MECHANICAL PROPERTIES OF FLUIDS

CHAPTER-9

CLASS XI

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PRESSURE: It is defined as the thrust ($\perp$r F) exerted per unit area.

$$\text{Pressure, } P = \frac{\text{Force, } F}{\text{Area, } A}$$

Unit - Pascal, Pa ; 1 Pa = 1 N/m^2

other units : atm : 1 atm = 1.013×10^5 Pa

1 torr = 133 Pa

1 bar = 10^5 Pa

Dimensional formula: $[ML^{-1}T^{-2}]$

Note: * Smaller the area over which the force acts, larger is the pressure exerted.

* Larger the area over which the force acts, smaller is the pressure exerted.

Density : Density, $\rho = \dfrac{\text{mass}, m}{\text{Volume}, V}$

nearly constant $\forall$ pressures for incompressible liquids.

Relative Density : R.D. of a substance = $\dfrac{\text{Density of substance}}{\text{Density of water at } 4^\circ C.}$

Density of water at $4^\circ c$ (277 K) = $1 \times 10^3\ kg/m^3$ or $1\ g/c.c.$

R.D. is a dimensionless positive scalar quantity.

RELATIVE DENSITY:

Compare

object 1

$x \ Kg/m^3$

object 2

$3x \ Kg/m^3$

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Density of object -1 w.r.t. object 2 :-

$$= \frac{\text{Density of object -1}}{\text{Density of object -2}} = \frac{\cancel{x}}{3\cancel{x}}$$

$$= \frac{1}{3}$$ ⟷ comparison

Density of object-2 w.r.t. object -1 :-

$$= \frac{\text{Density of object -2}}{\text{Density of object -1}} = \frac{3x}{x} = 3$$

NO UNITS

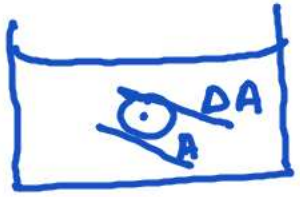
Fluid :- Liquids and gases can flow, are therefore, called fluids.

Assumptions: Liquids, we deal with are:

(i) incompressible $\Rightarrow$ Density - constant

(ii) Non-viscous

Pressure in a fluid :- $P = F/A$



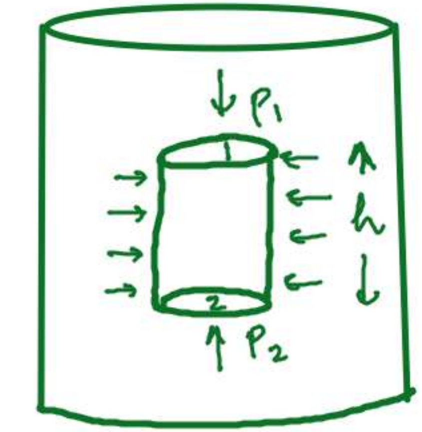
consider a pt., A and a small area containing the pt., A. Fluid on one side of the area presses the fluid on the other side & vice-versa

Pressure of the fluid at pt., A :

$$P = \lim_{\Delta A \to 0} \frac{F}{\Delta A}$$

for homogeneous and non-viscous fluid, P doesn't depend upon orientation of ΔA & we talk of pressure at a point for such fluids.

VARIATION OF PRESSURE WITH HEIGHT:



Consider a cylindrical element of fluid, having area of base, A and height, h. As the fluid is at rest,

Resultant horizontal forces = 0

Resultant Vertical forces = Weight of the element

$$(P_2 - P_1) A = mg$$

$$\Rightarrow (P_2 - P_1) A = \rho . V g \quad (\because m = V.\rho)$$

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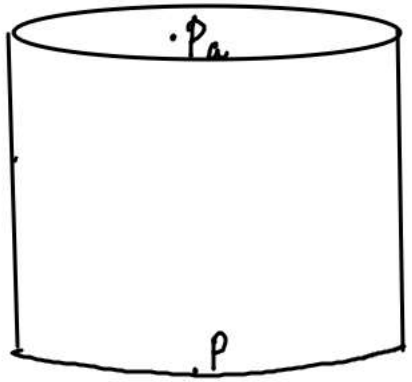
$$\Rightarrow (P_2 - P_1) \cancel{A} = \rho \cancel{A} h g \quad (\because V = Ah)$$

$$\Rightarrow \boxed{(P_2 - P_1) = \rho g h}$$

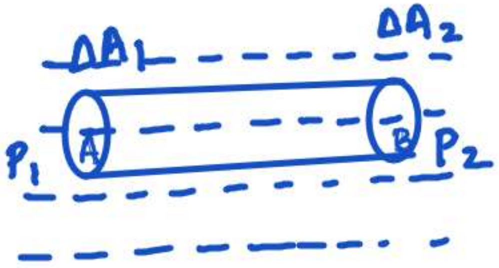


Replace P_1 by $P_a \rightarrow$ atmospheric Pressure & P_2 by P, we get

$$P = P_a + \rho g h$$

$$\Rightarrow \underbrace{P - P_a}_{\text{Gauge Pressure}} = \rho g h$$

VARIATION OF PRESSURE IN THE SAME HORIZONTAL LINE:



Consider two points A and B in the same horizontal line. Imagine, small vertical area ΔA_1 containing point, A and ΔA_2, containing point, B.

$$\Delta A_1 = \Delta A_2 = \Delta A$$

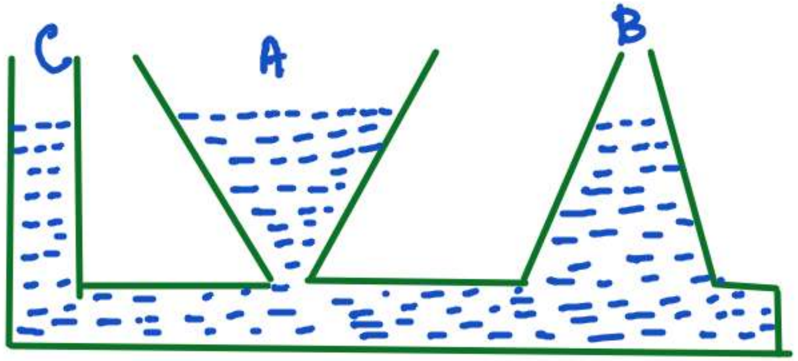
Pressure at A $= P_1$

Pressure at B $= P_2$

forces:- (i) $P_1 \Delta A$ towards right & (ii) $P_2 \Delta A$ towards left

$$P_1 \Delta A = P_2 \Delta A \quad \text{(for the fluid in equilibrium)}$$

$$\Rightarrow \boxed{P_1 = P_2}$$

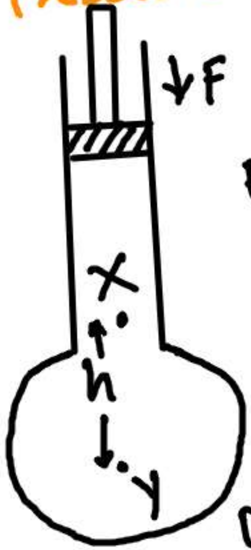


Hydrostatic Paradox: A, B and C are of different shapes. level of water in the three vessels is the same. though, they hold different amts of water. P→same ∵ h→same

PASCAL'S LAW :-

Pressure in a fluid at rest is same at all points if we ignore gravity.

* If the pressure in a liquid is changed at a particular point, the change is transmitted to the entire liquid without being diminished in magnitude.
* Liquid exerts pressure equally in all directions.
* Pressure difference - same b/w two given points in a fluid.



