EXPERIMENT No. – 01

Title: - Surface Tension

Practical Significance: Surface tension is the force that causes a liquid's surface to act like a stretched elastic membrane.

Surface tension is crucial in various processes and phenomena, including wetting and wettability, medicine, and product development.
It plays a significant role in washing, cleaning, printing, and coating.
Surface tension is also used in medicine to understand lung surfactant pathological states, such as adult respiratory distress syndrome, bronchial asthma, and pneumonia.
Inkjet printers rely on surface tension to turn liquid jets into droplets.
Surface and interfacial tension are also used in optimizing detergent formulations, tailoring paints, and developing drugs.
Surface tension is also essential in understanding the stability of emulsions in various applications.
In this experiment we will learn that how to determine the surface tension of water.

Relevant program outcomes:

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

3. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

4. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

5. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Relevant Course outcomes:

Students will be able to find the surface tension of water.

Practical learning outcomes:

Use travelling Microscope and capillary tube

1. To know the working principle and different parts of travelling microscope.
2. To know about the concept of capillary rise.
3. To determine the surface tension of water.

Practical skills:

1. EXPERIMENTAL SKILLS: - The learner develops experimental skills in practical work if she/he is able to
    1. comprehend the theory and objectives of the experiment.
    2. conceive the procedure to perform the experiment.
    3. set-up the apparatus in proper order.
    4. check the suitability of the equipment, apparatus, tools regarding their working and functioning.
    5. know the limitations of measuring device and find its least count, error etc.
    6. handle the apparatus carefully and cautiously to avoid any damage to the instrument as well as any personal harm.
2. **OBSERVATIONAL SKILLS: -** The learner develops observational skills in practical work if she/he is able to
    1. follow the correct sequence while making observations.
    2. take observations carefully in a systematic manner, keeping least count in mind.
    3. minimize some errors in measurement by repeating every observation independently a number of times.
3. **DRAWING SKILLS: -** The learner develops drawing skills for if she/he is able to make schematic diagram of the apparatus.

4. **REPORTING SKILLS**: - The learner develops reporting skills for presentation of observation data in practical work if she/he is able to
    1. record observations systematically and with appropriate units in a tabular form wherever desirable
    2. calculate error in the result
    3. state limitations of the apparatus/devices
    4. interpret the results, verify principles and draw conclusions and explore the scope of further investigation in the work performed.

Relevant affective domain related outcomes:

1. **Receiving: -**

   One of the earliest skills is the **receiving phenomena**, which in a nutshell means the person is able to listen and has a willingness to hear out others.

2. **Responding**

   Participating in discussions, asking questions, and presenting information to others are next-level skills that create a stronger foundation for interpersonal connection and expression.

Theoretical Background:

Surface tension has been well- explained by the molecular theory of matter. According to this theory, cohesive forces among liquid molecules are responsible for the phenomenon of surface tension. The molecules well inside the liquid are attracted equally in all directions by other molecules. The molecules on the surface experience an inward pull. So, a network is formed against the inward pull, in order to move a molecule to the liquid surface. It results in a greater potential energy on surface molecules. In order to attain minimum potential energy and hence stable equilibrium, the free surface of the liquid tends to have the minimum surface area and thereby it behaves like a stretched membrane. Surface tension is measured as the force acting normally per unit length on an imaginary line drawn on the free liquid surface at rest. It is represented by the symbol T (or S). It's S.I. The unit is Nm^{-1} and dimensional formula is $M^1L^0T^{-2}$.

When a capillary tube is dipped in a liquid, the liquid level either rises or falls in the capillary tube. The phenomena of rise or fall of a liquid level in a capillary tube is called capillarity or capillary action.

