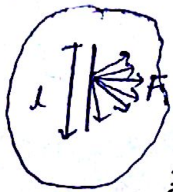
Handwritten Notes
On
Surface Tension

'SURFACE TENSION'

→ It is the property of surface of liq. by wich liquid tries to minimise its surface area.

→ It surface tension (σ or, T) is force acting per unit length on a line assumed on the surface of liquid on any one side of the line.



$$T \text{ or, } \sigma = \frac{F}{l}$$ ⇒ Act ⊥r to line assumed.

*unit → N/m Imp *Dimension $= \frac{MLT^{-2}}{L} = [MT^{-2}]$ *

** → It is the property of surface of liq. & does not depend on length of line used.

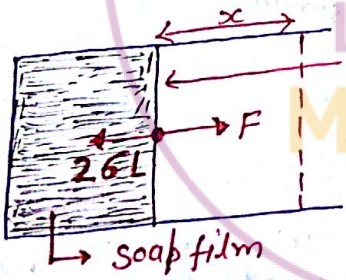
* → surface tension ↓ with rise in temp. & becomes zero at a critical temp. where interface b/w liquid & vapour disappear.

* → It depend on impurities & ↓se when impurities contaminate on the surface.

** → Generally, surface tenson ↑se with highly soluble impurities like (Nacl in water) & ↓ with sparangly soluble Impurities.

Work Done by surface Tension →

When surface area change



$F = 2\sigma L$

✓ $W_{net} = 0$

✓ $W_F + W_\sigma = 0$

✓ $W_F = -W_\sigma$

$W_\sigma = -Fx$

$= -2\sigma Lx$

$= -\sigma L(2x) = -\sigma \times 2(Lx)$

Work done by surface Tension $= \boxed{-\sigma(\Delta S)}$ (change in area)

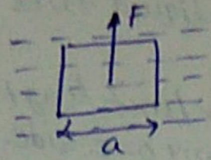
Work done on the surface is $\boxed{W = \sigma \times (\Delta S)}$

∴ Work done on the surface. & this work done ↑se the energy of surface.

A/F ** (Energy associated with the surface due to surface tension is also called 'surface energy') (Bcoz of this Reason liquid drops are spherical.)

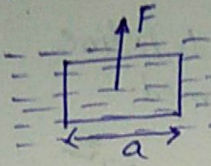
Force Required to Raise a Masses.

*|a| → square plate of side a from liquid surface.



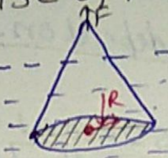
$$F = T(4L) = 4Ta$$

*|b| → square frame of wire side 'a'.



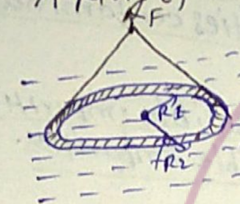
$$F = \text{Force on one surface} \times 4$$
$$= (T \times 2a) \times 4$$
$$= 8TA$$

*|c| → Disc of Radius 'R'



$$F = Tl$$
$$= T(2\pi r)$$

*|d| → A Ring of inner & outer radii R_1, R_2 $(R_1 < R_2)$



$$F = T \cdot 2\pi R_1 + T \cdot 2\pi R_2$$
$$= 2\pi T (R_1 + R_2)$$

Free surface →

Liquid drop

1-free surface

Bubble

Bubble in liq. (one free surface)

Bubble in air.

2-free surface.

* Work done to make a liquid drop.

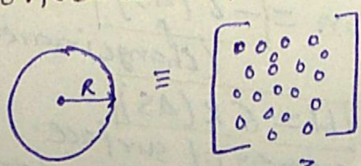
$$W = \sigma \times 4\pi r^2$$

(→ area; → surface tension)

* Work done to blow a blow a bubble in air

$$W = \sigma \times (4\pi r^2) \times 2 = \sigma \times 8\pi r^2$$

* Work done to split a liquid drop.



'n' identical drops. (each of radius 'r')

$$\rho \times \frac{4}{3}\pi R^3 = \rho \times \left(\frac{4}{3}\pi r^3\right) n \Rightarrow R = n^{1/3} r$$

$$W = (n^{1/3} - 1)\, \sigma \times 4\pi R^2$$

✓ If this process is consider as adiabatic then temp. of system will fall so,

$$\Delta\theta = \frac{3T}{\rho s J}\left(\frac{1}{r} - \frac{1}{R}\right)$$

When, Bigger drop ⟶ smaller drops
surface ↑
surface energy ↑
temp. of system ↓

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In this case,

$$\frac{\text{Initial surface energy}}{\text{Final surface energy}} = \frac{1}{N^{1/3}}$$

* Work done to ↑ Radius of a liq. drop from R_1 to R_2.

$$W = 4\pi T (R_2^2 - R_1^2)$$

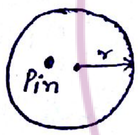
* Work done to ↑ radius of a soap bubble from R_1 to R_2.

$$W = 8\pi T (R_2^2 - R_1^2)$$

* Two identical liq. drop of Radius r_1 & r_2 combine to form a single spherical drop. In Isothermal condition then Ratio of new drop.

