TENDER HEART HIGH SCHOOL, SECTOR-33'B, CHD.

Date 6.5.24
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CLASS : IX SUBJECT : PHYSICS TEACHER: Charanjeet kaur

CHAPTER-5 PRINCIPLE OF FLOATATION

Good Morning Students! As we have already learnt earlier, Upthrust will be more if the volume of object is submerged more in liquid i.e. the upthrust exerted will be maximum when the body is completely immersed inside the liquid.

Case-1 - When Body will sink in liquid:

When $W > F_B$ i.e. the weight of body is more than the weight of displaced liquid, the body will sink (see figure-1). Here the apparent weight, A.W. = (Real W $- F_B$) and apparent weight will also be directed downwards. This is the case where ρ of liquid is less than ρ of solid (i.e. the body submerged in liquid)

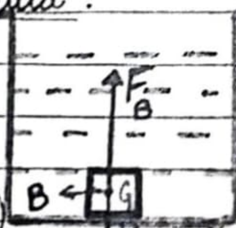


FIGURE-1

Case-2 - Case of floatation when the body is completely immersed in liquid:

When $W = F_B$, then the body will float just below the surface of liquid (as seen in figure-2). In case of this, $A \cdot W = 0$ (as, $A.W = R.W - F_B$ and $R.W = F_B$). Moreover, this is the case when $\rho_{liquid} = \rho_{Body}$

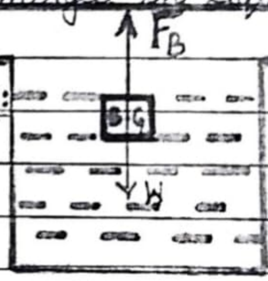


FIGURE-2

Case-3 - When the body floats partially above and partially below the surface of liquid: When $W < F_B$, then only that much portion of the body gets submerged by which the weight of displaced liquid becomes equal to the weight of the body. $(A \cdot W = 0)$

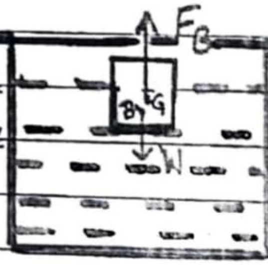


FIGURE-3

B stands for centre of buoyancy (upthrust acts from this point) whereas G stands for centre of gravity (weight acts downward from this point).

NOTE: For case-1 and 2, B and G lies at same point but in case-3, B lies below point G (no detail explanation is required here).

Thus, for a floating body:
Weight of body (W) = Weight of liquid displaced by the submerged part of the body (F_B)
$\therefore$ A.W = 0

RELATION BETWEEN VOLUME OF SUBMERGED PART OF FLOATING BODY, ρ_{BODY} AND ρ_{LIQUID}

Weight of the body, W = Volume of body $\times \rho_{BODY} \times g$

$$W = V_B \times \rho_B \times g \quad \text{—} \; (1)$$

Weight of liquid displaced by the body or upthrust,

$$F_B = \text{Volume of displaced liquid} \times \rho_{LIQUID} \times g$$
$$= v_L \times \rho_L \times g \quad \text{—} \; (2)$$

where, v_L = volume of displaced liquid
In case of floatation, $W = F_B$

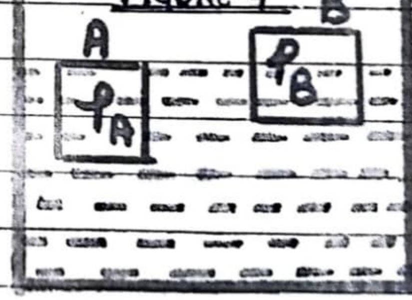
$$V_B \times \rho_B \times \cancel{g} = v_L \times \rho_L \times \cancel{g}$$

$$\boxed{\frac{v_L}{V_B} = \frac{\rho_B}{\rho_L}}$$

CONCLUSION: (1) A floating body of higher density has its more volume submerged inside the liquid and hence experiences higher upthrust than the body of low density.

