Cohesive Force:

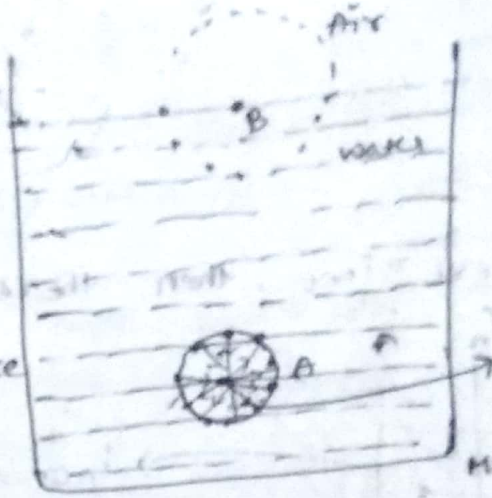
- Force acting b/w two similar type of molecules is called as Cohesive Force

Adhesive Force:-

- Force acting b/w two diff types of molecules is called as Adhesive Forces.

- According to property of molecules, cohesive may be stronger than adhesive.

- All molecules will experience downward force and then try to go into the liquid. That is why surface of a liquid always try to achieve minimum possible area.

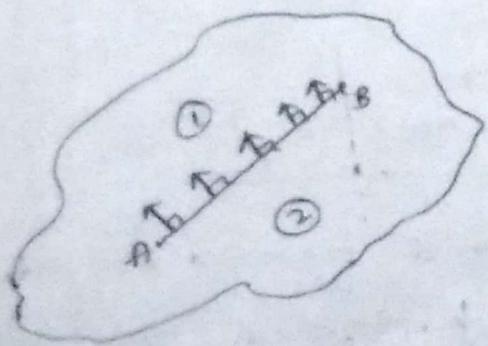


Mol. A will experience zero force

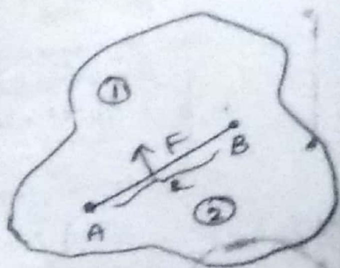
Mol. B may experience non zero Force.

SURFACE TENSION:

→ Force acting per unit length of imaginary line on the surface is called surface tension.



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



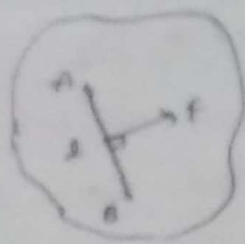
→ Force acting on any line on the surface is

$F = T \cdot l$ (length in contact)

→ surface Tension is a scalar quantity

(direction at a point on the surface

→ Force applied by surface tension is a vector quantity (will have defined direction)



SURFACE ENERGY:

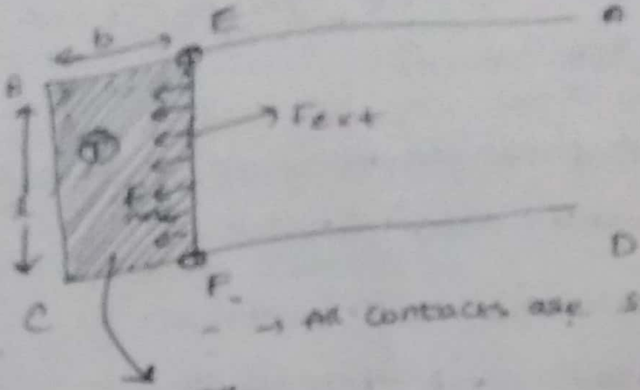
$F = T \cdot l$

Net force acting on the wire EF is

$F_{net} = 2T \cdot l$

(Front and Back)

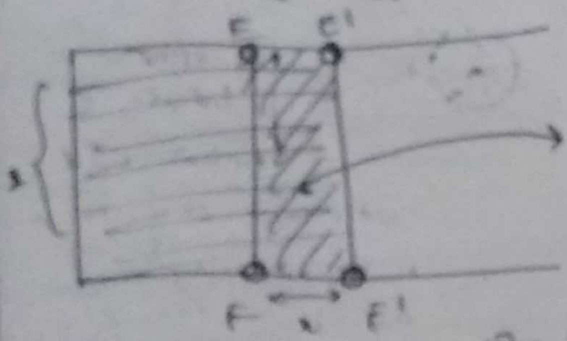
$F_{ext} = 2T(l)$



→ All contacts are smooth

soap film.

When $F_{ext} > F_{net}$, then there is change in area



increase in surface area of film $= 2lx$

Work done by external agent is

$W = F_{ext}(x) \cdot \cos 0°$

$= F_{ext}(x)$

$= 2T \cdot l \cdot x = T(\Delta A)$

$\Rightarrow \boxed{W_{ext} = T(\Delta A)}$

stored as energy in the surface.

increase in surface area.

$$\boxed{\text{Surface energy of any surface} = T\left(\text{area of surface}\right)}$$

Q1) If liquid drop of rad-R is divided into 10^6 small droplets. Find the work done in doing so, if surface tension is $S(or) T$?

3

Soln: By ~~Vol~~ mass conservation

$$\rho \times \frac{4}{3}\pi R^3 = 10^6 \left(\rho \times \frac{4}{3}\pi r^3 \right)$$

$$r = 10^{-2} R.$$

$$\boxed{r = \frac{R}{100}}$$

$$A_i = 4\pi R^2$$

$$A_f = \cancel{4\pi R}\ 4\pi r^2 \times 10^6 = 4\pi R^2 \times (100).$$

$$\Delta A = A_f - A_i = 396\pi R^2$$

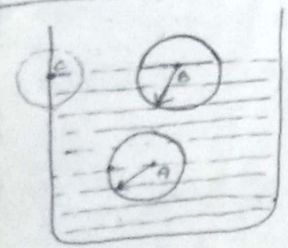
$$\boxed{W_{ext} = (T \times 396\pi R^2)}$$

→ If 10^6 droplets combined to form single drop; then the energy released $= \cancel{3696\pi}\ 396\pi T R^2$ $(A\downarrow)$.

↳ converted into heat.

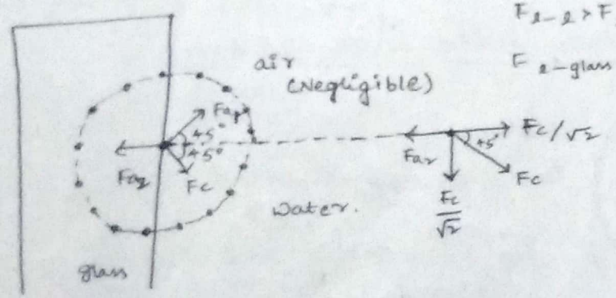
Heat gained by drop $= 396\pi T R^2$

ANGLE OF CONTACT: is defined as the angle made by tangent drawn to liquid miniscus with the line drawn ~~through~~ along vessel wall inside the liquid.



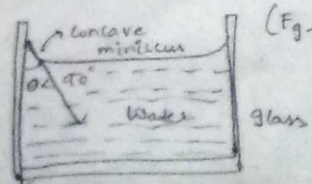
$F_{l-l} > F_{l-a}$

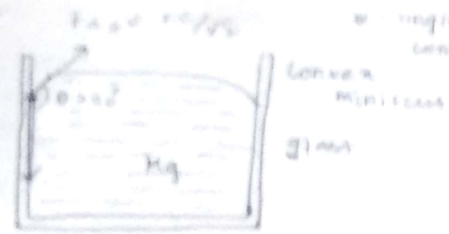
$F_{l-glass} > F_{l-a}$.