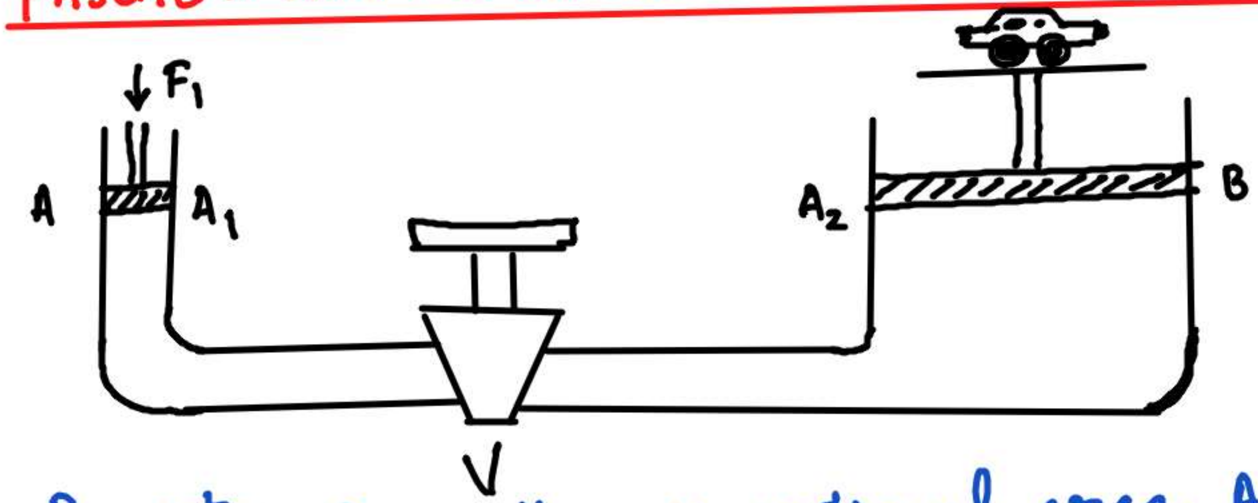
Consider a flask fitted with a piston, filled with liquid. External force, F is applied on the piston. Let 'A' be the area of cross-section of the piston.

Pressure just below the piston increases by (F/A).

__According to Pascal's law:__ Pressure at any pt; Y also increases by F/A.

On applying ext. force, F. 'h' has not been changed because, liquid is incompressible. & hence, ΔP remains unchanged. $\Delta P = \rho g h$ (no change in ΔP)

PASCAL'S LAW : APPLICATION : HYDRAULIC LIFT



to raise heavy loads (e.g. Car).

Valve, V allows the fluid to go from A to B.

A piston of small cross-sectional area, A_1 is used to exert a force, F_1, directly on the liquid. The Pressure, $P = F_1/A_1$ is transmitted throughout the liquid to the larger cylinder, attached with a larger piston of Area, A_2; which results in the upward force of $(P \times A_2)$. ∴ Piston is capable of supporting large force, F_2.

$$F_2 = P \times A_2 = \left(\frac{F_1}{A_1}\right) A_2$$

Since, $A_2 > A_1$ ∴ $\left(\frac{A_2}{A_1}\right) > 1 \Rightarrow F_2 > F_1$ (by the factor of $\frac{A_2}{A_1}$)

A_2/A_1 : Mechanical Advantage of the device.

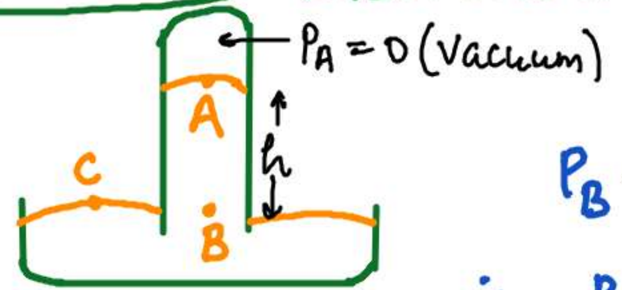
Atmospheric Pressure :

On the top of atmosphere, $P_{atm} = 0$

Pressure at a distance, h below the top $= \int_0^h \rho g \, dh$

(neither ρ nor g is constant, over large variations in heights)

Torricelli : Instrument - Barometer - for measuring P_{atm}.



P_C : atmospheric Pressure

$P_B = P_C$ (same horizontal line)

$\therefore \quad P_B =$ atm. Pressure, P_0

Let B be at a depth, h below A.

$\therefore \quad P_B = P_A + \rho g h$

$\Rightarrow \quad P_0 = 0 + \rho g h$

$\Rightarrow \quad \boxed{P_0 = \rho g h}$

ρ : density of Hg

76 cm of Hg

$P_0 = \rho g h$

$= (13.6 \times 10^3 \, Kg/m^3)(9.8 \, m/s^2)(0.76 \, m)$

$= 1.01 \times 10^5 \, Pa$

$=$ 1 atm

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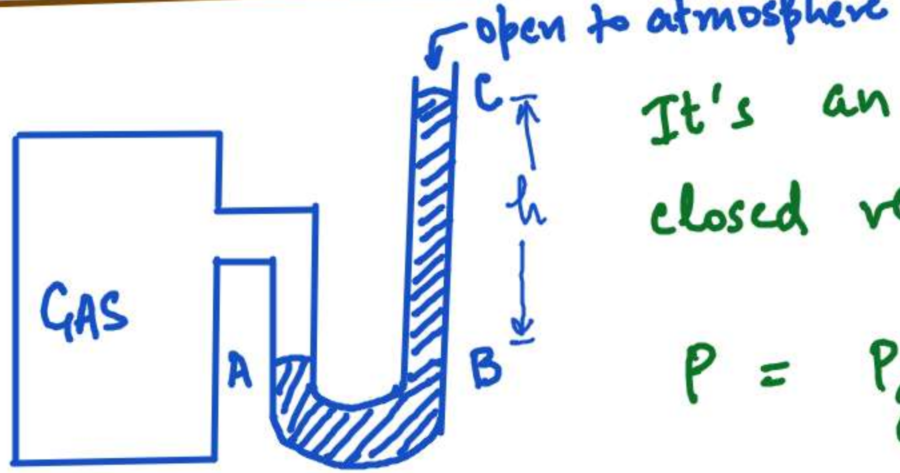
OPEN TUBE MANOMETER :-



It's an instrument used for measuring Pressure in a closed vessel containing gas.

$$P = P_{gas} = P_A = P_B = P_c + \rho g h$$

$$= P_0 + \rho g h \qquad (\because P_c = P_0 = \text{atm } P)$$

$\uparrow$ atm. Pressure.

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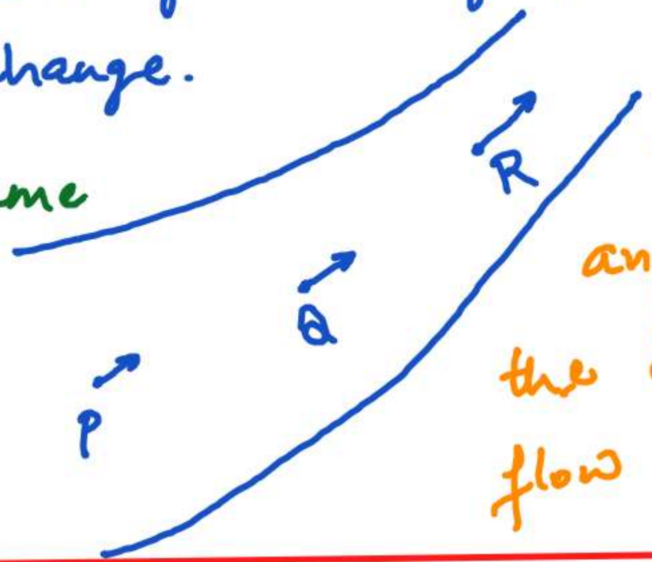
Excess Pressure, $P - P_0$ = guage Pressure.

$\underline{P - P_0 = \rho g h}$: $(P - P_0)$ is proportional to the manometer height, h.

FLOW OF FLUIDS:

1) **STEADY FLOW**: orderly / streamline / laminar :- Velocity at every point in the fluid remains constant. speed and direction may change.

All the particles reaching P will have the same speed at P. All the particles reaching R will have the same speed at R.
Each particle follows the same path as taken by the previous particle.



Tangent at any point gives the direction of fluid flow at that point.

2) **Turbulent Flow**:- Fluid flow remains steady if its velocity doesn't exceed a limiting value, called its critical velocity. beyond which the flow loses all streamlines & b'come zig-zag & sinuous, acquiring, what is called turbulence.
velocities of diff particles thro' the same pt. may be different & change eratically with time. e.g. High fall, fast flowing river etc.

LINE OF FLOW

Two streamlines can't intersect each other. Otherwise, the particle reaching at the intersection will have two different direction of motion, and the flow will no longer be steady, but turbulent.