For example (as seen in figure-4), $\rho_A > \rho_B$, that's why A is having more volume of itself in liquid than B. Now, $F_B \propto V_{submerged\ part}$, so F_B of liquid is exerted more on object A as compared to object B.

FIGURE-4



(2) In both cases - 2 and case-3 (explained on Page-1) i.e. the case of floatation, the upthrust by the liquid is same and is equal to the weight of the body.

(You may all take a break of 5 minutes and in the meanwhile read the conclusion written above again).

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APPLICATIONS OF PRINCIPLE OF FLOATATION

1.) **FLOATATION OF IRON SHIP**: ship are made of iron and still they do not sink because the ship is hollow and empty space in it contains air which makes its volume large and average density less than that of water. Even with a small portion of ship submerged in water, the weight of water displaced by the submerged part of ship becomes equal to the total weight of ship due to which its floats. Sea water has more density than river water. Thus, when a ship sails from a sea of higher density to river or sea of lower water density, it sinks further. This happens because to balance the weight of ship, a greater volume of water is required to be displaced in water of lower density in river. This is in accordance with law of floatation.

PLIMSOLL LINES: White line painted on the side of a ship is known as plimsoll lines. It indicates the safe limit for loading the ship in H_2O of $\rho = 10^3 kg/m^3$. A ship is not allowed to be loaded further when its plimsoll lines start touching the water level, so that when it sails in sea water of $\rho > 10^3 kg/m^3$, only the part of it below the plimsoll line remains submerged in water.

2.) **FLOATATION OF HUMAN BODY**: The average density of human body depends on the proportion of its constituents like bone, blood, muscle, fat and amount of air in lungs at that time. A good swimmer can float on water with his lungs filled with air and nose and mouth projecting just above the water surface as at that moment the weight of water displaced by him is nearly equal to his own weight.

3. FLOATATION OF SUBMARINES — A submarine can be made to dive into water or rise up to the surface of water as and when desired.

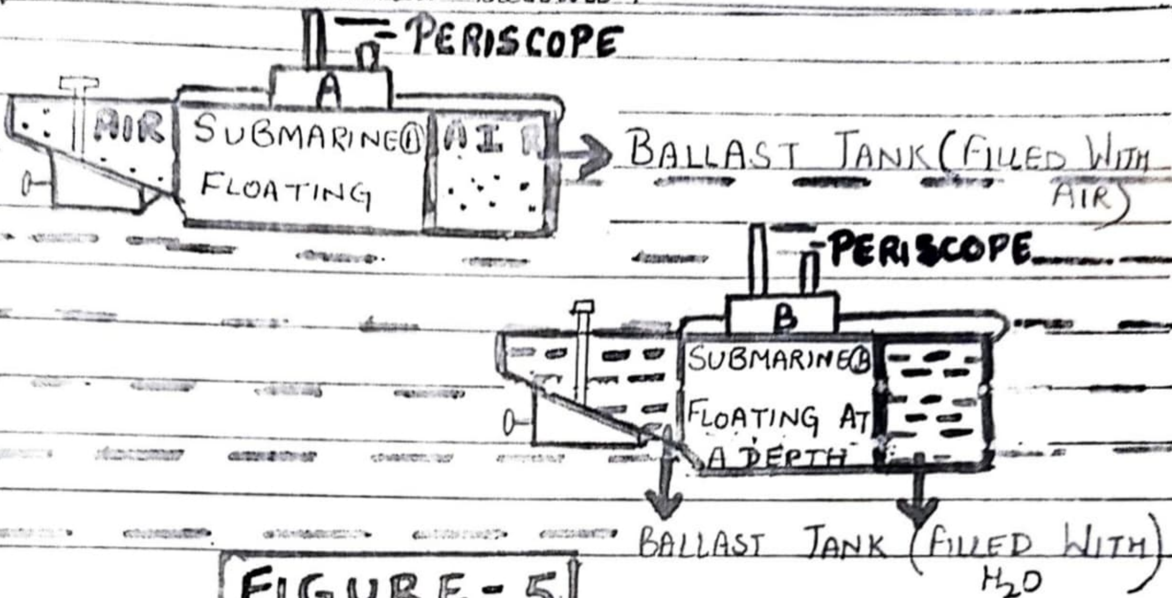
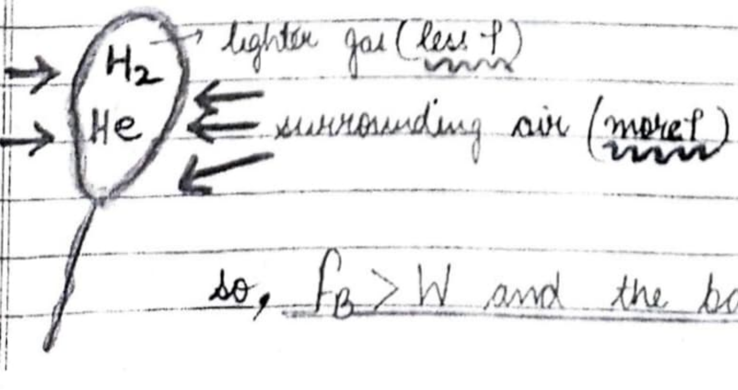