When a liquid rises in a capillary tube, the weight of the column of the liquid of density ρ inside the tube is supported by the upward force of surface tension acting around the circumference of the points of contact. Thus, surface tension;

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

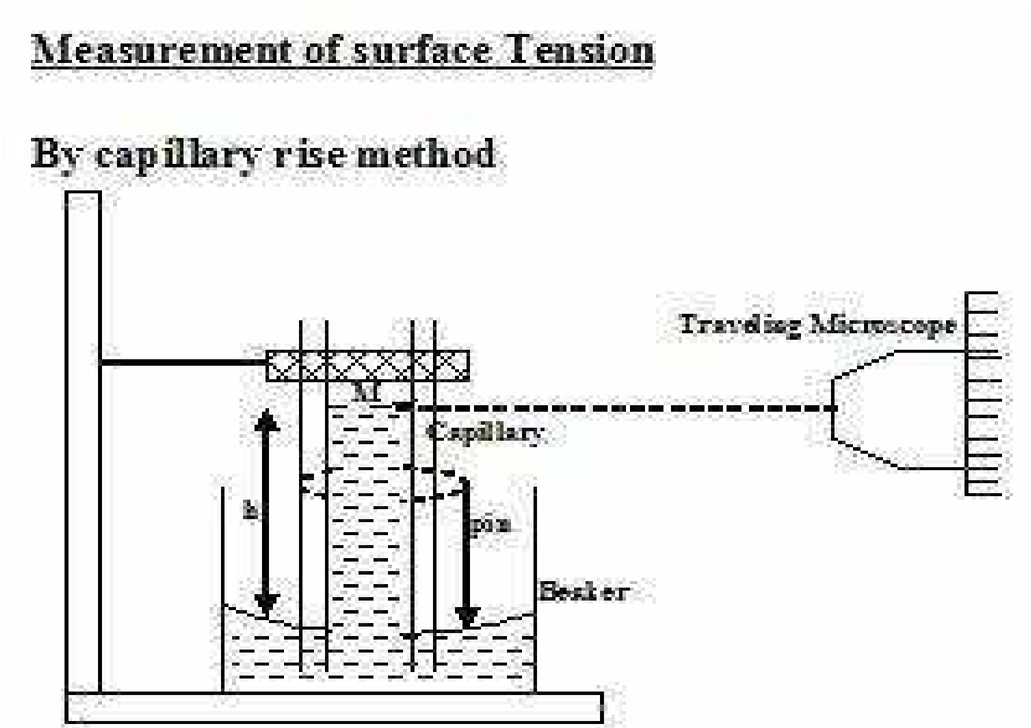
Where, h - height of the liquid column above the liquid meniscus