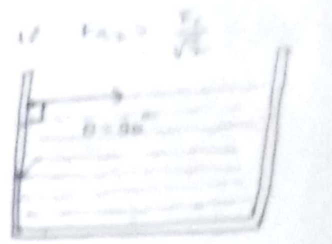


→ If $F_{a_2} > F_{ac}/\sqrt{2}$

$(F_{g-w} > F_{w-w})$

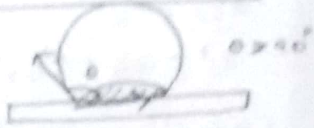






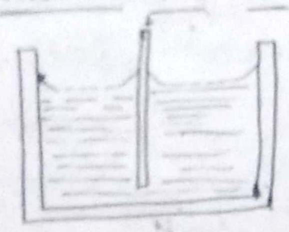
Wetting liquids

Non-wetting liquids

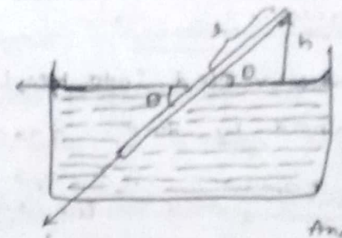


→ Angle of contact will depend on both solid and liquid combination.

FINDING THE ANGLE OF CONTACT OF A LIQUID:-



⇒



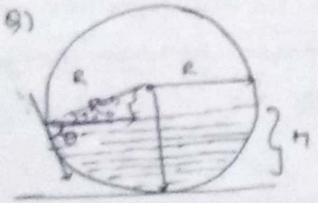
$\sin\theta = \frac{h}{l}$

$\theta = \sin^{-1}\left(\frac{h}{l}\right)$

↓

Angle of contact

Q)



Find the angle of contact.

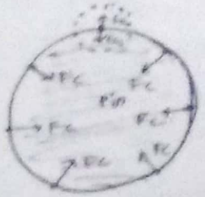
Sol:

$\sin(90° - \theta) = \frac{R-h}{R}$

$\cos\theta = 1 - \frac{h}{R}$

$\boxed{\theta = \cos^{-1}\left(1 - \frac{h}{R}\right)}$

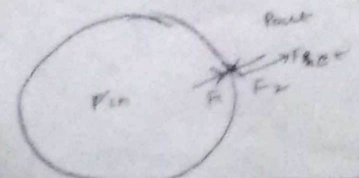
Excess pressure inside a liquid drop:

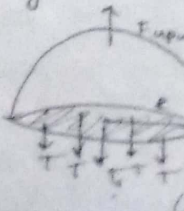


liq. drop

P_{ext} excess pressure $= \Delta P = P_{in} - P_{out} = ?$

Taking half a drop





F_{upward} (due to Press. diff.)

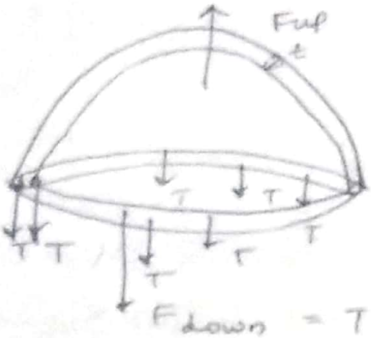
$F_{up} = (\Delta P)\pi r^2$

$F_{downward}$ (due to surface

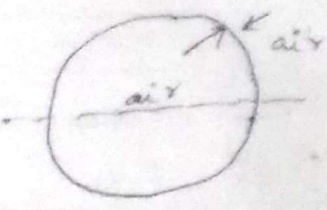
$T(2\cancel{\pi}\cancel{R}) = \Delta P(\cancel{\pi} R^2)$ [Equilibrium]

$\Delta P = \frac{2T}{R} \Rightarrow \boxed{P_{in} - P_{ext} = \frac{2T}{R}}$

Soap Bubble : (2 surfaces)



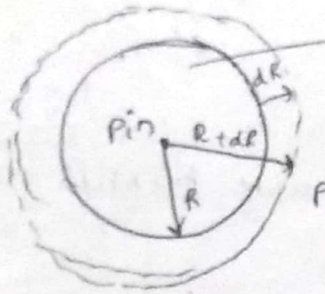
t is negligible



$F_{up} = (\Delta P)\pi R^2$

$F_{down} = T(2\pi R) \times 2.$

$(\Delta P)\cancel{\pi} R^{\cancel{2}} = T \times 4\cancel{\pi} R, \Rightarrow \boxed{\Delta P = \frac{4T}{R}}$



$F_{net} = (P_{in} - P_{ext})\,ds$

liq drop.

Increase in surface energy:

$\Delta E = T(\Delta A) = T(4\pi(R+dR)^2 - 4\pi R^2)$

$= 8\pi T R dR.$

work done by the pressure in change in volume =

$W = (\Delta P)(\Delta V)$

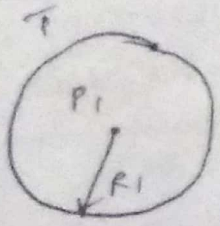
$= (\Delta P)(4\pi R^2 \cdot dR)$

$(\Delta P)4\cancel{\pi}R^{\cancel{2}}\,\cancel{dR} = \cancel{8}\cancel{\pi}T\cancel{R}\,\cancel{dR}$
2

$\Rightarrow \boxed{\Delta P = \frac{2T}{R}}$

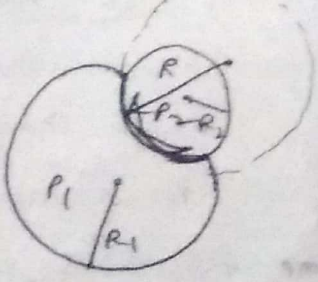
DOUBLE BUBBLE :-

P_0



$R_1 > R_2$

$P_2 > P_1$



$P_1 - P_0 = \frac{4T}{R_1}$

$P_2 - P_0 = \frac{4T}{R_2}$

$P_2 - P_1 = \frac{4T}{R}$

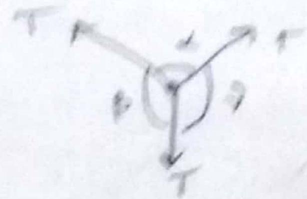
$\left(\frac{1}{R_2} - \frac{1}{R_1}\right) = \frac{1}{R}$

$\boxed{R = \frac{R_1 R_2}{R_1 - R_2}}$ Rad of curvature of common surface.

$P_0 > P_1 > P_2$
$P_2 - P_1 = \frac{4T}{R}$
$P_1 - P_2 = \frac{4T}{R}$ (for a surface)

NOTE: ~~Pressure~~ Pressure is always more on ~~than~~ concave side than convex side

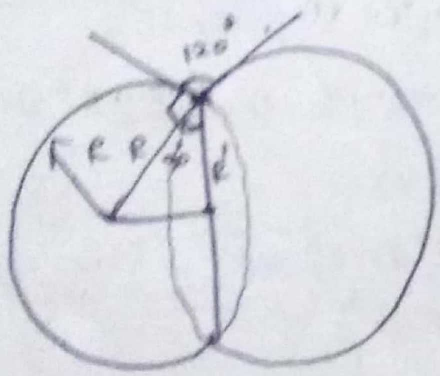
Particle is in equilibrium & similar (equal forces)



$\alpha = \beta = \gamma = 120^\circ$

→ If 2 similar bubbles are forming ~~double~~ bubble, common rad of curvature

$$R = \frac{R_1 R_2}{R_1 - R_2} = \infty \quad (R_1 = R_2)$$



$\frac{R'}{R} = \cos 30^\circ = \frac{\sqrt{3}}{2}$

$\boxed{R' = \frac{\sqrt{3} R}{2}}$

(5) If 2 soap bubbles of Radii R_1 & R_2 are combined to form a single bubble of radius R and 'T' is the surface tension

V is the change in volume of bubbles.