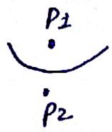
$$r = \sqrt{r_1^2 + r_2^2}$$

Excess Pressure → The extra pressure inside a drop or bubble.



Pout

$$P = P_{in} - P_{out} = \begin{cases} \frac{2\sigma}{r} ; & \text{For one free surface.} \\ \frac{4\sigma}{r} ; & \text{For two free surface.} \end{cases}$$



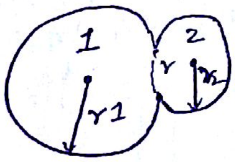
$P_1 > P_2$

$P_1 > P_2$

$P_1 - P_2 = \frac{2\sigma}{r}$

~~* ...~~

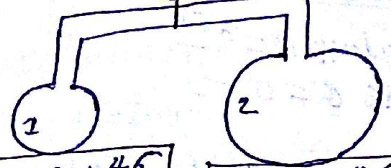
** Two soap/air bubble when made in contact to form double bubble.



$$r = \frac{r_1 r_2}{r_1 - r_2}$$

AIIMS ** When stopper/knob is opened how size of ① & ② will change.

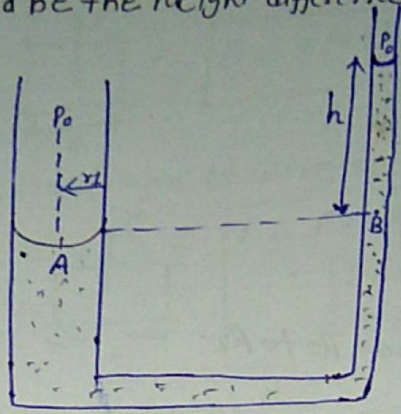
as, $r_1 < r_2$, $P_1 > P_2$; $\Delta P \propto \frac{1}{R}$



$P_1 = P_0 + \frac{4\sigma}{r_1}$ $P_2 = P_0 + \frac{4\sigma}{r_2}$

Hence, when stopper is opened smaller bubble reduces its size while bigger bubble expand its size.

** There is U-tube having their arms of Radius r_1 & r_2 ($r_1 > r_2$) then what would be the height difference of Hg. In both arm angle of contact 0°.

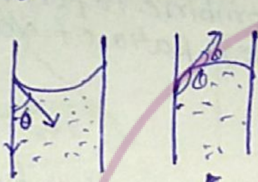


* $$h = \frac{2T}{\rho g}\left(\frac{r_1 - r_2}{r_1 r_2}\right)$$

Angle of contact (θ) →

θ = At meniscus, angle b/w tangent of liq. surface in contact & tangent on solid surface inside liquid.

FA → Adhesive force b/w solid & liquid molecule.
FC → cohesive force b/w liq. molecule.



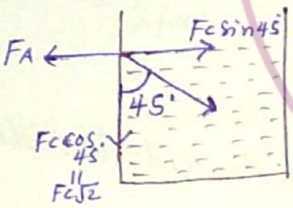
θ = acute angle
cohesive force (C.F) < *Adhesive force (AF)
(Wetting liq) ✓

θ = obtuse
[C.F > A.F]
*Non-Wetting liq ✓

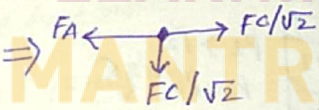
here [θ = 0°]
liq = water

*Solid ⇒ clean glass ✓

|i| → If $F_A = F_C/\sqrt{2}$



⇒

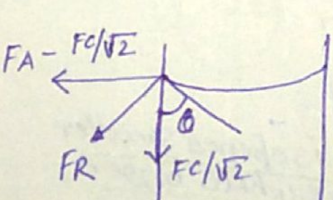


If, $F_A = F_C/\sqrt{2}$
then, $F_R = \frac{F_C}{\sqrt{2}}$ = downward

*[Angle of contact = 90°]

Imp * Eg → [Water in silver glass.]

