Surface Tension

(Questions & Answers) PART-B

e-content for B.Sc Physics (Honours)

B.Sc Part-I

Paper-I

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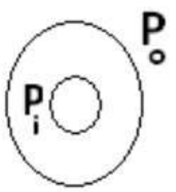
Que.10: Derive Laplace's law for spherical membrane. OR Derive an expression for excess pressure inside a liquid drop.

Ans:-



i. Free surface of drop or bubbles are spherical in shape.

Let, P_i = inside pressure of drop or air bubble

P_o = Outside pressure of bubble

r = radius of drop or bubble.

P_i - P_o = excess pressure

ii. Let the radius of drop increases from r to r+Δr so that inside pressure remains constant.

iii. Initial area of drop $A_1 = 4\pi r^2$, Final surface area of drop $A_2 = 4\pi(r + \Delta r)^2$
Increase in surface area

$$\Delta A = A_2 - A_1$$

$$= 4\pi[(r + \Delta r)^2 - r^2]$$

$$= 4\pi[r^2 + 2r\Delta r + (\Delta r)^2 - r^2]$$

$$= 4\pi[2r\Delta r + (\Delta r)^2]$$

$$\Delta A = 8\pi r\Delta r + 4\pi(\Delta r)^2$$

iv. As Δr is very small , $(\Delta r)^2$ is neglected

$$\Delta A = 8\pi r\Delta r$$

v. work done by force of surface tension

$$dW = T\Delta A = (8\pi r\Delta r)T$$

.....(i)

But $dW == F\,\Delta r = (P_i - P_o)A\Delta r$

from equation (i)

$$(8\pi r\Delta r)T = (P_i - P_o)A\Delta r$$

But surface area of sphere is $4\pi r^2$

$$(P_i - P_o) = \frac{(8\pi r\Delta r)T}{4\pi r^2\Delta r}$$

$$(P_i - P_o) = \frac{2T}{r}$$

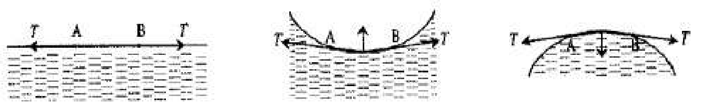
This is called Laplace's law of spherical membrane. in case of soap bubble there are two free surface in contact with air . hence the total increase in surface area is $2(8\pi r\Delta r)T$ and dW=$(16\pi r\Delta r)T$

hence

$$(\mathbf{P_i} - \mathbf{P_o}) = \frac{\mathbf{4T}}{\mathbf{r}}$$

Que10: Explain the nature of pressure on two side of liquid surface. Also, state their causes.

Ans: Pressure on two sides of a liquid surface:-The surface of the liquid is sometimes concave or convex due to angle of contact phenomenon



(a) (b) (c)

(1) If the surface of the liquid is **plane**, the force due to surface tension acting on two sides of the element AB are equal but opposite, so that the resultant force is zero . Therefore no pressure difference on two side of the plane surface. as shown in fig. a

(2) If the surface is **concave** , the forces of surface tension on the element AB produces the resultant force vertically upwards To counter balance the effect of this resultant force, the pressure on concave side is greater than that of convex side. As in fig.b.

(3) If the surface is convex the resultant force due to surface tension acting vertically downwards To counter balance the effect of this resultant force, the pressure on convex side is less than that of concave side. As shown in fig. c

Que. 11: What is capillarity? give its examples.

Ans:- A tube having a very small bore is called as capillary tube or capillary.

If the capillary tube is dipped in a liquid which partially wets or wholly wets the solid, there is rise of liquid in the capillary tube, If the capillary tube is dipped in the liquid which does not wets the solid, the liquid level lowered inside the capillary.

The phenomenon of rise or fall of a liquid inside a capillary tube is called as capillarity.

Examples of capillarity:-

(1) Blotting paper absorbs ink or water.

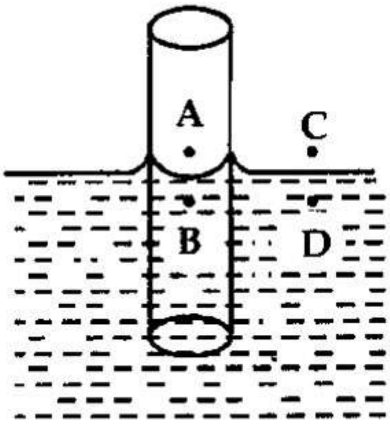
(2) Ink rises in a pen or oil rises up the wick of a lamp, due to capillary action.

(3) Water & minerals rise up through the root of the tree, due to capillary action.

(4) Oil rises up the wick of lamp on account of capillarity.

Que.12: Explain the cause of capillary action.

Ans:-Explanation of the capillary action:-



Suppose that capillary tube is dipped into a liquid, which wets the capillary tube. The shape of the water inside the capillary tube is concave.