ρ - Density of the liquid

r - Inner radius of the capillary tube

θ - Angle of contact

Experimental set-up: Fig: - 1



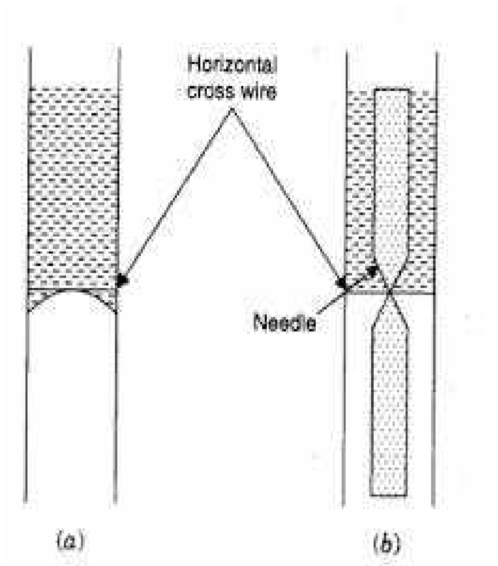


Fig: -2

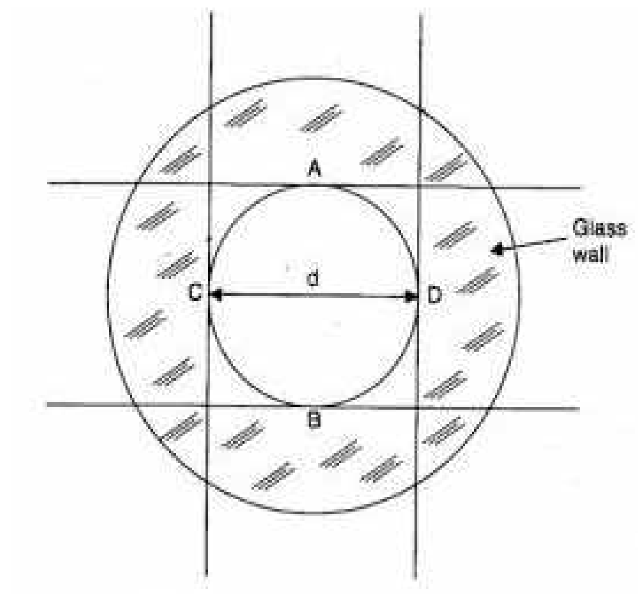


Fig: -3

Resources required:

S. No.	Name of equipment	Specifications	Quantity	Remark
1	A clean and dry capillary tube	1 feet length	1	
2	A tipped pointer	-	1	
3	A beaker containing water	200 ml	1	
4	A travelling microscope		1	
5	Adjustable wooden stand	1.5 feet height	1	
6	Clamps and stand	-	1	
7	Reading Lens		1	

Precautions:

1. The surface of water in the beaker should be free from dirt and grease. To ensure this, beaker should be carefully washed.
2. The capillary should be set vertically.
3. Diameter should be measured in two perpendicular directions.
4. The microscope should be horizontal so as to ensure a perfect vertical movement of the tube.
5. The cross wire should be tangential to the lower meniscus.

Procedure:

Fig: - 4

To set up the apparatus:

1. Place the adjustable height stand on the table.
2. Fix the capillary tube and the pointer in a cork,
3. Clamp it in a rigid stand so that the capillary tube and the pointer become vertical.
4. Adjust the height of the capillary tube, so that the capillary tube dip in the water in an open beaker.
5. Adjust the position of the pointer, such that its tip just touches the water surface.

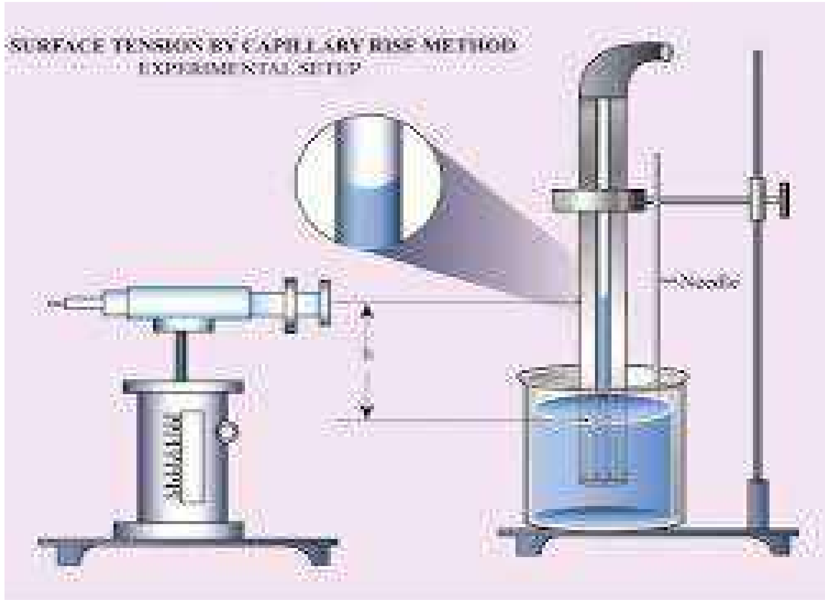


Fig: - 5

To find the capillary rise:

1. Find the least count of the travelling microscope for both the horizontal and the vertical scale.
2. Use following formula to find least count

$$Least\ count = \frac{\text{Value of one division of main scale}}{\text{Total number of divisions of vernier scale}}$$