S - change in surface area of bubbles.

P_0 - atmospheric pressure

→ Assume no leakage of air while forming the bubble and temp remains same.

Find the relation b/w P_0, T, S, V?

$n = n_1 + n_2$

$P_3 = P_0 + \frac{4T}{R}$

$\frac{P_3 V_3}{RT} = \frac{P_1 V_1}{RT} + \frac{P_2 V_2}{RT}$

$P_3 V_3 = P_1 V_1 + P_2 V_2$

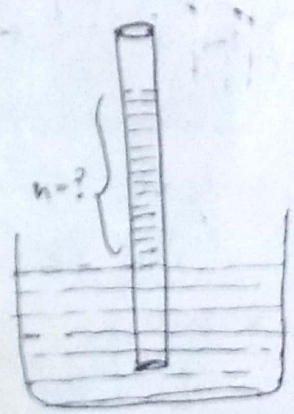
$$\left(P_0 + \frac{4T}{R}\right)\frac{4}{3}\pi R^3 = \left(P_0 + \frac{4T}{R_1}\right)\frac{4}{3}\pi R_1^3 + \left(P_0 + \frac{4T}{R_2}\right)\frac{4}{3}\pi R_2^3$$

$$\pi \times P_0 R^3 - P_0 R_1^3 - P_0 R_2^3 = \left(4T R_1^2 + 4T R_2^2 - 4T R^2 \times \pi\right) \times \frac{4}{3}$$

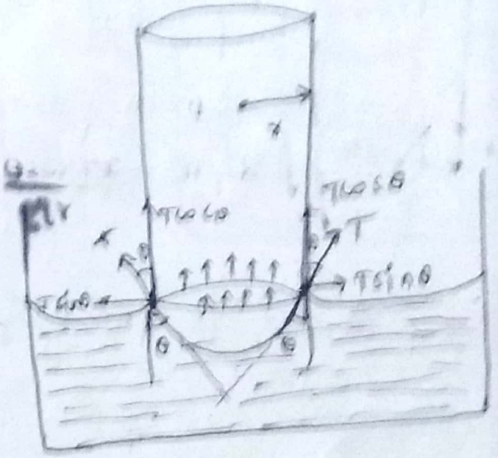
$P_0 \; \cancel{4T} \Rightarrow P_0 V = \frac{4T}{3}(S)$

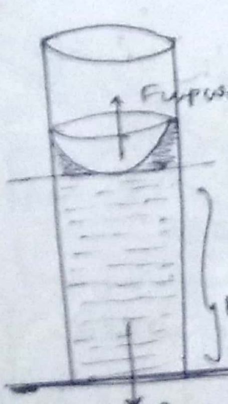
$-3P_0 V = 4TS \Rightarrow \boxed{3P_0 V + 4TS = 0}$

CAPILLARY RISE :-

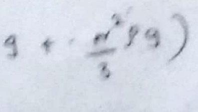


$\theta < 90^\circ$





$F_{upward} = T\cos\theta(2\pi R)$



$\pi r^3 - \frac{2}{3}\pi r^3$

Shaded Part $= \frac{\pi r^3}{3}$

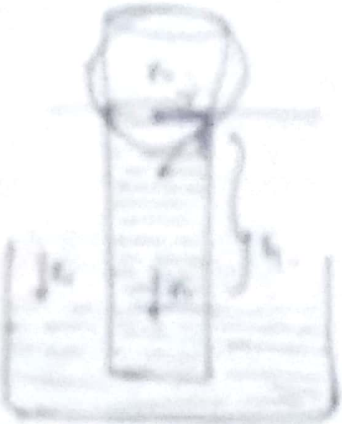
$W = \pi r^2 h(\rho)(g) + \frac{\pi r^3}{3}(\rho g)$

$2T\cos\theta\, \cancel{\pi} \cancel{r} = \cancel{\pi}\cancel{r}\left(r h \rho g + \frac{r^2}{3}\rho g\right)$

$\frac{2T\cos\theta}{r\rho g} = h + r/3$

$$\boxed{h \approx \frac{2T\cos\theta}{r\rho g}}$$

Method - 1



$P_{in} - P_{ext} = \frac{2T}{R}$

$P_0 - P = \frac{2T}{R}$

$\Rightarrow P = P_0 - \frac{2T}{R}$

$\Delta P = P_0 - P = \rho g h$

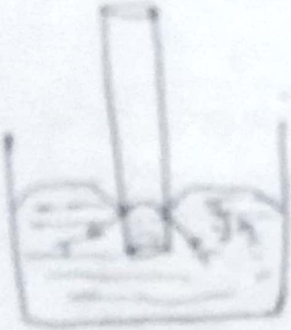
$\frac{2T}{R} = \rho g h$

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

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

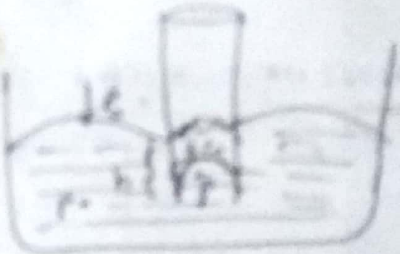
$\Rightarrow \boxed{h = \frac{2T\cos\theta}{r \rho g}}$

Case $\theta > 90^\circ$ (mercury)



$\theta > 90^\circ$

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

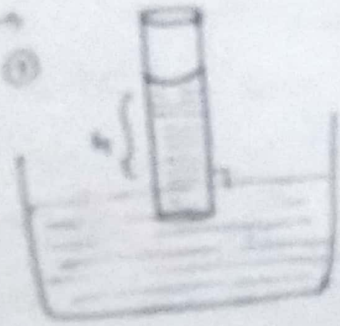


$P - P_0 = \frac{2T}{R}$

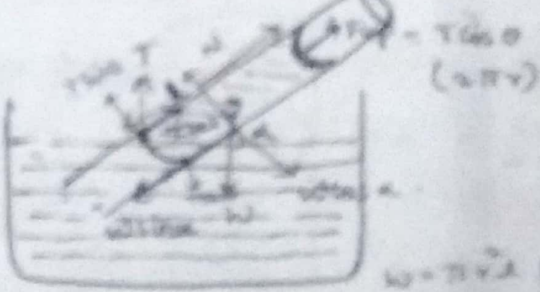
$P - P_0 = \rho g h$

$\frac{2T}{R} = \rho g h \rightarrow \boxed{h = \frac{2T\cos\theta}{r\rho g}}$

→ ①



②

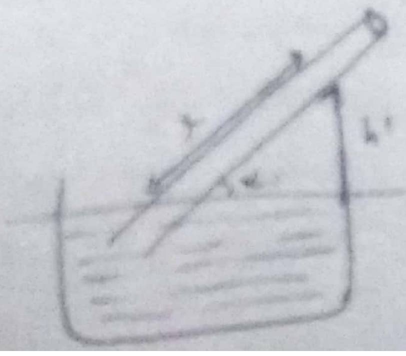


$T\cos\theta\,(2\pi r) = w\sin\alpha$

$T\cos\theta\,(2\cancel{\pi} r) = \cancel{\pi} r^2 l \rho g \sin\alpha$

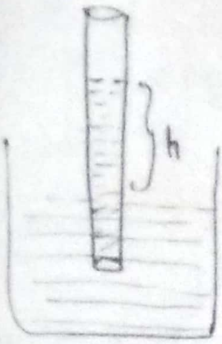
$l = \frac{2T\cos\theta}{r\rho g \sin\alpha}$