FIGURE-5

If a submarine is to dive, its ballast tank is filled with H_2O so that its density becomes greater than the density of sea water and submarine dives into water (as depicted in figure-5 submarine B). If submarine is to rise, water is forced out into the sea and compressed air is allowed to enter the ballast tank such that the average density of submarine decreases and it rises up to the surface of water.

4. RISING OF BALLOONS — When a light gas like hydrogen or helium is filled in a balloon, the weight of air by the inflated balloon (i.e. F_B) is more than the weight of the gas filled balloon and it rises up.



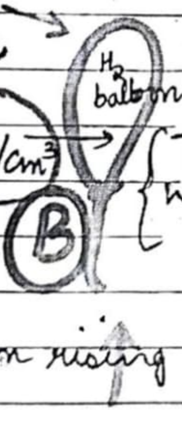
So, Weight of balloon $\propto \rho_{He \text{ or } H_2}$

$F_B \propto \rho_{\text{surrounding air}}$

so, $F_B > W$ and the balloon rises above

NOTE: If you blow air in a balloon and then tie it with a thread, then if you leave the balloon instead of rising above, it sinks down. Why? The balloon which is inflated by blowing air through your mouth is having CO_2 inside it. CO_2 is a denser gas as compared to the surrounding air and hence the weight of inflated balloon is more than the upthrust given by surrounding air and hence it does not rise and floats in air rather it sinks $\because \rho_{object} > \rho_{fluid}$.
(Fluid is surrounding air which is giving upthrust)
The balloon filled with H_2 and He does not rise indefinitely (i.e. these balloons will not continue to rise for indefinite period).

$\rho_{H_2} = \rho_{air}$ → Density of surrounding air $= 0.09 \times 10^{-3}\ g/cm^3$



$\rho = 0.09 \times 10^{-3}\ g/cm^3$ ← $(F_B = W)$

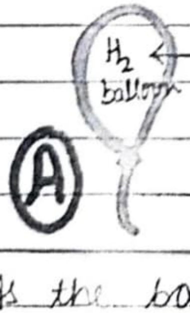
B

{The balloon will not rise further}

As we move at high altitude, ρ_{air} decreases

(refer Exercise-4(B))

↑ Balloon rising upward



← $\rho_{balloon} = 0.09 \times 10^{-3}\ g/cm^3$

A

$\boxed{\rho_{air} > \rho_{H_2} \quad F_B > Weight}$ **Balloon rises**

At this level, $\rho_{air} = 1.3\ kg/m^3$
$= 0.013\ g/cm^3$

As the balloon gradually rises above from point A to B, the density of surrounding air decreases due to which the upthrust also decreases ($F_B \propto \rho_{air}$). At a point, F_B = Weight of balloon (B in the above diagram). At this moment, the balloon will stop rising above.

