

# Surface Tension

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There are two types of molecular forces

**(i) Adhesive Force :** It is the force of attraction between molecules of different substances.

**(ii) Cohesive Force :** It is the force of attraction between molecules of the same substances.

The surface tension of a liquid is property which results from an imbalance of intermolecular attractive forces, the **cohesive forces** between molecules.

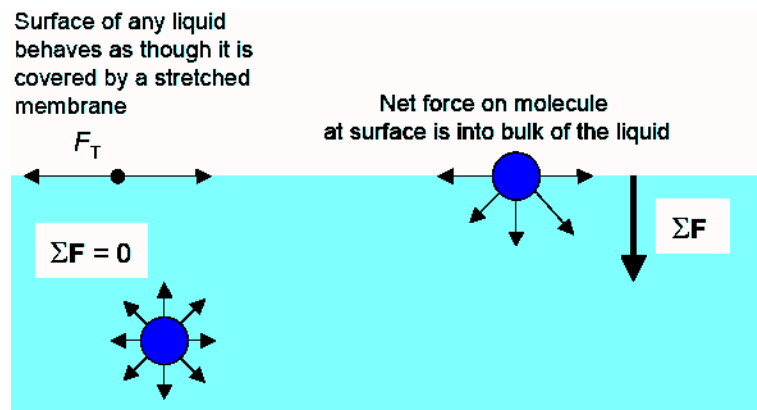
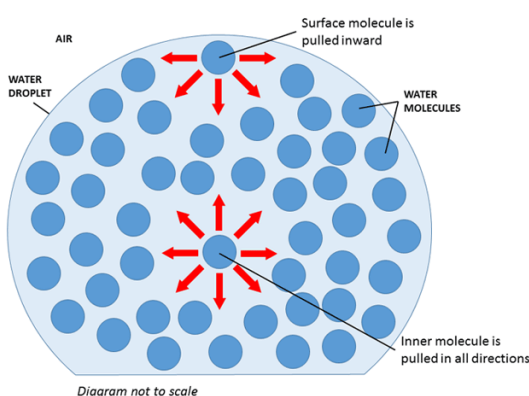
## Molecular range :

The maximum distance up to which the force of cohesion between two molecules can act is called molecular range. It is generally in the order of  $10^{-7}$  cm in case of solids and liquids.

## Sphere of influence :

A sphere drawn with the molecule as the centre and with radius equal to its sphere of influence, is called sphere of influence.

**Surface tension** is the property of a liquid surface by virtue of which it is acting as if it were a stretched elastic membrane. Cohesive forces between molecules cause the surface of a liquid to contract to the smallest possible surface area.



## Examples of Surface Tension :

- Because of this property, certain insects can stand on the surface of water. Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface.
- A carefully placed small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated to break up the surface tension, then needle will quickly sink.
- The surface tension of water provides the necessary wall tension for the formation of bubbles with water. *The tendency to minimize that wall tension pulls the bubbles into spherical shapes, since for a certain volume, a sphere has the least surface area.*
- Surface tension is responsible for the shape of liquid droplets. Although easily deformed, droplets of water tend to be pulled into a spherical shape by the cohesive forces of the surface layer.

Surface tension depends mainly upon the forces of attraction between the particles within the given liquid. Surface tension is the result of forces acting on the molecules of the free surface and tends to minimize its area.

**So, surface tension is defined as the force per unit length of a line drawn in the liquid surface, acting perpendicularly to it at every point and tending to pull the surface apart along the line. The unit of surface tension is N/m, which is equivalent to joules per square metre. Its dimensions are  $[M T^{-2}]$ .**

### Surface film :

The layers of liquid lying between a free surface and another plane inside the liquid, one molecular distance apart, is known as surface film.

### Surface Energy

When a molecule is brought from the interior of the liquid to the surface film, work has to be done against the downward cohesive force acting on it to pull it down. As a result potential energy of the molecules in the surface film is greater than that of those inside the liquid. Since the potential energy of the system tends to be minimum, the film tends to have the least surface area by making number of molecules in the surface film, as thickness of the surface film is constant. The potential energy per unit area of the surface film is called its surface energy.