TUBE OF FLOW

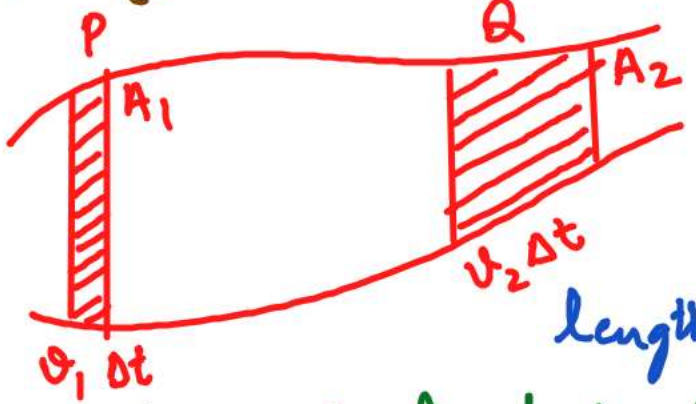
Take two areas, P and Q, normal to the direction of flow, and draw streamlines through their boundaries, a tubular portion of the liquid is enclosed by them, called "tube of flow".

Tube of flow, thus functions as a pipe of same shape as its own, with the fluid entering it at one end & leaving at the other.

Equation of continuity: Law of conservation of mass in fluid Dynamics :- Volume flux / flow rate - constant

Total mass going into the Tube through any cross-section
= Total mass coming out of the tube from any other cross-section.

ρ : const (Incompressible fluid)



Consider two cross-sections at pts P & Q.

Area of cross-sections at pts P & Q = A_1 & A_2 respectively

Speed of fluid = v_1 at P & v_2 at Q

Construct a cylinder of length, $v_1 \Delta t$ at P & cylinder of length, $v_2 \Delta t$ at Q.

Volume of fluid thro' P in time, Δt = $A_1 \cdot (v_1 \Delta t)$

Illy " " " " Q " " " = $A_2 (v_2 \Delta t)$

mass " " " P " " " = $A_1 \cdot (v_1 \Delta t) \rho$

" " " " Q " " " = $A_2 (v_2 \Delta t) \rho$

$\therefore A_1 (v_1 \Delta t) \rho = A_2 (v_2 \Delta t) \rho$

$\Rightarrow A_1 v_1 = A_2 v_2$

$\Rightarrow \boxed{Av = \text{constant}}$

If $A_1 > A_2 \Rightarrow v_1 < v_2$

It's associated with a change in Pressure in fluid flow

ENERGY OF THE FLUID: (i) K.E. (ii) P.E. (iii) Pressure Energy

Energy per unit mass per unit volume:

mass per unit volume / mass of unit volume of fluid : ρ

(i) K.E. (m, ρ, v) $= \frac{1}{2}mv^2$

K.E. per unit mass $= \frac{1}{2}v^2$

$\therefore$ K.E. per unit mass per unit volume $= \frac{1}{2}v^2 \times \rho = \frac{1}{2}\rho v^2$

(ii) P.E. $= mgh$

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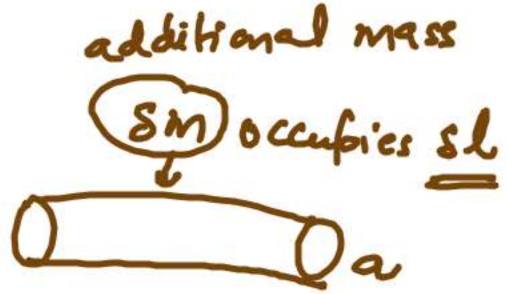
P.E. per unit mass $= gh$

$\therefore$ P.E per unit mass per unit volume $= gh \times \rho = \rho g h$



(iii) Pressure Energy :- cross-sectional area : a , Hydrostatic Pressure $= P$

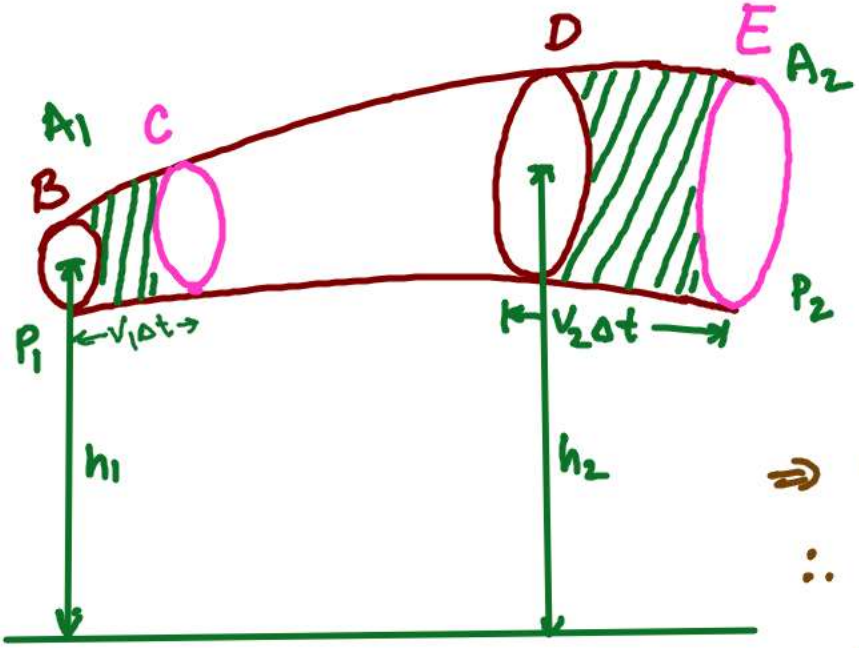
Pressure energy = W.D. on the mass, $\delta m = F \times \delta l = (Pa).\delta l$

Pressure energy per unit mass $= (Pa)\frac{\delta l}{\delta m} = (Pa)\frac{\delta l}{(a\delta l).\rho} = \frac{P}{\rho}$

Pressure energy per unit mass per unit volume $= \frac{P}{\rho} \times \rho = P$

BERNOULLI'S PRINCIPLE: Application of Work-Energy Theorem in fluid flow:

Total Energy of an incompressible, non-viscous fluid in steady flow remains constant throughout the flow. Bernoulli's equation relates pressure difference b/w two points in a pipe to both velocity changes (K.E. change) and elevation/height changes (P.E. change).



Consider the fluid initially lying b/w B & D.

In Δt : fluid of volume ΔV, has moved from B to C & D to E.

$BC = v_1 \Delta t$, $DE = v_2 \Delta t$

W.D. on the fluid at BC, $W_1 = P_1 A_1 (v_1 \Delta t) = P_1 \Delta V$

W.D. by the fluid at DE, $W_2 = P_2 A_2 (v_2 \Delta t) = P_2 \Delta V$

$\Rightarrow$ W.D. on the fluid at DE, $W_2 = -P_2 \Delta V$

$\therefore$ Total W.D. on the fluid $= W_1 - W_2 = (P_1 - P_2)\Delta V$

Mass passing through the pipe in time, Δt = $\Delta m = \rho A_1 v_1 \Delta t = \rho \Delta V$

Change in gravitational P.E. = $\Delta U = \Delta m g (h_2 - h_1) = \rho g \Delta V (h_2 - h_1)$

Change in K.E. = $\Delta K = \frac{1}{2}\Delta m (v_2^2 - v_1^2) = \frac{1}{2}\rho \Delta V (v_2^2 - v_1^2)$

BERNOULLI'S PRINCIPLE CONTD:

By using Work-Energy theorem, we get

$$(P_1 - P_2)\Delta V = \frac{1}{2}\rho\Delta V(v_2^2 - v_1^2) + \rho g \Delta V(h_2 - h_1)$$

$$\Rightarrow (P_1 - P_2) = \frac{1}{2}\rho(v_2^2 - v_1^2) + \rho g(h_2 - h_1)$$

$$\Rightarrow P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \quad -(1)$$: Bernoulli's Equation

$$\Rightarrow \boxed{P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}}$$

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For the fluid at rest : Eqn (1) becomes -

$$P_1 + \rho g h_1 = P_2 + \rho g h_2$$

$$\Rightarrow (P_1 - P_2) = \rho g(h_2 - h_1)$$

* Bernoulli's Eqn does not hold for non-steady, turbulent flows because of constant fluctuation in velocity and pressure.

