SAMPLE CONTENT

Precise

PHYSICS - I

STD. XII Sci.

Surface Tension

Dew Drops formed on the petals of flower are spherical in shape due to surface tension.

Target Publications Pvt. Ltd.

Written as per the revised syllabus prescribed by the Maharashtra State Board
of Secondary and Higher Secondary Education, Pune.

Precise

Physics – I

STD. XII Sci.

Salient Features

- Concise coverage of syllabus in Question Answer Format.
- Covers answers to all Textual Questions and Intext Questions.
- Includes Solved and Practice Numericals.
- Includes solved Board Questions from 2013 to 2018.
- Includes Board Question Papers of 2017 and 2018.
- Exercise, Multiple Choice Questions and Topic test at the end of each chapter for effective preparation.

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Preface

In the case of good books, the point is not how many of them you can get through, but rather how many can get through to you.

"Std. XII Sci. : PRECISE PHYSICS – I" is a compact yet complete guide designed to boost students' confidence and prepare them to face the conspicuous Std. XII final exam.
This book is specifically aimed at Maharashtra Board students. The content of the book is framed in accordance with Maharashtra State board syllabus and collates each and every important concept in question and answer format.
This book has been developed on certain key features as detailed below:

- **Question and Answer** are represented in **Tabular** format wherever needed to correlate between two concepts. **Stepwise explanation** for specific questions makes it easier to understand.
- **Solved Examples** provide step-wise solution to various numerical problems. This helps students to understand the application of different concepts and formulae.
- **Solutions to Board Questions** along with marking scheme (wherever relevant) have been included.
- **Notes** cover additional bits of relevant information about discussed topic.
- **Formulae** are provided in every chapter which are the main tools to tackle numericals.
- **Exercise** helps the students to gain insight on the various levels of theory and numercial-based questions.
- **Board Questions** section contains questions of past board question papers which fall under the new syllabus.
- **Multiple Choice Questions** and **Topic Test** assess the students on their range of preparation and the amount of knowledge of each topic.

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.

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A book affects eternity; one can never tell where its influence stops.

Best of luck to all the aspirants!

Yours faithfully,
Publisher

Edition: Second

PAPER PATTERN

- There will be one single paper of 70 Marks in Physics.
- Duration of the paper will be 3 hours.

Section A: **(8 Marks)**

This section will contain Multiple Choice Questions and Very Short Answer(VSA) type of questions.

There will be 4 MCQs and 4 VSA type of questions, each carrying one mark.

Students will have to attempt all these questions.

Section B: **(14 Marks)**

This section will contain 7 Short Answer (SA-I) type of questions, each carrying 2 marks.

Internal choice is provided for only one question.

Section C: **(33 Marks)**

This section will contain 11 Short Answer (SA-II) type of questions, each carrying 3 marks.

Internal choice is provided for only one question.

Section D: **(15 Marks)**

This section will contain 3 Long Answer (LA) type of questions, each carrying 5 marks.

Internal choice is provided for each question.

Distribution of Marks According to Type of Questions

Type of Questions		
MCQ	1 Mark each	4 Marks
VSA	1 Mark each	4 Marks
SA I	2 Marks each	14 Marks
SA II	3 Marks each	33 Marks
LA	5 Marks each	15 Marks

Index

Note: All the Textual questions are represented by * mark
All the Intext questions are represented by # mark

06 Surface Tension

Subtopics

6.1 Surface tension on the basis of molecular theory

The force of attraction or repulsion acting between the molecules of substances is called intermolecular force.

This force is more in solids, less in liquids and least in gases.

Properties:

i. These forces do not obey inverse square law.

ii. It is a force of very short range, about 10^{-9} m.

Q.1. *Define cohesive force. **OR** **What do you mean by cohesive force?** **[Feb 13 old course]**	**Q.2. *Define adhesive force.** **OR** **What do you mean by adhesive force?** **[Feb 13 old course]**
Ans:	**Ans:**
i. *The force of attraction between two molecules of the same substance is called cohesive force. This property is called cohesion.* ii. It exists in all substances, strongest in solids. The definite shape and rigidity of a solid body is due to cohesion. iii. It is stronger than adhesive force. iv. Examples: Force of attraction between two water molecules, force of attraction between two bromine molecules in a container. ***[½ Mark]***	i. *The force of attraction between two molecules of different substances is called adhesive force. This property of substance is called adhesion.* ii. It exists at the liquid-solid, liquid-gas interface. iii. It is weaker than cohesive force. iv. Examples: Sticking of paint on the wall, chalk particles on blackboard, water to the container, etc. ***[½ Mark]***

***Q.3. Define the following terms.**

i. Range of molecular attraction. [Feb 13 old course]

ii. Sphere of influence. [Feb 13 old course]

Ans: i. Range of molecular attraction:

The maximum distance between two molecules upto which the intermolecular forces are effective is called the range of molecular attraction.

It is of the order of 10^{-9} m in solids and liquids, so it is called short range force. ***[1 Mark]***

ii. Sphere of influence:

An imaginary sphere drawn with given molecule as centre and radius equal to the molecular range is called the sphere of influence.

The molecule is attracted by other molecule within a range of sphere of influence otherwise it is negligible. ***[1 Mark]***

Q.4. Define surface film and free surface of liquid.

Ans: Surface film:

A layer of surface of liquid whose thickness is equal to molecular range of attraction is called surface film.

All the molecules located inside the surface film experience inward attractive force.

Free surface of liquid:

Surface of liquid which is in contact with air is called free surface of liquid.

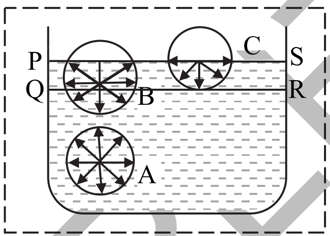
The free surface of liquid behaves as a stretched elastic membrane. A free surface always tries to minimise its surface area.

***Q.5. Explain surface tension on the basis of molecular theory.**

Ans: Molecular theory of surface tension:

i. Let PQRS = Surface film of liquid in a container containing liquid.
PQ = SR = Molecular range.

ii. Now consider three molecules A, B and C in a liquid in a vessel such that the molecule A is well inside the liquid, the molecule B within R is just below the free surface of liquid and molecule C is on the free surface as shown in the figure.



iii. The sphere of influence of the molecule A is entirely inside the liquid and the molecule is surrounded by its nearest neighbours on all sides. Hence, A is equally attracted from all sides, so that the resultant cohesive force acting on the molecule A is zero. The molecule A is free to move anywhere within the liquid.

iv. For the molecule B, a part of its sphere of influence is outside surface. This part contains air molecules whose number is negligible compared to the number of molecules in an equal volume of the liquid. Therefore, the molecule B experiences a net cohesive force downward.

v. For the molecule C, the upper half of the sphere of influence is outside the liquid surface. But number of air molecules in sphere of influence is very small as compared to liquid molecules. Therefore, the resultant cohesive force acting on the molecule C is maximum in downward direction.

vi. Thus, all molecules lying within a surface film experience a net inward pull which depends upon the relative number of molecules between lower and upper halves of sphere of influence.

vii. The surface area is proportional to the number of molecules on the surface. To increase the surface area, molecules must be brought to the surface from within the liquid. For this, work must be done against the cohesive forces. This work is stored in the form of potential energy which increases with increase in area. Liquid has a tendency to have minimum potential energy. To attain minimum potential energy, it tries to reduce the number of molecules on the surface so as to have minimum surface area. Thus, liquid behaves like a stretched elastic membrane.

6.2 Surface energy

Q.6. Define and explain the concept of surface energy. State its unit and dimensions.

Ans: Definition:

The extra energy that a liquid surface holds under isothermal condition is called surface energy.

Explanation:

i. A molecule well within the liquid is surrounded by the similar liquid molecules from all sides and hence there is no resultant force acting on it.

ii. A molecule within surface film is surrounded by similar liquid molecules only on one side of the surface.

iii. On the other side, it may be surrounded by air molecules or molecules of the vapour of the liquid, whose density is much less as compared to density of liquid molecules.

iv. Thus, there is a resultant inward force on a molecule in the surface film. This force tries to pull the molecule into the liquid.

v. Molecules are pulled from the surface layer to the interior of liquid and new molecules from the interior go towards the surface film to the empty space.

vi. When a molecule is taken from the inside to the surface layer work is done against the inward resultant force. This work is stored in the surface of liquid in the form of potential energy.

vii. Potential energy is greater for molecule at the surface film as compared to a molecule well inside the liquid.

viii. This extra potential energy is called the surface energy.

ix. Unit: J in SI system and erg in C.G.S. system.

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

Q.7. Define surface energy per unit area. State its units and dimensions.

Ans: i. *Potential energy per unit area of the liquid surface under isothermal condition is called surface energy per unit area.*

ii. Unit: J/m^2 in SI system and erg/cm^2 in CGS system ($1\ J/m^2 = 10^3\ erg/cm^2$)

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

***Q.8. Why do molecules of a liquid lying in the surface film possess extra energy?**

Ans: i. Molecules lying in the surface film are surrounded by liquid molecules as well as air molecules.

ii. Thus, there is a resultant downward force of cohesion which increases as we move from bottom to the top of surface film.

iii. To take molecule into surface film from anywhere below it, some work is to be done against the downward force of cohesion.

iv. This work is stored in the form of P.E. Thus, molecules of all liquids lying in the surface film possess extra energy.

6.3 Surface tension

***Q.9. Define and explain surface tension. Write down its unit and dimension.**

Ans: Definition:

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

If 'F' is the force acting on the imaginary line of length 'l' then surface tension 'T' is given by,

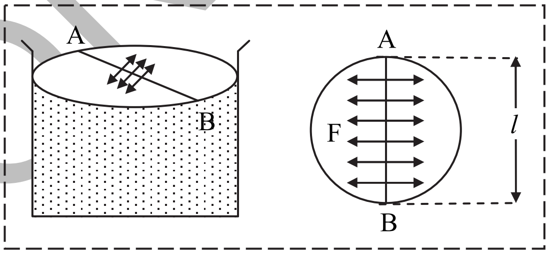
$$T = \frac{F}{l}.$$

Explanation:

i. Consider a free surface of liquid in a beaker which acts like a stretched membrane. All the molecules on the surface experience a stretching force.

ii. Imagine a straight line AB drawn on the free surface of the liquid. Molecules of liquid along this line will be acted upon by a force F on each side due to surface tension. This force per unit length of the line AB measures surface tension.

iii. The direction of surface tension is perpendicular to AB and tangential to liquid surface.



iv. Unit: N/m or J/m^2 in SI system and dyne/cm or erg/cm^2 in CGS system.
$1\ N/m = 10^3$ dyne/cm.

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

***Q.10. Obtain the dimensions of surface tension.**

Ans: i. Surface tension, $T = \frac{\text{Force}(F)}{\text{Length}(l)}$

$$\text{Dimensions of T} = \frac{\text{Dimension of force}}{\text{Dimension of length}} = \frac{[M^1L^1T^{-2}]}{[L]} = [M^1L^0T^{-2}]$$

ii. Also, surface tension is numerically equal to surface energy per unit area.

