ARCHIMEDES' PRINCIPLE

Statement:

" A body immersed wholly or partially in a fluid (liquid or gas) experiences an upthrust force in the vertical direction equal to the weight of the volume of the liquid displaced by the body ".

Exp. To prove the principle practically: -

1- Measure the weight of the body in air (real weight).

2- Measure the weight of the body in the liquid (apparent weight).

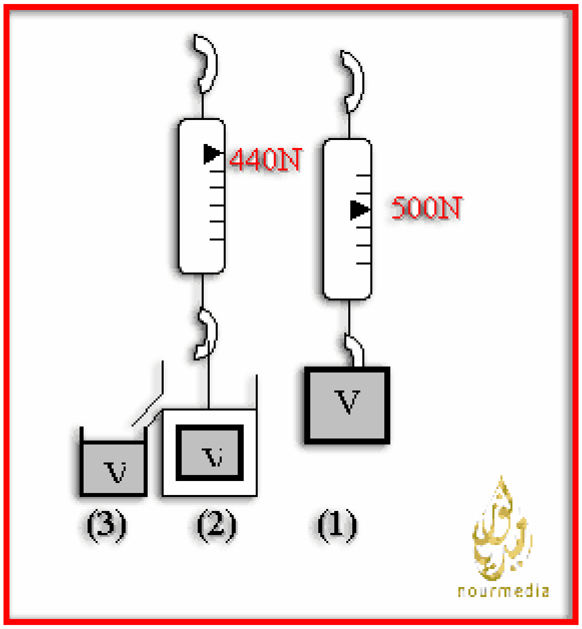
3- Measure the volume of displaced liquid.

4- Calculate the value of up thrust force .

$$F_b = \text{real weight} - \text{apparent weight}$$

5- Calculate the

$$\text{Weight of displaced liquid,} = M_L g = \rho_L V_{immersed} g$$



Conclusion - :

The upthrust force equals the weight of the displaced liquid by the immersed portion from the body.

The Mathematical drive- :

Prove that upthrust force is determined from the relation

$F_b = \rho_L V g$

Prove that upthrust force is caused by the difference in pressure.

Prove that upthrust force does not depend on atmospheric pressure.

Answer

Imagine a cylinder of liquid inside the liquid.

The forces that affect the Cylinder - :

1- Horizontal forces : -

Equal in magnitude and opposite in direction (cancel each other).

2- The vertical forces : -

a-A force F_1 acts on the upper base due to P_1

$F_1 = P_1A = (P_a + r\ g\ h$ (١A

F = ١P_a A + r g h ١A

b-A force F ٢acts on the lower base due to P ٢at depth h ٢

F ٢ =P٢A = (P_a + r g h (٢A

F ٢ =P_a A + r g h ٢A

F_b =F -٢F = ١P_a A+ r g h ٢ A -P_a A- r g h ١ A

F_b = r g h ٢A - r g h ١A

= r g A (h - ٢ h (١

But (h - ٢ h = (١ h

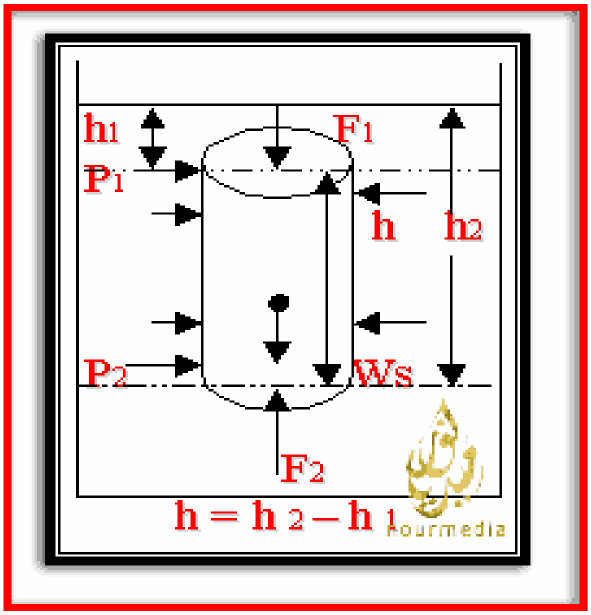
$F_b = \rho_L\ g\ A\ h$

$P_L\ V = M_L$

But Ah = V

$F_b = \rho_L g\ V = M_L\ g$

= weight of displaced liquid



-٣Weight of the cylinder- :

$W_S = m\,g = \rho_s V g$

The liquid is at rest and the cylinder is in equilibrium between its weight (which acts downwards) and F_b) which acts upward (

OR- :

The horizontal forces are equal and opposite in direction so they cancel each other .