→



$h' = (l)\sin\alpha$

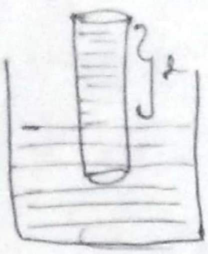
$\boxed{h' = \frac{2T\cos\theta}{r\rho g}}$ h



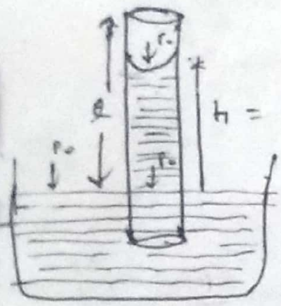
1) $h = \frac{2T\cos\theta}{\rho g r}$ when the arrangement is at rest (or) moving with const velocity

2) $h = \frac{2T\cos\theta}{r\rho(g+a)}$ when the arrangement is accelarating upwards.

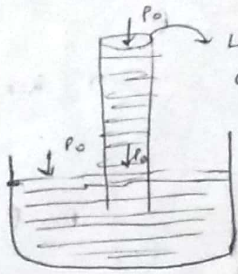
3) $h = \frac{2T\cos\theta}{r\rho(g-a)}$ when the arrangement is accelarating downward.



$h = l$, if arrangement is freely falling (even in gravity free space)

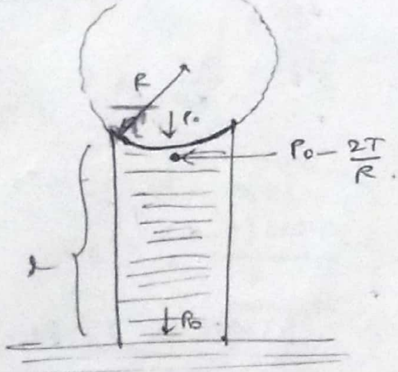


$h = \frac{2T\cos\theta}{r\rho g} < l$.



Liq. adjust its curvature so that it maintain pressure at the bottom is P_o

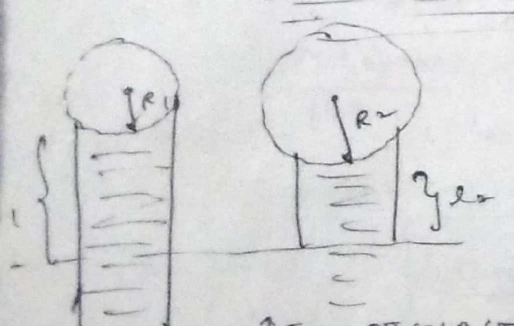
$l < h$.



$$P_o - \left(P_o - \frac{2T}{R}\right) = \rho g l$$

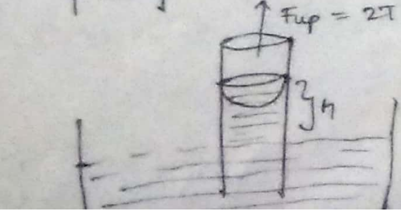
$$\frac{2T}{R} = \rho g l$$

$$\frac{2T}{\rho g} = Rl = \text{const}.$$



$l_2 < l_1$; $R_2 > R_1$

$$\boxed{l_1 R_1 = l_2 R_2}$$



$F_{up} = 2T\cos\theta\,(\pi r)$ Work done by Surface Tension Forces

$W = F \cdot h\cos 0°$

$= 2T\cos\theta\,(\pi r)\,(h)$

$W = (r\rho g h)(\pi r h) = \pi r^2 \rho g h^2$

increase in GPE of liquid

$= mg\left(\frac{h}{2}\right) = (\pi r^2 h)(\rho)(g)(h/2)$

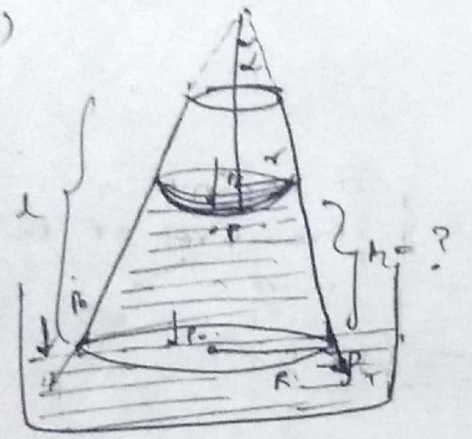
$= \frac{\pi r^2 \rho g h^2}{2}$

→ only half of work done by surface tension forces will be stored as GPE

→ Heat lost in the process of Capillary rise.

$$\boxed{H = \frac{\pi r^2 \rho g h^2}{2}}$$

Q)



θ - angle of contact

T - surface tension.

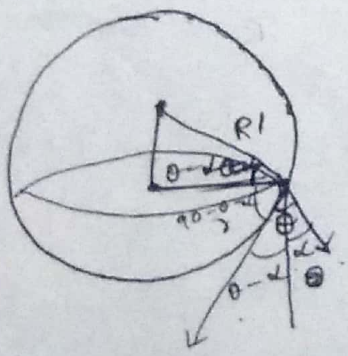
$P_0 - P = \frac{2T}{r}$.

$\tan\alpha = \frac{R}{l} = \frac{r}{l-h}$.

$r = \frac{R(l-h)}{l}$

Sol: $P_0 - P = \frac{2T}{R'}$, $\rho g h = \frac{2T}{R'}$ ⇒ $h = \frac{2T}{R'\rho g}$.

$P_0 - P = \rho g h$



$$\frac{2T\cos(\theta-\alpha)}{r} = \rho g h.$$

$$\frac{2T\cos(\theta-\alpha)\cdot l}{R\rho g} = \frac{h(l-h)}{}$$

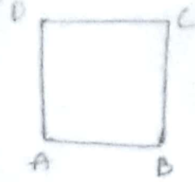
$$K = \frac{2T\cos(\theta-\alpha)\cdot l}{R\rho g}$$

$K = lh - h^2 \Rightarrow h^2 - lh + K = 0$

$h = \frac{l}{2} \pm \sqrt{\frac{l^2}{4} - K}$

$$\boxed{h = \frac{l}{2} \pm \sqrt{\frac{l^2}{4} - \frac{2T\cos(\theta-\alpha)\cdot l}{R\rho g}}}$$

1)



$R_{AB} = R_{BC} = \infty$

2)

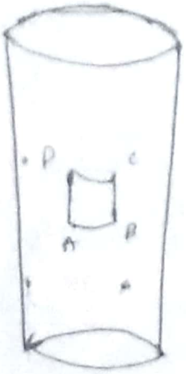
Solid sphere

$R_{AB} = R_{BC} = R$

$\Delta P = T\left(\frac{1}{R}+\frac{1}{R}\right)$

$\Delta P = \frac{2T}{R}$

3)