$\therefore$ $T = \frac{E}{A}$

$$\text{Dimensions of T} = \frac{\text{Dimension of surface energy}}{\text{Dimension of area}} = \frac{[M^1L^2T^{-2}]}{[L^2]} = [M^1L^0T^{-2}]$$

$\therefore$ Dimensions of surface tension is $[M^1L^0T^{-2}]$.

Q.11.*What is surface energy? Obtain the relation between surface tension and surface energy. **[Feb 13 old course]**

OR

Derive the relation between surface tension and surface energy per unit area. **[Mar 13]**

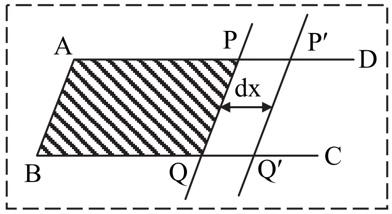
OR

Show that the surface tension of a liquid is numerically equal to the surface energy per unit area. **[Oct 13]**

Ans: Surface energy: *Refer Q.6*

Relation between surface tension and surface energy:

i. Let ABCD be a rectangular frame of wire, open along side CD, on which a wire PQ can slide without friction.



[Diagram – ½ Mark]

ii. The frame held in horizontal position is dipped into soap solution and taken out so that a soap film APQB is formed. Due to surface tension of soap solution, a force 'F' will act on the wire PQ which tends to pull it towards AB.

iii. Magnitude of force due to surface tension is, $F = 2Tl$. [$\because T = F/l$]

(A factor of 2 appears because soap film has two surfaces which are in contact with wire.)

iv. Let the wire PQ be pulled outwards through a small distance 'dx' to the position P′Q′, by applying an external force F′ equal and opposite to F. Work done by this force, $\Delta W = F'dx = 2Tldx$.

v. But, $2ldx = \Delta A$ = increase in area of two surfaces of film.

$\therefore$ $\Delta W = T\,\Delta A$ ***[½ Mark]***

vi. This work done is stored in the form of potential energy (surface energy).

$\therefore$ Surface energy, $E = T\Delta A$ ***[½ Mark]***

$\therefore$ $\frac{E}{\Delta A} = T$

Hence, surface tension = surface energy per unit area.

vii Thus, surface tension is equal to the mechanical work done per unit surface area of the liquid, which is also called as surface energy. *[**Explanation – ½ Mark]*

Q.12. How are small insects able to walk on the water surface?

Ans: i. The free surface of water behaves as stretched membrane due to surface tension.

ii. Due to weight of insect, the membrane is stretched. Thus surface tension acts in an inclined manner.

iii. The vertical component of surface tension balances the weight of the insect.

iv. Hence, insects are able to walk on the surface of water.

Q.13. Explain why oil spreads over the surface of water while water does not do so.

Ans: i. The surface tension of oil is less than the surface tension of water.

ii. Thus, when oil is dropped on the surface of water, it spreads in all directions due to the higher force of surface tension of water.

Q.14. Explain why the ends of a glass tube become round on heating.

Ans: i. When the ends of a glass tube are heated, the glass melts.

ii. Due to the surface tension, the molten glass tube tends to have minimum surface area.

iii. The molten glass at all points on the end of tube tends to take spherical shape and as such the ends become round.

Q.15. Give reason for the following.

i. Bristles of brush when taken out of liquid cling together.

ii. Rain drops are spherical.

iii. A small irregular piece of camphor dropped on the surface of pure water dances (helter-skelter) above the surface.

iv. Oil spreads on cold water but remains as a drop on hot water.

Ans: i. As water has no free surface, the tips of the bristle of the brush remain spreaded. A thin water film is formed at the tips of the bristle. When the brush is taken out of liquid, the surface of the water film occupies minimum possible area due to surface tension and the bristles cling together.

ii. Due to surface tension, the liquid tries to acquire minimum surface area. For a given volume, sphere has minimum surface area, therefore the liquid assumes the shape of a drop.

iii. Irregular shaped camphor dropped on water decreases the surface tension of the water gradually. Because of their irregular shape, the unbalanced forces make it move haphazardly in different directions.

iv. It is due to the fact that surface tension of oil is less than that of the cold water but is greater than that of the hot water.

Solved Examples

***Q.16. Calculate the force required to take away a flat circular plate of radius 0.01 m from the surface of water. The surface tension of water is 0.075 N/m.**

Solution:

Given: r = 0.01 m, T = 0.075 N/m

To find: Force (F)

Formula: $F = T \times l$

Calculation: The plate is flat

∴ Force due to surface tension acts on only one face

∴ $l = 2\pi r$

From formula,

$F = 0.075\ (2 \times 3.142 \times 0.01)$

$= 0.150 \times 3.142 \times 0.01$

∴ F = **0.004717 N**

Ans: The force required to take away the flat circular plate from the surface of water is **0.004717 N**.

***Q.17. A glass tube has inner diameter 1 mm and outer diameter 1.1 mm. When it is kept vertical and partially dipped in water, calculate the downward pull due to surface tension. [Surface tension of water = 75 dyne/cm]**

Solution:

Given: $d_1 = 1$ mm,

∴ $r_1 = \frac{d_1}{2} = \frac{1}{2} = 0.5$ mm $= 0.05$ cm,

$d_2 = 1.1$ mm

∴ $r_2 = \frac{d_2}{2} = \frac{1.1}{2} = 0.55$ mm $= 0.055$ cm,

T = 75 dyne/cm

To find: Force (F)

Formula: $F = Tl$

Calculation: $l = 2\pi(r_1 + r_2)$

From formula,

$F = 2\pi T\ (r_1 + r_2)$

$= 2 \times 3.142 \times 75\ (0.05 + 0.055)$

$= 2 \times 3.142 \times 75 \times 0.105$

∴ $F = 150 \times 3.142 \times 0.105$

∴ F = **49.49 dyne**

Ans: The downward pull due to surface tension is **49.49 dyne**.

Q.18. A capillary tube having inner diameter 1 mm and the outer diameter 4 mm hangs vertically from one arm of the balance. If the lower end of the tube just touches a liquid of surface tension 3×10^{-2} N/m, assuming that the liquid wets the tube, find the downward force due to surface tension acting on the tube.

Solution:

Given: $d_1 = 1$ mm, $r_1 = 0.5$ mm $= 0.5 \times 10^{-3}$ m,

$d_2 = 4$ mm, $r_2 = 2$ mm $= 2 \times 10^{-3}$ m,

$T = 3 \times 10^{-2}$ N/m

To find: Force (F)

Formula: $T = \frac{F}{l}$

Calculation: $l = 2\pi r_1 + 2\pi r_2 = 2\pi (r_1 + r_2)$

$= 2\pi\ (0.5 + 2) \times 10^{-3}$

$= 2\pi \times 2.5 \times 10^{-3}$

∴ $l = 5\pi \times 10^{-3}$ m

From formula,

$F = 3 \times 10^{-2} \times 5\pi \times 10^{-3}$

$= 15\pi \times 10^{-5} = 15 \times 3.14 \times 10^{-5}$

∴ F = $\mathbf{4.71 \times 10^{-4}}$ **N**

Ans: The downward force due to surface tension acting on the tube is $\mathbf{4.71 \times 10^{-4}}$ **N**.

***Q.19. A horizontal circular loop of wire of radius 0.02 m is lowered into crude oil and forms a film. The force due to surface tension of the liquid is 0.0113 N. Calculate the surface tension of crude oil. [July 18]**

Solution:

Given: r = 0.02 m, F = 0.0113 N

To find: Surface tension (T)

Formula: $F = Tl$

Calculation: As there are two sides of a circular loop acted upon by the force, $l = 2 \times 2\pi r$.

From formula,

$F = 4\pi rT$

∴ $T = \frac{F}{4\pi r}$

∴ $T = \frac{0.0113}{4 \times 3.142 \times 0.02}$

∴ T = **0.04495 N/m**

Ans: The surface tension of crude oil is **0.04495 N/m**.

Q.20. A ring is cut from a platinum tube having 8.6 cm internal and 8.8 cm external diameter and suspended from a pan of a balance so that its lower surface is horizontal. When this surface is brought into contact with water kept in a dish, an extra weight of 3.9 g is required just to pull the ring away from water. Calculate the surface tension of water. [g = 980 cm/s^2]

Solution:

Given: $r_1 = \frac{8.6}{2} = 4.3$ cm, $r_2 = \frac{8.8}{2} = 4.4$ cm, m = 3.9 g

To find: Surface tension (T)

Formula: $T = \frac{F}{l} = \frac{mg}{l}$

Calculation: $l = 2\pi(r_1 + r_2)$

$\therefore$ $l = 2\pi(4.3 + 4.4) = 2\pi \times 8.7$ cm

From formula,

$F = Tl = mg$

Now, $F = 2\pi \times 8.7 \times T = mg$

$\therefore$ $T = \frac{mg}{2\pi \times 8.7}$

$\therefore$ $T = \frac{3.9 \times 980}{2 \times 3.14 \times 8.7} \approx$ **70 dyne/cm**

Ans: The surface tension of water is **70 dyne/cm**.

Q.21. A drop of water of radius 6 mm breaks into number of droplets, each of radius 1 mm. How many droplets will be formed?

Solution:

Given: Radius of big drop, R = 6 mm,
Radius of smaller drop, r = 1 mm

To find: Number of droplets (n)

Formula: Number of droplets = $\frac{\text{Volume of big drop}}{\text{Volume of small drop}}$

Calculation: Volume of big drop,

$V_1 = \frac{4}{3}\pi R^3$

Volume of each small drop, $V_2 = \frac{4}{3}\pi r^3$

From formula,

$n = \frac{V_1}{V_2} = \frac{\frac{4}{3}\pi R^3}{\frac{4}{3}\pi r^3}$

$\therefore$ $n = \left(\frac{R}{r}\right)^3 = \left(\frac{6}{1}\right)^3 =$ **216**

Ans: **216** droplets will be formed.

Q.22. Calculate the work done when a spherical drop of mercury of radius 2 mm, falls from some height and breaks into a million droplets, each of the same size. The surface tension of mercury is T = 0.5 N/m.

Solution:

Given: $R = 2$ mm $= 2 \times 10^{-3}$ m, $n = 10^6$,
T = 0.5 N/m

To find: Work (W)

Formula: $W = T\Delta A$

Calculation: Volume of a single drop = $\frac{4}{3}\pi R^3$ and

Volume of a single droplet = $\frac{4}{3}\pi r^3$

$\therefore$ We have, $\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$ or $R^3 = nr^3$

$\therefore$ $r = \frac{R}{\sqrt[3]{n}} = \frac{2 \times 10^{-3}}{\sqrt[3]{10^6}} = 2 \times 10^{-5}$ m

From formula,

$W = T(n \times 4\pi r^2 - 4\pi R^2)$

$= 4\pi T(nr^2 - R^2)$

$= 4 \times 3.14 \times 0.5 \times [10^6 \times (2 \times 10^{-5})^2 - (2 \times 10^{-3})^2]$

$= 6.28 \times [(20 \times 10^{-3})^2 - (2 \times 10^{-3})^2]$

$= 6.28 \times (400 - 4) \times 10^{-6}$

$= 6.28 \times 396 \times 10^{-6}$

$\therefore$ $W = 2486.88 \times 10^{-6} =$ **2.486×10^{-3} J**

Ans: The work done when a spherical drop of mercury falls from some height and breaks into a million droplets is **2.486×10^{-3} J**.

