Chapter

10

Surface Tension

Intermolecular Force

The force of attraction or repulsion acting between the molecules are known as intermolecular force. The nature of intermolecular force is electromagnetic.

The intermolecular forces of attraction may be classified into two types.

Cohesive force	Adhesive force
The force of attraction between molecules of same substance is called the force of cohesion. This force is lesser in liquids and least in gases.	The force of attraction between the molecules of the different substances is called the force of adhesion.
Ex. (i) Two drops of a liquid coalesce into one when brought in mutual contact. (ii) It is difficult to separate two sticky plates of glass welded with water. (iii) It is difficult to break a drop of mercury into small droplets because of large cohesive force between the mercury molecules.	Ex. (i) Adhesive force enables us to write on the blackboard with a chalk. (ii) A piece of paper sticks to another due to large force of adhesion between the paper and gum molecules. (iii) Water wets the glass surface due to force of adhesion.

Note : ❑ Cohesive or adhesive forces are inversely proportional to the eighth power of distance between the molecules.

Surface Tension

The property of a liquid due to which its free surface tries to have minimum surface area and behaves as if it were under tension somewhat like a stretched elastic membrane is called surface tension. A small liquid drop has spherical shape, as due to surface tension the liquid surface tries to have minimum surface area and for a given volume, the sphere has minimum surface area.

Surface tension of a liquid is measured by the force acting per unit length on either side of an imaginary line drawn on the free surface of liquid, the direction of this force being perpendicular to the line and tangential to the free surface of liquid. So if F is the force acting on one side of imaginary line of length L, then $T = (F/L)$

(1) It depends only on the nature of liquid and is independent of the area of surface or length of line considered.

(2) It is a scalar as it has a unique direction which is not to be specified.

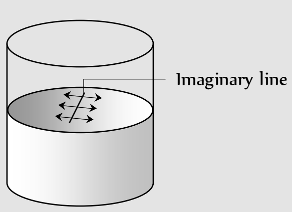
(3) Dimension : $[MT^{-2}]$. (Similar to force constant)

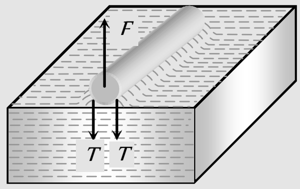
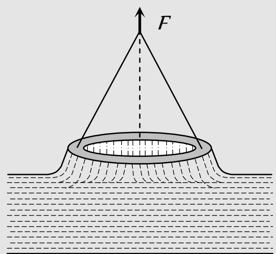
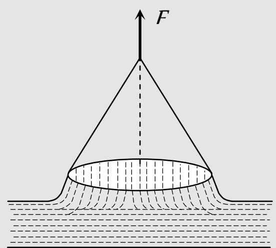
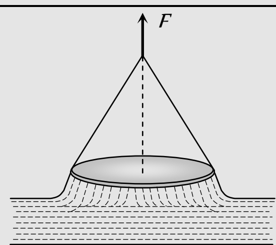
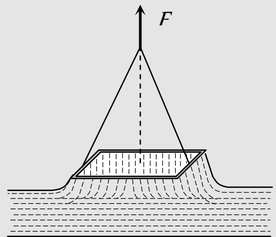
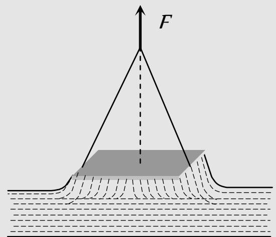
(4) Units : N/m (S.I.) and $Dyne/cm$ [C.G.S.]

(5) It is a molecular phenomenon and its root cause is the electromagnetic forces.

Force Due to Surface Tension

If a body of weight W is placed on the liquid surface, whose surface tension is T. If F is the minimum force required to pull it away from the water then value of F for different bodies can be calculated by the following table.

Body	Figure	Force
	 Fig. 10.1	

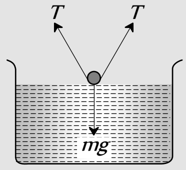
Needle (Length = l)		$F = 2lT + W$
Hollow disc (Inner radius = r_1 Outer radius = r_2)		$F = 2\pi(r_1 + r_2)T + W$
Thin ring (Radius = r)		$F = 2\pi(r + r)T + W$ $F = 4\pi rT + W$
Circular plate or disc (Radius = r)		$F = 2\pi rT + W$
Square frame (Side = l)		$F = 8lT + W$
Square plate		$F = 4lT + W$

Examples of Surface Tension

(1) When mercury is split on a clean glass plate, it forms globules. Tiny globules are spherical on the account of surface tension because force of gravity is negligible. The bigger globules get flattened from the middle but have round shape near the edges.

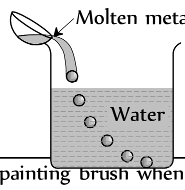
(2) When a greased iron needle is placed gently on the surface of water at rest, so that it does not prick the water surface, the needle floats on the surface of

water despite it being heavier because the weight of needle is balanced by the vertical components of the forces of surface tension. If the water

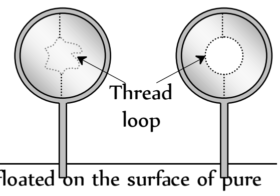


surface is pricked by one end of the needle, the needle sinks down.

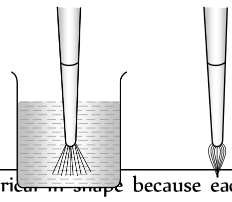
(3) When a molten metal is poured into water from a suitable height, the falling stream of metal breaks up and the detached portion of the liquid in small quantity acquire the spherical shape.



(4) Take a frame of wire and dip it in soap solution and take it out, a soap film will be formed in the frame. Place a loop of wet thread gently on the film. It will remain in the form, we place it on the film according to figure. Now, piercing the film with a pin at any point inside the loop, It immediately takes the circular form as shown in figure.



(5) Hair of shaving brush/painting brush when dipped in water spread out, but as soon as it is taken out, its hair stick together.



(6) If a small irregular piece of camphor is floated on the surface of pure water, it does not remain steady but dances about on the surface. This is because, irregular shaped camphor dissolves unequally and decreases the surface tension of the water locally. The unbalanced forces make it to move haphazardly in different directions.

