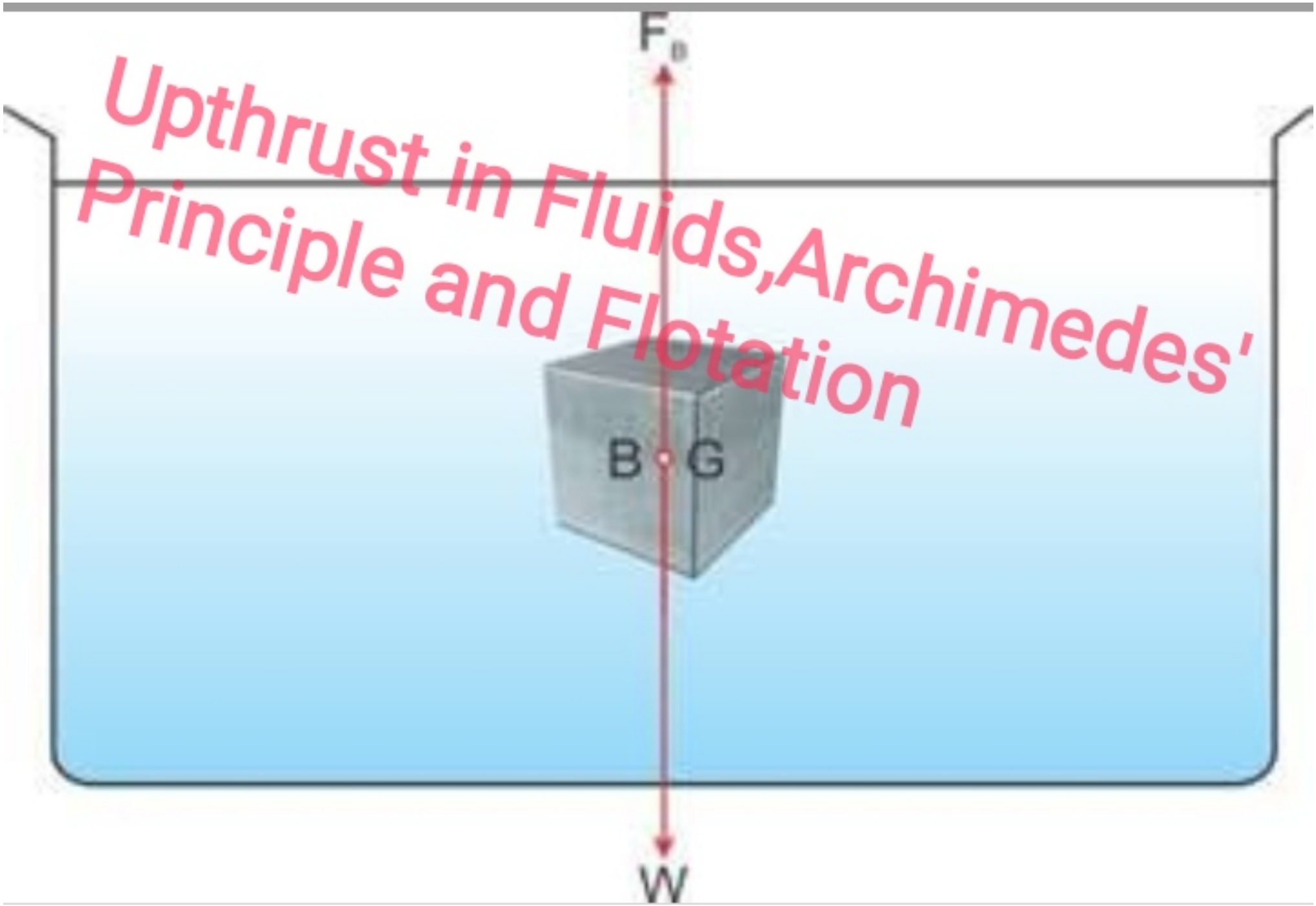
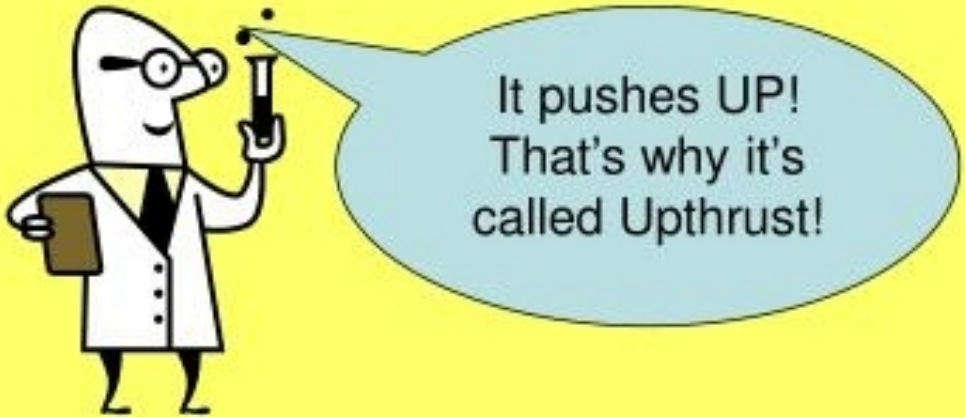