***Q.23. There is a soap film on a rectangular frame of wire of area 4 × 4 cm^2. If the area of the frame is increased to 4 × 5 cm^2, find the work done in the process. [S.T of soap film = 3 × 10^{-2} N/m]**

Solution:

Given: $A_1 = 4 \times 4$ cm^2 = 16 cm^2,
$A_1 = 16 \times 10^{-4}$ m^2,
$A_2 = 4 \times 5$ cm^2 = 20 cm^2,
$A_2 = 20 \times 10^{-4}$ m^2,
$T = 3 \times 10^{-2}$ N/m

To find: Work (W)

Formula: $W = T\Delta A$

Calculation: A soap film has two surfaces

$\therefore$ $W = 2T\Delta A$

$= 2T(A_2 - A_1)$

$= 2T(20 \times 10^{-4} - 16 \times 10^{-4})$

$= 2 \times 3 \times 10^{-2} \times 4 \times 10^{-4}$

$= 6 \times 4 \times 10^{-6}$
$= 24 \times 10^{-6}$ J

$\therefore$ Work done, W **= 2.4 × 10^{-5} J**

Ans: The work done in the process is **2.4 × 10^{-5} J**.

Q.24. A soap bubble of radius 12 cm is blown. Surface tension of soap solution is 30 dyne/cm. Calculate the work done in blowing the soap bubble. [Oct 13]

Solution:

Given: r = 12 cm, T = 30 dyne/cm

To find: Work (W)

Formula: $W = T \times \Delta A$

Calculation: Initial surface area of soap bubble = 0

Final surface area $A = 2 \times 4\pi r^2$

$\therefore$ Increase in surface area $\Delta A = 2 \times 4\pi r^2$

From formula,

$W = T \times 8\pi r^2$ ***[½ Mark]***

$= 30 \times 8 \times 3.14 \times (12)^2$ ***[½ Mark]***

$= 108518.4$ erg

$= 108518.4 \times 10^{-7}$ J

$\therefore$ W = **1.085 × 10^{-2} J**

Ans: The work done in blowing the soap bubble is **1.085 × 10^{-2} J.** ***[1 Mark]***

Q.25. Calculate the work done in increasing the radius of a soap bubble in air from 1 cm to 2 cm. The surface tension of soap solution is 30 dyne/cm. (π = 3.142) [Mar 18]

Solution:

Given: $r_1 = 1$ cm, $r_2 = 2$ cm, T = 30 dyne/cm

To find: Work (W)

Formula: $W = T\Delta A$

Calculation: $A_1 = 4\pi r_1^2 = 4\pi \times 1^2 = 4\pi$ cm^2

$A_2 = 4\pi r_2^2 = 4\pi \times 2^2 = 16\pi$ cm^2

$\Delta A = A_2 - A_1 = (16\pi - 4\pi) = 12\pi$ cm^2

Since soap bubble has two surfaces

From formula,

$W = 2T \times \Delta A$

$= 2 \times 30 \times 12\pi$

$= 2 \times 30 \times 12 \times 3.14$

$\therefore$ W = **2.26 × 10^3 erg**

Ans: The work done in increasing the radius of the soap bubble is **2.26 × 10^3 erg**.

Q.26. Two soap bubbles have radii in the ratio 4:3. What is the ratio of work done to blow these bubbles? [July 17]

Solution:

Given: $r_1 : r_2 = 4 : 3$

To find: $W_1 : W_2$

Formulae: W = 2TdA ***[½ Mark]***

Calculation: From formula,

Work done to blow both bubbles,

$W_1 = 2T\left(4\pi r_1^2\right)$ and $W_2 = 2T\left(4\pi r_2^2\right)$

[½ Mark]

$\therefore \quad \dfrac{W_1}{W_2} = \left(\dfrac{r_1}{r_2}\right)^2$ ***[½ Mark]***

$= \left(\dfrac{4}{3}\right)^2$

= 16 : 9

Ans: The ratio of work done to blow the bubbles is **16 : 9.** ***[½ Mark]***

***Q.27. Eight droplets of water, each of radius 0.2 mm, coalesce into a single drop. Find the change in total surface energy. [Surface tension = 0.072 N/m]**

Solution:

Given: n = 8, T = 0.072 N/m,

r = 0.2 mm = 0.2×10^{-3} m = 2×10^{-4} m

R = radius of coalesce drop

To find: Surface energy (E)

Formula: $E = T\Delta A$

Calculation: Volume of 8 drops of radius 'r' is equal to volume of single drop of radius 'R'.

$\therefore \quad \dfrac{4}{3}\pi r^3 n = \dfrac{4}{3}\pi R^3$

$\therefore \quad nr^3 = R^3$

$\therefore \quad R = r\sqrt[3]{n} = r\sqrt[3]{8} = 2r$

$R = 2 \times 2 \times 10^{-4}$ m

$R = 4 \times 10^{-4}$ m

Total work done to coalesce the drops

$W = T\Delta A$

This work is equal to change in surface energy.

$\therefore \quad E = T \times 4\pi (nr^2 - R^2)$

$= T \times 4\pi [8 \times (2 \times 10^{-4})^2 - (4 \times 10^{-4})^2]$

$= 4 \times 3.14 \times 0.072[8 \times 4 \times 10^{-8} - 16 \times 10^{-8}]$

$= 4 \times 3.14 \times 0.072 \times 16 \times 10^{-8}$

$\therefore$ E = **1.447 × 10^{-7} J**

Ans: The change in total surface energy is **1.447 × 10^{-7} J**.

***Q.28. The total energy of the free surface of a liquid drop is 2 × 10^{-4} π times the surface tension of the liquid. What is the diameter of the drop? [Assume all terms in SI unit]**

Solution:

Given: $E = 2 \times 10^{-4}\,\pi T$,

To find: Diameter of drop (d)

Formula: $E = T\Delta A$

Calculation: $\Delta A = 4\pi r^2$

From formula,

$E = 4\pi r^2 T$

$\therefore \quad 2 \times 10^{-4}\,\pi T = 4\pi r^2 T$

$\therefore \quad 2r^2 = 10^{-4}$

$\therefore \quad r^2 = \frac{10^{-4}}{2}$

$\therefore \quad r = \frac{10^{-2}}{\sqrt{2}}$

$d = 2r = \frac{2\times 10^{-2}}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}} = \sqrt{2} \times 10^{-2}$

$\therefore \quad d = \mathbf{1.414 \times 10^{-2}\ m}$

Ans: The diameter of the drop is $\mathbf{1.414 \times 10^{-2}\ m}$.

Q.29. The total energy of free surface of a liquid drop is 2π times the surface tension of the liquid. What is the diameter of the drop? [Assume all terms in SI unit] [Mar 17]

Solution:

Given: $E = 2\pi T$ ***[½ Mark]***

To find: Diameter of drop (d)

Formula: $E = T\Delta A$ ***[½ Mark]***

Calculation: From formula,

$\Delta A = \frac{E}{T}$

$\therefore \quad \Delta A = \frac{2\pi T}{T}$

$\therefore \quad \Delta A = 2\pi$ ***[½ Mark]***

We know, $\Delta A = 4\pi r^2$

$\therefore \quad 2\pi = 4\pi r^2$ ***[½ Mark]***

$\therefore \quad 4r^2 = 2$

$\therefore \quad r^2 = \frac{2}{4} = \frac{1}{2}$

$\therefore \quad r = \frac{1}{\sqrt{2}}$ m

$d = 2r$

$= 2 \times \frac{1}{\sqrt{2}} = \sqrt{2}$

$\therefore \quad d = \mathbf{1.414\ m}$

Ans: The diameter of the drop is **1.414 m.** ***[1 Mark]***

Q.30. The total free surface energy of a liquid drop is $\pi\sqrt{2}$ times the surface tension of the liquid. Calculate the diameter of the drop in S.I. unit. [July 16]

Solution:

Given: $E = \pi\sqrt{2}\,T$

To find: Diameter of drop (d)

Formula: $E = T\Delta A$

Calculation: $\Delta A = 4\pi r^2$

From formula,

$E = 4\pi r^2 T$

$\therefore \quad \pi\sqrt{2}\,T = 4\pi r^2 T$ ***[½ Mark]***

$\therefore \quad 4r^2 = \sqrt{2}$

$\therefore \quad r^2 = \frac{\sqrt{2}}{4} = \frac{1.414}{4}$

$r^2 = 0.3535$

$\therefore \quad r = \sqrt{0.3535}$

$r = 0.5946$ m ***[1 Mark]***

$\therefore \quad d = 2r = 2(0.5946)$

$\therefore \quad d = \mathbf{1.1892\ m}$

Ans: The diameter of the drop is **1.1892 m.** ***[½ Mark]***

Q.31. The energy of the free surface of a liquid drop is 5π times the surface tension of the liquid. Find the diameter of the drop in C.G.S. system. [Mar 16]

Solution:

Given: $E = 5\pi T$

To find: Diameter of the drop (d) in C.G.S. system

Formula: $E = T\Delta A$

Calculation: $\Delta A = 4\pi r^2$

From formula,

$E = 4\pi r^2 T$

$\therefore \quad 5\pi T = 4\pi r^2 T$ ***[½ Mark]***

$\therefore \quad 4r^2 = 5$

$\therefore \quad r = \sqrt{\frac{5}{4}} = \frac{\sqrt{5}}{2}$ ***[½ Mark]***

$\therefore \quad d = 2r = \sqrt{5} = \mathbf{2.236\ cm}$

Ans: The diameter of the drop is **2.236 cm.** ***[1 Mark]***

6.4 Angle of contact

Q.32. *What is meant by an angle of contact? State the main characteristics of angle of contact.

OR

Define the angle of contact and state its any 'two' characteristics. [Oct 14]

Ans: *When a liquid is in contact with a solid, the angle between tangent drawn to the free surface of the liquid and the surface of solid at the point of contact measured inside the liquid is called angle of contact.* ***[1 Mark]***

Characteristics:

i. The angle of contact is constant for a given liquid-solid pair.

ii. The value of angle of contact depends upon nature of liquid and solid in contact.

iii. It depends upon the medium which exists above the free liquid surface.

iv. The angle of contact changes due to impurity or temperature.

*[Any two characteristics – ½ **Mark each**]*

Q.33.*Explain why the free surface of some liquid in contact with a solid is not horizontal.

OR

Explain the formation of concave, convex and normal surface of liquid on the basis of molecular forces.