(7) Rain drops are spherical in shape because each drop tends to acquire minimum surface area due to surface tension, and for a given volume, the surface area of sphere is minimum.

(8) Oil drop spreads on cold water. Whereas it may remain as a drop on hot water. This is due to the fact that the surface tension of oil is less than that of cold water and is more than that of hot water.

Factors Affecting Surface Tension

(1) **Temperature :** The surface tension of liquid decreases with rise of temperature. The surface tension of liquid is zero at its boiling point and it vanishes at critical temperature. At critical temperature, intermolecular forces for liquid and gases becomes equal and liquid can expand without any restriction. For small temperature differences, the variation in surface tension with temperature is linear and is given by the relation

$$T_t = T_0(1 - \alpha t)$$

where T_t, T_0 are the surface tensions at t^oC and 0^oC respectively and α is the temperature coefficient of surface tension.

Examples : (i) Hot soup tastes better than the cold soup.

(ii) Machinery parts get jammed in winter.

(2) **Impurities :** The presence of impurities either on the liquid surface or dissolved in it, considerably affect the surface tension, depending upon the degree of contamination. A highly soluble substance like sodium chloride when dissolved in water, increases the surface tension of water. But the sparingly soluble substances like phenol when dissolved in water, decreases the surface tension of water.

Applications of Surface Tension

(1) The oil and grease spots on clothes cannot be removed by pure water. On the other hand, when detergents (like soap) are added in water, the surface tension of water decreases. As a result of this, wetting power of soap solution increases. Also the force of adhesion between soap solution and oil or grease on the clothes increases. Thus, oil, grease and dirt particles get mixed with soap solution easily. Hence clothes are washed easily.

(2) The antiseptics have very low value of surface tension. The low value of surface tension prevents the formation of drops that may otherwise block the entrance to skin or a wound. Due to low surface tension, the antiseptics spreads properly over wound.

(3) Surface tension of all lubricating oils and paints is kept low so that they spread over a large area.

(4) Oil spreads over the surface of water because the surface tension of oil is less than the surface tension of cold water.

(5) A rough sea can be calmed by pouring oil on its surface.

(6) In soldering, addition of 'flux' reduces the surface tension of molten tin, hence, it spreads.

Molecular Theory of Surface Tension

The maximum distance upto which the force of attraction between two molecules is appreciable is called molecular range $(\approx 10^{-9} m)$. A sphere with a molecule as centre and radius equal to molecular range is called the sphere of influence. The liquid enclosed between free surface (PQ) of the liquid and an imaginary plane (RS) at a distance r (equal to molecular range) from the free surface of the liquid form a liquid film.

To understand the concept of tension acting on the free surface of a liquid, let us consider four liquid molecules like A, B, C and D. Their sphere of influence are shown in the figure.

(1) Molecule A is well within the liquid, so it is attracted equally in all directions. Hence the net force on this molecule is zero and it moves freely inside the liquid.

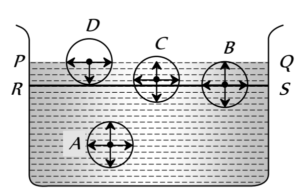


Fig. 10.2

(2) Molecule B is little below the free surface of the liquid and it is also attracted equally in all directions. Hence the resultant force acts on it is also zero.

(3) Molecule C is just below the upper surface of the liquid film and the part of its sphere of influence is outside the free liquid surface. So the number of molecules in the upper half (attracting the molecules upward) is less than the number of molecule in the lower half (attracting the molecule downward). Thus the molecule C experiences a net downward force.

(4) Molecule D is just on the free surface of the liquid. The upper half of the sphere of influence has no liquid molecule. Hence the molecule D experiences a maximum downward force.

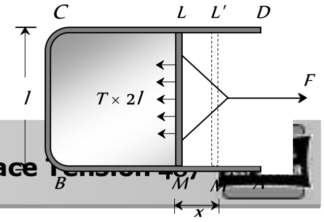


Fig. 10.3

Thus all molecules lying on surface film experiences a net downward force. Therefore, free surface of the liquid behaves like a stretched membrane.

Surface Energy

The molecules on the liquid surface experience net downward force. So to bring a molecule from the interior of the liquid to the free surface, some work is required to be done against the intermolecular force of attraction, which will be stored as potential energy of the molecule on the surface. The potential energy of surface molecules per unit area of the surface is called surface energy.

Unit : *Joule/m* (S.I.) *erg/cm* (C.G.S.)

Dimension : $[MT^{-2}]$

If a rectangular wire frame *ABCD*, equipped with a sliding wire *LM* dipped in soap solution, a film is formed over the frame. Due to the surface tension, the film will have a tendency to shrink and thereby, the sliding wire *LM* will be pulled in inward direction. However, the sliding wire can be held in this position under a force *F*, which is equal and opposite to the force acting on the sliding wire *LM* all along its length due to surface tension in the soap film.

If T is the force due to surface tension per unit length, then $F = T \times 2l$

Here l is length of the sliding wire *LM*. The length of the sliding wire has been taken as $2l$ for the reason that the film has got two free surfaces.

Suppose that the sliding wire *LM* is moved through a small distance *x*, so as to take the position $L'M'$. In this process, area of the film increases by $2l \times x$ (on the two sides) and to do so, the work done is given by

$$W = F \times x = (T \times 2l) \times x = T \times (2lx) = T \times \Delta A$$

$$\therefore \quad W = T \times \Delta A \qquad [\Delta A = \text{Total increase in area of the film}]$$

If temperature of the film remains constant in this process, this work done is stored in the film as its surface energy.

From the above expression $T = \dfrac{W}{\Delta A}$ or $T = W$ [If $\Delta A = 1$]

i.e. surface tension may be defined as the amount of work done in increasing the area of the liquid surface by unity against the force of surface tension at constant temperature.

