CHAPTER FOUR

DENSITY:

- The density of a body is defined as its mass per unit volume, i.e. density = $\frac{mass}{volume}$

Determination of the density of a regularly shaped body:

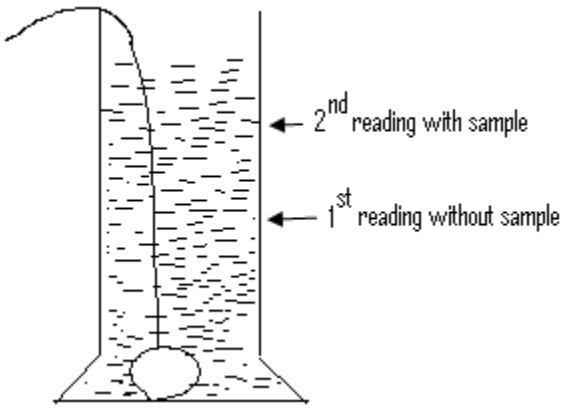
- Objects such as the cube, cuboid, cylinder and the sphere are examples of objects having regular shapes.

- In order to determine the density of any of such objects, one must go through the following steps:

(1) The mass of the body is ; found using a weighing machine or a spring balance.
(2) Since the body has a regular shape, its dimensions can be determined by means of measurement.
(3) Using these dimensions the volume of the material can be calculated.
(4) The mass is then divided by the volume to get the density.
(5) The unit of density is g/cm^3 (gcm^{-3}) or kg/m^3 (kgm^{-3}).

Determination of the density of an irregularly shaped objects:

Objects such as a stone or a piece of rock are examples of irregularly shaped objects. To determine the density of any such objects, one must go through the following steps:



(1) The mass of the object must first be determined, using a weighing machine.
(2) To determine the volume of the object, we first put water into a measuring cylinder and the volume of the water is noted.
(3) The object is attached to a thread, and then immersed into the water in the measuring cylinder.
(4) The difference between the first and the second volumes of water, within the measuring cylinder is noted.
(5) This difference is the same as the volume of the irregularly shaped object.
(6) The mass is then divided by the volume to get the density.

Apparent loss in weight:

- When a body is placed in water, its experiences an upward force called upthrust.
-The presence of this upthrust can be demonstrated by tying a length of cotton thread to a brick.
- Any attempt made to lift the brick by the cotton fails, through the breakage of the cotton.
- When the brick is immersed in water, it will be noted that it can easily be lifted, without any breakage in the cotton, so long as it remains in the water.
- It is as a result of the upthrust acting on the body, which explains why it was easily lifted when it was placed in the water.
- Archimedes principle states that when a body is wholly or partially immersed in a fluid, it experiences an upthrust which is equal to the weight of fluid displaced.

Reason why a body may sink or float in water:

If a body is placed in water and its density is less than that of water, then the body or material will float in water. On the other hand, if the density of the body or the material is greater than that of water, then the material or body will sink in water. For this reason, a piece of solid steel will sink in water, since its density is greater than that of water. But a ship made of steel will not sink, since its density is less than that of water. The density of such a ship will be less than that of water, since the ship has a hollow portion which contains air, which causes a decrease in its mass and as such, its density.

The submarine:

- This is a specially designed or made ship, which is capable of moving on the surface of the sea, or below the surface of the sea.
- The submarine has ballast tanks which can be filled or emptied when the need arises.
- By filling these tanks, the mass of the submarine is increased, causing an increase in its density
- Its density therefore becomes greater than that of water, causing it to dive or sink.
- In order for it to float or rise to the surface of the water, the water is rejected from the tanks using compressed air.
- A decrease in the mass of the submarine occurs, causing its density to fall and become less than that of water.
- The submarine therefore rises to the surface and floats.
- The buoyancy of the submarine, or the level to which it will sink or float in water, depends on the quantity of water in its ballast tanks.

Density and gases:

Gases also have densities just like solids or liquids. When the density of a particular gas is less than that of air, then that gas will rise in air. It is for this reason that a gas such as smoke or hydrogen rises in air. Also if a gas is put into a ballon and density of the gas within the ballon is less than that of air, then the ballon will rise in air. For this reason, a ballon filled with smoke or hydrogen will rise in air. On the other hand if the density of the gas within the balloon is greater than that of air, then the balloon will not rise in air.

Separation of substances of different densities:

If two liquids are immiscible or do not mix-together, then the one with the lower density will always float on top of the one with the higher density.
- If the two liquids are mixed, they can be separated by putting the mixture into a tall cylindrical jar, and allowing the mixture to stand long enough.
- This will cause the liquid mixture to separate into two layers with the less dense liquid floating on top.
- This can be poured out, while the more dense liquid remains in the jar.
- A powdered mixture of two solids substances can be separated by mixing them with

water, and shaking the mixture vigorously.
- When the shaking stops, the substance with the higher density will tend to settle to the bottom more rapidly than the less dense one.
- If the water is poured out while the mixture is being stirred, then the substance of the lower density will turn to be poured out with the water, while the one with the greater density will stay behind in the container.

Floating bodies:

When a piece of wood or any other material, whose density is less than that of water is placed in water, it will sink until the weight of the water it displaces, is just equal to the weight of the body. The body will then float. Even though the hydrogen ballon will ascend in air, it can be made to float if the quantity of gas it contains can be adjusted, so that its average density becomes equal to that of the surrounding air.

Uses of density:

(1) Used by chemists to determine how pure a substance is.
(2) Used by structural engineers to design structures such as bridges and buildings.