APPLICATIONS OF BERNOULII'S EQUATION:

1.) Hydrostatics

2.) Speed of Efflux : Torricelli's Law

3.) Venturi-meter

4.) Aspirator Pump

5.) The Pitot tube

6.) Vascular Flutter and Heart Attack

7.) Dynamic Lift

a) Ball moving without spin

b) Ball moving with spin — Magnus Effect

c) Aerodynamics — Aerofoil or lift on aircraft wing

Hydrostatics: Speed of fluid = 0 , everywhere

As, $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

If $v_1 = v_2 = 0$

$\therefore \quad P_1 + \rho g h_1 = P_2 + \rho g h_2$

$\Rightarrow \quad \boxed{(P_1 - P_2) = \rho g (h_2 - h_1)} \leftarrow$ Variation of P with depth.

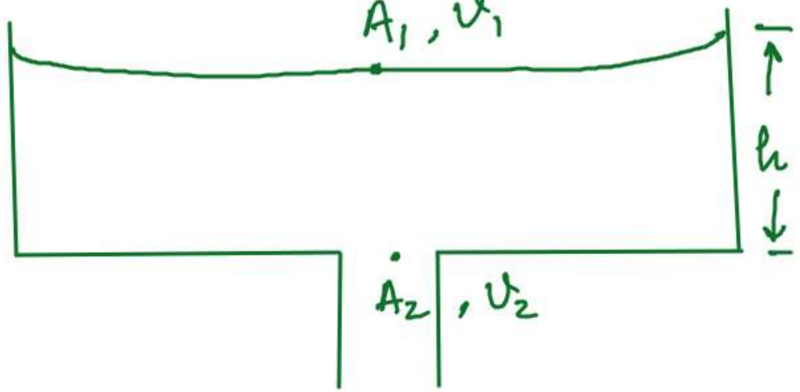
Speed of Efflux: Torricelli's Law:-

"Efflux" means fluid outflow.

Torricelli's law: Speed of liquid coming out through a hole, at depth, h, below the free surface is same as that of a particle fallen freely through a height, h under gravity.

i.e., $\boxed{v = \sqrt{2gh}}$

* Speed of the liquid coming out is called speed of Efflux.



$A_2 << A_1$

Both the cross-sections are open to atmosphere.

$\therefore \; P = P_a$

h → Height of the free surface above the hole.

As, $P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$ (Bernoulli's relation)

$\therefore \quad P_a + \frac{1}{2}\rho v_1^2 + \rho g h = P_a + \frac{1}{2}\rho v_2^2$ —— (1)

Also, $A_1 v_1 = A_2 v_2$

$\therefore$ eq^n (1) b'comes: $\frac{1}{2}\rho\left(\frac{A_2}{A_1}\right)^2 v_2^2 + \rho g h = \frac{1}{2}\rho v_2^2$

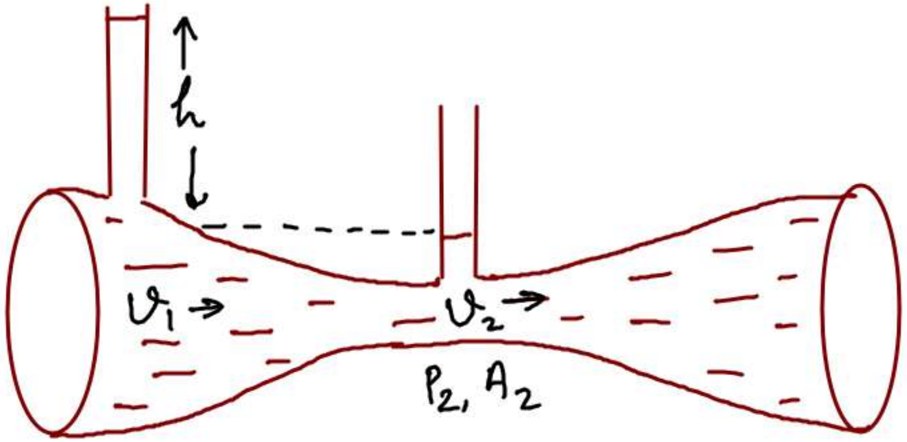
$\Rightarrow \left[1 - \left(\frac{A_2}{A_1}\right)^2\right] v_2^2 = 2gh$

As, $A_2 << A_1$

$\Rightarrow v_2^2 = 2gh$

$\therefore \boxed{v_2 = \sqrt{2gh}}$

Venturi-meter:



The Venturi-meter is a device to measure the flow speed of incompressible fluid.

As, $A_1 v_1 = A_2 v_2$ (eq^n of continuity) — (1)

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$ (Bernoulli's Eq^n)

$\Rightarrow (P_1 - P_2) = \frac{1}{2}\rho (v_2^2 - v_1^2)$ — (2)

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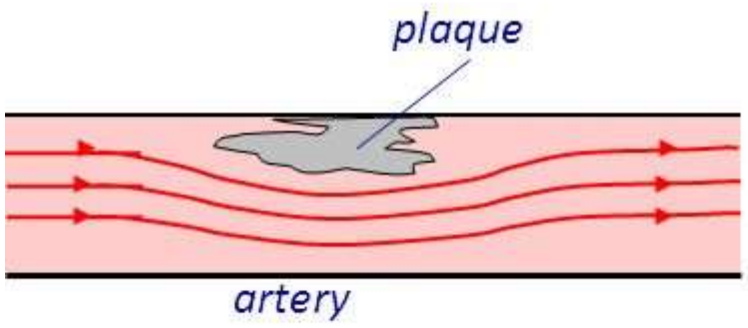
Also, $P_1 - P_2 = \rho g h$ — (3) (h : difference in heights of levels of liquid)

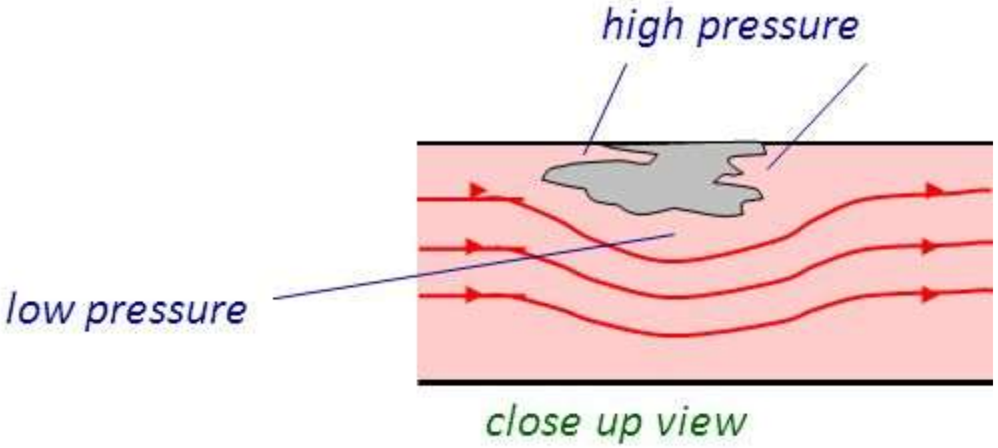
from (2) & (3): $\boxed{v_2^2 - v_1^2 = 2gh}$

Applications: (i) The carburetor of automobile has a Venturi channel (nozzle) through which air flows with high speed.

(ii) Filter pumps or Aspirators, Bunsen burner, atomisers & sprayers used for perfumes or to spray insecticides, work on the same principle.

Heart Attacks & Bernoulli





Arteries can become constricted with plaque (atherosclerosis), especially if one eats a poor diet and doesn't exercise. The red streamlines show the path of blood as it veers around the plaque. The situation is similar to air flowing around a curved airplane wing. The pressure is lower where the fluid (blood) is flowing faster. The pressure difference can dislodge the plaque. The plaque can then lodge in and block a smaller artery. If it blocks an artery supplying blood to the heart, a heart attack can ensue.

Vascular Flutter & Heart Attack:

The artery may get constricted due to the accumulation of plaque on its inner walls.