Work Done in Blowing a Liquid Drop or Soap Bubble

(1) If the initial radius of liquid drop is r_1 and final radius of liquid drop is r_2 then

$W = T \times$ Increment in surface area

$W = T \times 4\pi[r_2^2 - r_1^2]$ [drop has only one free surface]

(2) In case of soap bubble

$W = T \times 8\pi[r_2^2 - r_1^2]$ [Bubble has two free surfaces]

Splitting of Bigger Drop

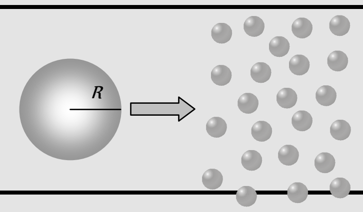
When a drop of radius R splits into n smaller drops, (each of radius r) then surface area of liquid increases. Hence the work is to be done against surface tension.

Since the volume of liquid remains constant therefore

$$\frac{4}{3}\pi R^3 = n\frac{4}{3}\pi r^3 \quad \therefore \; R^3 = nr^3$$

Work done $= T \times \Delta A = T \times$ [Total final surface area of n drops – surface area of big drop] $= T[n4\pi r^2 - 4\pi R^2]$

Various formulae of work done			
$4\pi T[nr^2 - R^2]$	$4\pi R^2 T[n^{1/3} - 1]$	$4\pi T r^2 n^{2/3}[n^{1/3} - 1]$	$4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$



If the work is not done by an external source then internal energy of liquid decreases, subsequently temperature decreases. This is the reason why spraying causes cooling.

By conservation of energy, Loss in thermal energy = work done against surface tension

$$JQ = W$$

$$\Rightarrow \quad JmS\,\Delta\theta = 4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\Rightarrow J\frac{4}{3}\pi R^3 d\, S\Delta\theta = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\left[\text{As } m = V \times d = \frac{4}{3}\pi R^3 \times d\right]$$

$$\therefore \text{ Decrease in temperature } \Delta\theta = \frac{3T}{JSd}\left[\frac{1}{r} - \frac{1}{R}\right]$$

where J = mechanical equivalent of heat, S = specific heat of liquid, d = density of liquid.

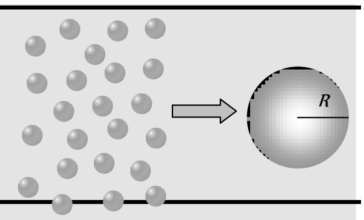
Formation of Bigger Drop

If n small drops of radius r coalesce to form a big drop of radius R then surface area of the liquid decreases.

Amount of surface energy released = Initial surface energy – final surface energy

$$E = n4\pi r^2 T - 4\pi R^2 T$$

Various formulae of released energy			
$4\pi T[nr^2 - R^2]$	$4\pi R^2 T(n^{1/3} - 1)$	$4\pi T r^2 n^{2/3}(n^{1/3} - 1)$	$4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$



(i) If this released energy is absorbed by a big drop, its temperature increases and rise in temperature can be given by $\Delta\theta = \frac{3T}{JSd}\left[\frac{1}{r} - \frac{1}{R}\right]$

(ii) If this released energy is converted into kinetic energy of a big drop without dissipation then by the law of conservation of energy.

$$\frac{1}{2}mv^2 = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\Rightarrow \frac{1}{2}\left[\frac{4}{3}\pi R^3 d\right]v^2 = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

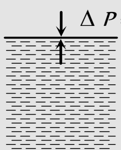
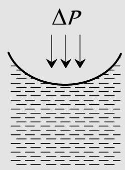
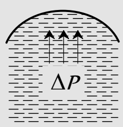
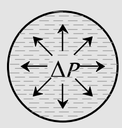
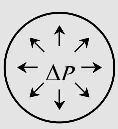
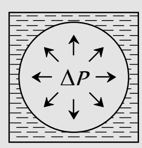
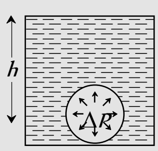
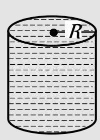
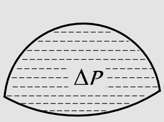
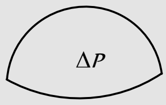
$$\Rightarrow v^2 = \frac{6T}{d}\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\therefore v = \sqrt{\frac{6T}{d}\left(\frac{1}{r} - \frac{1}{R}\right)}$$

Excess Pressure

Due to the property of surface tension a drop or bubble tends to contract and so compresses the matter enclosed. This in turn increases the internal pressure which prevents further contraction and equilibrium is achieved. So in equilibrium the pressure inside a bubble or drop is greater than outside and the difference of pressure between two sides of the liquid surface is called excess pressure. In case of a drop, excess pressure is provided by hydrostatic pressure of the liquid within the drop while in case of bubble the gauge pressure of the gas confined in the bubble provides it.

Excess pressure in different cases is given in the following table :

Plane surface	Concave surface
 $\Delta P = 0$	 $\Delta P = \frac{2T}{R}$
Convex surface	**Drop**
 $\Delta P = \frac{2T}{R}$	 $\Delta P = \frac{2T}{R}$
Bubble in air	**Bubble in liquid**
 $\Delta P = \frac{4T}{R}$	 $\Delta P = \frac{2T}{R}$
Bubble at depth *h* below the free surface of liquid of density *d*	**Cylindrical liquid surface**
 $\Delta P = \frac{2T}{R} + hdg$	 $\Delta P = \frac{T}{R}$
Liquid surface of unequal radii	**Liquid film of unequal radii**
 $\Delta P = T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$	 $\Delta P = 2T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$

Note : ❑ Excess pressure is inversely proportional to the radius of bubble (or drop), *i.e.*, pressure inside a smaller bubble (or drop) is higher than inside a larger bubble (or drop). That is why when two bubbles of different sizes are put in communication with each other, the air will rush from smaller to larger bubble, so that the smaller will shrink while the larger will expand till the smaller bubble reduces to droplet.

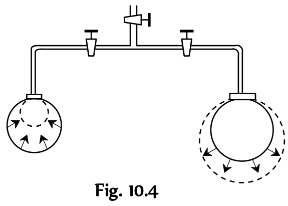


Fig. 10.4

Shape of Liquid Meniscus

We know that a liquid assumes the shape of the vessel in which it is contained *i.e.* it can not oppose permanently any force that tries to change its shape. As the effect of force is zero in a direction perpendicular to it, the free surface of liquid at rest adjusts itself at right angles to the resultant force.