3. Make the axis of the microscope horizontal.
4. Bring the microscope in front of the capillary tube.
5. Match the height of the microscope using the height adjusting screw with the water level in capillary tube.
6. Focus the water level inside the capillary tube
7. Clamp it when the capillary rise becomes visible.
8. Make the horizontal cross wire just touch the central part of the concave meniscus.
9. Note the reading (position of the microscope) on the vertical scale as-
    a. ***Read the Main Scale:***
        - Look at the main scale
        - Identify the location on the main scale which aligns to the zero level of vernier scale. (See figure-6)
        - Note down the measurement main scale in the observation table.

    b. ***Read the Vernier Scale:***
        - Look at the Vernier scale and
        - Find the line on it that best aligns with a line on the main scale. (See figure-6)

- Note the value indicated by the Vernier scale.
- Multiply the value of vernier scale to the least count
- Note down this multiplied vernier scale reading in the observation table.

c. ***Calculate the Measurement (b):***

- Add the measurement from the main scale to the measurement from the Vernier scale.

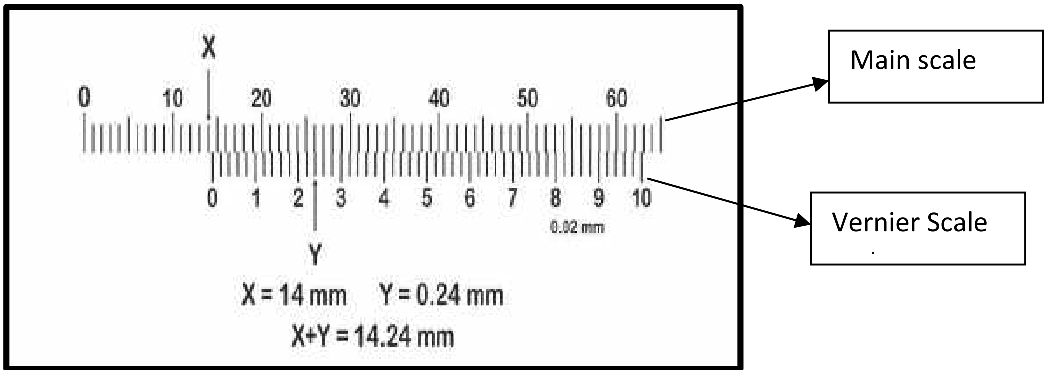


Figure: - 6

10. Now, carefully remove the beaker containing water
11. Move the microscope horizontally and bring it in front of the pointer.
12. Lower height of the microscope
13. Focus the tip of the pointer
14. Make the horizontal cross wire touch the tip of the pointer.
15. Note down the reading (a) of vertical scale by repeating the steps of point 9.
16. The difference (b-a) in the two readings (i.e., height of water meniscus and height of the tip of pointer) will give the capillary rise (h) of the given liquid.
17. We can repeat the experiment by changing the height of the capillary tube on the stand.

To find the internal diameter of the capillary tube:

1. Place the capillary tube horizontally on the adjustable stand.
2. Focus the microscope on the end of capillary tube which was dipped in water.
3. Make the horizontal cross- wire touch the inner circle at A (see fig 3).
4. Note microscope reading on the vertical scale.
5. Down the microscope to make the horizontal cross wire touch the circle at B (fig 3).

6. Note the vertical scale reading.
7. The difference between the two readings will give the vertical internal diameter (AB) of the tube.
8. Move the microscope on the horizontal scale and make the vertical cross wire touch the inner circle at C (fig 3).
9. Note microscope reading on the horizontal scale.
10. Move the microscope to the right to make the vertical cross wire touch the circle at D (fig 3).
11. Note the horizontal scale reading.
12. The difference between the two readings will give the horizontal internal diameter (CD) of the tube.
13. We can calculate the diameter of the tube by calculating the mean of the vertical and horizontal internal diameters.
14. Half of the diameter will give the radius of the capillary tube.

