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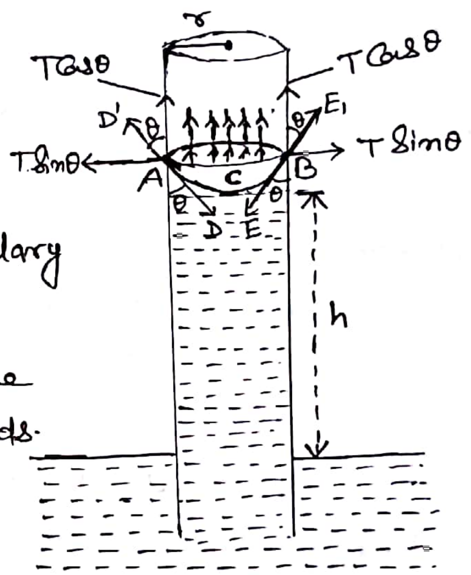
B.Sc (part-I) Hons

Paper-1

Method of finding surface tension of a liquid by by the rise of liquid in a Capillary tube.

The Surface tension of those liquids whose angle of Contact with glass is zero or very small, Can be determined by measuring their rise in a glass capillary tube.

Suppose a liquid, whose surface tension is T and angle of Contact with glass is θ, rise in a glass capillary tube of radius r. The surface ACB inside the tube is Concave upwards. It is in Contact with the glass along a circle



whose circumference is $2\pi r$. This may be called circle of Contact. The liquid surface pulls the glass in-wards at all points of the circle of contact with a force T per unit length. This force, at any point on the circle of Contact, is directed in wards along the tangent to the liquid surface at the point. For example at point A and B is directed along the tangent AD and BE, where AD and BE make ~~an~~ an angle θ with the the wall of tube.

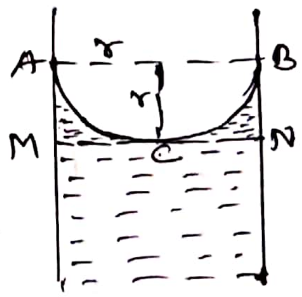
By the ~~Neto~~ Newton's law of action and reaction, the glass also pulls the liquid outwards at all points of the circle of Contact with an equal force T per unit length. At points A and B this force is directed along AD' and BE' respectively.

At each point it can be resolved in to two components. $T\cos\theta$ per unit length acting vertically upwards and $T.\sin\theta$ per unit length acting Horizontally outwards. Now considering the entire circumference $2\pi r$ of the circle of contact for each horizontal components $T.\sin\theta$ there is an equal and opposite component so that the two neutralise each other. The virtical components are, however, in the same direction. Therefore, they added together and give a total upward force upon the liquid of magnitude.

$$T\cos\theta \times 2\pi r \quad \text{——} \; (1)$$

This force supports the weight of the liquid column raised above the level outside the tube.

Let h be the height of the lowest pointe of the liquid surface above the outside level. Below c, the column is a cylinder of height h and radus r, and hence of valume $\pi r^2 h$. Beside this there is some liquid is the menicus i.e. between ACB and MCN If the tube is narrow, the liquid surface ACB is hemispherical, and its radus may be taken equal to the radius of the tube, If the angle of contact is small. Then volume of the liquid above C



$$= (\text{volume of cylinder ABNM} - \text{volume of hemisphere ACB})$$

$$= \left(\pi r^2 \cdot r - \frac{2}{3}\pi r^3\right)$$

$$= \left(\pi r^3 - \frac{2}{3}\pi r^3\right)$$

$$= \frac{1}{3}\pi r^3$$

∴ Total volume of the raised liquid $= \pi r^2 h + \frac{1}{3}\pi r^3$

$$= \pi r^2 (h + r/3)$$

or weight of raised liquid $= \pi r^2 (h + r/3) \times \rho \times g$

where ρ is density of the liquid.

Since this weight is balanced by the force given by (1) we have.

$$T \cos\theta \times 2\pi r = \pi r^2 (h + r/3) \rho g$$

$$\text{or, } T = \frac{\pi r^2 (h + r/3) \rho g}{2\pi r \cos\theta}$$

$$\therefore \boxed{T = \frac{r(h + r/3)\rho g}{2\cos\theta}}$$

$r/3$ can be neglected compared ~~to~~ to h. Further for liquids which wet the glass the angle of contact is practically zero so that the $\cos\theta = 1$

Hence

$$\boxed{T = \frac{r h \rho g}{2}}$$

This is the surface tension of a liquid by the rise of liquid in a capillary tube.