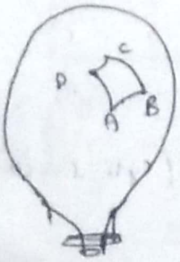
$R_{AB} = R'$

$R_{BC} = \infty$

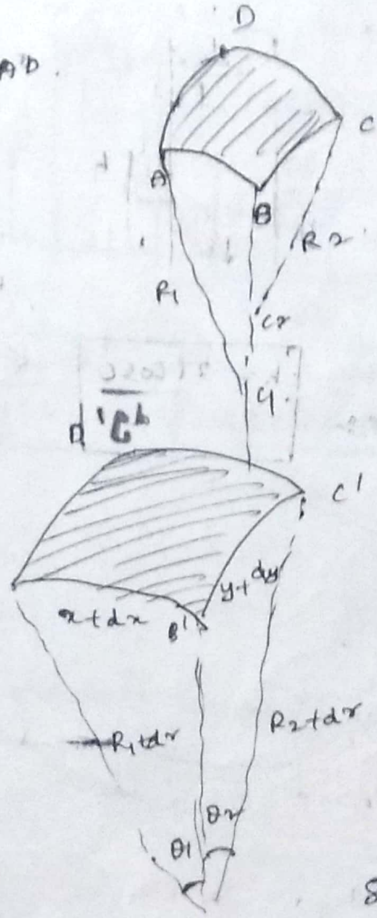
$\Delta P = \frac{T}{R}$ (liquid)

$\Delta P = \frac{2T}{R}$ (soap soln)

→ If we assume a ballon.



$R_{AB} \neq R_{AD}$.



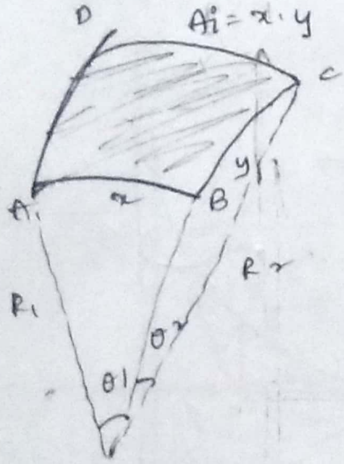
$\Delta P = P_{in} - P_{ext}$

$= T\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$ ↳ liq. surface

$\Delta P = P_{in} - P_{out}$

$= 2T\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$ ↳ Film

$A_i = x \cdot y$



$x = R_1\theta_1$;

$y = R_2\theta_2$

$A_f = (R_1+dr)\theta_1 \cdot (R_2+dr)\theta_2$

Surface Energy ↑

$E = T(\Delta A)$.

$\Delta A = A_f - A_i$

$= (R_1+dr)\theta_1 (R_2+dr)\theta_2 - R_1R_2\theta_1\theta_2$

$\Delta A = (R_1+R_2) \cdot dr \cdot \theta_1 \cdot \theta_2$

Work done by excess pressure

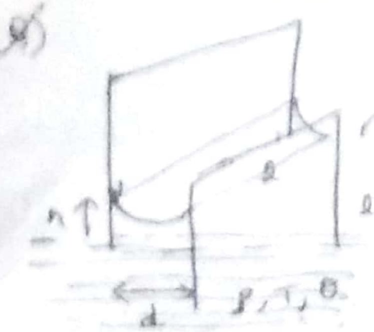
$W = \Delta P(\Delta V) = \Delta P(R_1R_2\theta_1\theta_2) \cdot dr$.

$\Rightarrow T(R_1+R_2)\cancel{dr}\cancel{\theta_1}\cancel{\theta_2}$

$= \Delta P(R_1R_2)\cancel{\theta_1 \cdot \theta_2 dr}$

$\Rightarrow \boxed{\Delta P = T\left(\frac{1}{R_1}+\frac{1}{R_2}\right)}$

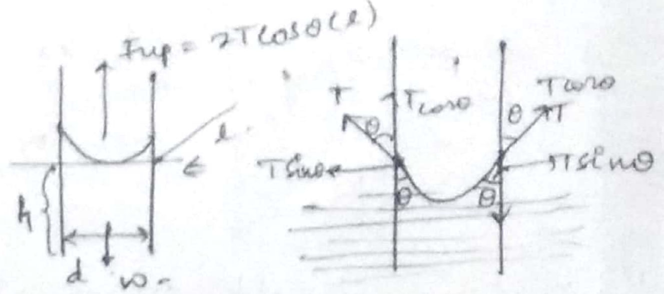
Q)



Find the height raised in b/w 2 plates.

(12)

Soln.

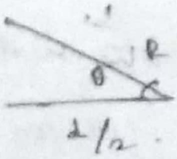


$$w = (l\,d\,h)(\rho)(g)$$

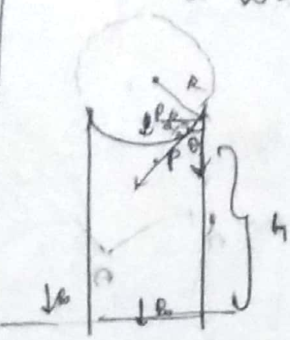
$$\rho \cancel{l} d h g = 2T\cos\theta \cancel{l}$$

$$\boxed{h = \frac{2T\cos\theta}{\rho d g}}$$

Press. diff method:



$$R = \frac{d}{2\cos\theta}$$



$\cancel{P_0 \; P_0}$

$$P_0 - P = \rho g h$$

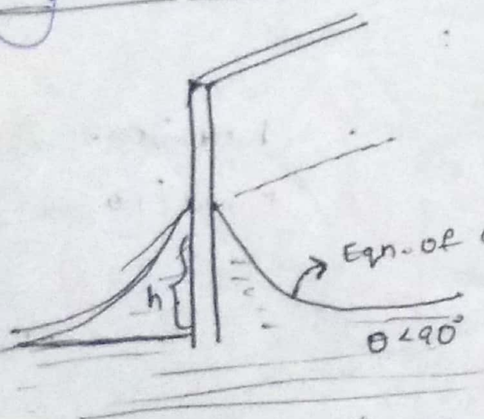
$$P_0 - P = \frac{T}{R} \text{ (cylindrical)}$$