When a capillary tube is dipped in a liquid, the liquid surface becomes curved near the point of contact. This curved surface is due to the resultant of two forces *i.e.* the force of cohesion and the force of adhesion. The curved surface of the liquid is called meniscus of the liquid.

If liquid molecule A is in contact with solid (*i.e.* wall of capillary tube) then forces acting on molecule A are

(i) Force of adhesion F_a (acts outwards at right angle to the wall of the tube).

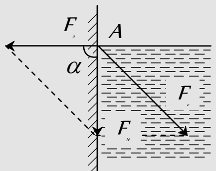
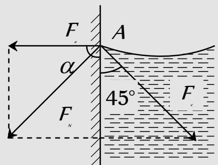
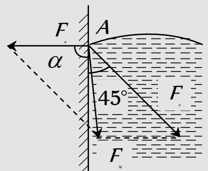
(ii) Force of cohesion F_c (acts at an angle 45° to the vertical).

Resultant force F_R depends upon the value of F_a and F_c.

If resultant force F_R make an angle α with F_a.

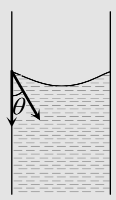
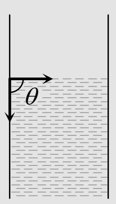
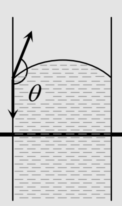
Then $\tan\alpha = \dfrac{F_c \sin 135^o}{F_a + F_c \cos 135^o} = \dfrac{F_c}{\sqrt{2}\,F_a - F_c}$

By knowing the direction of resultant force we can find out the shape of meniscus because the free surface of the liquid adjust itself at right angle to this resultant force.

If $F_c = \sqrt{2}Fa$	$F_c < \sqrt{2}Fa$	$F_c > \sqrt{2}Fa$
$\tan\alpha = \infty$ ∴ $\alpha = 90°$ *i.e.* the resultant force acts vertically downwards. Hence the liquid meniscus must be horizontal.	$\tan\alpha$ = positive ∴ α is acute angle *i.e.* the resultant force directed outside the liquid. Hence the liquid meniscus must be concave upward.	$\tan\alpha$ = negative ∴ α is obtuse angle *i.e.* the resultant force directed inside the liquid. Hence the liquid meniscus must be convex upward.
		
Example: Pure water in silver coated capillary tube.	Example: Water in glass capillary tube.	Example: Mercury in glass capillary tube.

Angle of Contact

Angle of contact between a liquid and a solid is defined as the angle enclosed between the tangents to the liquid surface and the solid surface inside the liquid, both the tangents being drawn at the point of contact of the liquid with the solid.

$\theta < 90°$ $F_a > \dfrac{F_c}{\sqrt{2}}$ concave meniscus. Liquid wets the solid surface	
$\theta = 90°$ $F_a = \dfrac{F_c}{\sqrt{2}}$ plane meniscus. Liquid does not wet the solid surface.	
$\theta > 90°$ $F_a < \dfrac{F_c}{\sqrt{2}}$ convex meniscus. Liquid does not wet the solid surface.	

(i) Its value lies between 0° and 180°

$\theta = 0^o$ for pure water and glass, $\theta = 8^o$ for tap water and glass, $\theta = 90^o$ for water and silver

$\theta = 138^o$ for mercury and glass, $\theta = 160^o$ for water and chromium

(ii) It is particular for a given pair of liquid and solid. Thus the angle of contact changes with the pair of solid and liquid.

(iii) It does not depends upon the inclination of the solid in the liquid.

(iv) On increasing the temperature, angle of contact decreases.

(v) Soluble impurities increases the angle of contact.

(vi) Partially soluble impurities decreases the angle of contact.

Capillarity

If a tube of very narrow bore (called capillary) is dipped in a liquid, it is found that the liquid in the capillary either ascends or descends relative to the surrounding liquid. This phenomenon is called capillarity.

The root cause of capillarity is the difference in pressures on two sides of (concave and convex) curved surface of liquid.

Examples of capillarity :

(i) Ink rises in the fine pores of blotting paper leaving the paper dry.

(ii) A towel soaks water.

(iii) Oil rises in the long narrow spaces between the threads of a wick.

(iv) Wood swells in rainy season due to rise of moisture from air in the pores.

(v) Ploughing of fields is essential for preserving moisture in the soil.

(vi) Sand is drier soil than clay. This is because holes between the sand particles are not so fine as compared to that of clay, to draw up water by capillary action.

Ascent Formula

When one end of capillary tube of radius r is immersed into a liquid of density d which wets the sides of the capillary tube (water and capillary tube of glass), the shape of the liquid meniscus in the tube becomes concave upwards.

R = radius of curvature of liquid meniscus.

T = surface tension of liquid

P = atmospheric pressure

Pressure at point A = P, Pressure at point B = $P - \frac{2T}{R}$

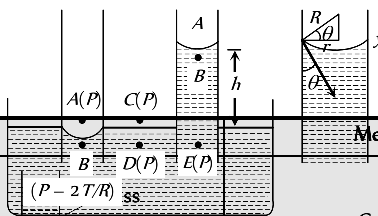


Fig. 10.5

Pressure at points C and D just above and below the plane surface of liquid in the vessel is also P (atmospheric pressure). The points B and D are in the same horizontal plane in the liquid but the pressure at these points is different.

In order to maintain the equilibrium the liquid level rises in the capillary tube upto height h.

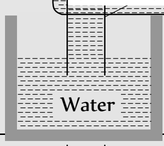
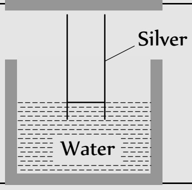
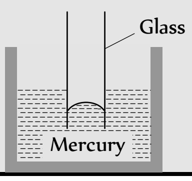
Pressure due to liquid column = pressure difference due to surface tension

$$\Rightarrow hdg = \frac{2T}{R}$$

$$\therefore\ h = \frac{2T}{Rdg} = \frac{2T\cos\theta}{rdg} \qquad \left[\text{As } R = \frac{r}{\cos\theta}\right]$$

(i) The capillary rise depends on the nature of liquid and solid both *i.e.* on T, d, θ and R.