Upthrust in Fluids,Archimedes' Principle and Flotation

What's upthrust?

- Upthrust is a force that only exists in fluids, such as lakes, oceans, swimming pools and even cups of tea!
- It is a push that always goes straight up, against the direction of gravity.



Upthrust in action

This boat has gravity pulling it down, and the upthrust of the water pushing up. Because the forces are balanced, the ship floats.

What would happen if the forces weren't balanced?

More examples of upthrust

If you let go of your drinking straw, it floats up and sometimes tries to bob out of the glass!

Floating in the sea

- Salty seas have more upthrust. It's much easier to float in a sea than in a swimming pool.

- The Dead Sea is the saltiest sea on earth. It's REALLY easy to float on it!

Shape affects upthrust.

- The larger the surface area of an object, the more the upthrust.

Imagine trying to hold this large beach ball, and this small tennis ball, under the water. Which would be easier?

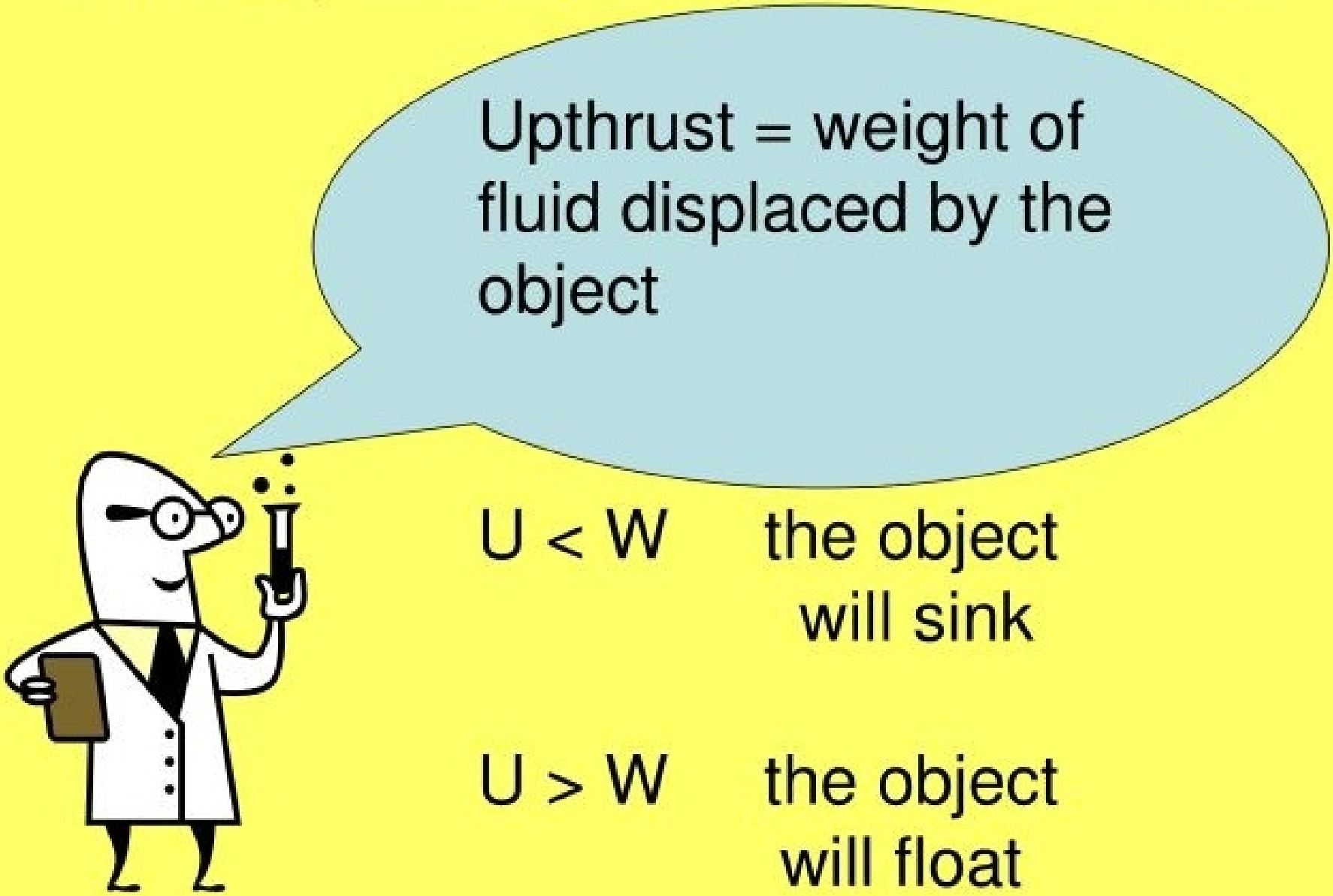
- That's why swimmers float on their backs, not upright in the water.