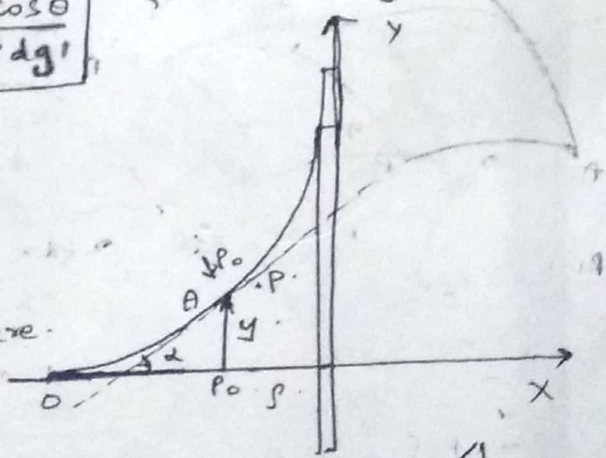
$$\frac{T}{R} = \rho g h$$

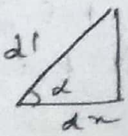
$$h = \frac{T}{R\rho g}$$

$$\boxed{h = \frac{2T\cos\theta}{\rho d g}} \Leftarrow$$

Eqn. for curvature:-







$$P_0 - P = \rho g y \qquad P_0 - P = T/R$$

$$\frac{T}{R} = \rho g y$$

$$\frac{T}{dl/d\alpha} = \rho g y$$

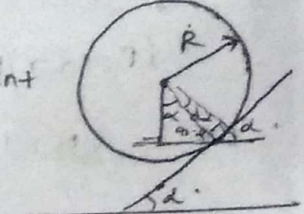
$$T(d\alpha) = dl \cdot \rho g y$$

$$T \cdot d\alpha = \frac{dy}{\sin\alpha} \cdot \rho g y$$

$$T\int_0^\alpha \sin\alpha \cdot d\alpha = \rho g \int_0^y y \cdot dy.$$

α – anglemade by tangent at a point

y – height



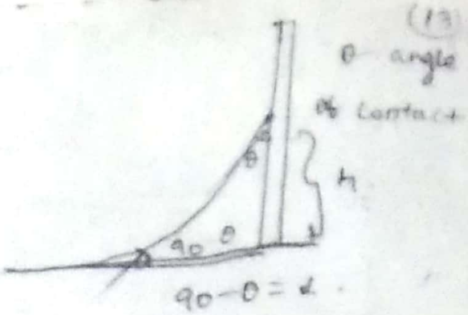
$$dl = \cancel{R\sin\alpha}\; R \cdot d\alpha$$

$$\sin\alpha = \frac{dy}{dl}$$

$$dl = \frac{dy}{\sin\alpha}$$

$$\Rightarrow T(-\cos\alpha)_0^{\alpha} = \frac{\rho g y^2}{2}$$

$$\boxed{T(1-\cos\alpha) = \frac{\rho g y^2}{2}}$$



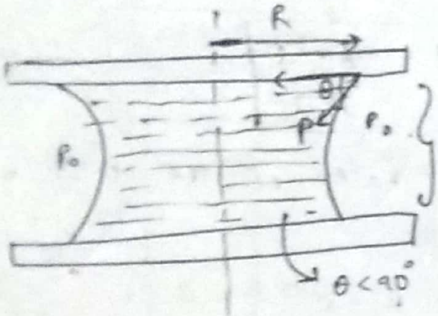
$$\Rightarrow T(1-\sin\theta) = \frac{\rho g h^2}{2}$$

$$\boxed{h = \sqrt{\frac{2T(1-\sin\theta)}{\rho g}}}$$

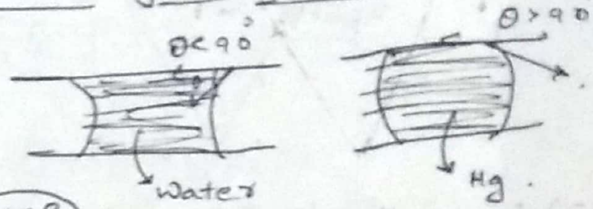
if $\theta = 0$ (completely wetting liquid).

$$\boxed{h = \sqrt{\frac{2T}{\rho g}}}$$

→ Force required to separate glass plates:-

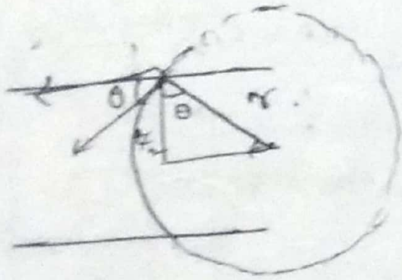


$t \ll R$



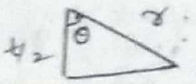
$$P_0 - P = T\left(\frac{1}{r} + \cancel{\frac{1}{R}}\right)$$ Neglected

$r \ll R$



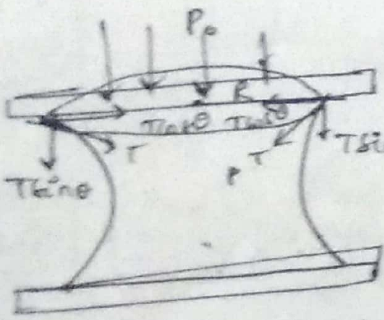
$$P_0 - P = T/r.$$

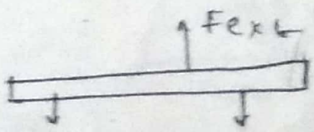
$$P_0 - P = \frac{2T\cos\theta}{t}$$



$$r = \frac{t}{2\cos\theta}$$

$$\boxed{P = P_0 - \frac{2T\cos\theta}{t}}$$





$F = \Delta P(\pi R^2)$ $T\sin\theta(2\pi R)$

↓ Force due to Pressure diff.

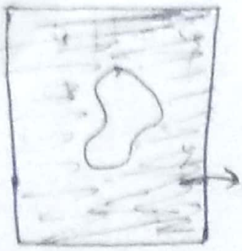
↳ Force due to S.T

$$F_{ext} = \Delta P(\pi R^2) + 2T\sin\theta(\pi R)$$

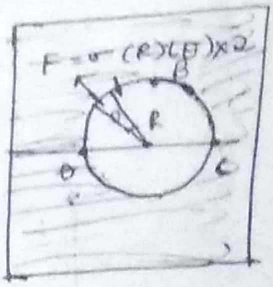
$$F_{ext} = \left(\frac{2T\cos\theta}{t}\right)\pi R^2 + 2T\sin\theta(\pi R)$$

If $\theta = 0$, $\boxed{T_{ext} = \frac{2T(\pi R^2)}{t}}$

Q)



→ When punctured in middle ⇒

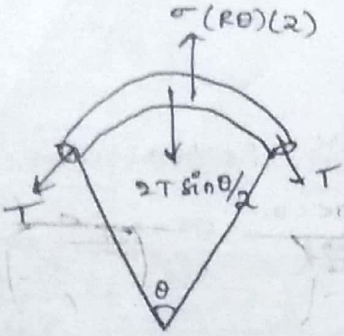


→ Find the tension acting in thread?

σ – Surface tension.

l – length of thread.

Sol:

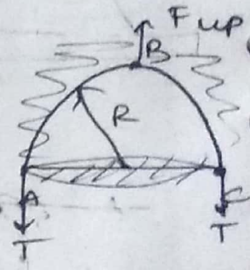


$2\sigma(R)(\theta) = 2T(\theta/2)$. [Fce]

$T = 2\sigma R$. $\quad l = 2\pi R$

$\boxed{T = \frac{2\sigma l}{2\pi}}$

→ Find the force acting on the half of the thread by soap film.



Sol: $F = (\sigma)(2)(\pi R)$.

$= 2F(l/2) \neq \sigma l$.

$2\pi R = l$.

$\pi R = l(2)$

$\frac{l}{\pi} = 2R$

$F_{up} = 2T$

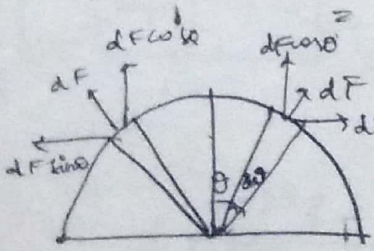
$= 2\left(\frac{\sigma l}{\pi}\right)$ (or)

$= 4\sigma R$.

~~$F_{up} = \Delta P(\pi R^2)$~~

$\Rightarrow F_{up} = 2\sigma(2R)$

$= \cancel{4\pi R}\ 4\sigma R$.