Ans: i. To explain the phenomena, suppose a liquid molecule 'A' is situated in the liquid surface which is in contact with the solid as shown in figure (a).

ii. Sphere of influence is drawn, which shows that sphere of influence is partly in solid, liquid and air.

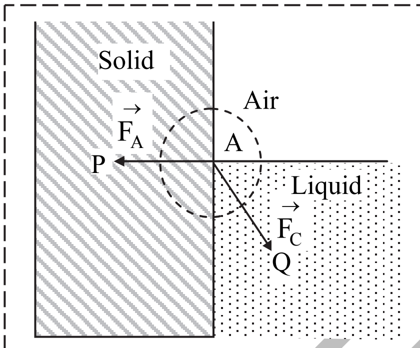


Figure (a)

iii. The molecule 'A' is acted upon by the following four forces:

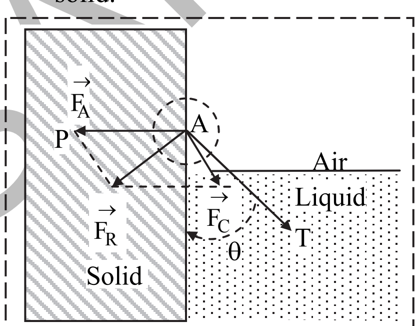
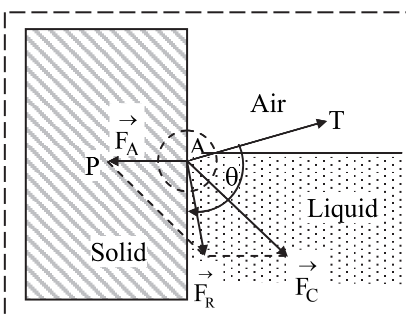
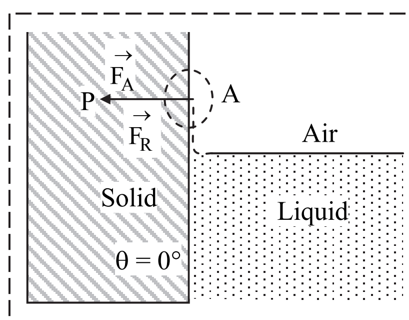
a. Net adhesive force exerted by the molecules of the solid $\overline{AP}$ as $\vec{F}_A$.

b. Net cohesive force exerted by the molecules of liquid $\overline{AQ}$ as $\vec{F}_C$.

c. Net adhesive force exerted by the molecules of air, as the number of air molecule in sphere of influence of molecules 'A' is very small. Hence, resultant adhesive force between air and liquid is neglected.

d. Gravitational force is equal to the weight of the molecule. It is also small and therefore neglected.

iv. So the behaviour of the molecule depends upon two forces $\vec{F}_A$ and $\vec{F}_C$.

Different cases of liquid-solid interaction		
Case 1: Liquid partially wets solid	**Case 2: Liquid does not wet solid**	**Case 3: Liquid completely wets solid**
i. Resultant adhesive force between liquid and solid on molecule A > resultant cohesive force between liquid molecules. i.e., $\vec{F}_A > \vec{F}_C$ ⇒ Resultant force $\vec{F}_R$ lies inside solid.  **Figure (b)**	i. Resultant adhesive force between liquid and solid on molecule A < resultant cohesive force between liquid molecules i.e., $\vec{F}_A < \vec{F}_C$ ⇒ Resultant force $\vec{F}_R$ lies inside liquid.  **Figure (c)**	i. Resultant adhesive force between liquid and solid on molecule A > > > resultant cohesive force, i.e., $\vec{F}_A >>> \vec{F}_C$ ⇒ Resultant force $\vec{F}_R$ lies along $\vec{F}_A$ as shown in the figure below.  **Figure (d)**

ii. In equilibrium state, tangent AT to liquid surface is $\perp^r$ to $\vec{F}_R$ iii. Hence, liquid creeps upwards on solid surface. iv. Liquid surface in contact with solid is concave upward. v. Angle of contact is acute. vi. Example: Kerosene - glass	ii. In equilibrium state, tangent AT to liquid surface is $\perp^r$ to $\vec{F}_R$ iii. Hence, liquid creeps downwards on solid surface. iv. Liquid surface in contact with solid is convex upward. v. Angle of contact is obtuse. vi. Example: Mercury - glass	ii. In equilibrium state, free surface of liquid is $\perp^r$ to $\vec{F}_R$ iii. Only gravitational force acts vertically downwards on molecule A. iv. Liquid surface in contact with solid is normal. v. Angle of contact is zero. vi. Example: Pure water - clean glass.

***Q.34. Draw labelled diagram to show angle of contact between**
i. Pure water and clean glass
ii. Mercury and clean glass

Ans: i. *Refer Q.33* (figure d)
ii. *Refer Q.33* (figure c)

***Q.35. "The shape of impure water meniscus is concave whereas the shape of mercury meniscus is convex", explain.**

Ans: i. Consider a liquid drop at equilibrium on the surface of a glass plate (solid).

ii. Three interfaces are formed:
a. solid-liquid,
b. solid-air and
c. liquid-air

iii. Let,
T_1 = surface tension for the solid-liquid interface.
T_2 = surface tension for the solid-air interface.
T_3 = surface tension for the liquid-air interface.
θ = angle of contact between solid and liquid as shown in figure (a).

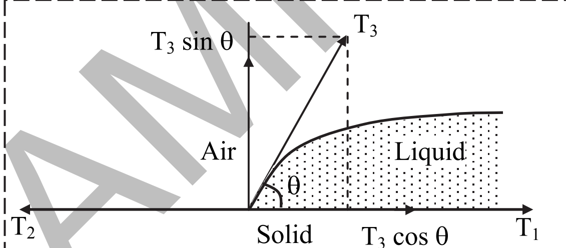


Figure (a)

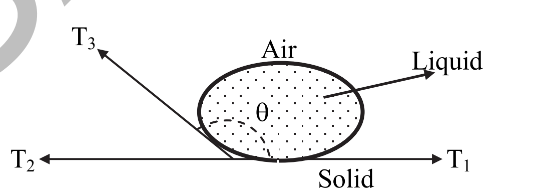


Figure (b)

iv. T_3 can be resolved into two components:
$T_3 \cos\theta$ along horizontal and
$T_3 \sin\theta$ along vertical.

v. The drop is in equilibrium. Therefore, the horizontal components must balance each other.

$\therefore$ $T_3 \cos\theta + T_1 = T_2$

$\therefore$ $T_3 \cos\theta = T_2 - T_1$

$\therefore$ $\cos\theta = \dfrac{T_2 - T_1}{T_3}$ ....(1)

vi. In case of impure water, $T_2 > T_1$.

$\therefore$ $\cos\theta$ is positive. Hence, angle of contact is acute. Thus, shape of meniscus is concave.

vii. If mercury drops are taken on the glass plate as shown in figure (b), then $T_2 < T_1$.

$\therefore$ $\cos\theta$ is negative.

$\therefore$ θ lies between 90° and 180° i.e., angle of contact is obtuse.

Thus, shape of mercury meniscus is convex.

***Q.36. Explain: Water on a clean glass surface tends to spread out, while mercury on the same surface tends to form a drop.**
(NCERT)

Ans: i. For mercury-glass interface, angle of contact is obtuse.

ii. In order to achieve this obtuse value of angle of contact, the mercury tends to form a drop.

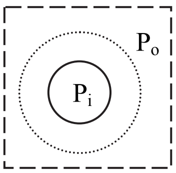
iii. In case of water-glass interface, the angle of contact is acute. To achieve this acute value of angle of contact, water tends to spread.

***Q.37. Explain excess of pressure about drop of liquid and soap bubble.**

OR

Derive Laplace's law for spherical membrane of bubble due to surface tension. **[Mar 16]**

Ans: Expression for excess pressure inside a drop:



i. Free surface of drops or bubbles are spherical in shape.
Let,
P_i = inside pressure of a drop or air bubble
P_o = outside pressure of bubble
r = radius of drop or bubble.

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 $A_2 = 4\pi(r+\Delta r)^2$ ***[½ Mark]***

Increase in surface area,

$$\Delta A = A_2 - A_1 = 4\pi[(r + \Delta r)^2 - r^2]$$
$$= 4\pi[r^2 + 2r\Delta r + \Delta r^2 - r^2]$$
$$= 8\pi r\Delta r + 4\pi\Delta r^2$$

iv. As Δr is very small, the term containing Δr^2 can be neglected.

∴ $\Delta A = 8\pi r\Delta r$ ***[½ Mark]***

v. Work done by force of surface tension,
$dW = T\Delta A = (8\pi r\Delta r)T$ ….(1) ***[½ Mark]***

But,
∴ $dF = (P_i - P_o)A$ ***[½ Mark]***
$dW = F\Delta r = (P_i - P_o)A\Delta r$ ***[½ Mark]***
From equation (1),
$(P_i - P_o)A\Delta r = (8\pi r\Delta r)T$

∴ $P_i - P_o = \dfrac{8\pi r\Delta rT}{4\pi r^2\Delta r}$ [∴ $A = 4\pi r^2$]

∴ $P_i - P_o = \dfrac{2T}{r}$ ….(2)

[½ Mark]

Equation (2) represents excess pressure inside a drop or air bubble. It is also called Laplace's law of spherical membrane.

Solved Examples

***Q.38. What should be the diameter of a soap bubble, in order that the excess pressure inside it is 51.2 N/m²? [S.T. of soap solution = 3.2 × 10⁻² N/m]**

Solution:

Given: $P = 51.2\ N/m^2$, $T = 3.2 \times 10^{-2}\ N/m$

To find: Diameter (d)

Formula: $P = \dfrac{4T}{r}$

Calculation: From formula,

$$r = \frac{4T}{P} = \frac{4 \times 3.2 \times 10^{-2}}{51.2} = 2.5 \times 10^{-3}\ m$$

∴ $d = 2r = \mathbf{5 \times 10^{-3}\ m}$

Ans: The diameter of the soap bubble should be **5×10^{-3} m**.

Q.39. A raindrop of diameter 4 mm is about to fall on the ground. Calculate the pressure inside the raindrop. [Surface tension of water T = 0·072 N/m, atmospheric pressure = 1·013 × 10⁵ N/m²] **[Oct 15]**

Solution:

Given: T = 0·072 N/m,
d = 4mm
∴ $r = 2 \times 10^{-3}$ m,
$P_o = 1.013 \times 10^5\ N/m^2$

To find: Pressure inside the raindrop (P_i)

Formula: $P_i = P_o + \dfrac{2T}{r}$ ***[½ Mark]***

Calculation: From formula,

$$P_i = 1.013 \times 10^5 + \frac{2 \times 0.072}{2 \times 10^{-3}}$$ ***[½ Mark]***

∴ $P_i = \mathbf{1.01372 \times 10^5\ Pa}$

Ans: The pressure inside the raindrop is **1.01372×10^5 Pa**. ***[1 Mark]***

6.5 Capillarity and capillary action

A glass tube having a very fine bore and uniform cross section is called a capillary tube.