(ii) Capillary action for various liquid-solid pair.

	Meniscus	Angle of contact	Level
	Concave	$\theta < 90^\circ$	Rises
	Plane	$\theta = 90^\circ$	No rise, no fall
	Convex	$\theta > 90^\circ$	Fall

(iii) For a given liquid and solid at a given place

$$h \propto \frac{1}{r} \qquad [\text{As } T, \theta, d \text{ and } g \text{ are constant}]$$

i.e. lesser the radius of capillary greater will be the rise and vice-versa. This is called **Jurin's law**.

(iv) If the weight of the liquid contained in the meniscus is taken into consideration then more accurate ascent formula is given by

$$h = \frac{2T\cos\theta}{rdg} - \frac{r}{3}$$

(v) In case of capillary of insufficient length *i.e.* $L < h$, the liquid will neither overflow from the upper end like a fountain nor will it tickle along the vertical sides of the tube. The liquid after reaching the upper end will increase the radius of its meniscus without changing nature such that :

$hr = Lr'$ $\quad\because\ L < h \therefore\ r' > r$

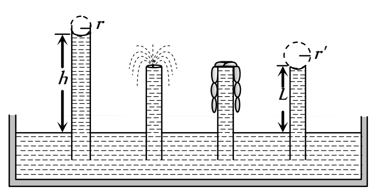


Fig. 10.6

(vi) If a capillary tube is dipped into a liquid and tilted at an angle α from vertical, then the vertical height of liquid column remains same whereas the length of liquid column (l) in the capillary tube increases.

$$h = l\cos\alpha \quad \text{or} \quad l = \frac{h}{\cos\alpha}$$

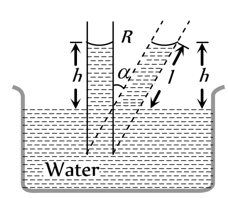


Fig. 10.7

(vii) It is important to note that in equilibrium, the height h is independent of the shape of capillary if the radius of meniscus remains the same. That is why the vertical height h of a liquid column in capillaries of different shapes and sizes will be same if the radius of meniscus remains the same.

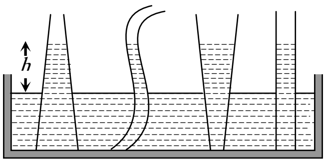


Fig. 10.8

Shape of Drops

Whether the liquid will be in equilibrium in the form of a drop or it will spread out; depends on the relative strength of the force due to surface tension at the three interfaces.

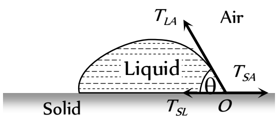


Fig. 10.9

T_{LA} = surface tension at liquid-air interface, T_{SA} = surface tension at solid-air interface.

T_{SL} = surface tension at solid-liquid interface, θ = angle of contact between the liquid and solid.

For the equilibrium of molecule

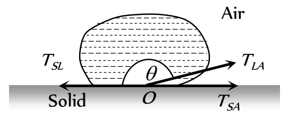


Fig. 10.10

$T_{SL} + T_{LA}\cos\theta = T_{SA}$ or $\cos\theta = \dfrac{T_{SA} - T_{SL}}{T_{LA}}$

Special Cases

$T_{SA} > T_{SL}$, $\cos\theta$ is positive *i.e.* $0^o < \theta < 90^o$.

This condition is fulfilled when the molecules of liquid are strongly attracted to that of solid.

Example : (i) Water on glass.

(ii) Kerosene oil on any surface.

$T_{SA} < T_{SL}$, $\cos\theta$ is negative *i.e.* $90^o < \theta < 180^o$.

This condition is fulfilled when the molecules of the liquid are strongly attracted *to* themselves and weakly *w.r.t.* that of solid.

Example : (i) Mercury on glass surface.

(ii) Water on lotus leaf (or a waxy or oily surface)

$(T_{SL} + T_{LA}\cos\theta) > T_{SA}$

In this condition, the molecule of liquid will not be in equilibrium and experience a net force at the interface. As a result, the liquid spreads.

Example : (i) Water on a clean glass plate.

Useful Facts and Formulae

(1) **Formation of double bubble** : If r_1 and r_2 are the radii of smaller and larger bubble and P_0 is the atmospheric pressure, then the pressure inside them will be $P_1 = P_0 + \dfrac{4T}{r_1}$ and $P_2 = P_0 + \dfrac{4T}{r_2}$.

Now as $r_1 < r_2$ $\therefore$ $P_1 > P_2$

So for interface

$$\Delta P = P_1 - P_2 = 4T\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \quad ...(i)$$

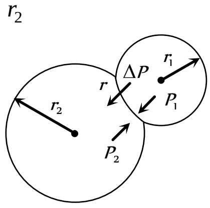


Fig. 10.11

As excess pressure acts from concave to convex side, the interface will be concave towards the smaller bubble and convex towards larger bubble and if r is the radius of interface.

$$\Delta P = \frac{4T}{r} \quad ...(ii)$$

From (i) and (ii) $\dfrac{1}{r} = \dfrac{1}{r_1} - \dfrac{1}{r_2}$

$\therefore$ Radius of the interface $r = \dfrac{r_1 r_2}{r_2 - r_1}$

(2) **Formation of a single bubble**

(i) Under isothermal condition two soap bubble of radii '*a*' and '*b*' coalesce to form a single bubble of radius '*c*'.