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NUMERICALS OF EXERCISE — 5 (C)

1. Weight of rubber Ball $= V_{Ball} \times \rho_{Ball} \times g$

$F_B = V_{\text{submerged part of ball in } H_2O} \times \rho_{H_2O} \times g$ = upthrust

According to principle of floatation, F_B = Weight

$V_{\text{submerged part}} \times \rho_{H_2O} \times \cancel{g} = V_{Ball} \times \rho_{Ball} \times \cancel{g}$

$$\frac{2}{3} V_{ball} \times (1000\ kg/m^3) = V_{ball} \times \rho_{Ball} \quad \text{— (1)}$$

GIVEN → $\frac{1}{3}^{rd}$ Volume of rubber ball is outside the water.
This means that $\left(V - \frac{1}{3}V\right)$ volume is floating in water which comes to be $\frac{2}{3}V$

So, $\frac{2}{3} \times \cancel{V} \times 1000\ kg/m^3 = \cancel{V} \times \rho_{Ball}$ (By equation 1)

so, $\rho_{ball} = \frac{2}{3} \times 1000\ kg/m^3 = 666.\bar{6}\ kg/m^3$

$\rho_{ball} = 667\ kg/m^3$ (after rounding)

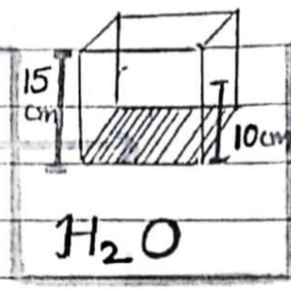
4. Let the total volume of wax → be V_1
and the volume of wax submerged in brine → be V_2
now, upthrust given by Brine (F_B) = Weight of wax W

$V_2 \times \rho_{Brine} \times \cancel{g} = V_1 \times \rho_{wax} \times \cancel{g}$

$$\frac{V_2}{V_1} = \frac{\rho_{wax}}{\rho_{Brine}} = \frac{0.95\ g/cm^3}{1.1\ g/cm^3} = 0.86.$$

∴ the fraction of immersed in brine (water with salt in it) = 0.86.

6. CASE-1 : Volume = (l x b) x h
Volume = area x height
Uniform area
(base is entirely submerged in water) as well as spirit



So, Weight of wood = upthrust given by H_2O

$V_{wood} \times \rho_{wood} \times \cancel{g} = V_{\text{submerged part}} \times \rho_{H_2O} \times \cancel{g}$

$\cancel{Area} \times 15cm \times \rho_{wood} = \cancel{Area} \times 10\,cm \times 1\,g/cm^3$

$\rho_{wood} = \frac{10 \times 1}{15}\,g/cm^3 = 0.\bar{6}\,g/cm^3$

$\rho_{wood} = 0.6666\ldots g/cm^3 = 0.667\,g/cm^3$ (upto 3 decimal places)

CASE-2 : Weight of wood = upthrust given by spirit

$V_{wood} \times \rho_{wood} \times \cancel{g} = V_{\text{submerged part}} \times \rho_{spirit} \times \cancel{g}$
(from part 1)

$A \times 15 \times \frac{10}{\cancel{15}} = Area \times 12 \times \rho\,(g/cm^3)$

$\therefore \rho_{spirit} = \frac{10}{12} = \frac{5}{6} = 0.833\,g/cm^3$

($\rho_{wood} = \frac{10}{15}\,g/cm^3 = 0.667\,g/cm^3$ was calculated in case-1. This value is used on L.H.S in case-2)

INSTRUCTIONS : Students are advised to go through the given notes carefully and then read the theory of Exercise - 5(C).

HOMEWORK : Students are required to do the tick marked questions and numericals in Physics notebook.

(Thank you!) (LAST PAGE)