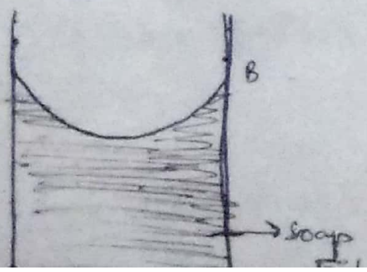


$dF = \sigma\ \cancel{(2R)}$

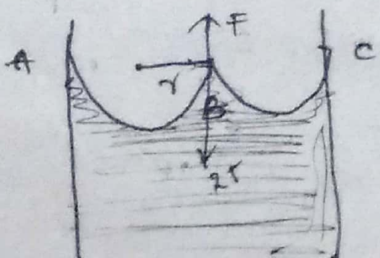
$2\sigma(R\,d\theta)$.

$F_{net} = \int_0^{\pi/2} 2\,dF\cos\theta = \int_0^{\pi/2} 4\sigma R\cos\theta \cdot d\theta = 4\sigma R\left[\sin\theta\right]_0^{\pi/2} = 4\sigma R$

Q)



⇒



Find the surface tension of soap film?

length of thread is – l

Sol:

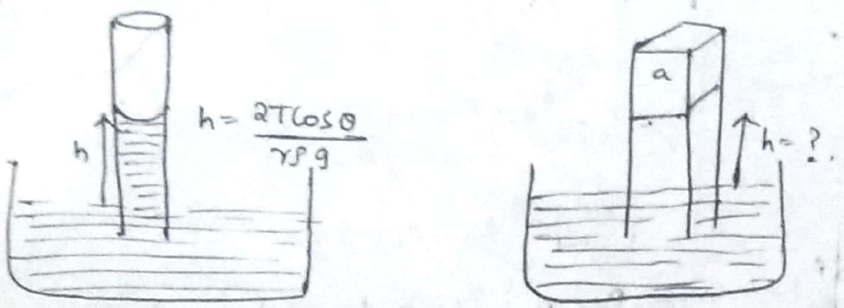
$\cancel{F = (\ )(2)(l)}$ $\quad F = 2T$ $\qquad l = \pi R \rightarrow R = l/\pi$

$\cancel{F = 4\sigma R}$ $\quad T = 2\sigma(r)$.

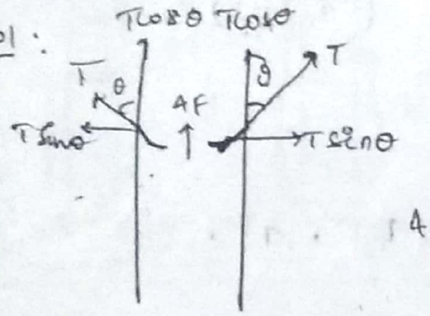
$F = 2(2\sigma r) \Rightarrow F = \frac{2\sigma R}{2} = 2\sigma(R) = \frac{2\sigma l}{\pi}$

$$\boxed{\sigma = \frac{F\pi}{2l}}$$

(8)



Sol:

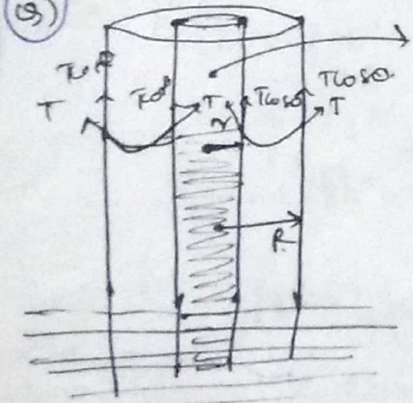


$F_{up} = (T\cos\theta\,(a))\,4,$

$4T\cos\theta\,(a) = a^2 h \rho g.$

$$\boxed{h = \frac{4T\cos\theta}{a\rho g}}$$

(9)



→ solid cyl.

Find the height raised by liq. in this arrangement?

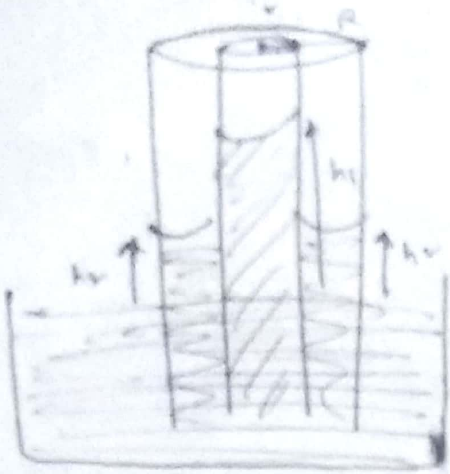
Sol. $F_{up} = T\cos\theta(2\pi R + 2\pi r)$.

Wt $= \rho(\pi)(R^2 - r^2)(h)(g)$

$2T\cos\theta\,(\cancel{\pi})(\cancel{R+r}) = (\rho)(\cancel{\pi})(\cancel{R+r})(R-r)(h)(g)$

$$\boxed{h = \frac{2T\cos\theta}{(R-r)\rho g}}$$

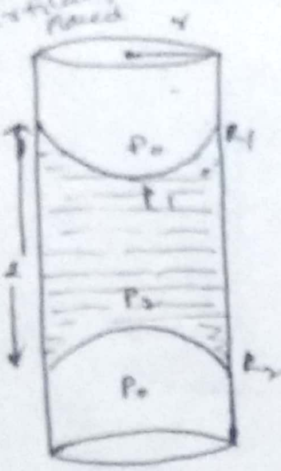
Q)



$$h_1 = \frac{2T\cos\theta}{r\rho g}$$

$$h_2 = \frac{2T\cos\theta}{(R-r)\rho g}$$

Q) vertically placed



$$P_0 - P_1 = \frac{2T}{R_1}$$

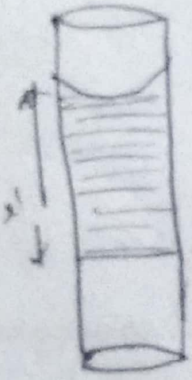
$$P_0 - P_2 = \frac{2T}{R_2}$$

$$P_2 - P_1 = \rho g l$$

$$P_2 - P_1 = 2T\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\boxed{2T\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \rho g l}$$

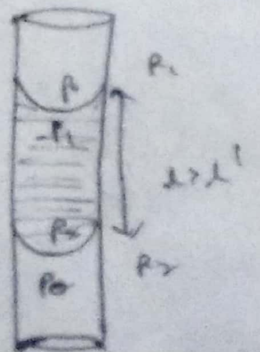
→ If water is added from up $l\uparrow$: $R_2\uparrow$ R_1 is const.



l' - length of liquid column when the Radius of curv. at bottom $= \infty$ (flat)

$$2T\left(\frac{1}{R_1} - \cancel{\frac{1}{R_2}}\right) = \rho g l'$$
$$\quad 0$$

$$\frac{2T}{R_1} = \rho g l'$$



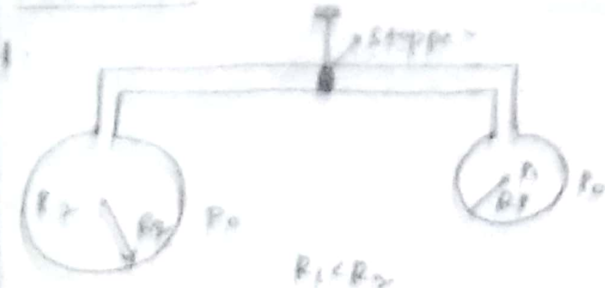
$$2T\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \rho g l$$

R_2 min. value $= r$

$$2T\left(\frac{1}{R_1} + \frac{1}{r}\right) > \rho g l_{max}$$

PROBLEMS:

1.