Floating bodies in liquids:

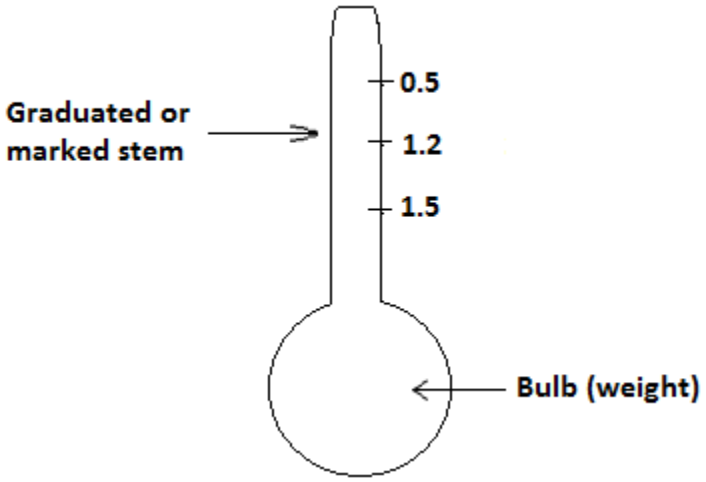
- According to the principle of floatation, a body placed in a liquid sinks and only floats when the weight of the liquid displaced, is just equal to the weight of the body.
- The weight of a liquid decreases as the density of the liquid decreases.
- For this reason, If a body is placed in a liquid and the density of the liquid decreases, then more of the liquid must be displaced for the weight of the displaced liquid to become equal to that of the body, i.e.to balance the weight of the body.
- In order to displace more of the liquid, then the body must sink further into the liquid.
- In other words, if a body moves from a high density liquid into another of lower density, it sinks in order to displace more water to balance its weight.
- Also, if the body moves from a liquid of low density, into another with higher density, then it must rise, since a lesser amount of the liquid must be displaced, in order to balance its weight.

Boats and ships:

- A boat or a ship displaces its own weight of water.

- If a ship has been fully loaded to the current level in waters of high density, and then it moves into waters of lower density, it sinks deeper.
- This is due to the fact that it must displace more of the lower density liquid to equalize or balance its weight, in accordance with the principle of floatation, and the new level the ship sinks to may be so dangerous that a storm may cause the ship to sink.
- Insurance companies therefore have lines called primsoll lines marked on the ships, so that the loading of the ship can be done to safe or different levels with regard to the type of waters it is to travel through.
- Loading is done to a particular level in cold winter waters, done to another level in the warm waters of the tropics and done to a different level in fresh waters.

The hydrometer:



- The hydrometer is a device or an instrument which is used to determine the density of a liquid.
- If liquids of different densities are taken and a particular body is placed in each in turn or one after the other, the body will sink to a different level in each liquid.
- This is so in order to displace the right amount of liquid, which balances the weight of the body concerned in each case.
- For the lower the density of a liquid, the deeper will be the level to which a body will

sink in it and the hydrometer works on this principle.
- The hydrometer consists of a weight in the form of a bulb, and attached to this bulb is marked or a graduated stem with different density values marked on it.
- The function of the weight is to keep the hydrometer erect in water or the liquid.

- When placed in a particular liquid, the density of the liquid determines the level to which the hydrometer will sink, so as to displace the right amount of liquid to balance its weight (weight of the hydrometer).
- The hydrometer therefore sinks to a particular level in the liquid, and the level is then read from the markings on the stem of the hydrometer as the density of the liquid.

The relative density:

- The relative density of a substance is the ratio of the mass of any given volume of the substance, to the mass of an equal volume of water.

- Relative density = $\frac{mass\ of\ any\ volume\ of\ the\ substance}{mass\ of\ an\ equal\ volume\ of\ water}$.

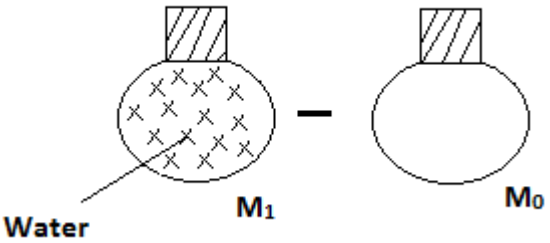
- The relative density is also = $\frac{Weight\ of\ any\ volume\ of\ the\ substances}{weight\ of\ an\ equal\ volume\ of\ water}$

How to find or measure the relative density of a liquid:

- For this, we make use of the relative density bottle, which gives us the same volume no matter the type of liquid we put into it.
- The empty density bottle is weighed with its stopper.
- The bottle is then completely filled with water and the stopper inserted.
-The excess water which comes out is wiped and the bottle containing the water is weighed.
- The bottle is emptied and dried, filled with the liquid whose relative density is wanted and the stopper inserted.
- The excess liquid that comes out of the bottle is cleaned and the bottle containing the liquid is weighed.

Results:
Mass of empty bottle and the stopper = M_0.
Mass of bottle with water and stopper = M_1.
Mass of water = $M_1 – M_0$.

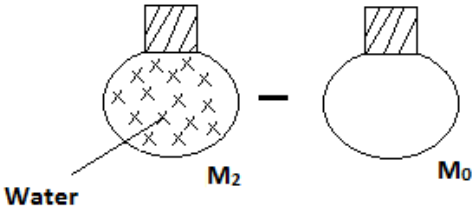
i.e. Mass of water =



Mass of bottle, the liquid and stopper = M_2.

Mass of the liquid = $M_2 - M_0$,

i.e. Mass of liquid =



The relative density of the liquid = $\frac{Massof\ any\ volume\ of\ the\ liquid}{mass\ oof\ an\ equal\ volume\ of\ water}$

$= \frac{m_2 - m_0}{m_1 - m_o}$.