(You *can* stay afloat like this, but it's harder work, called "treading water". If you stopped moving your feet you'd sink, because the force of gravity would be stronger than the upthrust.)

Submarines

- Submarines are specially designed to sail underwater. They fill up with water which makes them weigh more. More weight = more gravity. The gravity is greater than upthrust, so the submarine sinks.

All very interesting, but so what?



BUOYANCY

When a body is immersed in a liquid then an upward force acts on it in upward direction is called upthrust or buoyant force and the property of liquid to exert force is called buoyancy.

Example

(a) A rubber tube filled with air is pushed in a big tub full of water we feel an upward force which opposes the push and we find it difficult to push the air tube further into the water. It is also observed that the air tube is pushed more and more into water, more and more force is needed to push the air tube further into water till it completely immersed. When the rubber tube is fully immersed inside the water, a constant force is still needed to keep it stationary in that position. Now if rubber tube is released, it bounces back to the surface and floats on the surface of water.

Explanation : When the air filled rubber tube is put on the water, two forces act on it

(i) weight w due to gravity pulls downwards.

(ii) upthrust (f) due to water upwards.

Now when tube floats freely then weight is equal tube to upthrust ($w = f$) and when air filled tube is pushed in water, upthrust increases and becomes maximum (f') when tube is completely immersed in water. So when tube is released, tubes bounces because f' (upthrust) is more than weight of the tube. To keep the tube immersed in water, an external downward force, ($f' - w$) is required to balance.

(b) A balloon filled with hydrogen gas (less denser than air) rises up due to fluid upthrust or air buoyant force. Therefore, like liquid gases also have the property of the buoyancy.

CONDITIONS OF FLOATATION

As mentioned earlier, when a body floats on the surface of liquid (say water), two forces act on it : (i) Weight of body (w) downwards and (ii) upthrust (f) acts upwards. Now three possibilities are there :

1. $f > w$ *i.e.,* upthrust is more than weight of body, body will not sink or it immerses partially.
2. $f = w$ *i.e.,* upthrust is equal to weight of the body and body immersed completely and floats and its apparent weight is zero.
3. $f < w$ *i.e.,* weight of the body is more then the upthrust, the body will sink in the liquid and it goes down in the water with an acceleration $\left(a = \frac{w - f}{m} \right)$, neglecting the viscus force of the liquid.

FACTORS AFFECTING UPTHRUST

The upthrust has following factors on which it depends :

[A] Volume of Body

Larger is the volume of body more is the upthrust.

