Subject	Physics
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PHYSICS	Paper I: Mechanics & Properties of Matter
	Module 1: Surface Tension

Objectives:

1. To Study the Surface Tension Phenomenon
2. Effect of Temperature on Surface Tension
3. Application of Surface Tension
4. Measurement of Surface Tension

Outcomes:

1. Understand the origin of surface tension
2. Understand the effect of temperature of Surface Tension

Table of Content

1. Introduction:

Surface tension is a molecular phenomenon governed by two types of molecular forces, viz. **adhesive forces** and **cohesive forces**.

Adhesive force: It is the force of attraction between molecules of different substances.

Cohesive force: It is the force of attraction between molecules of a same substance.

Molecular range: The maximum distance up to which the force of attraction between molecules can act is called their molecular range. In case of solids and liquids, it is of the order of 10^{-9} m.

Definition:

Surface tension is defined as the force per unit length at right angles to an imaginary line drawn in the free surface of a liquid.

Surface tension is also defined as surface energy per unit area of the liquid surface.

Dimensions: $[M^1L^0T^{-2}]$

Units: C.G.S. unit is dyne/cm or erg/cm^2.

S.I. unit is N/m or J/m^2.

Explanation of surface tension:

Surface tension is explained on the basis of molecular theory by Laplace. The molecules in the interior of the liquid are equally attracted by cohesive forces in all directions. So there is no net force on such molecules. But the molecules at the surface are attracted by cohesive forces due to liquid molecules in the downward direction and by adhesive forces due to air molecules in the upward direction. The net force acting on the surface molecules is the downward pull giving rise to the property of surface tension.

In other words, to bring a molecule from inside the liquid to the surface, work is to be done against cohesive forces. This work is stored in the form of potential energy in the surface molecules. So surface molecules have greater potential energy. To minimize the potential energy, surface film tries to reduce the number of molecules in it. Thus free surface of a liquid always tries to contract and minimize its area. This tendency of the liquid is the phenomenon of surface tension.

2. Factors Affecting Surface Tension:

Surface tension of a liquid is affected by following factors :

(i) Contamination of the liquid surface: Any type of impurity present in the liquid, even in traces, changes the surface tension of the liquid appreciably.

(ii) Presence of dissolved substance in the liquid: Effect of dissolved substance on the surface tension of a liquid depends upon the solubility of the substance in the liquid. Substances like NaCl and $ZnSO_4$ which are highly soluble in water invariably increase surface tension of water. The substances, which are sparingly soluble, decrease the surface tension of the liquid.

For example, phenol or soap solution decreases the surface tension of water.

(iii) Change of temperature: Surface tension of a liquid varies with its temperature. It decreases with the increase in temperature. The variation of surface tension of a liquid with its temperature is given by the relation

$$T = T_o (1 - bt)^n$$

where, b and n are constants, t is the temperature of the liquid measured in degree centigrade scale, T and T_o are surface tension of the liquid at t° C and 0 °C respectively.

The surface tension becomes zero at critical temperature t_c.

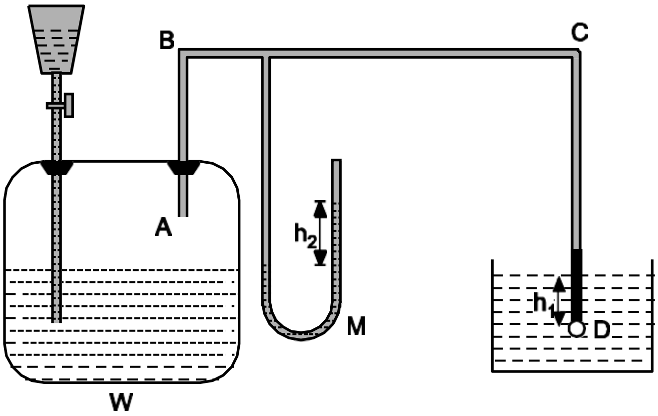
It gives $(1 - bt_c) = 0$

or $$b = \frac{1}{t_c}$$

3. Measurement of Surface Tension by using Jaeger's Method:

Principle : Working principle of Jaeger's method is that the pressure inside an air bubble in a liquid is greater than the pressure outside it by $\frac{2T}{r}$.

Apparatus :



Working : The apparatus consists of a Woulf's bottle W. In one mouth glass pipe ABCD is fitted. The other mouth is fitted with a dropping funnel containing water. To this tube a manometer M, containing low density liquid is joined. The end D of the tube CD is drawn into a fine capillary. This end dips 2 to 3 cm into the liquid of which surface tension is to be determined.

