Chapter 4…
Surface Tension

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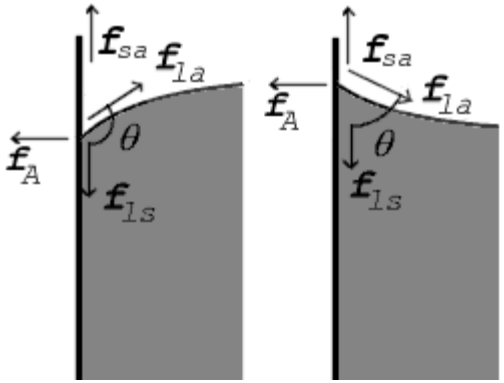
- **Introduction :**
- **Surface tension** is the elastic tendency of a fluid surface which makes it acquire the least surface area possible. Surface tension allows insects (e.g. water striders), usually denser than water, to float and stride on a water surface.
- At liquid–air interfaces, surface tension results from the greater attraction of liquid molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion).
- The net effect is an inward force at its surface that causes the liquid to behave as if its surface were covered with a stretched elastic membrane. Thus, the surface becomes under tension from the imbalanced forces, which is probably where the term "surface tension" came from .Because of the relatively high attraction of water molecules for each other through a web of hydrogen bonds, water has a higher surface tension (72.8 millinewtons per meter at 20 °C) compared to that of most other liquids. Surface tension is an iportant factor in the phenomenon of capillarity.

- Surface tension has the dimension of force per unit length, or of energy per unit area. The two are equivalent, but when referring to energy per unit of area, it is common to use the term surface energy, which is a more general term in the sense that it applies also to solids.
- In materials science, surface tension is used for either surface stress or surface free energy.

- (a) Fig Water beading On a leaf
- (b) Fig Water strider walking on the water surface

- **Surface Tension:**
- Free surface of a liquid has tendency to contract in surface area is called **surface tension.**
- **SI unit** of Surface tension: **N/m. or (J/m^2).**
- Its Dimension is $[M^0L^1T^{-2}]$.
- **Angle of Contact** : The angle measured from the side of the liquid, between the tangent to the solid surface inside the liquid and tangent to the free liquid surface at the point of contact between solid and liquid surfaces.



- **Capillary Rise Method:**
- Let us consider a capillary tube of uniform bore dipped vertically in a beaker containing water. Due to surface tension, water rises to a height h in the capillary tube as shown in Fig..
- The surface tension T of the water acts inwards and the reaction of the tube R outwards. R is equal to T in magnitude but opposite in direction. This reaction R can be resolved into two rectangular components.
- (i) Horizontal component $R \sin \theta$ acting radically outwards
- (ii) Vertical component $R \cos \theta$ acting upwards.
- The horizontal component acting all along the circumference of the tube cancel each other whereas the vertical component balances the weight of water column in the tube.

- Total upward force = R cos θ circumference of the tube
- (i.e) F = 2πr R cos θ or F = 2πr T cos θThis upward force is responsible for the capillary rise. As the water column is in equilibrium, this force acting upwards is equal to weight of the water column acting downwards.
- F = w.
- T = hgrρ/2cosΘ
- h = 2TCosΘ/ρgr

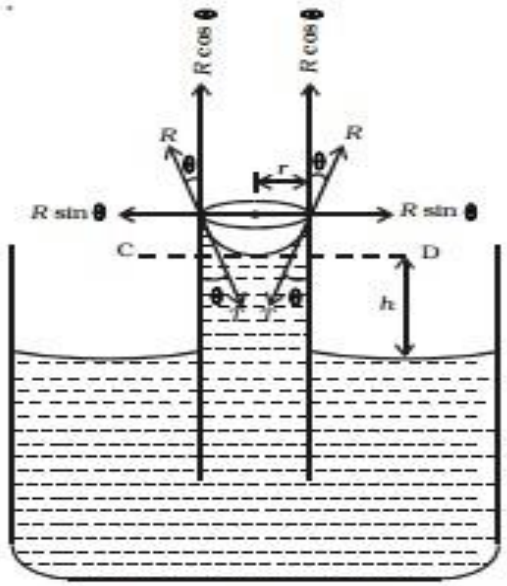


Fig. Surface tension by capillary rise method

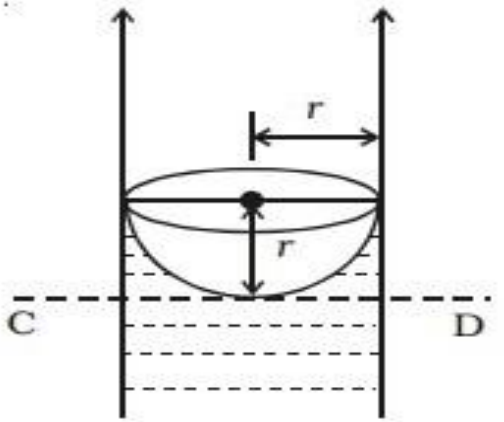


Fig. Liquid meniscus

- **Experimental measurement of surface tension of a liquid by using capillary rise:**
- A clean capillary tube of uniform bore is fixed vertically with its lower end dipping into water taken in a beaker. A needle N is also fixed with the capillary tube as shown in the Fig.. The tube is raised or lowered until the tip of the needle just touches the water surface. A travelling microscope M is focused on the meniscus of the water in the capillary tube. The reading R_1 corresponding to the lower meniscus is noted. The microscope is lowered and focused on the tip of the needle and the corresponding reading is taken as R_2. The difference between R_1 and R_2 gives the capillary rise *h*.