The up thrust force due to the difference in pressure between the lower and the upper bases.

$F_b = \Delta P\,A$

But ΔP between any two points in the liquid equals $\rho_L g\,h$

$F_b = P_L\,g\,h\,A$

But A h = V

$F_b = \rho_L V g$

F_b = The weight of displaced liquid.

= Weight of the cylinder

The liquid is at rest, and the cylinder is suspended and its apparent weight equals zero.

Because $F_b = W_S$

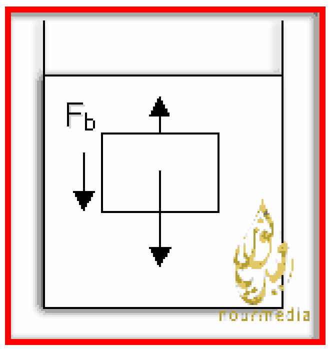
The sinking body- :

Replace the imaginative cylinder with another one of denser substance.

$\downarrow W_S < F_b$

$\rho_s V g < \rho_L V g$

$\rho_s < \rho_L$ for solid body (not hollow .(



The sinking body has an apparent weight that equals- :

Apparent weight = real weight - F_b

Apparent weight for the sinking body is positive.

Because the real weight > upthrust force.

It causes pressure on the bottom of the container.

$$P = \frac{\text{Apparent weight}}{\text{Area}}$$

The suspended solid body- :

When the weight of the body equals the up thrust force the body is suspended.

$W_S = F_b$

$\rho_s V g = \rho_L V g$

$\rho_s = \rho_L$ for solid body (not hollow (

Example: cold Aniline in warm water Apparent weight = 0

The suspended hollow body- :

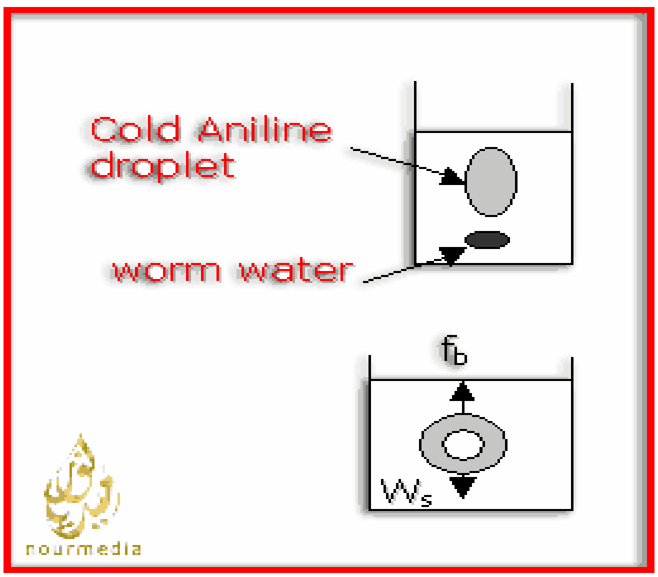
$W_S = F_b$

$M_{crust}\, g = \rho_L V g$

$M_{crust} = \rho_L V$

$\rho_s V_{crust} = \rho_L V$

$$V_{crust} = \frac{\rho_L V}{\rho_S}$$



The Floating body- :

