Experiment NO: 05

Experiment Name: To determine the surface tension of water by capillary tube method.

Theory:

When glass is dipped into a liquid water, it becomes wet. When a fine clean bore glass capillary is dipped into such a liquid it is found to rise in it. until the top of the column of water is at a vertical height 'h' above the free surface of the liquid outside the capilary. The reason for this rise is the surface tension, which is due to the attractive force between the molecules of the liquid. Such forces called cohesive forces try to make the surface of the water as small as possible. This is why a drop of liquid is of spherical shape.

In Fig: 1 AB is the water level rise due to the surface tension. The surface tension Force will act towards upward direction & the weight of AB water will act on towards downward direction. From this ~~opposition~~ opposite force the water level got a equilibrium position AB.

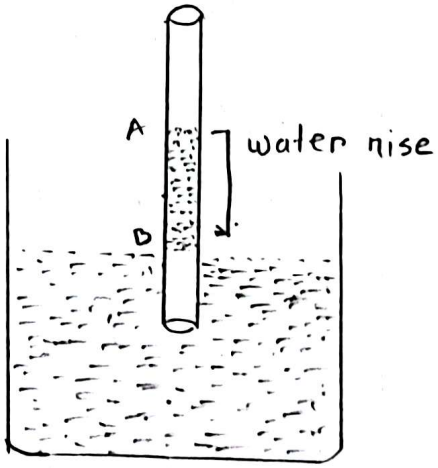

Fig: 1

In Fig-2 we can see that the water level rise. The miniscus point of the water along the tangent Tsinθ will be cancel out from both side & Tcosθ will act according to normal rule.

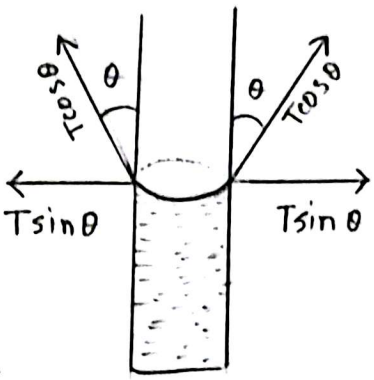

Fig-2

Now the circumference of the circle is $2\pi r$. so total point on the circumference of the circle is will be the total surface Tension. ∴ Total Tension $= 2\pi r \times T\cos\theta$

In Fig-3 the total volume is,

$V_{ABCD} + V_{CDFF}$

$= \pi r^2 l + (\pi r^2 \cdot r - \frac{1}{3}\pi r^3)$

$= \pi r^2 l + \pi r^3 - \frac{1}{3}\pi r^3$

$= \pi r^2 l + \frac{1}{3}\pi r^3$

$= \pi r^2 (l + \frac{1}{3} r) = V$

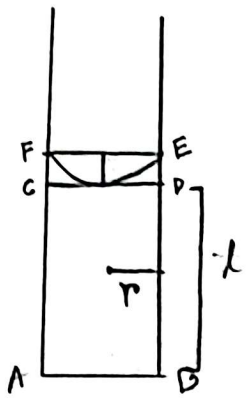

Fig-3

so V is the total volume.

now, weight $M = V\rho$

$= \pi r^2 (l + \frac{1}{3} r) \times \rho$

Mass $W = Mg$

$= \pi r^2 (l + \frac{1}{3} r) \times \rho \times g$

So, Surface Tension = Total Mass of water

$$\Rightarrow 2\pi r T\cos\theta = \pi r^2\left(1+\frac{r}{3}\right)\times\rho\times g$$

$$\therefore T = \frac{\pi r^2\left(1+\frac{r}{3}\right)\times\rho\times g}{2\pi r\cos\theta} = \frac{r\left(1+\frac{r}{3}\right)\times\rho\times g}{2\cos\theta}$$

here we will consider that our water is 100% ponified, so the angle $\theta = 0^\circ$.

Apparatus:

1. A clean and dry capillary Tube
2. A Tipper pointer.
3. A beaker containing water
4. A travelling microscope
5. clamps and stand.

Result:

The calculated surface Tension $T' = 0.0985\ Nm^{-1}$

. The actual surface Tension $T = 0.072\ Nm^{-1}$

$$\text{so error} = \left(\frac{0.072 - 0.0985}{0.072}\right)\times 100$$

$$= -36.80\%$$

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Data collection:

Table 1: Measurement of inside radius (r) of the tubes

Tube no.	Readings in cm for the bore										Difference diameter $D=X_2-X_1$ (cm)	Radius $r=D/2$ (cm)	Mean Radius r
	Left side (X_2)					Right side(X_1)							
	M.S.R (cm)	V.S. D	V.C (cm)	V.S.R (cm)	Total Reading (x_1) cm	M.S.R (cm)	V.S. D	V.C (cm)	V.S.R (cm)	Total Reading (x_2) cm			
A	10.55	49	0.001	0.049	10.099	10.9	45	0.001	0.095	10.945	0.896	0.448	0.451 c.m
B	10.55	42	0.001	0.049	10.042	10.9	50	0.001	0.095	10.950	0.908	0.454	

Table 2: Determination of the height of the column of water 'h'

No. of observation	Radius of the water meniscus					Reading at the tip of pointer					Height $h = h_1 - h_2$ cm	Mean Height h
	MSR x (cm)	VSD N	VC (cm)	VSR $y = N \times V.C.$ (cm)	Total Reading $= x + y$ h_1 cm	MSR x (cm)	VSD N	VC (cm)	VSR $y = N \times V.C.$ (cm)	Total Reading $= x + y$ h_2 cm		
1	9.6	17	0.001	0.017	9.617	9.3	20	0.001	0.020	9.320	0.297	0.295 cm
2	9.6	21		0.021	9.621	9.3	27		0.027	9.327	0.294	
3												
4												

calculation:

From Table 1 $r = 0.0951\ cm = 0.00951\ m$

From Table 2 $l = 0.2955\ cm = 0.002955\ m$

For pure water $\theta = 0^\circ$

and density $\rho = 1000\ kg/m^3$

$\therefore$ Surface Tension,

$$T = \frac{\pi r^2 \left(l + \frac{r}{3}\right) \times \rho \times g}{2\pi r \cos\theta}$$

$$= \frac{\pi r \left(l + \frac{r}{3}\right) \times \rho \times g}{2} \quad [\theta = 0^\circ]$$

$$= \frac{0.00951 \left(0.002955 + \frac{0.00951}{3}\right) \times 1000 \times 9.8}{2}$$

$$= \frac{0.00951 \left(4.45 \times 10^{-3}\right) \times 9.8 \times 1000}{2}$$

$$= 0.0985\ N m^{-1}$$

Precission:

- As we consider our water to be 100% pure, so the value of $\theta = 0^\circ$
- To Focus the travelling microscope we are very carefull about our eys, as it contain a high powered glass.
- In the travelling microscope we have seen the capillary tube exactly opposite cause there is convex lens. And convex lens always gives us a upside down image of a object.
- In this whole experiment we have to be very carefull during the determination process of r and l.

Reference:

(i) lab manual

(ii) class lecture note by Md. Sharif Ahmed sir.