If the external pressure is P_0 then pressure inside bubbles

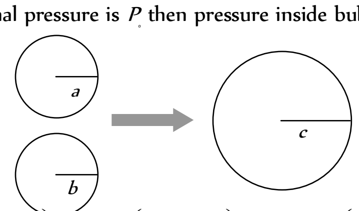


Fig. 10.12

$P_a = \left(P_0 + \dfrac{4T}{a}\right)$, $P_b = \left(P_0 + \dfrac{4T}{b}\right)$ and $P_c = \left(P_0 + \dfrac{4T}{c}\right)$

and volume of the bubbles

$V_a = \dfrac{4}{3}\pi a^3$, $V_b = \dfrac{4}{3}\pi b^3$, $V_c = \dfrac{4}{3}\pi c^3$

Now as mass is conserved $\mu_a + \mu_b = \mu_c$

$$\Rightarrow \frac{P_aV_a}{RT_a}+\frac{P_bV_b}{RT_b}=\frac{P_cV_c}{RT_c}$$

$$\left[\text{As } PV=\mu RT,\ \ i.e.,\ \mu=\frac{PV}{RT}\right]$$

$$\Rightarrow P_aV_a+P_bV_b=P_cV_c \qquad ...(i)$$

[As temperature is constant, *i.e.*, $T_a=T_b=T_c$]

Substituting the value of pressure and volume

$$\Rightarrow \left[P_0+\frac{4T}{a}\right]\left[\frac{4}{3}\pi a^3\right]+\left[P_0+\frac{4T}{b}\right]\left[\frac{4}{3}\pi b^3\right]$$

$$=\left[P_0+\frac{4T}{c}\right]\left[\frac{4}{3}\pi c^3\right]$$

$$\Rightarrow 4T(a^2+b^2-c^2)=P_0(c^3-a^3-b^3)$$

$\therefore$ Surface tension of the liquid $T=\dfrac{P_0(c^3-a^3-b^3)}{4(a^2+b^2-c^2)}$

(ii) If two bubble coalesce in vacuum then by substituting $P_0=0$ in the above expression we get

$$a^2+b^2-c^2=0 \quad \therefore\ c^2=a^2+b^2$$

Radius of new bubble $=c=\sqrt{a^2+b^2}$ or can be expressed as $r=\sqrt{r_1^2+r_2^2}$.

(3) The difference of levels of liquid column in two limbs of *U*-tube of unequal radii r_1 and r_2 is

$$h=h_1-h_2=\frac{2T\cos\theta}{dg}\left[\frac{1}{r_1}-\frac{1}{r_2}\right]$$

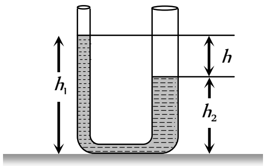


Fig. 10.13

(4) A large force (*F*) is required to draw apart two glass plate normally enclosing a thin water film because the thin water film formed between the two glass plates will have concave surface all around. Since on the concave side of a liquid surface, pressure is more, work will have to be done in drawing the plates apart.

$F=\dfrac{2AT}{t}$ where *T*= surface tension of water film, *t*= thickness of film, *A* = area of film.

(5) When a soap bubble is charged, then its size increases due to outward force on the bubble.

(6) The materials, which when coated on a surface and water does not enter through that surface are known as water proofing agents. For example wax *etc*. Water proofing agent increases the angle of contact.

(7) Values of surface tension of some liquids.

Liquid	Surface tension *Newton/metre*
Mercury	0.465
Water	0.075
Soap solution	0.030
Glycerine	0.063
Carbon tetrachloride	0.027
Ethyl alcohol	0.022

Tips & Tricks

✍ Surface tension does not depend on the area of the surface.

✍ When there is no external force, the shape of a liquid drop is determined by the surface tension of the liquid.

✍ Soap helps in better cleaning of clothes because it reduces the surface tension of the liquid.

✍ If a beaker is filled with liquid of density ρ upto a height *h*, then the mean pressure on the walls of the beaker is $h\rho g/2$.

✍ The pressure on the concave side of a curved surface is always greater than that on its convex side.

✍ Molecular forces do not obey the inverse square law of distance.

✍ The molecular forces are of electrical origin.

✍ Work done in forming a soap bubble of radius *R* is $8\pi R^2T$, where $T=$ surface tension.

✍ Energy is always required to split a drop of liquid into a number of small drops. It is because, the surface area of the small drops formed is greater than the surface area of the original single drop.

✍ Work done in breaking a drop of radius *R* into *n* drops of equal size $=4\pi R^2T(n^{1/3}-1)$.

Same amount of energy is liberated in combining *n* drops into a single drop.

✍ When the liquid drops merge into each other to form a larger drop, energy is released.

✍ Surface tension of molten cadmium increases with the increases in temperature.

✍ Detergents decrease both the angle of contact as well as surface tension.

✍ Angle of contact is independent of the angle of inclination of the walls.

✍ The materials used for water proofing increases the angle of contact as well as surface tension.

✍ A liquid does not wet the containing vessel if its angle of contact is obtuse.

✍ In case of liquids which do not wet the walls of the containing vessel, the force of adhesion is less than $1/\sqrt{2}$ times the force of cohesion.

✍ The liquid rises in a capillary tube, when the angle of contact is acute.

✍ The height of the liquid column in a capillary tube on the moon is six times that on the earth.

✍ Angle of contact between a liquid and a solid surface. Increases with increase in temperature of the liquid and decreases on adding impurity to the liquid.

✍ For a liquid – solid interface, if the angle of contact is acute, then

(i) The liquid will wet the solid.

(ii) The liquid will rise in the capillary tube made of such a solid and

(iii) Meniscus of the liquid will be concave.

✍ In case the angle of contact is obtuse, then

(i) The liquid will not wet the solid.

(ii) The liquid will get depressed in the tube and

(iii) Meniscus of the liquid will be convex.

✍ When the capillary tube is of insufficient length, the liquid will not overflow. It rises upto the top end of the tube and then adjusts the radius of curvature of its meniscus.