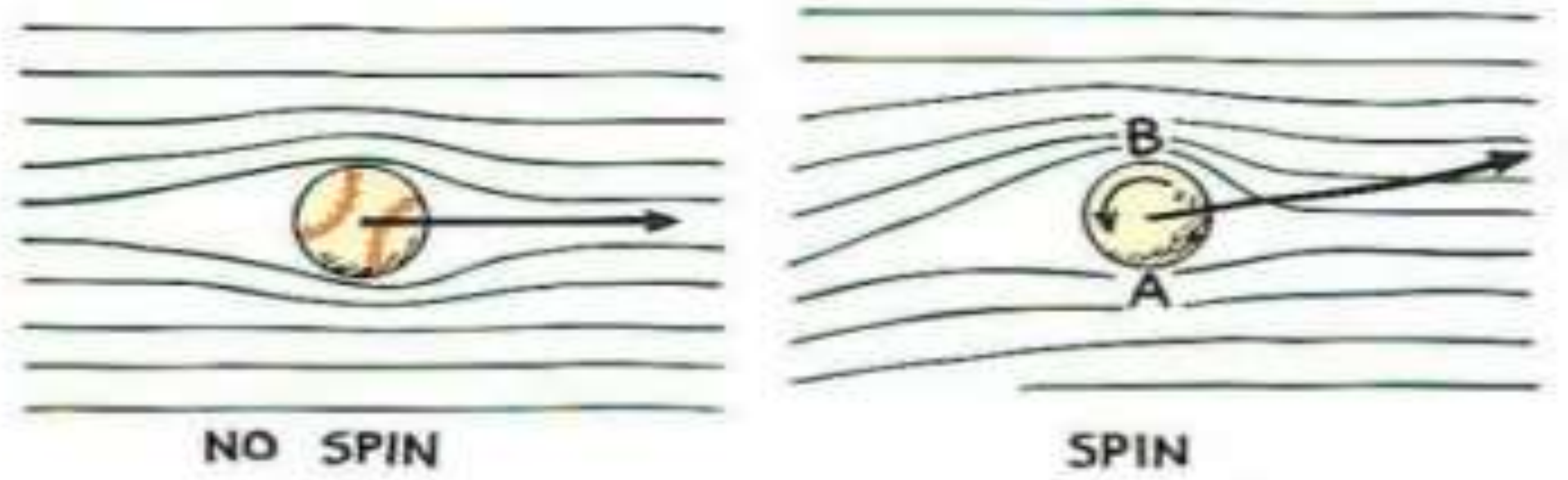
In order to drive the blood through this constriction, speed of flow is raised. Inside pressure drops and artery may collapse, due to external pressure.

The heart exerts further pressure to open this artery and forces the blood through.

As the blood rushes through the opening, the internal pressure once again drops leading to vascular flutter, which can lead to dislodgement of plaque that can then go and block a smaller vessel leading to heart attack.

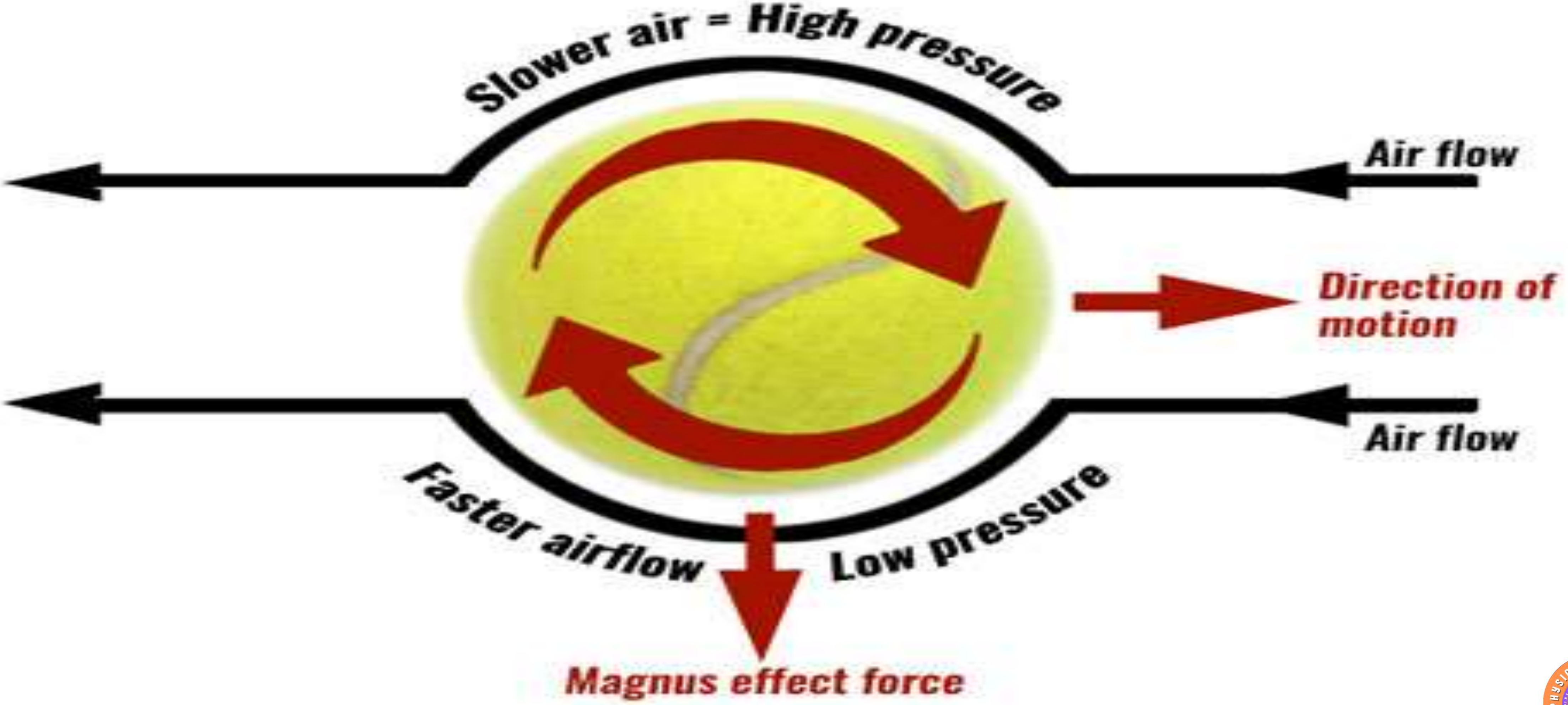
Bernoulli's Principle

Application - Tennis Ball



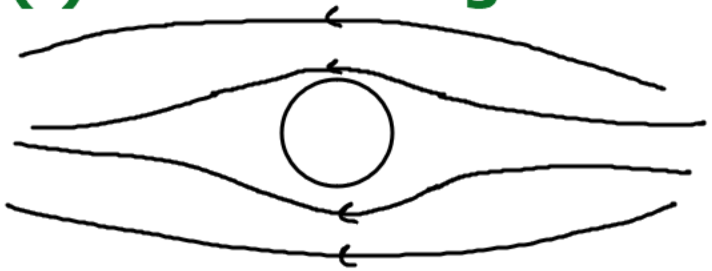
Spin & The Magnus Effect

The spin on the ball slows down the air flow on one side and speeds it up on the other side creating a pressure difference and causing the ball to move.

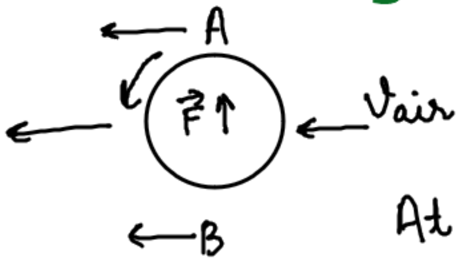


Dynamic Lift: It is the force that acts on a body by virtue of its motion through a fluid.

(i) Ball moving without spin: The velocity of fluid (air) above and below the ball at corresponding points is the same, resulting in zero pressure difference. The air, therefore exerts no upward or downward force on the ball.



(ii) Ball moving with spin:



At point A, air is dragged by the spin of ball and its speed increases.

At point B, opposite drag & therefore speed decreases.