Observations

Room temperature =__________°C

Value of one main scale division of travelling microscope, x =_________cm

Total number of divisions of Vernier scale, n = _______cm

Least count = x/n = _______ cm

(A) For the height of water column "h" in capillary tube.

S. No.	Reading for the upper surface of water in the beaker			Reading for the meniscus of Water in capillary			Height of Water Meniscus In capillary h=(b-a) cm
	M.S. Reading (in cm)	V.S. Reading (in cm)	Total Reading (a) cm	M.S. Reading (in cm)	V.S. Reading (in cm)	Total Readings (b) cm	
1.							
2.							
3.							

Mean value of "h" = _________ cm

(B) For the radius "r" of capillary tube.

S. NO.	Left edge of Capillary tube			Right edge of Capillary tube			diameter d=(b-a) cm	Radius r=d/2 cm	Mean r cm
	M.S. cm	V.S. cm	Total (a)	M.S. cm	V.S. cm	Total (b)			
1.									
2.									

Calculations:

In the relation $$T = \frac{r\left(h+\frac{r}{3}\right)\rho.g}{2}$$

r= _______cm, g= _______cm/sec ², h= _______cm

Results:

Surface tension of water at ______°C = ___________ dynes/ cm

Interpretation of results:

Find percentage error

Conclusion:

The **surface tension of water** was determined using the given experimental setup and appropriate formula. The calculated value is close to the standard value at room temperature, indicating good agreement with theory. Small variations may occur due to experimental errors. The experiment demonstrates the concept of surface tension and intermolecular forces in liquids.

Recommendations:

1. The apparatus should be properly cleaned to remove dust or grease before performing the experiment.
2. Measurements should be taken carefully to minimize observational errors.
3. The experiment should be carried out at a constant temperature since surface tension depends on temperature.
4. The experiment should be repeated several times and the average value should be taken for better accuracy.

References/ suggestions for further readings:

Assessment Scheme /Rubrics (Process & Product):

S.N.	Scale ⇨ / Criteria ⇩	Poor	Satisfactory	Good	Excellent
1	**Understanding of Experiment**	Shows little understanding of the aim and theory of the experiment.	Basic understanding of the aim but explanation is incomplete.	Good understanding of the aim and theory with minor gaps.	Demonstrates clear and thorough understanding of the aim and underlying theory.
2	**Experimental Procedure & Handling of Apparatus**	Unable to follow procedure properly; improper handling of apparatus.	Follows procedure with guidance; handling of apparatus needs improvement.	Performs experiment correctly with minimal guidance.	Performs experiment independently with proper handling of apparatus.
3	**Observation & Data Recording**	Observations are incomplete or incorrect; data not properly recorded.	Records basic observations but with some errors or missing details.	Observations recorded correctly with minor mistakes.	Observations are complete, accurate, and systematically recorded.
4	**Graph / Calculations / Analysis**	Graphs or calculations missing or incorrect.	Graphs or calculations attempted but contain noticeable errors.	Graphs and calculations mostly correct with minor errors.	Graphs, calculations, and analysis are accurate and clearly presented.
5	**Neat and Clean Reporting of Practical Record**	Record is untidy with overwriting and missing diagrams or sections.	Record is somewhat neat but contains formatting or labeling issues.	Record is neat with properly drawn diagrams and organized content.	Record is very neat, well organized, and professionally presented.
6	**Viva / Conceptual Questions**	Unable to answer basic questions related to the experiment.	Answers some questions but lacks clarity in concepts.	Answers most questions correctly with reasonable explanation.	Answers confidently with clear conceptual understanding.
7	**Precautions**	Not known	Known but not understand	Known and understand	Known, understand and also know the importance
8	**Safety measures**	Doesn't follow	Follow but reason is not known	Follow and reason is known	Follow known and understand
9	**Team work ability**	Doesn't participate and perform the experiment	Perform but not interact with group	Perform and participate	Perform, participate, lead actively