## Free Energy of a surface and Surface Tension :

Let us consider a rectangular frame of wire PQRS with a horizontal movable wire AB, which can move up or down along the plane of PQRS. A soap film is formed across AQRB, by dipping it in a soap solution. The wire AB is pulled upwards by the surface tension of the film, acting perpendicular to the wire and in the plane of the film. To keep the wire in position, a force has to be applied downwards, equal and opposite to the upward force due to surface tension. Let the downward force to be applied is  $F$ , which includes the weight of the wire AB. Let us assume that  $T$  be the surface tension of the film. Therefore, upward force acting on the wire is

$$F_{\text{upward}} = 2 \cdot AB \cdot T = 2lT;$$

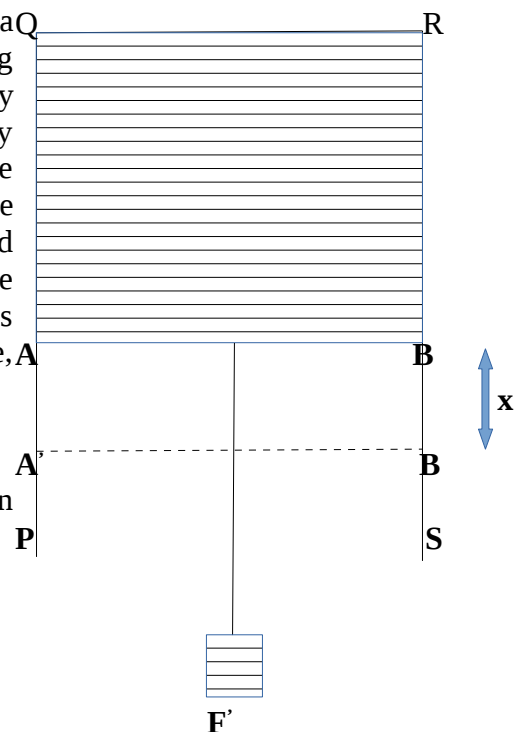
because the film has two surfaces and each has a surface tension  $T$ .

Here,  $l$  is the length of the wire AB.

Since, the film is in equilibrium

**Upward force = Downward Force**

$$2lT = F$$



Now, the wire AB is pulled downwards through a small distance  $x$  to the new position A'B'. So the film has got extended by an area  $lx$ , on each side.

Therefore, work done =  $Fx = 2lTx$

The film gets cooled on being stretched, because the drawing out of the molecules from the interior against the attractive force results in retardation of their thermal agitation, resulting in lowering of temperature. Therefore, it takes up heat from the atmosphere to maintain its temperature at constant value. This heat absorbed together with the mechanical work done, forms the energy of the new surface area  $2lx$  of the film.

If  $E$  is the surface energy of the film and  $Q$  ergs of heat is absorbed per unit area of the new surface area formed, we can write

$$E \cdot 2lx = T \cdot 2lx + Q \cdot 2lx$$

or

$$E = T + Q$$

or

$$T = E - Q$$

= Surface Energy – Heat Energy per unit area

= Potential Energy per unit area

Therefore,

$T =$  work done in creating unit area of the skin of the film.

That means, the surface tension of a liquid may be defined as the amount of work done in increasing the surface area of the liquid film by unity.

## Pressure Difference across a liquid surface

### Case of Drops and Bubbles

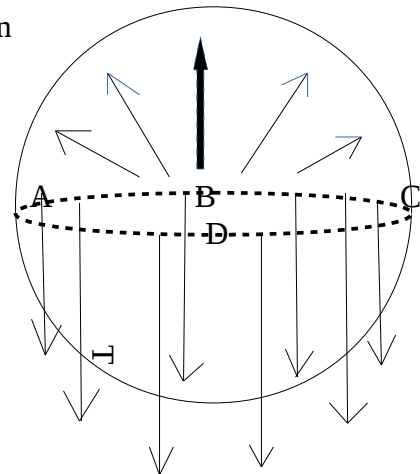
(a) **Excess pressure inside a liquid drop :** Here, the molecules near the surface of a drop, experience a resultant pull inwards. Therefore, the pressure inside it must be greater than the pressure outside it. Let this excess pressure inside, over the pressure outside be  $p$ . If  $r$  is the radius of the drop and  $T$  is the surface tension of the liquid, the upward thrust on the plane ABCD, due to the excess pressure  $p$  is  $p \pi r^2$ . (considering the equilibrium of one-half of drop)

Again, force due to surface tension acting downwards on ABCD is  $2\pi r.T$

$$p \cdot \pi r^2 = 2\pi r.T$$

or

$$p = \frac{2T}{r}$$



(b) **Excess of pressure inside a soap bubble :** In case of soap bubble, there are two surfaces, as it is like a spherical shell having an inner and an outer surface. So, force due to surface tension will be  $2(2\pi r.T)$ . Therefore, for equilibrium we have

$$p \cdot \pi r^2 = 2(2\pi r.T)$$

or

$$p = \frac{4T}{r}$$

**Special Case :** In case of bubble formed inside a liquid, just like an air bubble inside water, we need to consider only one surface and hence it is to be considered like a liquid drop.

So excess pressure for a air bubble inside a liquid is  $\frac{2T}{r}$ .