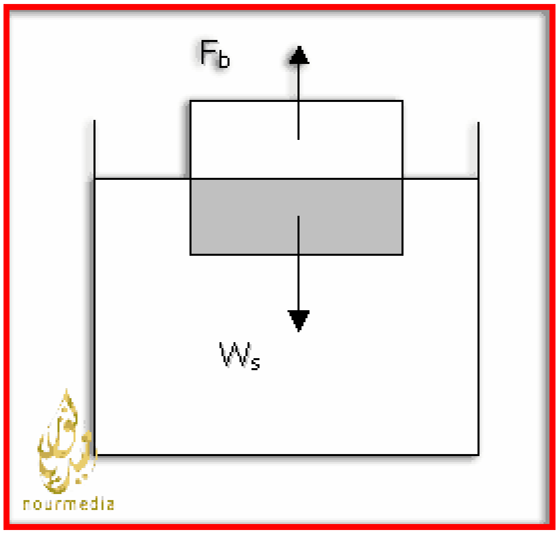
$W_S = F_b$

$Mg = \rho_L V_{immersed}\, g$

$M_S = \rho_L V_{\text{immersed}}$

$P_S V = \rho_L V_{\text{immersed}}$

$$\frac{P_s}{P_L} = \frac{V^{`}}{V}$$



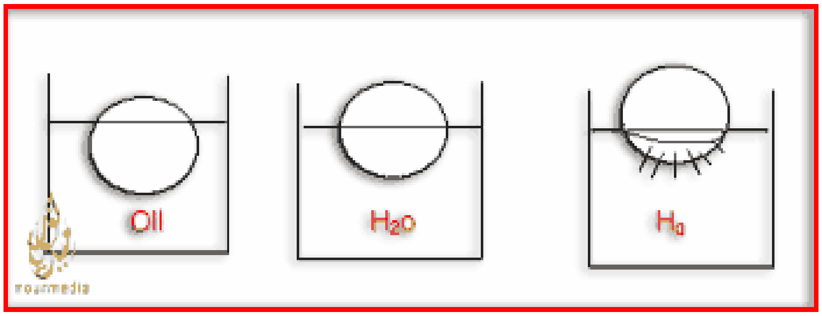
• =Apparent weight

$_S$W = $_b$Because F

- :The Floating law

A body floating over the surface of a liquid experiences an up thrust“ on equal to the weight of the volume of theforce in the vertical directi liquid displaced by the submerged part and equal to the weight of the ”.floating body

$$F_b = W_S = \rho_L V g$$



- :The mathematical formula of floating law

$_SW =_b F$

$\rho_L \acute{} V_{immersed} = \rho_S V$

$$\frac{P_S}{P_L} = \frac{V^{`}}{V}$$

- :١Q

will the Fb vary in ،ree different liquidsIf the same body is placed in th ؟the three cases

Answer

on the three cases $_SW = _b$Because F .No

- :٢Q

؟Is there any up thrust force on a body on the bottom of the sea

Answer

= and its pressure on the bottom ،Yes $\frac{\text{Apparent weight}}{\text{Area}}$

- :٣Q

t force on the submarine below water change byDoes the buoyan ؟changing its depth

Answer

.because its volume is constant ،No

- :٤Q

؟Why ؟on a ship in fresh water equal that in salty water $_b$Does F

Answer

.in the two cases $_sW$ = $_b$because F ،Yes

The methods for solving problems

- :Floating body -١

$_bF = {_S}W$

$= M g \rho_L V' g$

$Mg = \rho_L V'$

$P_S V = \rho_L V'$

$$\frac{P_S}{P_L} = \frac{V'}{V}$$

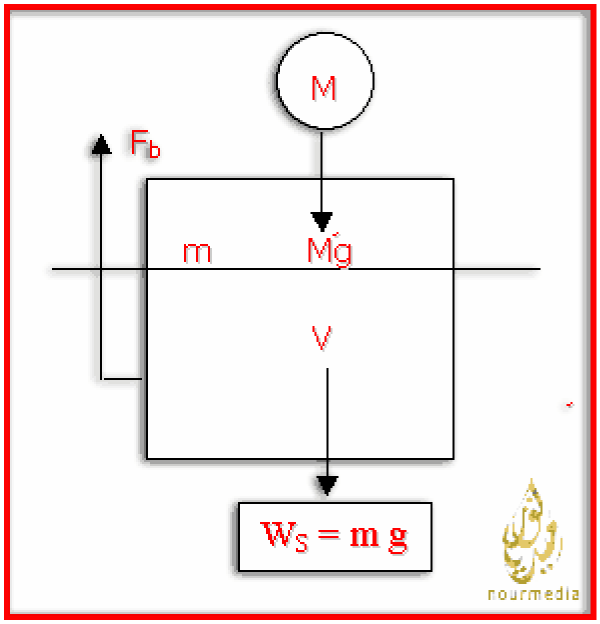
2- A mass is placed on a floating body:

