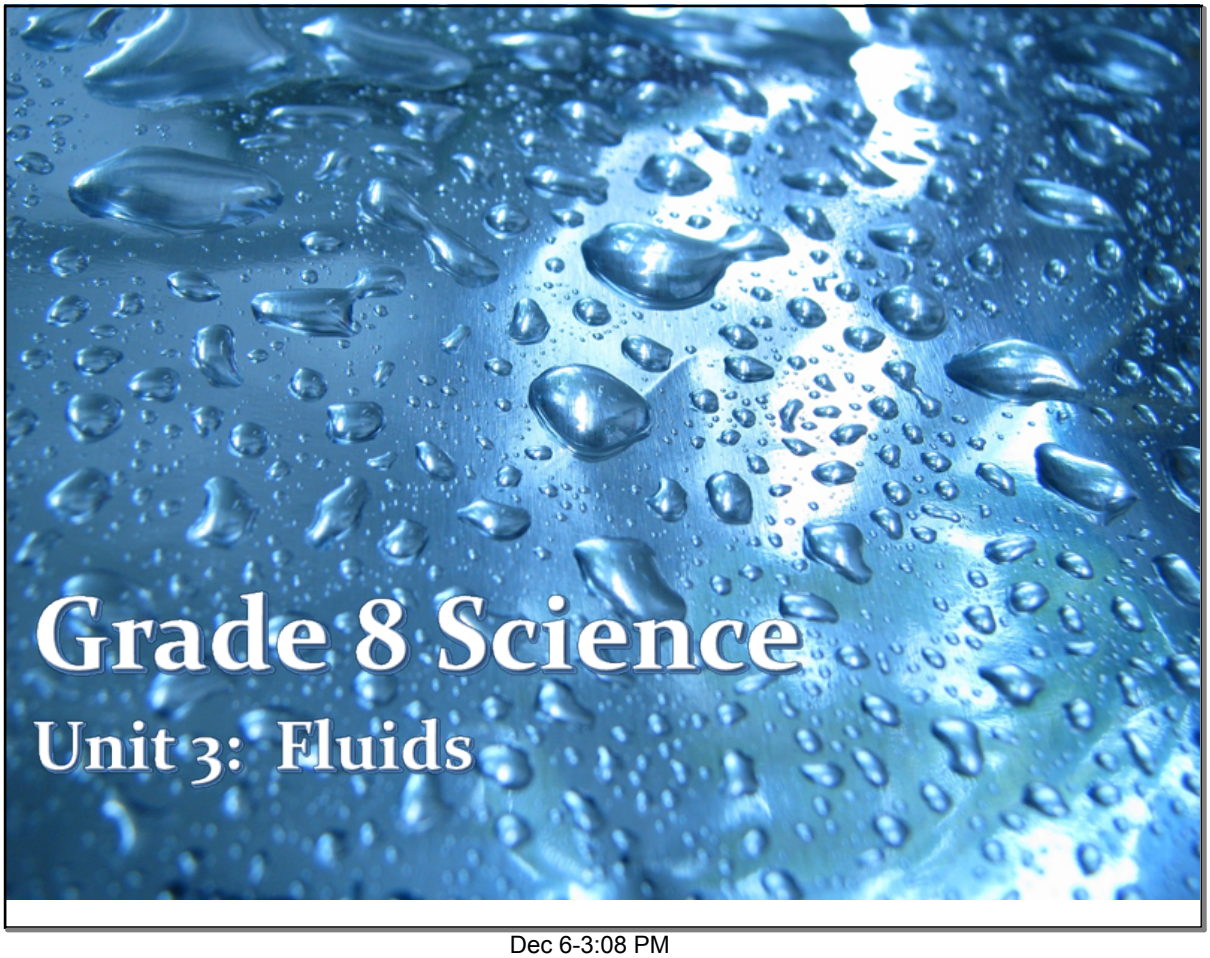

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Density

Over the last two periods we discussed/observed the concept of density. What have we learned?

- Density is a ratio of mass to volume
- Density describes how much matter is packed into a space
- Density is a property of both solids and fluids
- For any one type of matter, the solid state is more dense than the liquid state, both of which are more dense than the gaseous state (water is an exception)
- Density is related to floating and sinking
- Objects of the same type of matter (at the same temperature) have the same density, regardless of the size
- To determine the volume of an object, you can submerse it in water and measure the amount of water displaced
- There are three equations that may be used in density problems, depending on what you are trying to solve:

$D = m / V$ $m = D \times V$ $V = m / D$

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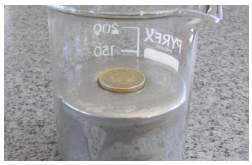
Density

What is the difference between being in water vs being in air?

Because we are less dense than water we float on it. We are more dense than air, so we sink in air.

There are many things that will float in air. There are also many things that will float on other substances, yet sink in water. All of this depends on density.



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Density

We have indicated that density determines the floating or sinking of an object. If an object is more dense than the fluid it is in, it will sink. If it is less dense, then it will float.

So, why is it that a freighter, made from steel - a substance with a density of 8 g/cm^3, is able to float on water, which we determined has a density of 1 g/ml?

Note, 1 ml is equivalent to 1 cm^3.