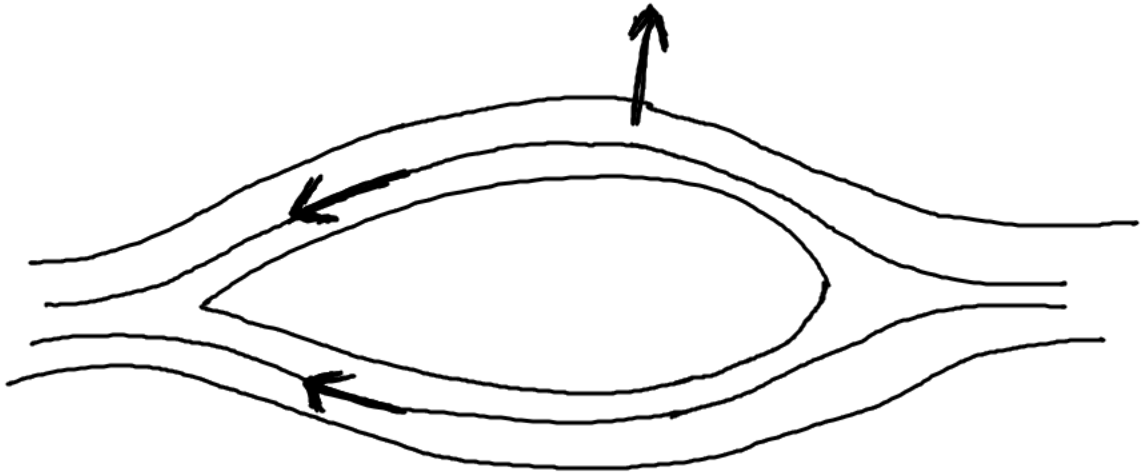
Pressure of air is reduced on A side and increased on B side.

$\therefore$ Net force: from B side to A side due to pressure difference.

This force causes the deviation of the plane of motion.

This dynamic lift due to spinning is called Magnus Effect.

(iii) Aerodynamics:



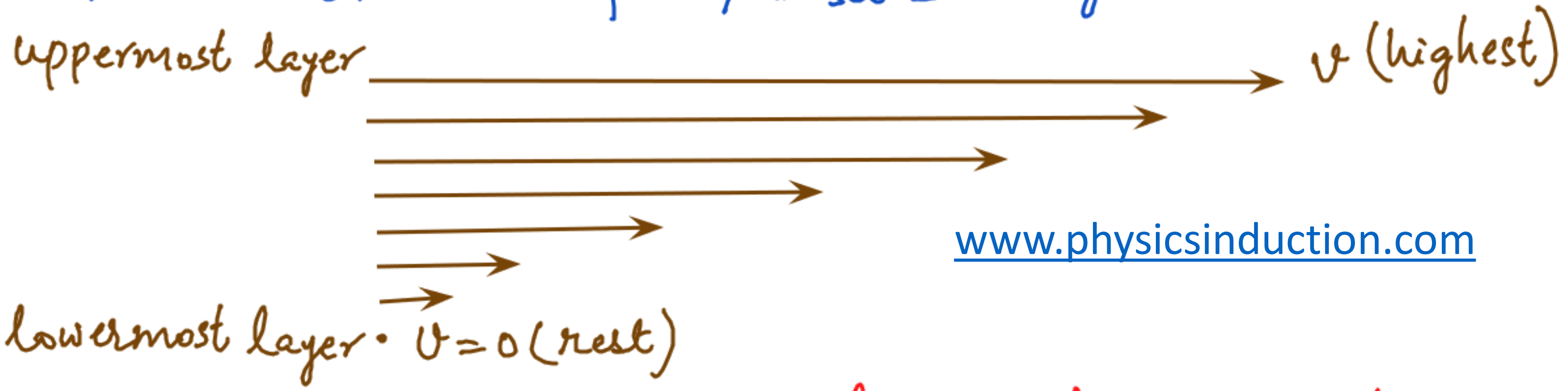
When the airfoil moves against the wind, the orientation of the wing relative to flow direction causes the streamlines to crowd together above the wing more than those below it. The flow speed on top is higher than that below it.

The air rushing past it gains a higher speed on the top side than on the bottom. This causes an upward force on the wings, which balances the weight of the plane.

VISCOSITY: Resistance to fluid motion/shearing motion : Internal friction

It arises on account of frictional forces b/w adjacent layers, as they slide past one another.

<u>Viscous Force / Viscous Drag</u> :- The tangential backward dragging force, coming into play, in between two adjacent layers of a liquid and tending to oppose the relative motion between them, is called viscous force/Viscous Drag.



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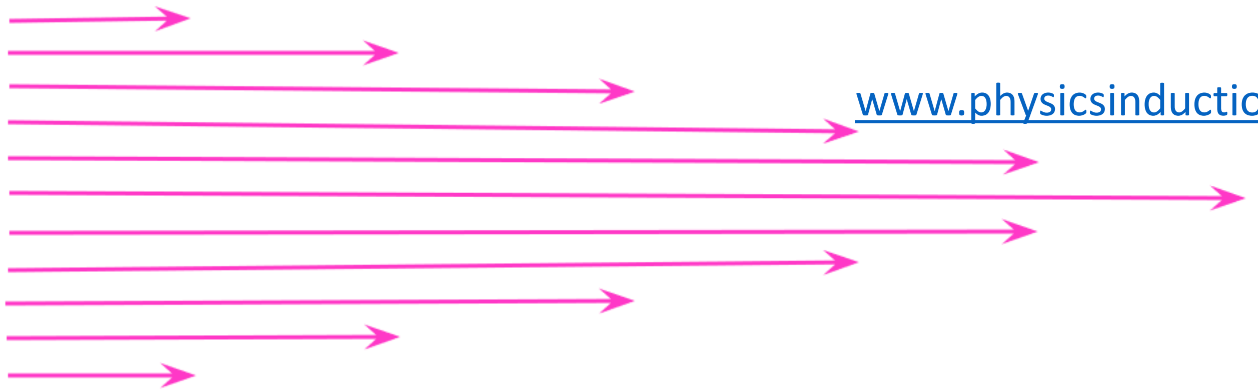
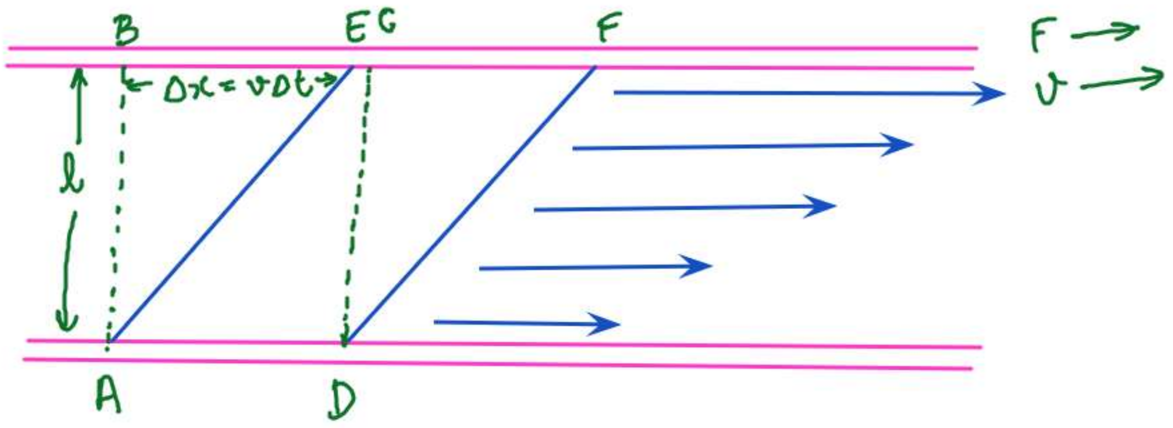
* The velocities of layers increase uniformly from bottom (zero velocity) to the top layer (velocity, v).
* For any layer of liquid, its upper layer pulls it forward while lower layer pulls it backward. This results in force between the layers. This type of flow is known as <u>laminar</u>.

When a fluid is flowing in a pipe or a tube, then velocity of the liquid layer along the axis of the tube is maximum and decreases gradually as we move towards the walls where it becomes zero.





In time Δt, a portion of liquid, which has the shape, ABCD, take the shape AEFD.