Example: Blood capillaries, vascular bundles in plants tissue etc.

If a capillary tube is dipped in a liquid which partially or completely wets the solid then the liquid level rises inside the tube.

If a capillary tube is dipped in a liquid which does not wet the solid, then the liquid level falls inside the capillary tube.

***Q.40. What is capillarity? Give some applications of capillarity.**

Ans: Capillary action or capillarity:

The phenomenon of rise or fall of liquid level inside a capillary tube when it is dipped in the liquid is called capillary action or capillarity.

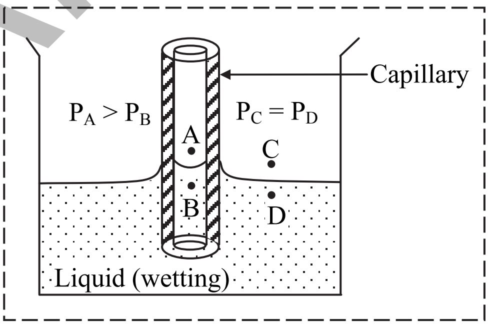
Applications of capillarity:

i. Blotting paper contains small pores. These pores act as capillaries and hence quickly absorb ink.
ii. Wick in oil lamp contains threads, which act as capillaries and oil rises up in the wick of the lamp.
iii. Sap and water rise upto the topmost leaves in the tree by capillary action.
iv. Towel used in every day life is made up of cotton. It absorbs water or moisture from the body due to capillarity of towel.
v. Piece of sponge retains water, due to capillarity.

Q.41. Explain the rise of liquid in the capillary on the basis of pressure difference. [Mar 14]

Ans: Explanation of capillary action:

i. Suppose a capillary tube is dipped into water.
ii. Consider the situation before the movement of water inside the capillary. The shape of the surface of water in the capillary is concave.
iii. Let us consider three molecules in the liquid as shown in the figure. Molecule A is just above the curved surface inside the capillary. B is just below the curved surface inside the capillary. C is just above the plane surface outside the capillary. D is just below the plane surface outside the capillary and is at the same horizontal level as that of B.



*[Diagram – ½ **Mark**, Labelling – ½ **Mark**]*

iv. Let P_A, P_B, P_C and P_D be the pressures at points A, B, C and D respectively.
v. Since pressure on concave side of liquid surface is greater than that on the convex side.

$\therefore$ $P_A > P_B$

As the pressure is same on both sides of a plane surface,

$\therefore$ $P_C = P_D$

$P_A = P_C$ = atmospheric pressure

$\therefore$ $P_D > P_B$

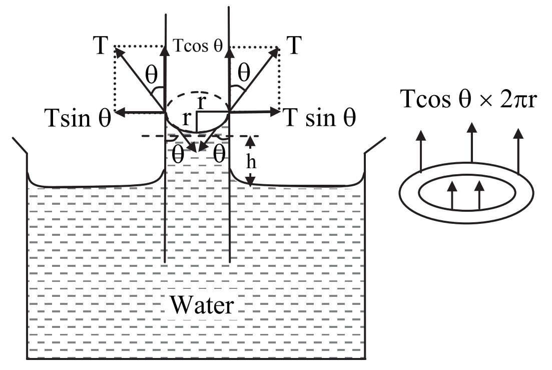
vi. Though the points B and D are at same horizontal level in the liquid, the pressure at point D is greater than that at point B. Therefore, the liquid cannot remain in equilibrium and it flows into the capillary tube and rises above the point B, till the pressure at B becomes the same as that at D. This is why liquid rises up inside the capillary tube.
vii. For mercury, liquid meniscus is convex, therefore pressure at a point just below the curved surface is more than the point at same horizontal level outside the capillary, due to which liquid flows outside the capillary and fall of liquid inside the capillary is observed.

*[**Explanation – **1 Mark**]*

***Q.42. Obtain an expression for the rise of liquid in a capillary tube.**

Ans: Expression for capillary rise:

i. When glass capillary tube is dipped into a liquid, then the liquid rises in the capillary.
Let, r = radius of capillary tube
h = height of liquid level in the tube
T = surface tension of liquid
ρ = density of liquid
g = acceleration due to gravity



Rise of liquid in capillary tube

ii. The force of magnitude T acts on unit length of liquid surface which is in contact with wall of capillary tube.
This force can be resolved into two components:
a. T cosθ-vertically upward and
b. T sinθ-along horizontal

iii. Vertical component is effective. Horizontal component is not responsible for capillary rise.

iv. Total vertical force acting on liquid column
= force per unit length × circumference
= T cosθ × 2πr

v. Upward force balances weight of liquid column.
It is given by, $W = mg = V\rho g = \pi r^2 h\rho g$
where, V = volume of liquid rise in the tube.

vi. If liquid in meniscus is neglected, then for equilibrium.,
$2\pi r\, T \cos\theta = \pi r^2 h \rho g$

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

$\therefore \quad h = \dfrac{2T\cos\theta}{r\rho g}$ ….(1)

This is the required expression for rise of liquid in capillary tube.
If r and T being given, then h can be easily determined.

vii. From equation (1), it can be concluded that,
a. $h \propto \dfrac{1}{r}$ b. $h \propto \dfrac{1}{\rho}$
c. $h \propto T$
where, ρ = constant.

viii. For pure water, θ = 0°
$\therefore \quad \cos 0° = 1, \rho = 1$ g / cc
In this case, $T = \dfrac{hrg}{2}$
$\Rightarrow h = \dfrac{2T}{rg}$

***Q.43. What will happen to the rise of liquid in a capillary tube if its top end is closed?**

Ans: i. There is a small rise in the capillary tube, if the top of capillary tube is closed.
ii. It is so because the rise of liquid in capillary tube due to surface tension is opposed by the downward force exerted by the compressed air above the liquid in the tube.
iii. This downward force increases with increase in height of liquid column.
iv. Therefore, a small rise of liquid column is possible in a capillary tube with a closed top.

***Q.44. When a chalk piece is immersed in water, bubbles are emitted. Why?**

Ans: i. When a chalk piece is immersed in water then pores of chalk act as capillaries.
ii. Water begins to rise in these capillaries expelling the air inside it.
iii. Thus, expelled air comes out on the surface of water in the form of bubbles.

***Q.45. "Tents are coated with a thin layer of aluminium hydroxide," Why?**

Ans: i. Tents and umbrella cloth are made of tightly-woven fabric so that water with its high surface tension cannot easily penetrate.
ii. But falling raindrops can overcome the surface tension and wet the fabric which will then start seeping of water to its other side.
iii. Aluminium hydroxide is water insoluble and water repellent. Thus, it drains off the raindrops before they can wet the fabric.
iv. Hence, tents are coated with a thin layer of aluminium hydroxide.

Solved Examples

Q.46. Water rises to a height 3.2 cm in a glass capillary tube. Find the height to which the same water will rise in another glass capillary having half area of cross section.
[Oct 14]

Solution:

Given: $h_1 = 3.2$ cm, $A_2 = \dfrac{A_1}{2}$

To find: Height to which water will rise (h_2)

Formula: $h \propto \dfrac{1}{r}$

Calculation: From formula,
$h_1 r_1 = h_2 r_2$ ***[½ Mark]***

$\therefore \quad \pi r_2^2 = \dfrac{\pi r_1^2}{2}$

$\Rightarrow r_2 = \dfrac{r_1}{\sqrt{2}}$

$\therefore \quad h_2 = \dfrac{3.2 \times r_1}{r_1/\sqrt{2}}$ *[½ Mark]*

$= 3.2 \times \sqrt{2}$

$= \mathbf{4.525\ cm}$

Ans: Water will rise to a height of **4.525 cm**.

[1 Mark]

***Q.47. A capillary tube of radius 0.5 mm is dipped vertically in a liquid of surface tension 0.04 N/m and relative density 0.8 g/cc. Calculate the height of capillary rise, if the angle of contact is 10°. [g = 9.8 m/s²]**

Solution:

Given: $r = 0.5\ mm = 0.5 \times 10^{-3} m = 5 \times 10^{-4} m$,

$T = 0.04\ N/m$,

$\rho = 0.8\ g/cc = \dfrac{0.8 \times 10^{-3}}{10^{-6}} = 800\ kg/m^3$,

$\theta = 10°$, $g = 9.8\ m/s^2$

To find: Height (h)

Formula: $T = \dfrac{rh\rho g}{2\cos\theta}$

Calculation: From formula,

$h = \dfrac{2T\cos\theta}{r\rho g}$

$\therefore \quad h = \dfrac{2 \times 0.04 \times \cos 10°}{5 \times 10^{-4} \times 800 \times 9.8}$

$h = \dfrac{2 \times 0.04 \times 0.9848}{5 \times 800 \times 9.8 \times 10^{-4}} = 2.01 \times 10^{-2}\ m$

$\therefore \quad h \approx \mathbf{2\ cm}$

Ans: The height of capillary rise is **2 cm**.

***Q.48. The tube of a mercury barometer is 1 cm in diameter. What correction due to capillarity with effect of meniscus is to be applied to barometer reading if surface tension of mercury is 435.5 dyne/cm and angle of contact of mercury with glass is 140°? [Density of mercury = 13600 kg/m³]**

Solution:

Given: $T = 435.5\ dyne/cm = 0.4355\ N/m$,

$\theta = 140°$, $\rho = 13600\ kg/m^3$, $d = 1\ cm$,

$\therefore \quad r = 0.5\ cm = 5 \times 10^{-3}\ m$

To find: Height (h)

Formula: $T = \dfrac{rh\rho g}{2\cos\theta}$

Calculation: From formula,

$h = \dfrac{2T\cos\theta}{r\rho g}$

$\therefore \quad h = \dfrac{2 \times 0.4355 \times \cos 140°}{5 \times 10^{-3} \times 13600 \times 9.8}$

$= \dfrac{0.8710 \times \cos(90° + 50°)}{5 \times 13.6 \times 9.8}$

$= \dfrac{0.8710(-\sin 50°)}{5 \times 13.6 \times 9.8}$

$= \dfrac{-0.8710 \times 0.7660}{68.0 \times 9.8}$

$= -1.001 \times 10^{-3}\ m$

$\therefore \quad h = -1.001\ mm$

Negative sign indicates that mercury level will be lowered by 1.001 mm. Hence, to get correct reading h = 1.001 mm has to added.

$\therefore \quad h = \mathbf{1.001\ mm}$

Ans: The correction due to capillarity with effect of meniscus which needs to be applied to the barometer reading is **1.001 mm**.

