SURFACE TENSION

Some Important concepts

Cohesive forces: Force of attractn betn the molecule of same substance. e.g small droplets of water coalesce into one.

Adhesive forces: Force of attractn betn the molecule of diffn substance.

Range of Molecular forces:
→ max. distance from a molecule upto which molecular force is effective.
→ about 10^{-9} m.

Sphere of influence: An imaginary sphere, with molecule at its centre and radius as range of molecular forces.

Surface Film: Surface layer of liquid with thickness equal to range of molecular attractn.

Free surface: Surface of a liquid which does not experience any shear stress.

SURFACE TENSION

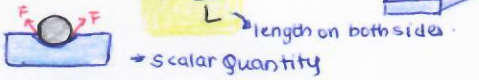
"The property of a liquid due to which its surface tries to have minimum surface area and it behaves like stretched membrane is Surface Tension"

→ It tries to minimize surface area bcz free surface has max. potential energy due to unbalanced forces.

"Surface Tension (T) is the tangential force acting per unit length on both sides of an imaginary line drawn on free surface of liquid."

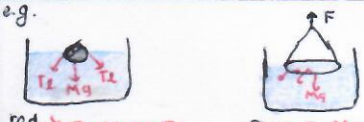
$$T = \frac{F}{L}$$

L → length on both sides



→ scalar quantity
→ depends on nature of liquid
→ S.T decreases, if temp. increases.
→ If insoluble impurities added, S.T decreases.

e.g.

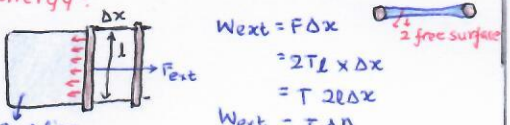


rod → $F = Mg + 2T\ell$.

Ring $F = Mg + 2(2\pi r)T$
$= Mg + 4\pi rT$.

SURFACE ENERGY

"Free surface of fluid has some potential energy stored in it which is called surface energy"



$W_{ext} = F\Delta x$
$= 2T\ell \times \Delta x$
$= T\ 2\ell\Delta x$
$W_{ext} = T\Delta A$.

surface energy = $T\Delta A$.

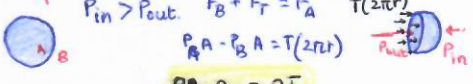
$$\Delta U = T\Delta A$$

→ both surface area.

Surface ~~energy~~ tension is also surface energy per unit area.

*EXCESS PRESSURE IN... *

1. Drop.

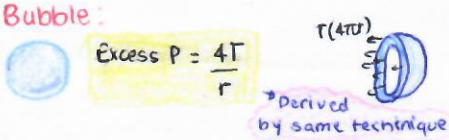


$P_{in} > P_{out}$. $F_B + F_T = F_A$

$P_A A - P_B A = T(2\pi r)$

$$P_A - P_B = \frac{2T}{r}$$

2. Bubble:



Excess $P = \frac{4T}{r}$

→ Derived by same technique.

3. Solid Cylinder.

$P_{ex} = \frac{T}{R}$.

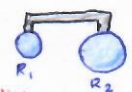
4. Cylindrical film

$P_{ex} = \frac{2T}{R}$.

5. SHAPE having two radii of curvature

$$P_{ext} = T\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

CONNECTING SOAP BUBBLES



$R_1 < R_2$

$P_{ex,1} = P_0 + \frac{4T}{R_1}$

$P_{ex2} = P_0 + \frac{4T}{R_2}$.

$P_1 > P_2$.

∴ Larger bubble becomes more big and smaller becomes more small.

ANGLE OF CONTACT (wetting angle)

"Angle betn surface of contact and outline of contact surface is described as contact angle"
→ it is a measure of wettability of solid by liquid.

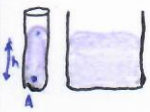
obtuse — bad wetting — $F_{adh} < F_{coh}$ — glass & water

acute — good wetting — $F_{adh} > F_{coh}$ — Hg & glass

0° — complete wetting — pure water & clean glass

SHAPE OF MENISCUS

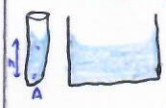
*CONVEX MENISCUS:



$\theta > 90^\circ$, due to cohesive attractn.
→ e.g Hg.

$$P_A = P_{atm} + \frac{2T}{R} + h\rho g.$$

*CONCONCAVE MENISCUS:



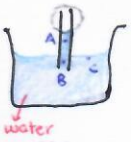
$\theta < 90^\circ$, due to adhesive attractn
→ e.g water.

$$P_A = P_{atm} - \frac{2T}{R} + h\rho g.$$

CAPILLARY ACTION (capillarity)

"The phenomenon of rise or fall of a liquid inside a capillary tube when it is dipped in liquid is capillarity"

CAPPILARY RISE:



-rise occurs in liquids having contact angle acute.

R → radius of curvature of meniscus
r → radius of tube. T → surface tension
θ → contact angle

$P_A = P_{atm} - \frac{2T}{R}$ $P_B = P_C$

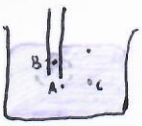
$$h = \frac{2T}{R\rho g}.$$

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

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

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

CAPILLARY FALL



→ fall occurs in liquids having contact angle obtuse.

$P_B = P_0 + \frac{2T}{R}$ $P_C = P_0 + h\rho g$.

After deriving, it appears to be same as rise.

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

Note: If $\theta = 0^\circ$ then $r = R$, and shape formed is hemisphere. and thats the time when bubble is formed.

CAPILLARY ACTION WITH INSUFFICIENT HEIGHT

$\frac{2T}{\ell} = h\rho g$ $\frac{2T'}{R'} = h'\rho g$

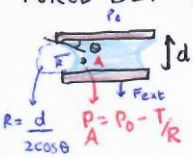
$hR = \frac{2T}{\rho g}$ $h'R' = \frac{2T}{\rho g}$

$h'R' = hR$

*Liquid does not overflow.

*If height decreases then radius of meniscus increases

FORCE BETN PARALLEL PLATES



$F_{ext} = P_0 A - \left[P_0 A - \frac{T}{R}A\right]$ (cylinder)

$= \frac{TA}{R}$

$$F_{ext} = \frac{TA\,2\cos\theta}{d}$$