$W_S + W_{mass} = F_b$

$M g + m g = \rho_L V' g$

$M + m = \rho_L V'$

$\rho_S V + m = \rho_L V'$

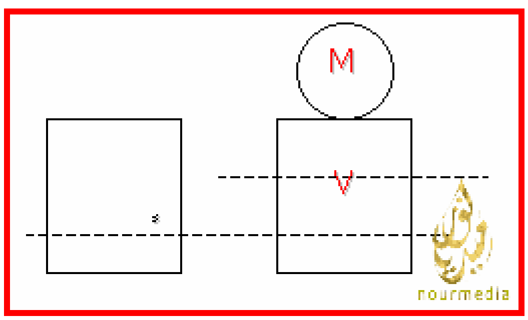


- :The additional weight only -٣

$_bF = M\,g$

$= M\,g\,\rho_L\;V'\,g$

$M = \rho_L V'$



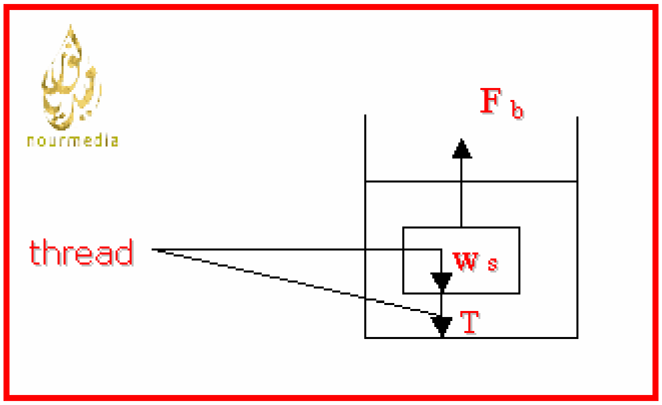
4- Suspended body by a thread tied to the bottom: -

$F_b = W_S + T$

$T = F_b - W_S$

$T = \rho_L\;V\,g - \rho_s V\,g$

$T = \rho_s V\,g\,(\rho_L - \rho_s)$



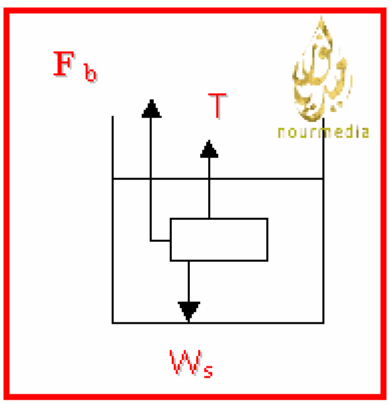
The body is suspended by tied to upward: -

$T + F_b = W_S$

$T = W_S - F_b$

$T = \rho_S - V g \rho_L V g$

$) V g = T \rho_S - \rho_L ($

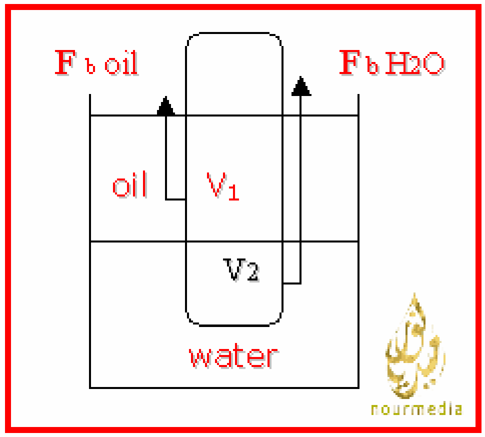


$F_{b\ Oil} + F_b^{H_2O}\ {}_S W =$

$\rho_{Oil} + g_{١} V \rho_{H_2O}\ mg = g\ {}_{٢}V$

$\rho_{Oil} + {}_{١}V \rho_{H_2O} V\ {}_S P = {}_{٢}V$

$\rho_{Oil} + {}_{١}V\ \rho_{H_2O} = ({}_{١}V - V)\ \rho_s V$



- :OR

ρ_{Oil} + (٢V - V) ρ_{H_2O} = ٢V ρ_s V

A is constant

- :OR

ρ_{Oil} + (٢h - h) ρ_{H_2O} = ٢h ρ_s h