Shear strain $= \dfrac{\Delta x}{l}$

Strain rate : Rate of change of strain $= \dfrac{\Delta x}{l\Delta t} = \dfrac{v}{l}$

Coefficient of viscosity.

$$\eta = \frac{F/A}{v/l} = \frac{Fl}{vA}$$

S.I. Unit:- Poiseiulle

other Units : $N\,s\,m^{-2}$, $Pa\,s$

Dimensions :- $[M L^{-1} T^{-1}]$

* Viscosity of liquids decreases with temperature, while it increases, in the case of gases.

STOKES' LAW: A body falling through a viscous medium, always encounters an opposing viscous drag, which increases with velocity of falling body.

Assumptions:- (i) Body - perfectly rigid and smooth

(ii) medium - homogeneous

(iii) There exists no slip b/w the body and the medium.

(iv) No eddies & waves set up in the medium.

Viscous Drag force, $F = 6\pi\eta r v$

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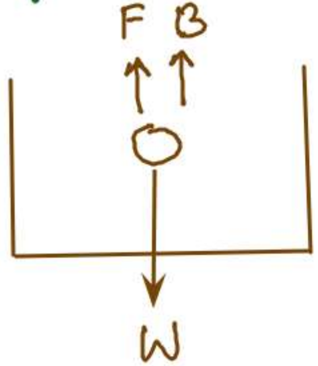
Terminal Velocity:- $F \propto v$



$F = W - B$

initially, $v = 0 \Rightarrow F = 0$

At a certain instant,

$F = W - B$,

net force $= 0$

object falls with constant velocity called terminal velocity, v_0

Weight, W of the spherical body

$$W = \frac{4}{3}\pi r^3 \rho g$$

Weight of the displaced medium, B:

$$B = \frac{4}{3}\pi r^3 \sigma g$$

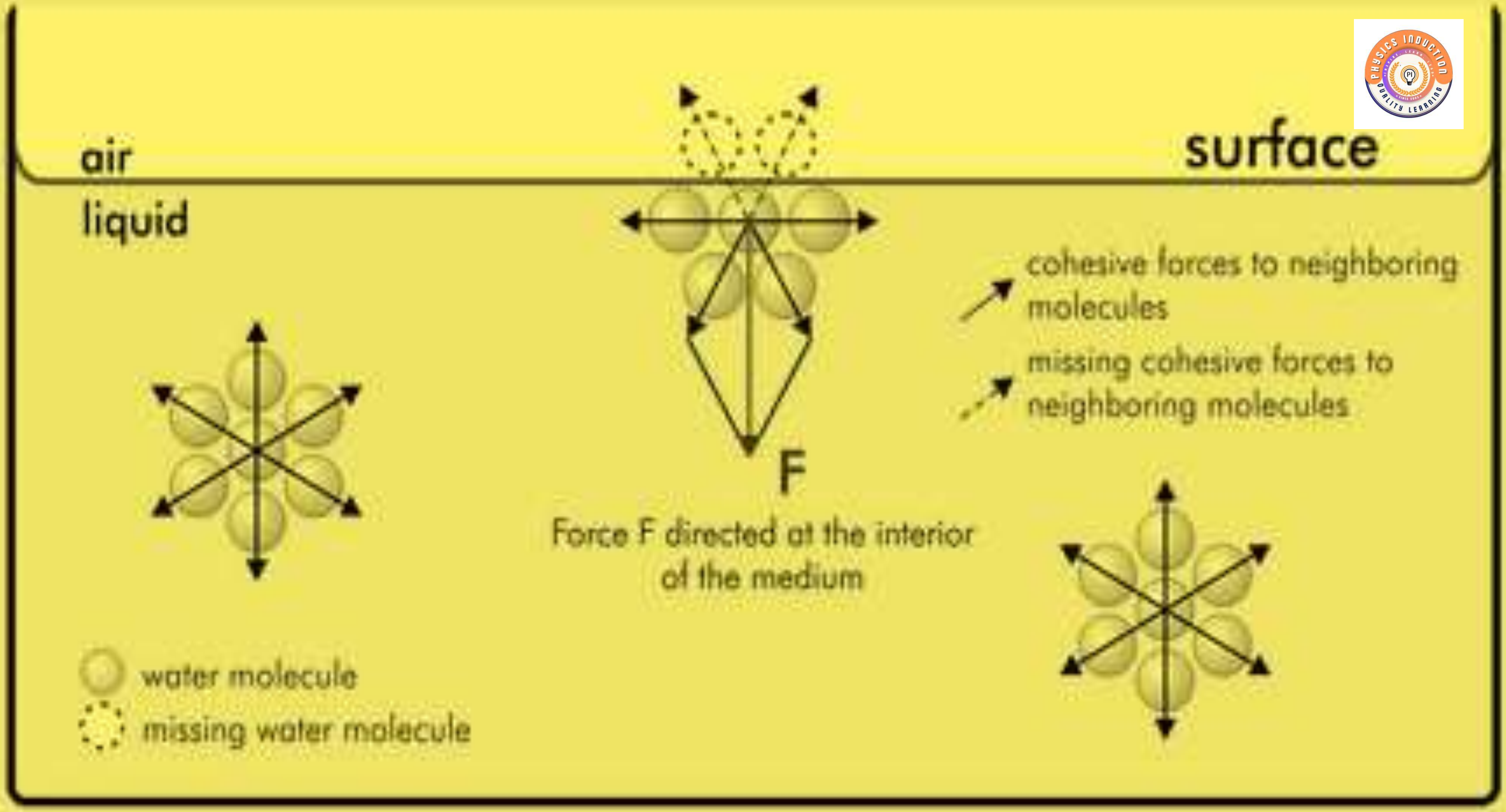
$\therefore$ Resultant downward force

$$= \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

At terminal velocity, v_0

$$F = 6\pi\eta r v_0 = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

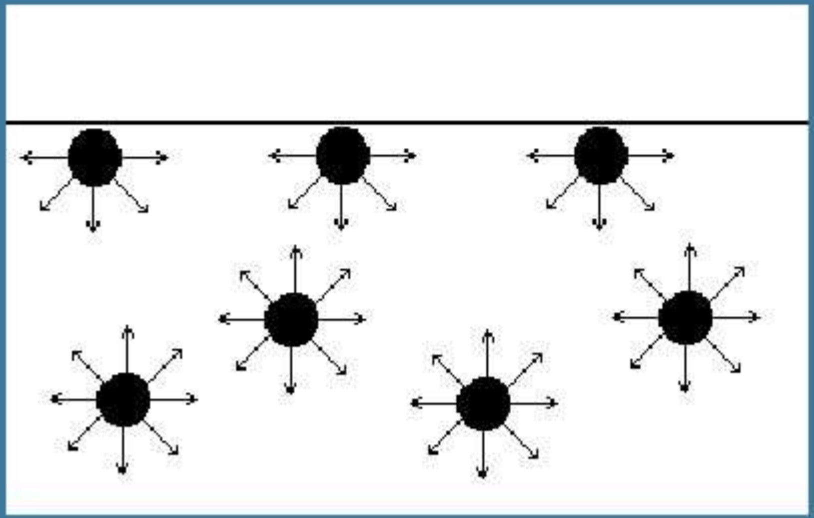
$$\Rightarrow \boxed{v_0 = \frac{2}{9} \cdot \frac{(\rho - \sigma) r^2 g}{\eta}}$$



air
surface
liquid
cohesive forces to neighboring molecules
missing cohesive forces to neighboring molecules
F
Force F directed at the interior of the medium
water molecule
missing water molecule

Surface Tension

- The molecules of a liquid will attract each other
- In the body of the liquid this attraction is equal all round
- At the surface, the attraction is unbalanced
- This imbalance of attractive forces is called *surface tension*



SURFACE TENSION: It's force per unit length or Surface Energy per unit area.

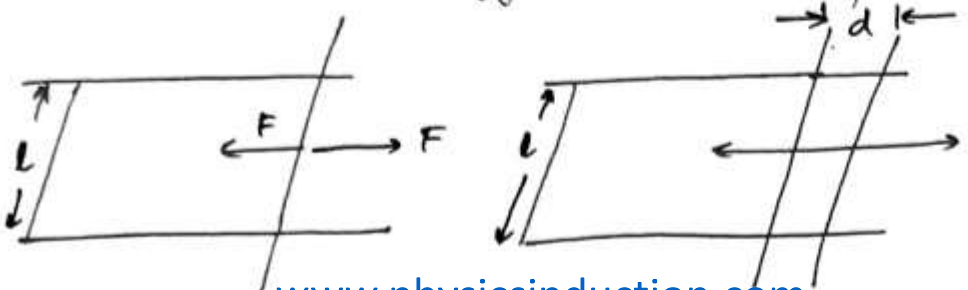
$$S = \frac{F}{l} \quad : \quad \text{Unit } N/m$$

OR

$$S = \frac{U}{A} \quad : \quad J/m^2$$

* The value of surface Tension depends on temperature.
* It decreases with rise in temperature for a liquid.