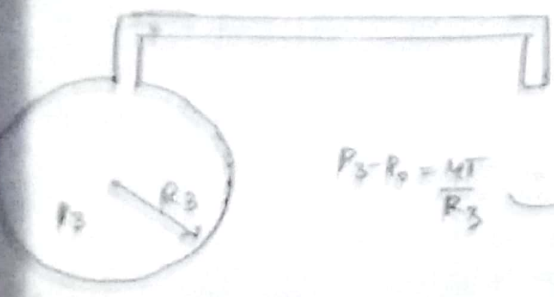
$P_1 - P_0 = \frac{4T}{R_1}$

$P_2 - P_0 = \frac{4T}{R_2}$

$P_1 > P_2$

$R_1 < R_2$

→ If stopper is removed, smaller bubble shrinks; larger bubble expands

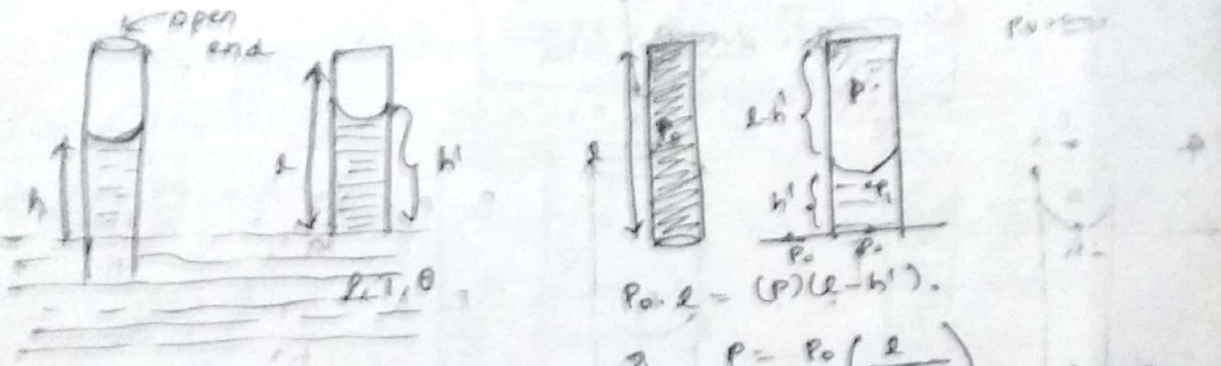


$n_3 = n_1 + n_2$

$P_3 - P_0 = \frac{4T}{R_3} \longrightarrow P_3V_3 = P_2V_2 + P_1V_1$

$\cancel{\left(P_0 + \frac{4T}{R_3}\right)}$

2.



$P_0 \cdot l = (P)(l-h')$.

$P = P_0\left(\frac{l}{l-h'}\right)$

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

$P - P_1 = 2T/R$

$P_0 - P_1 = \rho g h'$

$P_1 = P_0 - \rho g h'$

$P - P_0 + \rho g h' = \frac{2T}{R}$

$P_0\left(\frac{l}{l-h'} + 1\right) + \rho g h' = \frac{2T}{R}$

$P_0\left(\frac{2l-h'}{l-h'}\right) + \rho g h' = \frac{2T}{R}$.

(OR)

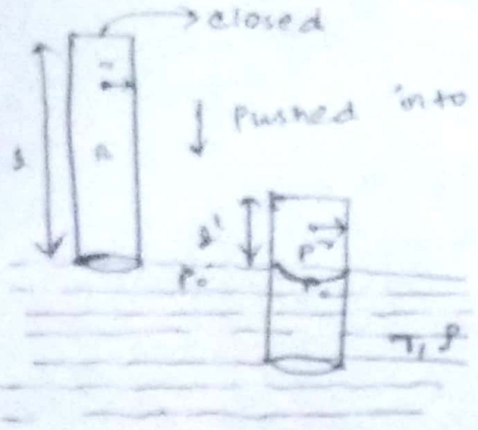
$P_0(l) = \left(\frac{2T\cos\theta}{r} + P_0 - \rho g h'\right)(l-h')$

$P_0 l = \frac{2T\cos\theta\, l}{r} + \cancel{P_0 l} - \rho g h' l - \left(\frac{2T\cos\theta}{r}\right)h' - P_0 h' + \rho g (h')^2$

$\Rightarrow \underbrace{\rho g}_{K_1}(h')^2 - \underbrace{\left[\rho g l + P_0 + \frac{2T\cos\theta}{r}\right]}_{K_2} h' + \underbrace{\frac{2T\cos\theta\, l}{r}}_{K_3}$

$\Rightarrow h' = \frac{K_2 \pm \sqrt{K_2^2 - 4K_1K_3}}{2K_1}$

3.



→ If level of water inside capilliary and outside of it, coincides than find the length of capilliary outside the water. ($l' = ?$).

Sol :-

$$P_0(l) = P(l') \quad —①$$

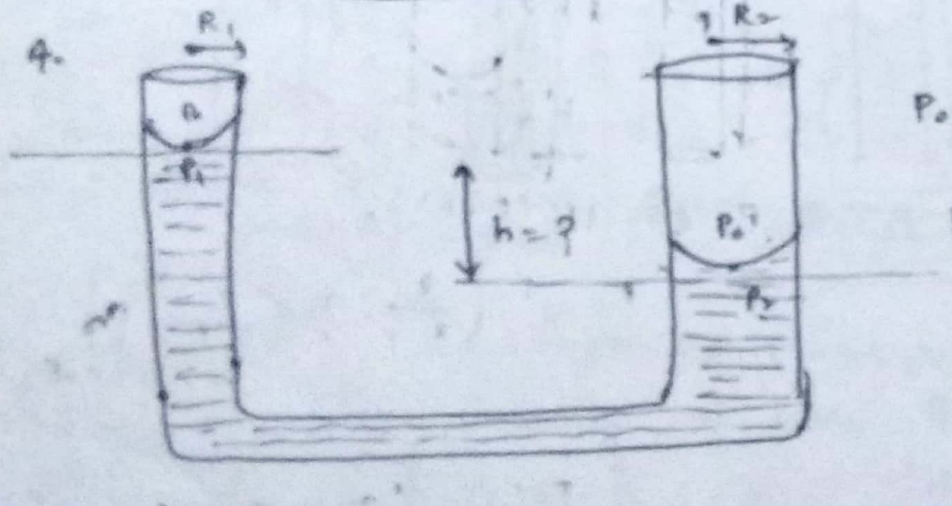
$$R = \frac{r}{\cos\theta}$$

$$P - P_0 = \frac{2T}{R}$$

$$\left(P_0 + \frac{2T\cos\theta}{r}\right)(l') = P_0 l$$

$$\boxed{l' = \frac{P_0 l}{P_0 + \frac{2T\cos\theta}{r}}}$$

4.



$$P_0 - P_1 = \frac{2T}{r_1} = \frac{2T\cos\theta}{R_1}$$

$$P_0 - P_2 = \frac{2T}{r_2} = \frac{2T\cos\theta}{R_2}$$

$$P_2 - P_1 = \rho g h$$

$$(\cos\theta)\,2T\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \rho g h \Rightarrow h = \frac{2T}{\rho g}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)\cos\theta$$

5.