The liquid rises into the capillary tube CD due to capillary action and the miniscus is nearly spherical. When water from the dropping funnel is allowed to enter slowly into the Woulf's bottle, an equal amount of air forces into the tube ABCD. The liquid in the tube CD goes down slowly and forms a bubble at the end. When the pressure inside the bubble increases, radius of the bubble gradually decreases. It attains hemispherical shape of radius r equal to that of the end D of the capillary tube. Now, the difference h_2 in the levels in the two limbs of the manometer is maximum and is noted. The bubble becomes unstable and breaks. The radius r of the opening end D of the capillary is found out by a microscope.

If ρ is the density of the manometric liquid and P is the atmospheric pressure, then the pressure inside the bubble just before it breaks is $P + h_2\rho g$.

If σ is the density of the experimental liquid and h_1 is the depth of free end of the capillary below the free surface of the liquid, then the pressure outside the bubble just before it breaks is $P + \sigma h_1 g$.

It gives the excess pressure inside the bubble

$$= (P + h_2\rho g) - (P + \sigma h_1 g) = g(\rho h_2 - \sigma h_1)$$

Now, if T is the surface tension of the liquid, then the excess pressure inside the bubble is $\frac{2T}{r}$.

$$\therefore \qquad \frac{2T}{r} = g(\rho h_2 - \sigma h_1)$$

$$\text{or} \qquad T = \frac{rg}{2}(\rho h_2 - \sigma h_1)$$

Thus, by measuring h_1 and h_2, surface tension of any given liquid can be determined.

Advantages of Jaeger's method :

1. Surface tension of a liquid at various temperatures can be measured.
2. Surface tension of a solution at any concentration can be determined.
3. One can compare the surface tension of different liquids.
4. This method does not require the knowledge of angle of contact.
5. Small quantity of liquid is sufficient.

4. Applications of Surface Tension

1. **In lubrication oils, certain ingradients are added, so that the surface tension of the mixture is reduced, so that the lubricating oil spreads over the solid surface easily.**
2. **The paints have low surface tension, so that they can spread properly.**
3. **When soap is dissolved in water, the surface tension in solution is very much reduced. Thus solution spreads over larger areas make them wet. This helps in washing of cloths.**
4. **Soap is added in tooth paste which reduces the surface tension and enables the solution of the paste to spread over large area and a better mouth wash is possible.**
5. **Under storm conditions, to calm the sea waves, oil is spread over the sea water which reduces surface tension of water. This helps in damping the sea waves.**
6. **The soldering material is heated to reduce its surface tension, so that it can easily spread on PCB.**

Summary

- The surface tension in liquid can be understood on the basis of molecular forces.
- The surface tension decreases with increasing temperature. The dissolved substances in liquid also affect the surface tension
- The surface tension of liquid can be measured by using Jaeger's Method.
- The surface tension property of liquid is used in many applications.

References and Know More

Video 1:

https://drive.google.com/file/d/1psXh3oLhgF3B1UG_mvnaVT1baXAcFUoh/view?usp=sharing

Video 2:

https://www.youtube.com/watch?v=IjD5e33FnP0

Video 3:

https://www.youtube.com/watch?v=HTEbpvc-NTU

Know More:

Suggested Reading/Web Links

https://en.wikipedia.org/wiki/Surface_tension

http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html

Assignment:

Quiz on what we learned: Multiple Choice Question.

1. **The C.G.S. unit of surface tension is_______________.**
   (a) Dyne .cm (b) dyne/cm^2 (c) dyne/cm d) cm/dyne

2. **The basic reason of surface tension is the tendency of the surface of liquid to _________**
   (a) Expand (b) maintain the area (c) contract (d) either expand or contract.

3. **If 'T' is the surface tension of a liquid then the excess pressure inside the liquid drop of radius 'r' is___________________.**
   (a) $\frac{2T}{r}$ (b) $\frac{4T}{r}$ (c) $\frac{T}{4r}$ (d) $\frac{T}{2r}$

4. **With increasing temperature, the surface tension of liquid _____________**
   (a) increases (b) decreases (c) become zero (d) remain constant

5. **The profile of advancing liquid in the capillary tube is a ___________**
   (a) Parabola (b) Hyperbola (c) catenary (d) Ellipse.

Answers:

1 (c)	2 (c)	3 (a)	4 (b)
5 (a)			

Feedback:

1) How was the learning experience?

Outstanding/Excellent / Nice /Good/Fair

2) Which aspect do you like most?

Introduction/Concept/Diagrams/Exercise/Applications

3) Anything else to be added?

Applications/Problems/Illustrations/Notes/Videos

4) Which point was not up to the mark and need revision?

Introduction/Concept/Diagrams/Exercise/Applications

5) Suggestions if any:

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Name of the student and class (Roll No.):

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