***Q.49. Calculate the density of paraffin oil, if a glass capillary of diameter 0.25 mm dipped in paraffin oil of the surface tension 0.0245 N/m rises to a height of 4 cm. [Angle of contact of paraffin oil with glass is 28° and g = 9.8 m/s²] [Mar 14]**

Solution:

Given: $d = 0.25\ mm$

$\therefore \quad r = \dfrac{d}{2} = \dfrac{0.25}{2}$

$= 0.125\ mm$

$= 0.125 \times 10^{-3}\ m$

$T = 0.0245\ N/m$,

$h = 4\ cm = 0.04\ m$,

$\theta = 28°$, $g = 9.8\ m/s^2$

To find: Density (ρ)

Formula: $T = \dfrac{rh\rho g}{2\cos\theta}$

Calculation: From formula,

$\rho = \dfrac{2T\cos\theta}{rhg}$ *[½ Mark]*

$\therefore \quad \rho = \dfrac{2 \times 0.0245 \times \cos 28°}{0.125 \times 10^{-3} \times 0.04 \times 9.8}$ *[1 Mark]*

$= \dfrac{2 \times 0.0245 \times 0.8829}{0.125 \times 10^{-3} \times 0.04 \times 9.8}$ *[½ Mark]*

$\therefore \quad \rho = \mathbf{882.9\ kg/m^3}$

Ans: The density of paraffin oil is **882.9 kg/m³**.

[1 Mark]

Q.50. A capillary tube 2 mm in diameter is immersed in a beaker of mercury. The mercury level inside the tube is found to be 0.5 cm below the level of the reservoir. Determine the contact angle between the mercury and the glass.
[T_m = 0.4 N/m, ρ_m = 13.6 × 10^3 kg/m^3]

Solution:

Given: d = 2 mm,

∴ r = 1 mm = 1×10^{-3} m,

h = –0.5 cm = -5×10^{-3} m

Negative sign indicates depression of liquid level.

$T_m = 0.4$ N/m, $\rho_m = 13.6 \times 10^3$ kg/m^3

To find: Contact angle (θ)

Formula: $T = \dfrac{h\rho gr}{2\cos\theta}$

Calculation: From formula,

$$\cos\theta = \frac{h\rho gr}{2T}$$

$$= \frac{-5\times10^{-3}\times13.6\times10^{3}\times9.8\times1\times10^{-3}}{2\times0.4}$$

$$= \frac{-68\times9.8}{0.8}\times10^{-3}$$

$$= \frac{-666.4}{0.8}\times10^{-3}$$

$$= -833\times10^{-3}$$

∴ $\cos\theta = -0.8330$

∴ $-\cos\theta = 0.8330$

$\cos(\pi - \theta) = 0.8330$

$\pi - \theta = \cos^{-1}(0.8330) = 33°36'$

∴ $\theta = 180 - 33°36'$

∴ $\theta =$ **146°24′**

Ans: The contact angle between mercury and glass is **146°24′**.

6.6 Effect of impurities and temperature on surface tension of liquid

***Q.51. Explain the effect of presence of impurities on surface tension of liquid.**

Ans: Effect of impurities on surface tension:

The effect of impurities on surface tension of liquid can be either due to soluble impurities or insoluble impurities on the surface of liquid.

i. **Effect of soluble impurities:**
In the case of highly soluble impurities like common salt, the solute molecules are attracted more strongly to liquid molecules. This results in increase of surface tension because the force of attraction of solute molecules exceeds surface energy.

ii. **Effect of insoluble or partly soluble impurities:**
If impurity is insoluble or partly soluble in liquid, surface tension of liquid decreases. This is because liquid molecules move inside the surface of liquid. In place of these molecules, the insoluble or partly soluble impurity added takes up the place. This gives higher concentration of solute molecules in outer layer than in interior of liquid. This results in decrease of surface tension.
Example: Soap or detergent in water decreases the surface tension of water and helps in cleaning of cloths.

Q.52. Explain the effect of temperature on surface tension.

Ans: Effect of temperature on surface tension:

i. In most of the liquids, surface tension decreases with increase in temperature. When the liquid is heated, the molecules of liquid are in random motion with greater velocity.

ii. Faster moving molecules of hot liquid are not bounded together as strongly as those in cooler liquid. Hence, surface tension of the liquid decreases with increase in temperature.

iii. In small range of temperature, surface tension varies as,
$T = T_0 (1 - \alpha\Delta t)$
where,
T_0 = surface tension at 0 °C,
T = surface tension at t °C,
α = temperature coefficient of liquid,
Δt = temperature difference

Q.53. Define critical temperature. Explain the effect of contamination on surface tension.

Ans: Definition: *The temperature at which surface tension of liquid becomes zero is called critical temperature.*

Effect of contamination on surface tension:

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

***Q.54. A steel blade floats on the surface of pure water but sinks when detergent is added to the water. Why?**

Ans: i. When a steel blade is kept on pure water gently, then blade starts floating on the water surface. It is so because at the surface film of water, weight of the blade is balanced by vertical component of force due to surface tension.

∴ $Mg = T \sin\theta \times 2l$

where, M = mass of the blade

ii. When detergent is added in water, surface tension of water reduces.

In this case, $Mg > T \sin\theta \times 2l$

Hence, steel blade sinks.

***Q.55. What is the effect of temperature on angle of contact?**

Ans: As temperature increases, surface tension decreases thus angle of contact decreases.

Solved Examples

***Q.56. The surface tension of water at 0 °C is 70 dyne/cm. Find surface tension of water at 25 °C. [α for water = 0.0027/ °C]**

Solution:

Given: $T_0 = 70$ dyne/cm, $t_1 = 0$ °C, $t_2 = 25$ °C, $\alpha = 0.0027$ /°C

To find: Surface tension (T)

Formula: $T = T_0 (1 - \alpha\Delta t) = T_0 [1 - \alpha (t_2 - t_1)]$

Calculation: From formula,

$T = 70 [1 - (0.0027 \times 25)]$

$= 70 [1 - 0.0675]$

$= 70 \times 0.9325$

∴ T = **65.275 dyne/cm**

Ans: The surface tension of water at 25 °C is **65.275 dyne/cm**.

Q.57. The surface tension of water at 0 °C is 75.5 dyne/cm. Calculate surface tension of water at 25 °C. [α for water = 2.7 × 10⁻³/ °C]

[Mar 15]

Solution:

Given: $T_0 = 75.5$ dyne/cm, $t_1 = 0$ °C, $t_2 = 25$ °C, $\alpha = 2.7 \times 10^{-3}$ /°C

To find: Surface tension (T)

Formula: $T = T_0 [1 - \alpha(t_2 - t_1)]$ ***[½ Mark]***

Calculation: From formula,

$T = 75.5[1 - 2.7 \times 10^{-3}(25)]$ ***[½ Mark]***

$= 75.5[1 - 0.0675]$

= **70.40 dyne/cm**

Ans: The surface tension of water at 25 °C is **70.40 dyne/cm**. ***[1 Mark]***

Q.58. The surface tension of water at 0 °C is 75.5 dyne/cm. Find surface tension of water at 25 °C. [α for water = 0.0021/°C]

[Mar 13]

Solution:

Given: $T_0 = 75.5$ dyne/cm, $t_1 = 0$ °C, $t_2 = 25$ °C, $\alpha = 0.0021$ /°C

To find: Surface tension (T)

Formula: $T = T_0 (1 - \alpha\Delta t) = T_0 [1 - \alpha (t_2 - t_1)]$ ***[½ Mark]***

Calculation: From formula,

$T = 75.5 [1 - (0.0021 \times 25)]$ ***[½ Mark]***

$= 75.5 [1 - 0.0525]$

$= 75.5 \times 0.9475$

∴ T = **71.54 dyne/cm**

Ans: The surface tension of water at 25 °C is **71.54 dyne/cm**. ***[1 Mark]***

Miscellaneous

***Q.59. A mercury drop of radius 0.5 cm falls from a height on a glass plate and breaks up into a million droplets, all of the same size. Find the height from which the drop must have fallen. [Density of mercury = 13600 kg/m³, Surface tension of water = 0.465 N/m]**

Solution:

Given: $R = 0.5$ cm $= 0.5 \times 10^{-2}$ m, $n = 10^6$, $\rho = 13600$ kg/m³, $T = 0.465$ N/m

To find: Height (h)

Formulae: i. $W = T\Delta A$

ii. P.E. = mgh

Calculation: Volume of single big drop, $V = \frac{4}{3}\pi R^3$

Volume of single small droplet $= \frac{4}{3}\pi r^3$

∴ Volume of n droplets $= n \times \frac{4}{3}\pi r^3$

∴ $\frac{4}{3}\pi R^3 = n \frac{4}{3}\pi r^3$

∴ $R^3 = nr^3$

∴ $r = \frac{R}{\sqrt[3]{n}} = \frac{0.5\times10^{-2}}{\sqrt[3]{10^6}} = \frac{0.5\times10^{-2}}{10^2}$

∴ $r = 0.5 \times 10^{-4}$ m

The single drop falls from height h, hence its P.E. = mgh

This P.E. is equal to the work done due to change in area of drop. Change in surface area, $\Delta A = (4\pi r^2 n - 4\pi R^2)$.

From formula (i),

$W = T\Delta A = T(n4\pi r^2 - 4\pi R^2)$

$W = 4\pi T(nr^2 - R^2)$

From formula (ii),

P.E = Work done

$\therefore \quad mgh = 4\pi T(nr^2 - R^2)$

But, $m = \frac{4}{3}\pi R^3\rho$

$\therefore \quad \frac{4}{3}\pi R^3\rho gh = 4\pi T(nr^2 - R^2)$

$\therefore \quad \frac{R^3\rho gh}{3} = T(nr^2 - R^2)$

$\therefore \quad h = \frac{3T(nr^2 - R^2)}{R^3\rho g}$

$= \frac{3\times0.465\left[10^6\left(0.5\times10^{-4}\right)^2 - \left(0.5\times10^{-2}\right)^2\right]}{\left(0.5\times10^{-2}\right)^3\times13600\times9.8}$

$\therefore \quad h = \frac{3\times0.465\left[\left(0.25\times10^{-2}\right) - \left(0.25\times10^{-4}\right)\right]}{0.125\times10^{-6}\times1.36\times10^4\times9.8}$

$= \frac{3\times0.465\times0.25\left[10^{-2} - 10^{-4}\right]}{0.125\times0.0136\times9.8}$

$= \frac{3\times0.465\times0.25\times10^{-2}\left[1 - 10^{-2}\right]}{0.125\times0.0136\times9.8}$

$= \frac{3\times0.465\times0.25(1 - 0.01)}{0.125\times1.36\times9.8}$

$= \frac{3\times0.465\times25\times0.99}{12.5\times1.36\times9.8}$

$\therefore \quad h = \mathbf{0.2072\ m}$

Ans: The height from which the drop must have fallen is **0.2072 m**.