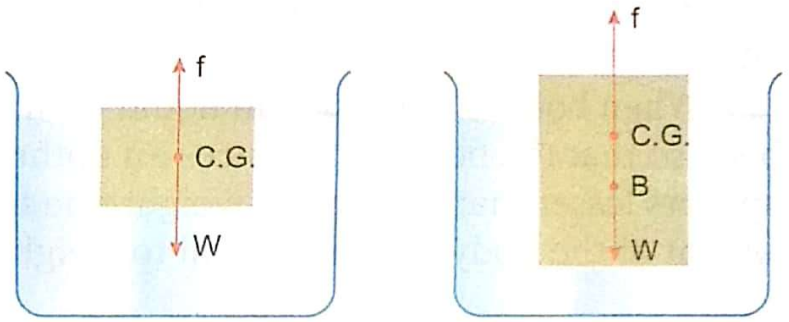
When two air filled tubes of different volume are pushed in water than it is difficult to push the tube of more volume because of more upthrust as compared to air tube of less volume due to less upthrust. Therefore, it is clear that upthrust depends on the volume of the immersed body.

[B] Density of the Fluid (Liquid)

If we push a rubber tube filled with air in sea water and in river water than more pushing force is needed in sea water (due to its high density) due to more upthrust. Therefore it is clear upthrust depends on density *i.e.*, larger is the density more is the upthrust.

[C] The Centre of Gravity of the Displaced Fluid

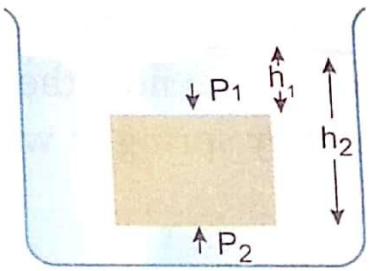
For a body of uniform dimensions and immersed in a liquid the centre of buoyancy coincides with the centre of gravity as shown in the diagram.



But if a body floats partially and it is a non-uniform dimension body like shown in the figure, the centre of buoyancy *B* is at the centre of gravity of the displaced liquid *i.e.*, at the centre of gravity of the immersed part of the body and it lies below the centre of the gravity *G* of the entire body. The weight of the body acts at C.G. (downwards) but the upthrust acts upwards at point *B* and both weight and upthrust are equal.

CAUSE OF UPTHRUST

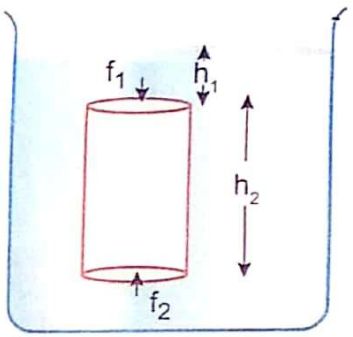
When a body is immersed in liquid then a liquid pressure acts on it and it depends on the depth of body from the free surface of liquid. This liquid pressure remains same at same depth but it is more for lower surface of immersed body than the upper surface of the body.



Let a body is immersed in water and its upper and lower surface are at a depth of h_1 and h_2. Pressure on lower surface is P_2 acting upwards and P_1 on the upper surface acting downwards ($P_2 > P_1$ as $h_2 > h_1$). So net force acting upwards in the form of upthrust $= (P_2 - P_1)A$. The thrust on side surface of body gets neutralised due to equal and opposite forces.

MATHEMATICAL EXPRESSION FOR UPTHRUST

When a body is completely immersed or partially the upthrust acting on it is equal to the weight of liquid displaced.



Let a cylindrical body is immersed in liquid (water) and its upper circular, lower circular faces are at a depth h_1 and h_2.

$\therefore$ $P_1 = h_1\, d\, g$ (on upper surface)

and $P_2 = h_2\, d\, g$ (on lower surface)

and the corresponding thrusts

$f_1 = P_1 A = A\, h_1\, d\, g$ (on upper surface downward)

$f_2 = P_2 A = A\, h_2\, d\, g$ (upwards on lower surface)

Net or resultant thrust (buoyant force in upward direction is

$$f_2 - f_1 = A\, h_2\, d\, g - Ah_1\, d\, g$$
$$= A(h_2 - h_1)d\, g$$
$$= Vdg$$
$$= mg$$

where d = Density of liquid

V = Volume

g = Acceleration due to gravity

$\therefore$ Upthrust $= mg$

= Weight of liquid displaced

Hence, it is proved that upthrust is equal to weight of liquid displaced.

Home-Work

1. Give reason why, a block of plastic when released under water comes up to the surface of water.

2. A steel needle sinks in water but a steel ship floats. Explain how.

3. The volume of 40 g of a solid is 15 cm3. If the density of water is 1g/cm3, will the solid float or sink? Why?

4. What happens when :

(a) Buoyant Force exerted by the fluid is less than the weight of the body ?

(b) Buoyant Force exerted by the fluid is equal to the weight of the body ?