Ordinary Thinking

Objective Questions

Surface Tension

1. The value of surface tension of a liquid at critical temperature is
   (a) Zero (b) Infinite
   (c) Between 0 and ∞ (d) Can not be determined
2. The spherical shape of rain-drop is due to [CPMT 1976, 90; NCERT 1982; AIIMS 1998; MH CET 2000; DCE 1999; AFMC 1999; CPMT 2001; AFMC 2001]
   (a) Density of the liquid (b) Surface tension
   (c) Atmospheric pressure (d) Gravity
3. Surface tension is due to
   (a) Frictional forces between molecules
   (b) Cohesive forces between molecules
   (c) Adhesive forces between molecules
   (d) Gravitational forces
4. When there is no external force, the shape of a liquid drop is determined by [CPMT 1988, 86; DPMT 1982]
   (a) Surface tension of the liquid
   (b) Density of liquid
   (c) Viscosity of liquid
   (d) Temperature of air only
5. Soap helps in cleaning clothes, because [DPMT 1983, 2001]
   (a) Chemicals of soap change
   (b) It increases the surface tension of the solution
   (c) It absorbs the dirt
   (d) It lowers the surface tension of the solution
6. A pin or a needle floats on the surface of water, the reason for this is [MP PET/PMT 1988; CPMT 1975]
   (a) Surface tension (b) Less weight
   (c) Upthrust of liquid (d) None of the above
7. Coatings used on raincoat are waterproof because
   (a) Water is absorbed by the coating
   (b) Cohesive force becomes greater
   (c) Water is not scattered away by the coating
   (d) Angle of contact decreases
8. If temperature increases, the surface tension of a liquid [MP PMT 1994; EAMCET (Engg.) 1995; RPET 2003]
   (a) Increases (b) Decreases
   (c) Remains the same (d) Increases then decreases
9. A drop of oil is placed on the surface of water. Which of the following statement is correct [NCERT 1976; DPMT 1982]
   (a) It will remain on it as a sphere
   (b) It will spread as a thin layer
   (c) It will be partly as spherical droplets and partly as thin film
   (d) It will float as a distorted drop on the water surface
10. The temperature at which the surface tension of water is zero
   (a) $0°C$ (b) 277 K
   (c) $370°C$ (d) Slightly less than 647 K
11. A small air bubble is at the inner surface of the bottom of a beaker filled with cold water. Now water of the beaker is heated. The size of bubble increases. The reason for this may be
   (a) Increase in the saturated vapour pressure of water
   (b) Root mean square velocity of air molecules inside the bubble increases
   (c) Decrease in surface tension of water
   (d) All of the above
12. The spiders and insects move and run about on the surface of water without sinking because
   (a) Elastic membrane is formed on water due to property of surface tension [AIIMS 1980]
   (b) Spiders and insects are lighter
   (c) Spiders and insects swim on water
   (d) Spider and insects experience upthrust
13. Small droplets of a liquid are usually more spherical in shape than larger drops of the same liquid because [EAMCET 1988]
   (a) Force of surface tension is equal and opposite to the force of gravity
   (b) Force of surface tension predominates the force of gravity
   (c) Force of gravity predominates the force of surface tension
   (d) Force of gravity and force of surface tension act in the same direction and are equal
14. Hairs of shaving brush cling together when it is removed from water due to
   (a) Force of attraction between hair
   (b) Surface tension
   (c) Viscosity of water
   (d) Characteristic property of hairs
15. A square frame of side L is dipped in a liquid. On taking out, a membrane is formed. If the surface tension of the liquid is T, the force acting on the frame will be [MP PMT 1990; DPMT 2004]
   (a) 2 TL (b) 4 TL
   (c) 8 TL (d) 10 TL
16. Water does not wet an oily glass because
   (a) Cohesive force of oil>> adhesive force between oil and glass
   (b) Cohesive force of oil > cohesive force of water
   (c) Oil repels water
   (d) Cohesive force for water > adhesive force between water and oil molecules
17. A water drop takes the shape of a sphere in a oil while the oil drop spreads in water, because
   (a) C.F. for water > A.F. for water and oil
   (b) C.F. for oil > A.F. for water and oil
   (c) C.F. for oil < A.F. for water and oil
   (d) None of the above
   (A.F. = adhesive force C.F. = cohesive force)
18. Which of the fact is not due to surface tension
   (a) Dancing of a camphor piece over the surface of water
   (b) Small mercury drop itself becomes spherical
   (c) A liquid surface comes at rest after stirring
   (d) Mercury does not wet the glass vessel
19. In the glass capillary tube, the shape of the surface of the liquid depends upon [MP PMT 1989]
   (a) Only on the cohesive force of liquid molecules

(b) Only on the adhesive force between the molecules of glass and liquid

(c) Only on relative cohesive and adhesive force between the atoms

(d) Neither on cohesive nor on adhesive force

20. Force necessary to pull a circular plate of 5 *cm* radius from water surface for which surface tension is 75 *dynes/cm*, is [MP PMT 1991]

(a) $30 dyne$ (b) 60 *dynes*

(c) 750 *dynes* (d) 750 π *dynes*

21. The property of surface tension is obtained in

(a) Solids, liquids and gases (b) Liquids

(c) Gases (d) Matter

22. The surface tension of a liquid [MNR 1990]

(a) Increases with area

(b) Decreases with area

(c) Increase with temperature

(d) Decrease with temperature

23. If two glass plates are quite nearer to each other in water, then there will be force of

(a) Attraction (b) Repulsion

(c) Attraction or repulsion (d) None of the above

24. On mixing the salt in water, the surface tension of water will

(a) Increase (b) Decrease

(c) Remain unchanged (d) None of the above

25. The maximum force, in addition to the weight required to pull a wire of 5.0 *cm* long from the surface of water at temperature 20°*C*, is 728 *dynes*. The surface tension of water is

(a) 7.28 *N/cm* (b) 7.28 *dyne/cm*

(c) 72.8 *dyne/cm* (d) 7.28×10² *dyne/cm*

26. Consider a liquid contained in a vessel. The liquid solid adhesive force is very weak as compared to the cohesive force in the liquid. The shape of the liquid surface near the solid shall be