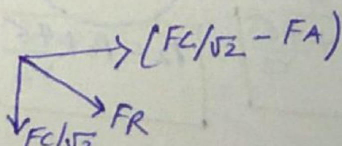
|ii| → If $F_A > F_C/\sqrt{2}$



θ < 90° (Acute angle)
Such liq wet the solid surface. **

Imp
* For normal water glass θ = 8°
* For pure water glass θ = 0°

|iii| → If $F_A < F_C/\sqrt{2}$
then θ > 90° (obtuse angle)
From such liq surface is not wet. Eg → *glass Hg
*[θ = 135°]



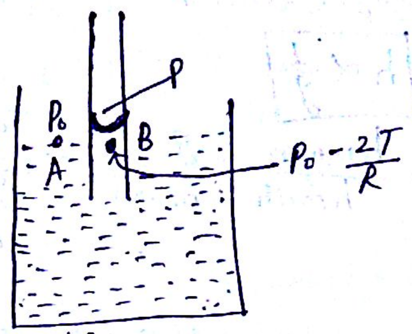
Rise of liquid level in a capillary tube →

$P_A = P_B$

$P_0 = P_0 - \frac{2T}{R} + h\rho g$

$\frac{2T}{R} = h\rho g$

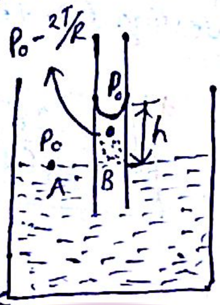
* $$h = \frac{2T}{R\rho g}$$



Meniscus.

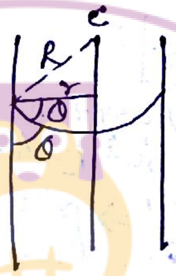
R → Radius of curvature of

$P_A \neq P_B$



Let, r → radius of curvature

θ → angle of contact.



$\cos\theta = r/R$

$R = \frac{r}{\cos\theta}$

$\therefore h = \frac{2T}{\frac{r}{\cos\theta}\rho g}$

* $$h = \frac{2T\cos\theta}{r\rho g}$$

|i| → For liquid-gas →

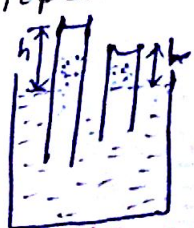
θ, T, ρ → const.

$\therefore$ $h \propto \frac{1}{r}$ ⟹ Zurin Law (BHU)

* $$h_1 r_1 = h_2 r_2$$

|ii| → If capillary has insufficient length then water can't come out from top but radius of meniscus at top does not change.

* $$Lr = Lr^{-1}$$



|iii| → If capillary is inclined at angle 'θ' with vertical.

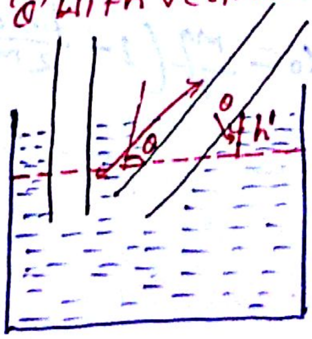
Let, L = length of liq. column in inclined tube

then, $h' = h$

$L\cos\theta = h$

* $$L = \frac{h}{\cos\theta}$$

$L > h$



$\cos\theta = \frac{h'}{L}$

$L = \frac{h'}{\cos\theta}$

Imp ** → Height raised in capillary tube is found to be 'h' on earth surface. If all exp. is taken at Moon then height rise become.

$g_{moon} = \frac{g_{earth}}{6}$

$$\boxed{h \propto \frac{1}{g}}$$

$$\frac{h_{Moon}}{h_{earth}} = \frac{g_e}{h_{moon}} = \frac{g_e}{\frac{g_e}{6}} \therefore \boxed{h_m = 6h_e}$$ * (Six)

NOTE → * If cohesive force (C.F) are less than adhesive force (A.F) i.e $\theta \Rightarrow$ acute or, liq is wetting liq. then the level of liq in capillary tube will rise.

* $$\boxed{h = \frac{2\sigma\cos\theta}{\rho g R}}$$ * $$\boxed{h = \frac{2\sigma}{r\rho g} = \frac{2\sigma}{\rho g r}}$$

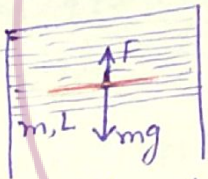
✓* In any capillary

$$\boxed{hr = const.}$$

i.e If capillary tube is of insufficient length of liq. will not over flow but Radius of meniscous ↑se.

$$hr = h'r' \Rightarrow \boxed{r' = \frac{hr}{h'}}$$

Imp ✓* If needle is in equilibrium find surface tension of soap film.



$$F = mg$$

$$\sigma \times 2L = mg \Rightarrow \boxed{\sigma = \frac{mg}{2L}}$$ *

Imp ✓* If capillary & beker system is taken at the ** artificial satellite or, * Freely falling lift then height rise in capillary is equal to its Full length.

A uniform cyllinder of length 'L' & Mass 'M' having cross-section area 'A' suspended, with its length vertical, from a fixed point by a massless spring such that it is half submerged in a liq. of density 'σ' at eqm position. The extension x_0 of the spring when it is in eqm →

$$\boxed{x_0 = \frac{Mg}{K}\left(1 - \frac{LA\sigma}{2M}\right)}$$ *