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Density

When an object is not made from a single material, or when an object contains enclosed voids, then we can not simply use the density of the material. However, we can use the same calculation to determine "Average Density."

$$\text{Average Density} = \frac{\text{Total Mass of Object, Contents and Voids}}{\text{Volume Taken up by Object, Contents and Voids}}$$

If we consider the freighter, the materials used to make the freighter are 8 times more dense than the water. As long as the overall volume of the ship is composed of less than 1/8 steel and over 7/8 air (which has negligible mass) then the boat will float.

When you consider that cargo will be added, people will be on board, the shape of the boat, and that there are waves in the ocean, then you need to change that ratio to ensure that the freighter will not sink... we will come back to this.

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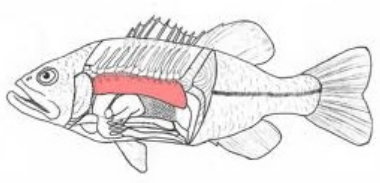
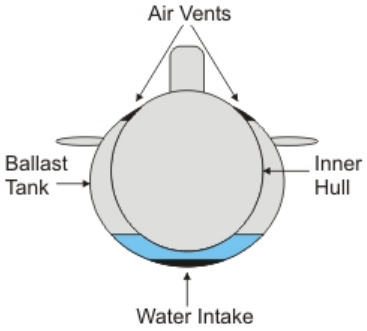
Average Density

Average density has practical applications, both in nature and in man-made objects. How do these two examples use average density to control sinking or floating?



Many fish have an organ called a "swim bladder." This organ will take in and release air, helping the fish to change depth in the water.

A submarine has tanks on the outside of it that contain a mixture of air and water. There are multiple openings that allow the ratio of water to air to be changed. They can open a set of doors that allows water to come in and air to be forced out. They can also open a single set of doors, pumping in air to force the water out.



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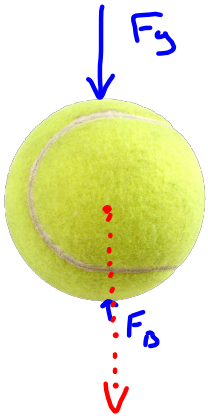
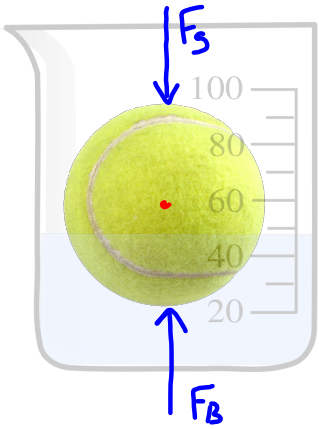
_____?

So, now we understand how a very heavy object can float. Our next question is what causes things to float? To answer this, we need to go back to grade 7, and our unit on Structural Strength and Stability.





What is this upward force called? Buoyancy

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Buoyancy

Buoyancy	*The ability of a fluid to support an object floating on or in the fluid.*
Buoyant Force	*The upward force exerted on objects submerged in or floating on a fluid.*

All fluids, liquids and gases, will exert a buoyant force on all objects. The value of that force depends on the density of the fluid. Why is it that a highly dense fluid will exert a larger buoyant force?

High density means more mass per unit volume, which means more particles in any one particular area. In order for something to sink it would need to move all of those particles out of the way. However, each of those particles is attracted to the particles around it, and so if the force of gravity pushing on the object is not strong enough, the fluid particles will hold up the object.

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Buoyancy

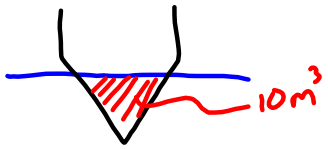
Now we can look back at the freighter. In order for a boat like that to be used, it has to be safe. And, to be safe, it has to float high enough on the water so that it will not sink with rough waves. The science behind this was documented by Archimedes, 2300 years ago. He determined that a floating object will displace a quantity of fluid equal in weight to the object itself.

For example, if a boat has a weight of 100 000 N, then it will displace (move) water with a weight of 100 000 N.

100 000 N is the weight of 10 000 kg of water (or 10 000 000 g)

10 000 000 g of water takes up 10 000 000 cm^3 of space (or 10 m^3)

So, when building the boat it must be designed, knowing 10 cubic meters of boat will be underwater.



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Buoyancy

Let's check our understanding:

1. Why does a piece of Lego sink in oil, but float on water?

$D_{oil} < D_{lego} < D_{H_2O}$

2. Why will a hollow steel ball float, but a much smaller solid steel ball sink?

Avg $D_{Hollow} \ll D_{solid}$ Could have same mass, but $V_{Hollow} \gg V_{solid}$.

3. A fluid has a density of 1.5 g/cm^3 and a solid object has a density of 1.2 g/cm^3. If the solid object is 10 cm^3, how much of it would be submerged in the fluid when it is placed on the surface?

Amount submerged is equal to amount of water displaced. Need to find how much water has same mass as solid object.

Solid: $D = 1.2\ g/cm^3$, $V = 10\ cm^3$, $m = ?$

$m = DV$, $m = 1.2 \times 10$, $m = 12\ g$

Fluid: $m = 12\ g$, $D = 1.5\ g/cm^3$, $V = ?$

$V = \frac{m}{D}$, $V = \frac{12}{1.5}$, $V = 8\ cm^3$

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