Let us consider four points A,B,C,&D such that (1) **A** is just above the curve surface, inside the capillary (2) **B** is just below the curve surface inside the capillary (3) **C** is just above the plane surface of the water & (4) **D** is just inside the plane surface of water, outside the capillary. Let $\mathbf{P_A}$, $\mathbf{P_B}$, $\mathbf{P_C}$ & $\mathbf{P_D}$ be the pressures at the points **A, B, C, &D** respectively. Since pressure on the concave since is greater than that of convex $\mathbf{P_A > P_B}$ as the pressure on the both of plane surface is same we have $\mathbf{P_C = P_D}$

AS $\mathbf{P_A = P_C = atmospheric\ pressure}$

i.e. $\mathbf{P_A = P_D}$

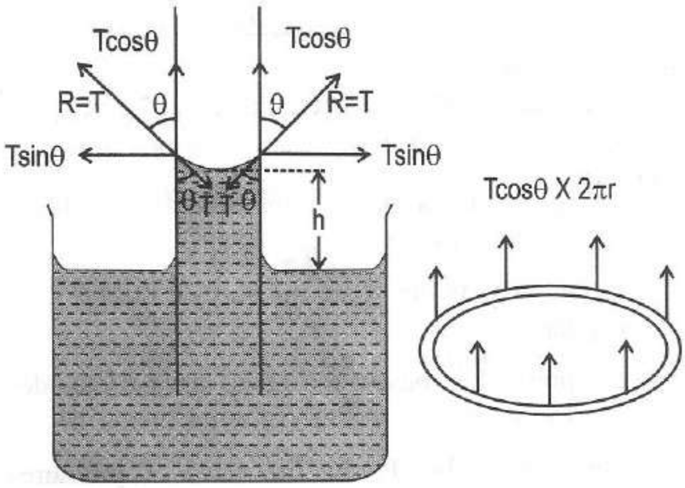
$\therefore\ P_D > P_B$

Therefore pressure at D is greater than that of the point **B** hence there is flow of liquid from the point **D** to the point **B** , inside the capillary so that liquid rises in the capillary tube, still the pressure at **B** is same that the point **D. I.e. for the liquid which is partially wets or completely wets the capillary ,there is rise of the liquid. for the liquid which does not wets the solid**

i .e. mercury in the capillary, surface is convex. Hence there is fall of liquid inside the capillary for it we have $\mathbf{P_A < P_B}$ $\therefore$ $\mathbf{P_D < P_B}$ $\therefore$ fall of liquid in the capillary tube

Que. 13 : Derive $\mathbf{T = \frac{hr\rho g}{2\cos\theta}}$

Ans: Rise of a liquid in the a capillary tube:-



Rise of liquid in capillary tube

If a glass capillary tube is inserted into a liquid which wets the glass, the liquid rises in the capillary to a height **h**. If **T** is the surface tension of the liquid, a force of magnitude **T** acts on each it length of the liquid surface, which is contact with the wall of the capillary. This force acts along a tangent to the liquid meniscus, making an angle $\boldsymbol{\theta}$ with the wall of the capillary.

The force of reaction on each unit length can be resolved in two components,

i. vertical component $\boldsymbol{T\cos\theta}$ &

ii. Horizontal component $\mathbf{T}\,\mathbf{sin}\,\boldsymbol{\theta}$.

All horizontal cancel each other, while vertical com. Add to each other. The liquid surface inside the capillary is in contact with capillary along a length $\boldsymbol{2\pi r}$**,** which is circumference of it.The total vertical force acting on the liquid column inside the capillary is $\boldsymbol{2\pi rTcos\theta}$,

$$\mathbf{V = volume\ of\ liquid\ column}$$

$$\mathbf{M = mass\ of\ it}\ \&$$

$$\boldsymbol{\rho} = \mathbf{density\ of\ liquid}$$

$$\therefore \boldsymbol{V = area \times height = \pi r^2 h}$$

$$\therefore \ \boldsymbol{M = volume \times density = \pi r^2 h\,\rho}$$

The weight of liquid column

(W) $= \mathbf{Mg} = \ \boldsymbol{\pi}\mathbf{r^2 h}\,\boldsymbol{\rho}\,\mathbf{g}$= total downward force(gravitational force) for the equilibrium of the liquid column

We have,

$$\textbf{upword force} = \textbf{downward force}$$

$$2\pi r T\cos\theta = \pi r^2 h \rho g$$

$$\therefore \quad T = \frac{hr\rho g}{2\cos\theta}$$

$$\therefore \quad h = \frac{2T\cos\theta}{r\rho g}$$

This formula is used to determine the surface tension of the liquid in the capillary.

Que. 14 : Explain the effect of impurity and temperature on surface tension.

Ans: Effect of impurity on surface tension:

if the surface of a liquid contains impurities of any kind, there is a marked change in the surface tension of the liquid.

(1) when the highly **soluble inorganic** substance like sodium chloride is dissolved in water, the surface tension of water increases

(2) When a sparingly soluble substance like phenol, is dissolved in water, decreases the surface tension.

(3) When soap is dissolved in water, the surface tension of the solution decreases to a great extent. This is the reason why a soap bubble in air remains stable for a reasonable time or why soap is used for washing clothes.

Effect of temperature on surface tension:- Surface tension of a liquid depends on the temperature. Surface tension of the liquid decreases as the temperature increases. Only in case of molten copper & cadmium, the surface tension increases with the rise in the temperature.

The temperature at which surface tension of liquid is zero such temperature called as the critical temperature of the liquid.

Effect of contamination on surface tension :

The presence of dust particles or lubricating materials on the liquid surface decreases its surface tension.

Important formulae

i. Surface tension

$$T = \frac{F}{l}\ , \quad \mathbf{T} = \frac{\mathbf{hr\rho g}}{\mathbf{2\cos\theta}}$$

ii. Work done = surface area x surface tension.

$$W = T \times dA$$

iii. Laplace's law of spherical membrane

$$(\mathbf{P_i} - \mathbf{P_o}) = \frac{\mathbf{2T}}{\mathbf{r}}$$

iv. Laplace's law of spherical membrane (hollow sphere)

$$(\mathbf{P_i} - \mathbf{P_o}) = \frac{\mathbf{4T}}{\mathbf{r}}$$