Formulae

1. **Surface tension:** $T = \frac{F}{l}$

2. **Force due to surface tension:** $F = T \times l$
   i. For circular thick ring,
   $F = F_1 + F_2 = T \times 2\pi r_1 + T \times 2\pi r_2$
   $= 2\pi T(r_1 + r_2)$
   ii. For a thin ring, $F = Tl = T \times 2\pi(r + r)$
   $= 4\pi rT$
   iii. For circular plate, $F = Tl = T \times 2\pi r$
   $= 2\pi rT$
   iv. For square frame, $F = Tl = T \times 2 \times 4l$
   $= 8Tl$
   v. For square plate, $F = Tl = T \times 4l = 4Tl$
   vi. For rectangular frame, $F = Tl$
   $= T(4l + 4b)$
   vii. For rectangular plate, $F = Tl$
   $= T(2l + 2b)$

3. **Surface energy:** $E = T\Delta A$

4. **Excess pressure inside an air bubble:**
   $P = \frac{2T}{r}$

5. **Excess pressure inside a soap bubble:**
   $P = \frac{4T}{r}$

6. **Total pressure in the air bubble at a depth h below the surface of liquid of density ρ:**
   $P = P_o + h\rho g + \frac{2T}{r}$

7. **Work done in forming a liquid drop of radius r and surface tension T:**
   $W = 4\pi r^2 T$

8. **Work done in increasing radius of air bubble from r_1 to r_2:**
   $W = 4\pi T\left(r_2^2 - r_1^2\right)$

9. **Work done to split a liquid drop of radius R into n identical droplets:**
   $W = 4\pi r^2 T(n^{1/3} - 1)$

10. **Work done to form a bigger drop of liquid by n identical droplets each of radius r:**
    $W = 4\pi r^2 T(n - n^{2/3})$

11. **Work done in forming soap bubble of radius r:** $W = 8\pi r^2 T$

12. **Work done in increasing radius of soap bubble from r_1 to r_2:**
    $W = 8\pi T\left(r_2^2 - r_1^2\right)$

13. **Rise or fall of liquid in capillary tube:**
    $h = \frac{2T\cos\theta}{r\rho g}$

14. **Variation of surface tension with temperature:** $T = T_0(1 - \alpha\Delta t)$

Exercise

One Mark Questions

1. Give two examples each of adhesive and cohesive forces in nature.

Ans: *Refer Q.1 and Q.2*

2. Define sphere of influence.

Ans: *Refer Q.3(ii)*

*3. Define angle of contact.

Ans: *Refer Q.32*

4. State any two characteristics of angle of contact.

Ans: *Refer Q.32*

5. Define critical temperature.

Ans: *Refer Q.53*

Two Marks Questions

1. Explain the concept of surface tension. State its units and dimensions.

Ans: *Refer Q.9*

2. Derive the dimensional formula of surface tension.

Ans: *Refer Q.10*

3. Obtain the relation between surface energy and surface tension.

Ans: *Refer Q.11*

4. What is capillarity? Give any 'two' applications of capillarity. **[July 18]**

Ans: *Refer Q.40*

5. How do impurities affect the surface tension of a liquid?

Ans: *Refer Q.51*

6. Why does a steel blade sink in soap water but floats on the surface of pure water?

Ans: *Refer Q.54*

7. Draw a neat labelled diagram showing forces acting on the meniscus of water in a capillary tube. **[Oct 15]**

OR

Draw a neat labelled diagram of rise of liquid in capillary tube showing different components of tension (force). **[July 16]**

Ans: *Refer Q.42 (Diagram only)*
*[Diagram – **1 Mark**, Labelling – **1 Mark**]*

8. Draw a neat, labelled diagram for a liquid surface in contact with a solid, when the angle of contact is acute. **[Mar 17]**

Ans: *Refer Q.33 (figure b)*
*[Diagram – **1 Mark**, labelling – **1 Mark**]*

9. Define surface tension and surface energy. **[July 17]**

Ans: *Refer Q.9, Q.6, (Definitions only)*
*[Definition – **1 Mark each**]*

10. Calculate the work done in increasing the radius of a soap bubble from 2 cm to 8 cm, the surface tension of soap solution is 30×10^{-3} N/m.

Ans: 45.2×10^{-4} J

11. Two soap bubbles have radii in the ratio 2:3. Compare the excess of pressure inside these bubbles.

Ans: 3 : 2

12. A water film is formed between two straight parallel wires of 10 cm each with separation of 0.1 cm. If the distance between the wire is increased by 0.1 cm, how much work is done? [T = 0.072 N/m]

Ans: 1.44×10^{-5} J

13. A needle 5 cm long can just rest on the surface of water without wetting. What is its weight? [Surface tension of water = 0.07N/m]

Ans: 0.007 N

14. A drop of radius 4 cm is broken into 125 equal small drops. Calculate the work done if surface tension of water is 75×10^{-3} N/m.

Ans: 6.03×10^{-3} J

Three Marks Questions

1. i. Define surface energy. **[1 M]**

   Ans: *Refer Q.6*

   ii. Explain the reason behind the extra energy possessed by molecules of a liquid lying in the surface film. **[2 M]**

   Ans: *Refer Q.8*

2. Explain phenomenon of surface tension using molecular theory.

Ans: *Refer Q.5*

3. With the help of neat labelled diagram, derive an expression for the rise of liquid in a capillary tube.

Ans: *Refer Q.42*

4. i. Define capillarity. **[1 M]**
Ans: *Refer Q.40*

ii. Draw neat labelled diagram explaining the capillary rise in capillary tube. **[2 M]**
Ans: *Refer Q.42 (Diagram only)*

5. Derive an expression for excess pressure inside a drop of liquid. **[Mar 15]**
Ans: *Refer Q.37*
*[Description – ½ **Mark**, Expression for ΔA – **1 Mark**, Expression for dW in terms of surface tension and pressure difference – ½ **Mark each**, Expression for pressure difference – ½ **Mark**]*

6. Derive Laplace's law for a spherical membrane. **[Mar 18]**
Ans: *Refer Q.37*

*7. Explain why angle of contact of mercury with glass is obtuse while that of water with glass is acute. **(NCERT)**
Ans: *Refer Q.35*

8. A ring of glass is cut from a tube having 7.4 cm internal and 7.8 cm external diameter. This ring with its lower side horizontal is suspended from one arm of a balance so that the lower edge is just immersed in a vessel of water. It is found that an additional weight of 3.62 g must be placed in the other scale pan to compensate for the pull of surface tension on the ring. Calculate the S. T. of water. [g = 9.8 m/s^2]
Ans: 7.43×10^{-2} N/m

Five Marks Questions

1. Define angle of contact. Explain why the free surface of some liquid in contact with a solid is curved.
Ans: *Refer Q.32, Q.33*

2. i. Explain the cause of capillary action in a capillary tube. **[2 M]**
Ans: *Refer Q.41*

ii. Water rises to a height of 10 cm in a capillary tube, and mercury falls to a depth of 3.42 cm in the same capillary tube. Angle of contact of mercury glass interface is 135°. Calculate the ratio of surface tension for water and mercury. **[3 M]**
Ans: 0.152

Board questions

Theory:

1. What is capillarity? How is it used to determine the surface tension of a liquid which wets the glass? **[Mar 96, 00, 02]**
2. Define angle of contact. When it will be acute and obtuse? **[Mar 97]**
3. Define surface tension. Describe capillary tube experiment to determine the surface tension of a liquid with necessary formula. **[Mar 97, 03, Oct 98]**
4. What is surface energy? Obtain the relationship between surface tension and surface energy. **[Mar 98, Oct 01]**
5. Define molecular range and sphere of influence. What do you mean by adhesive and cohesive forces? **[Oct 00]**
6. Define surface tension. State its S.I unit and dimensions. State any two characteristics of angle of contact. State any two applications of capillarity. **[Oct 02]**
7. Define-surface tension. Obtain its dimensions. **[Mar 03]**
8. Explain why the angle of contact is acute for kerosene glass pair and is obtuse for mercury glass pair. **[Oct 03, Mar 12]**
9. Define range of molecular attraction and sphere of influence. **[Oct 04]**
10. Define
    i. Surface tension
    ii. Angle of contact. **[Oct 05]**
11. What is angle of contact? Explain why the upper surface of mercury in a glass capillary tube is convex while for kerosene it is concave. **[Mar 06]**
12. Explain on the basis of molecular theory, why liquid surface in a container are sometimes
    i. convex upwards
    ii. concave upwards **[Oct 06]**
13. Define the terms:
    i. Sphere of influence
    ii. Angle of contact. **[Mar 08]**
14. Define surface tension. Explain the effect of impurity on surface tension. **[Oct 08]**
15. Draw a neat diagram for the rise of liquid in a capillary tube showing the components of a surface tension T. **[Mar 10]**

16. Define angle of contact. State its any two characteristics. **[Oct 11]**

Numericals:

17. Find the work done in blowing a soap bubble of radius 5 cm. Surface tension of soap solution is 25 dyne/cm. **[Mar 96, Oct 00]**

Ans: 15710 erg

18. A drop of mercury of radius 0.1 cm is broken into 8 droplets of same size. Find the work done if the surface tension of mercury is 540 dyne/cm. **[Mar 98]**

Ans: 67.82 erg

19. A liquid rises to a height of 9 cm in a glass capillary of radius 0.02 cm. What will be the height of liquid column in a glass capillary of radius 0.03 cm? **[Oct 98]**

Ans: 6 cm

20. A capillary tube of uniform bore is dipped vertically in water which rises by 7 cm in the tube. Find the radius of the capillary if the surface tension of water is 70 dyne/cm. [g = 980 cm/s^2] **[Mar 99]**

Ans: 0.0204 cm

21. Calculate the work done in breaking a mercury drop of radius 1 mm into one thousand droplets of the same size. Surface tension of mercury is 525×10^{-3} N/m. **[Mar 99]**

Ans: 5.94×10^{-5} J

22. A liquid of density 900 kg/m^3 rises to a height of 9 mm in a capillary tube of 2.4 mm diameter. If the angle of contact is 25°, find the surface tension of the liquid. [g = 9.8 m/s^2] **[Oct 99]**

Ans: 52.55 dyne / cm

23. Eight droplets of mercury each of radius 1 mm coalesce into a single drop. Find change in the surface energy. Surface tension of mercury is 0.465 N/m. **[Mar 01, Oct 04]**

Ans: 2.337×10^{-5} J

24. Water rises to a height of 5 cm in a certain capillary tube. In the same capillary tube, mercury is depressed by 1.54 cm. Compare the surface tensions of water and mercury. [Given: Density of water = 1000 kg/m^3, Density of mercury = 13600 kg/m^3, Angle of contact for water = 0° and Angle of contact for mercury = 130°] **[Oct 01]**

Ans: $T_w / T_{Hg} = 0.1535$

25. A soap bubble has diameter 2 cm. Calculate the work done to increase its diameter to 6 cm. [Surface tension of soap solution is 35 dynes/cm] **[Mar 02]**

Ans: 7038 erg

26. A glass plate 9.5 cm long and 0.5 cm thick is suspended in a trough containing water so that its length just touches the water surface. Calculate the downward force due to surface tension acting on the plate. [Surface tension of water = 72 dyne/cm] **[Oct 02]**

Ans: 1440 dyne

27. Compare the amounts of work done in blowing two soap bubbles of radii in the ratio 4 : 5. **[Mar 05]**

Ans: $\frac{W_1}{W_2} = \frac{16}{25}$

28. A drop of mercury 2 mm in diameter breaks into a million small spherical droplets, all of same size. Calculate the work done. (Surface tension of mercury = 460×10^{-3} N/m.) **[Oct 11]**

Ans: 2.288×10^{-3} J

Multiple Choice Questions

1. The spherical shape of rain-drop is due to
   (A) density of the liquid.
   (B) surface tension.
   (C) atmospheric pressure.
   (D) gravity.

