Surface Tension

Capillarity – Excess Pressure

1. **Angle of contact(θ)**
   a. It is the angle between the tangent drawn at the point of contact of a solid and liquid and the surface of solid within the liquid.
   b. The angle of contact depends on solid-liquid pair, temperature and impurities.
   c. The angle of contact is not altered by the amount of inclination of solid object in the liquid.
   d. For pure water and glass, the angle of contact is zero.
   e. For mercury and glass, angle of contact is about 140° ≈ 139°C.
   f. For silver and water angle of contact is 90°.
   g. For ordinary water angle of contact is about 8°.
   h. If a liquid wets the solid, then the angle of contact is less than 90° and if the liquid doesn't wet the solid, then the angle of contact is greater than 90°.
2. **Capillarity**
   a. The property of rise or fall of a liquid due to surface tension in a capillary tube is known as capillarity.
   b. Oil ascends in a wick due to capillarity.
   c. Flow of ink through a nib is due to capillarity.
   d. A painter's brush under water has its hair spread but on withdrawal from water they adhere to each other due to surface tension.
   e. Ploughing of land brings moisture to the top by capillary action.
   f. The addition of a detergent decreases the surface tension and angle of contact.
   g. Wetting agents are used in detergents in order to clean clothes.
   h. The addition of a water proofing agent like waxy substance to a liquid increases angle of contact.
   i. If the angle of contact (θ) is acute ($\theta < 90°$), there will be capillary rise. e.g.: water in glass capillary.

j. If the angle of contact (θ) is obtuse ($\theta > 90°$), there will be capillary depression. e.g.: mercury in capillary.

k. If the angle of contact is 90°, there will be neither rise nor fall. e.g.: water in silver capillary.

3. S.T. by capillary method

a. When a capillary tube of radius r is immersed in a liquid , the upward force on the liquid inside the capillary tube is given by (θ is the angle of contact) $F = 2\pi r T\cos\theta$

b. In capillary rise the force due to surface tension in upward direction is equal to the weight of liquid column $2\pi r T\cos\theta = mg$.

c. Surface tension by capillary rise method.

$$T = \frac{rdg(h + r/3)}{2\cos\theta} \approx \frac{rhdg}{2\cos\theta} \text{ if } h >> r$$

In the case of pure water, $T = \frac{rhdg}{2}$.

d. **Jurin's law:** According to Jurin's law, inversely the height of the liquid (h) risen in capillary tube is proportional to the radius (r) rh = constant or $h_1r_1 = h_2r_2$

e. A graph between h and r is a rectangular hyperbola.

f. If a liquid rises to a height 'h' in a capillary tube and the tube is inclined at an angle 'α' to the vertical, the length of the liquid column inside the tube increases but the vertical height to which the liquid rises remains the same.

$L = \frac{h}{\cos\alpha}$ Where L = length of the liquid column inside the tube.

g. If a capillary tube is dipped in water in a satellite, the water level will rise to the full length of the tube.

h. In a capillary tube of insufficient length, the liquid rises to the top end of the tube and the radius of curvature of the meniscus increases. $h_1r_1 = h_2r_2$

Where r_1 and r_2 is the radius of curvature of the meniscus

i. In an artificial satellite (or) in a freely falling lift the liquid rises in the top end of the tube. The liquid does not overflow.

j. The height of the liquid column remaining in the capillary tube  $h = \frac{4T}{rdg}$

k. PE of the liquid = $\frac{2\pi T^2}{dg}\cos\theta$ d- Density of liquid

l. Two parallel square glass plates of side l are separated in air by a small distance x. The combination is dipped vertically into a liquid of surface tension T, density d and angle of contact < 90°. If the plane of the plates is perpendicular to the liquid surface, the height to which the liquid rises in between the plates is

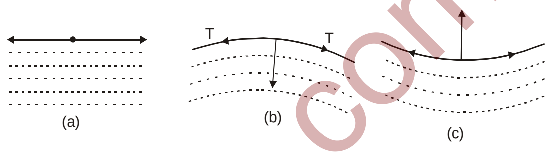
$$h = \frac{2T\cos\theta}{xdg}$$

4. Excess Pressure

1. **Pressure difference across a surface film**

   a. If the liquid surface is plane, the net force on the liquid molecule on the surface is zero.

   b. If the liquid meniscus is concave upwards, the net force is directed out wards.



   c. If the liquid meniscus is convex upwards, the net force is directed inwards.

2. Excess pressure in a drop of liquid of radius r is given by P = 2T/r.
3. Excess pressure in a soap bubble of radius r is given by P = 4T/r.
4. Excess pressure inside a soap bubble present in a liquid P = 2T/r, where r is radius and T is surface tension.
5. If an air bubble of radius r is in a lake

   a) At a depth h, $P = P_0 + hdg + \frac{2T}{R}$

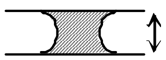
   b) At the surface inside the liquid

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

   c) Outside the surface $P = P_0 + \frac{4T}{R}$

6. If a liquid drop is present between two glass plates separated by a distance ‘d’ then

   Excess pressure = $P = \frac{2T}{d}$ and



   Force required separating the glass plates is

   $$F = \frac{2T}{d}A = \frac{2Tm}{\rho d^2} = \frac{2T}{V}A^2$$

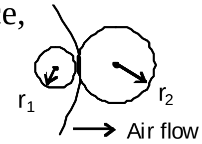
   ρ – Density of the liquid

   m – Mass of the drop

   V – Volume of the drop

A – Area of the drop

7. When two bubbles of radii r_1 and r_2 combine to have a common surface, the radius of curvature of the common surface $r = \frac{r_1 r_2}{r_2 - r_1}$



8. Two soap bubbles of radii r_1 and r_2 combine into a single bubble of radius r isothermally. If the change in volume is V and change in area is A, atmospheric pressure is P, then

a) 3PV + 4TA = 0

b) $T = \frac{P(r^3 - r_1^3 - r_2^3)}{4(r_1^2 + r_2^2 - r^2)}$