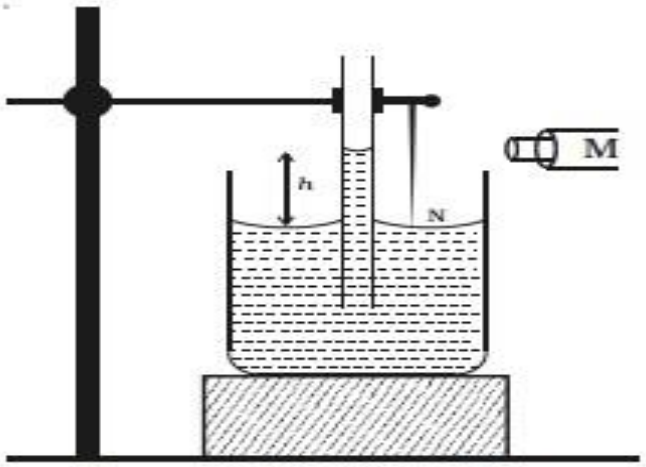
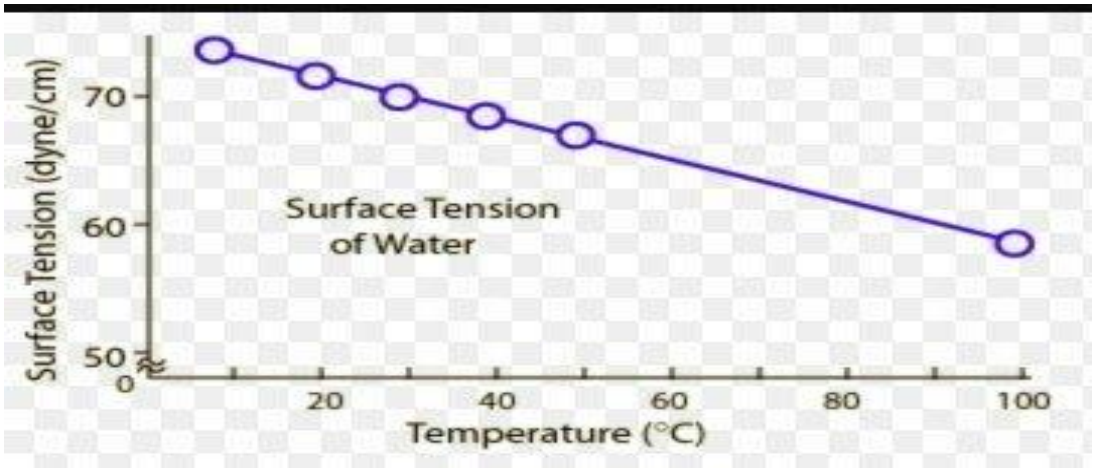


Fig. Surface tension by capillary rise method

- The radius of the capillary tube is determined using the travelling microscope. If ρ is the density of water then the surface tension of water is given by
- $T = hr\rho g / 2\cos\Theta$, $\Theta = 0^\circ$, $\cos 0 = 1$.
- $T = hr\rho g / 2$
- where g is the acceleration due to gravity.

Factors affecting surface tension:

- *Impurities present in a liquid appreciably affect surface tension.* A highly soluble substance like salt increases the surface tension whereas sparingly soluble substances like soap decreases the surface tension.
- *The surface tension decreases with rise in temperature.* The temperature at which the surface tension of a liquid becomes zero is called critical temperature of the liquid.
- **Effect of temperature :**
- Oxygen in the atmosphere is known to decrease the surface tension of various substances.



- Temperature ↑ surface tension ↓
- At Critical temperature Surface tension: Zero
- Critical temperature of water 3744K
- Surface tension Increase with impurity.

- **Application of surface tension:**
- Surface tension of soap solution is less, it can spread over large areas and wash clothes more effectively, since the dirt particles stick to the soap molecules.
- In soldering, addition of flux reduces the surface tension of molten tin. Hence, it spreads.
- Antiseptics like dettol have low surface tension, so that they spread faster.
- Surface tension prevents water from passing through the pores of an umbrella.
- A duck is able to float on water as its feathers secrete oil that lowers the surface tension of water.