2. The surface tension of a liquid is T. The increase in its surface energy on increasing the surface area by A is
   (A) $\frac{A}{T}$ (B) A^2T
   (C) AT (D) A^2T^2

3. Absorption of water by filter paper is due to ________.
   (A) cohesion
   (B) capillarity
   (C) adhesion
   (D) elasticity

4. If T is the surface tension of soap solution, the amount of work done in blowing a soap bubble from a diameter D to 2D is
   (A) $2\pi D^2T$ (B) $4\pi D^2T$
   (C) $6\pi D^2T$ (D) $8\pi D^2T$

5. When two soap bubbles of radius r_1 and r_2 ($r_2 > r_1$) coalesce, the radius of curvature of common surface is
(A) $r_2 - r_1$
(B) $\frac{r_2 - r_1}{r_1 r_2}$
(C) $\frac{r_1 r_2}{r_2 - r_1}$
(D) $r_2 + r_1$

6. Angle of contact for the pair of pure water with clean glass is _______. **[Oct 15]**
(A) acute
(B) obtuse
(C) 90°
(D) 0°

7. A soap bubble A of radius 0.03 m and another soap bubble B of radius 0.04 m are brought together so that the combined bubble has a common interface of radius r, then the value of r is
(A) 0.06 m
(B) 0.012 m
(C) 0.12 m
(D) 0.035 m

8. Which of the following is incorrect?
(A) Angle of contact, $\theta < 90$, if cohesive force < adhesive force.
(B) Angle of contact, $\theta > 90$, if cohesive force > adhesive force.
(C) Angle of contact, $\theta = 90$, if cohesive force = adhesive force.
(D) If the radius of capillary is reduced to half, the rise of liquid column becomes four times.

9. The work done in blowing a soap bubble from initial diameter of 4 cm to final diameter of 40 cm is [S.T of soap bubble is 0.04 N/m]
(A) 398×10^{-2} J
(B) 39.8×10^{-2} J
(C) 3.98×10^{-2}J
(D) 3981×10^{-2} J

10. A rectangular film of a liquid is 5 cm long and 4 cm wide. If the work done in increasing its area to 7 cm × 5 cm is 0.06 J, the surface tension of the solution is: **[July 18]**
(A) 0.02 J/ m^2
(B) 0.2 J/ m^2
(C) 2 J/ m^2
(D) 20 J/ m^2

11. 'n' droplets of equal size of radius r coalesce to form a bigger drop of radius R. The energy liberated is equal to _______.
(T = Surface tension of water) **[Mar 13]**
(A) $4\pi R^2 T[n^{\frac{1}{3}} - 1]$
(B) $4\pi r^2 T[n^{\frac{1}{3}} - 1]$
(C) $4\pi R^2 T[n^{\frac{2}{3}} - 1]$
(D) $4\pi r^2 T[n^{\frac{2}{3}} - 1]$

12. 1000 tiny mercury droplets coalesce to form a bigger drop. In this process, temperature of the drop _______ . **[July 17]**
(A) increases
(B) may increase or decrease
(C) decreases
(D) does not change

13. The value of surface tension of a liquid at critical temperature is _______.
(A) zero
(B) infinite
(C) between 0 and ∞
(D) unpredictable

14. When the temperature increases, the angle of contact of a liquid _______.
(A) increases
(B) decreases
(C) remains unchanged
(D) first increases and then decreases

15. A big drop of radius R is formed from 1000 droplets of water. The radius of a droplet will be **[Oct 13]**
(A) 10 R
(B) $\frac{R}{10}$
(C) $\frac{R}{100}$
(D) $\frac{R}{1000}$

16. As the length of capillary tube is insufficient, the rise of liquid in it will be up to the top, in the absence of ________. **[Feb 13 old course]**
(A) insoluble impurity
(B) soluble impurity
(C) gravity
(D) critical temperature

17. The lower end of a capillary tube is dipped in a liquid whose angle of contact is 90°. The liquid
(A) will neither rise nor fall inside the tube.
(B) will rise inside the tube.
(C) will rise to the top of tube.
(D) will fall inside the tube.

18. If two capillary tubes of different diameters are partially dipped in the same liquid vertically, then the rise of liquid ______. **[July 16]**
(A) is same in both the tubes.
(B) is more in the tube of larger diameter.
(C) will not be in smaller diameter tube.
(D) is more in the tube of smaller diameter.

19. Nature of meniscus for liquid of angle of contact 0° will be
(A) plane (B) parabolic
(C) semi-spherical (D) cylindrical

20. Water rises to a height 'h' in a capillary at the surface of earth. On the surface of the moon, the height of water column in the same capillary will be
(A) 6h (B) 1/6 h
(C) h (D) zero

21. Oil spreads over the surface of water where as water does not spread over the surface of the oil because
(A) surface tension of water is very high.
(B) surface tension of water is very low.
(C) viscosity of oil is high.
(D) viscosity of water is high.

22. The surface tension for pure water in a capillary tube experiment is
(A) $\frac{\rho g}{2hr}$ (B) $\frac{2}{hr\rho g}$
(C) $\frac{r\rho g}{2h}$ (D) $\frac{hr\rho g}{2}$

23. When the common salt is dissolved in pure water, the surface tension of the solution is _______ that of pure water.
(A) less than (B) equal to
(C) greater than (D) half

24. A glass capillary tube of radius 1 mm dip into a liquid of density 0.8×10^3 kg/m^3. The liquid rises to a height of 3 cm and the angle of contact is 5°. The surface tension of liquid is
(A) 0.24 N/m (B) 0.12 N/m
(C) 1.2×10^{-3} N/m (D) 1.2×10^{-4} N/m

25. Waterproofing agent changes the angle of contact
(A) from obtuse to acute
(B) from acute to obtuse
(C) from obtuse to $\pi/2$
(D) from acute to $\pi/2$

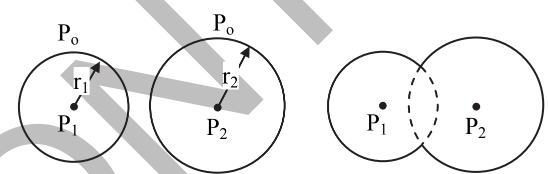
26. In which of the following substances, surface tension increases with increase in temperature? **[Oct 14]**
(A) Copper (B) Molten copper
(C) Iron (D) Molten iron

Answers to Multiple Choice Questions

1.	(B)	2.	(C)	3.	(B)	4.	(C)
5.	(C)	6.	(D)	7.	(C)	8.	(D)
9.	(C)	10.	(D)	11.	(A)	12.	(A)
13.	(A)	14.	(A)	15.	(B)	16.	(C)
17.	(A)	18.	(D)	19.	(C)	20.	(A)
21.	(A)	22.	(D)	23.	(C)	24.	(B)
25.	(B)	26.	(B)				

Hints to Multiple Choice Questions

5. When two soap bubbles of same material having different radii r_1 and r_2 ($> r_1$) are combined to form a double bubble, then



$$P_1 - P_o = \frac{4T}{r_1}$$

and $P_2 - P_o = \frac{4T}{r_2}$

$$\Rightarrow P_1 - P_2 = 4T\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

But $P_1 - P_2 = P = \frac{4T}{R_o}$

where, R_o is radius of the common surface.

$$\Rightarrow R_o = \frac{r_1 r_2}{r_2 - r_1}.$$

10. $A_1 = 5 \times 10^{-2} \times 4 \times 10^{-2} = 20 \times 10^{-4}$ m^2
$A_2 = 7 \times 10^{-2} \times 5 \times 10^{-2} = 35 \times 10^{-4}$ m^2
∴ $W = T \times 2\Delta A$
∴ $T = \frac{W}{2\Delta A} = \frac{0.06}{2(35\times10^{-4} - 20\times10^{-4})}$
$= \frac{0.06}{2\times15\times10^{-4}} = 20$ J/m^2

18. $h = \frac{2T\cos\theta}{r\rho g}$

$h \propto \frac{1}{r}$

TOPIC TEST

Total : 25 Marks

Section A (1 × 5 = 5 Marks)

Choose the correct alternative.

1. If we draw a graph between the height of liquid in a capillary tube against the reciprocal of radius of the tube for a given liquid then we get _______.
   (A) straight line (B) circle
   (C) hyperbola (D) parabola

2. One thousand small water droplets of equal size combine to form a big drop. The ratio of the final surface energy to the total initial surface energy of water droplets is
   (A) 1 : 1000 (B) 10 : 1
   (C) 1 : 10 (D) 1000 : 1

Answer the following.

1. What is the effect of temperature on angle of contact?
2. Define surface film.
3. State expression for rise of pure water in capillary tube.

Section B (2 × 3 = 6 Marks)

1. Prove that the surface tension of a liquid is numerically equal to the surface energy per unit area.
2. A thin wire is bent in the form of a rectangle of length 4 cm and breadth 3 cm. How much force due to the surface tension do the sides experience when a soap film is formed in the frame? [S.T of soap solution = 0.030 N/m]

OR

2. Explain the rise of liquid in capillary tube in the basis of pressure difference
3. A soap bubble has radius 4 cm. What is the amount of additional work done in increasing its radius further by 2 cm? [Surface tension of soap = 0.03 N/m.]

Section C (3 × 3 = 9 Marks)

1. Explain the effect of impurities and temperature on the surface tension.
2. i. State any two characteristics of angle of contact. **[1 M]**
   ii. Calculate the work done in order to triple the radius of a water drop of radius 2 cm. The surface tension of water is 75 dyne/cm. **[2 M]**
3. i. Define surface energy per unit area. **[1 M]**
   ii. Why do the ends of a glass tube become round on heating? **[2 M]**

OR

3. Derive Laplace's law for spherical membrane of bubble.

Section D (5 × 1 = 5 Marks)

1. i. What is capillarity? State any two applications of capillary. **[2 M]**
   ii. A capillary tube is kept in a vessel containing Hg. The level of Hg in capillary tube is found to be 2 cm, below the level of Hg in the vessel. If the same capillary tube is dipped in water, then calculate the rise of water in it. The angle of contact for water and Hg are respectively 0° and 135°; and S.T of water = 72×10^{-3} N/m., S.T. of Hg = 465×10^{-3} N/m. **[3 M]**

OR

1. i. Discuss the molecular theory of surface tension. **[3 M]**
   ii. If the surface tension of water is 0.06 N m^{-1}, then calculate the capillary rise in a tube of a diameter 1 mm assuming $\theta = 0°$. **[2 M]**