SURFACE ENERGY:- When a molecule is taken from inside to the surface layer, work is done against the inward force while moving up in the layer. P.E. is increased due to this work. A molecule on the surface has greater P.E. than the molecule inside. The extra energy that the surface layer has is called surface Energy.



Consider a horizontal liquid film. Suppose, we move the bar by a small distance, d
∴ area of the surface is increased
⇒ more energy
⇒ W.D. against the internal force.

$$W = \vec{F}\cdot\vec{d} = Fd\cos 0^\circ = Fd$$

$V = S(2dl)$ as, a film has two sides, so there are 2 surfaces.

Area of 1 surface $= d \cdot l$
" " 2 surfaces $= 2dl$

$$\Rightarrow S(2dl) = Fd$$

$$\Rightarrow S = \frac{Fd}{2dl} \Rightarrow \boxed{S = \frac{F}{2l}}$$

Surface Energy is the energy of the interface b/w two material and depends on both of them.

Change in S.E.

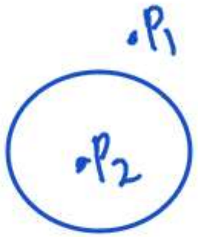
$$\Delta U = S_{la} \cdot \Delta A$$

$$= S_{la}\left[4\pi(r+\Delta r)^2 - 4\pi r^2\right]$$

$$= S_{la}\left[\cancel{4\pi r^2} + \underset{\text{neglected}}{4\pi \Delta r^2} + 8\pi r \Delta r - \cancel{4\pi r^2}\right]$$

$$= 8\pi r \Delta r \cdot S_{la} \quad \text{— (1)}$$

$$\underline{W_{expansion}} = \left[(P_2 - P_1) \cdot 4\pi r^2\right] \cdot \Delta r \quad \text{— (2)}$$



from (1) & (2)

$$(P_2 - P_1) \cdot 4\pi r^2 \Delta r = 8\pi r \Delta r \cdot S_{la}$$

$$\Rightarrow P_2 - P_1 = \frac{{}^{2}\cancel{8}\cancel{\pi}\cancel{r}\cancel{\Delta r} S_{la}}{{}_{1}\cancel{4}\cancel{\pi} r^{\cancel{2}} \cancel{\Delta r}}$$

$$\Rightarrow \boxed{P_2 - P_1 = \frac{2S_{la}}{r}}$$

Important Points :-

* S.E. depends on the materials on both sides of the surface.
  - ⇒ If the molecules of the materials attract each other, S.E. is reduced.
  - ⇒ " " " " " " repel " " , S.E. is increased.

* If $U_{fs} < U_{sa} + U_{fa}$ ⇒ fluid will stick to the solid surface.

*

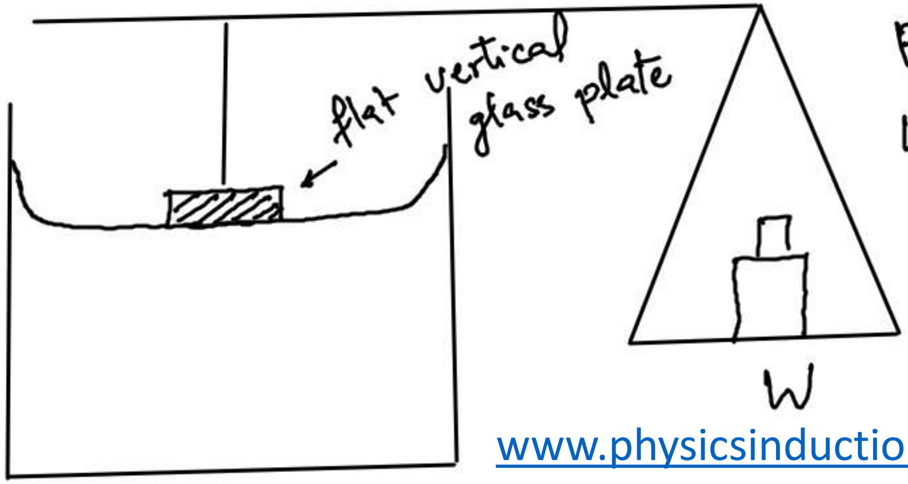
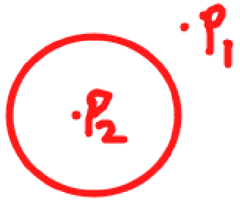


plate is balanced by weights on other side.
Weights are added till the plate just clears water.
Suppose, the additional weight required is W.
∴ Surface Tension of the liquid-air interface:

$$\boxed{S_{la} = \frac{W}{2l} = \frac{mg}{2l}}$$

where, $m \rightarrow$ extra mass
& $l \rightarrow$ length of the plate edge

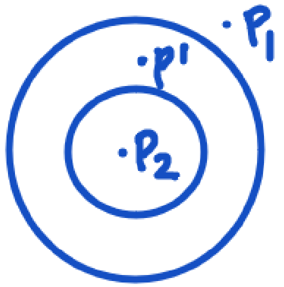


1.) Excess Pressure inside a drop : $\boxed{P_2 - P_1 = \frac{2S}{R}}$

for a drop, Pressure on concave side > Pressure on convex side

Pressure inside is greater than pressure outside by $(2S/R)$.

2.) Excess Pressure in a soap bubble :-



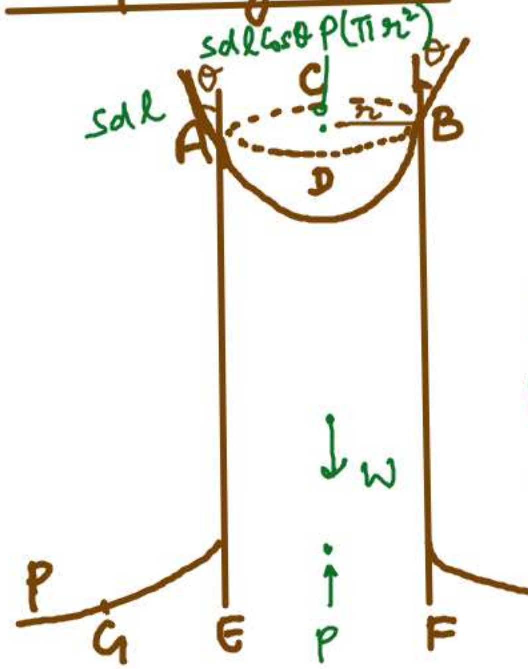
outer surface : $P' - P_1 = \frac{2S}{R}$ — ①

Inner surface : $P_2 - P' = \frac{2S}{R}$ — ②

① + ② ⇒

$$\boxed{P_2 - P_1 = \frac{4S}{R}}$$

Capillary Rise :-



A tube of radius, r dipped in a liquid of surface Tension, S & density, ρ. let the contact angle be θ. If the radius is small, surface in the tube is nearly spherical. liquid is contained in volume, ABFE.

Forces acting :-

F_1 : by the surface of tube on ABCD of liquid

F_2 : due to pressure of air above ABCD.

F_3 : due to pressure of liquid below EF.

W : Weight of ABEF (liquid)

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Consider a small particle, dl of $2\pi r$.

$F_1 = \int S\,dl\cos\theta = S\cos\theta \int dl = 2\pi r . S\cos\theta$.

$F_2 = P_a(\pi r^2) \downarrow$

$F_3 = P_a(\pi r^2) \uparrow$ & $W = mg = \pi r^2 h \rho g$

$\vec{F}_2 = -\vec{F}_3 \Rightarrow$ cancel each other.

$\Rightarrow W = F_1$

$\Rightarrow \pi r^2 h \rho g = 2\pi r . S\cos\theta$

$\Rightarrow \boxed{h = \frac{2S\cos\theta}{r\rho g}}$