(a) Horizontal (b) Almost vertical

(c) Concave (d) Convex

27. At which of the following temperatures, the value of surface tension of water is minimum [MP PMT/PET 1998]

(a) 4°C (b) 25°C

(c) 50°C (d) 75°C

28. If a glass rod is dipped in mercury and withdrawn out, the mercury does not wet the rod because [MP PET 1995]

(a) Angle of contact is acute

(b) Cohesion force is more

(c) Adhesion force is more

(d) Density of mercury is more

29. Mercury does not wet glass, wood or iron because [MP PET 1997]

(a) Cohesive force is less than adhesive force

(b) Cohesive force is greater than adhesive force

(c) Angle of contact is less than 90°

(d) Cohesive force is equal to adhesive force

30. Surface tension of a liquid is found to be influenced by [ISM Dhanbad 1994]

(a) It increases with the increase of temperature

(b) Nature of the liquid in contact

(c) Presence of soap that increases it

(d) Its variation with the concentration of the liquid

31. When a drop of water is dropped on oil surface, then [RPMT 1997]

(a) It will mix up with oil

(b) It spreads in the form of a film

(c) It will deform

(d) It remains spherical

32. Two pieces of glass plate one upon the other with a little water in between them cannot be separated easily because of

(a) Inertia (b) Pressure

(c) Surface tension (d) Viscosity

33. Small liquid drops assume spherical shape because [JIPMER 1997]

(a) Atmospheric pressure exerts a force on a liquid drop

(b) Volume of a spherical drop is minimum

(c) Gravitational force acts upon the drop

(d) Liquid tends to have the minimum surface area due to surface tension

34. A thin metal disc of radius r floats on water surface and bends the surface downwards along the perimeter making an angle θ with vertical edge of the disc. If the disc displaces a weight of water W and surface tension of water is T, then the weight of metal disc is

(a) $2\pi rT + W$ (b) $2\pi rT\cos\theta - W$

(c) $2\pi r\text{T}\cos\theta + W$ (d) $W - 2\pi rT\cos\theta$

35. A 10 *cm* long wire is placed horizontally on the surface of water and is gently pulled up with a force of 2 ×10⁻² *N* to keep the wire in equilibrium. The surface tension, in *Nm*⁻¹, of water is

(a) 0.1 (b) 0.2

(c) 0.001 (d) 0.002

36. It is easy to wash clothes in hot water because its [RPMT 2000]

(a) Surface tension is more

(b) Surface tension is less

(c) Consumes less soap

(d) None of these

37. Due to which property of water, tiny particles of camphor dance on the surface of water [MNR 1994] [RPMT 1999]

(a) Viscosity (b) Surface tension

(c) Weight (d) Floating force

38. The force required to separate two glass plates of area $10^{-2} m^2$ with a film of water 0.05 *mm* thick between them, is (Surface tension of water is 70×10^{-3} *N/m*) [KCET 2000; Pb. PET 2001: RPET 2002]

(a) 28 *N* (b) 14 *N*

(c) 50 *N* (d) 38 *N*

39. Oil spreads over the surface of water whereas water does not spread over the surface of the oil, due to [MH CET 2001]

(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

40. Cohesive force is experienced between [MH CET 2001]

(a) Magnetic substances

(b) Molecules of different substances

(c) Molecules of same substances

(d) None of these

41. The property utilized in the manufacture of lead shots is [AIIMS 2002]

(a) Specific weight of liquid lead
(b) Specific gravity of liquid lead
(c) Compressibility of liquid lead
(d) Surface tension of liquid lead

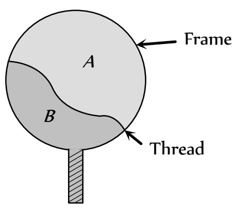
42. The dimensions of surface tension are [MH CET 2002]

(a) $[MLT^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^0T^{-2}]$ (d) $[ML^{-1}T^{-2}]$

43. A wooden stick $2m$ long is floating on the surface of water. The surface tension of water 0.07 *N/m*. By putting soap solution on one side of the sticks the surface tension is reduced to 0.06 *N/m*. The net force on the stick will be [Pb. PMT 2002]

(a) 0.07 *N* (b) 0.06 *N*
(c) 0.01 *N* (d) 0.02 *N*

44. A thread is tied slightly loose to a wire frame as in figure and the frame is dipped into a soap solution and taken out. The frame is completely covered with the film. When the portion *A* punctured with a pin, the thread. [KCET 2004]



(a) Becomes concave toward *A*
(b) Becomes convex towards *A*
(c) Remains in the initial position
(d) Either (a) or (b) depending on the size of *A w.r.t. B*

45. The force required to take away a flat circular plate of radius 2 *cm* from the surface of water, will be (the surface tension of water is 70 *dyne/cm*) [Pb. PET 2001]

(a) 280π *dyne* (b) 250π *dyne*
(c) 140π *dyne* (d) 210π *dyne*

46. Surface tension may be defined as [CPMT 1990]

(a) The work done per unit area in increasing the surface area of a liquid under isothermal condition
(b) The work done per unit area in increasing the surface area of a liquid under adiabatic condition
(c) The work done per unit area in increasing the surface area of a liquid under both isothermal and adiabatic conditions
(d) Free surface energy per unit volume

Surface Energy

1. Energy needed in breaking a drop of radius *R* into *n* drops of radii *r* is given by [CPMT 1982, 97]

(a) $4\pi T(nr^2 - R^2)$ (b) $\frac{4}{3}\pi(r^3n - R^2)$
(c) $4\pi T(R^2 - nr^2)$ (d) $4\pi T(nr^2 + R^2)$

2. The potential energy of a molecule on the surface of liquid compared to one inside the liquid is [MP PMT 1993]

(a) Zero (b) Smaller
(c) The same (d) Greater

3. Two droplets merge with each other and forms a large droplet. In this process [CBSE PMT 1993; RPMT 1997, 2000; CPMT 2001; BHU 2001; AFMC 2002]

(a) Energy is liberated
(b) Energy is absorbed
(c) Neither liberated nor absorbed
(d) Some mass is converted into energy

4. A drop of liquid of diameter 2.8 *mm* breaks up into 125 identical drops. The change in energy is nearly (S.T. of liquid =75 *dynes/cm*)

(a) Zero (b) 19 *erg*
(c) 46 *erg* (d) 74 *erg*

5. Radius of a soap bubble is '*r*', surface tension of soap solution is *T*. Then without increasing the temperature, how much energy will be needed to double its radius [CPMT 1991; Pb. PMT 2000; RPET 2001]

(a) $4\pi r^2T$ (b) $2\pi r^2T$
(c) $12\pi r^2T$ (d) $24\pi r^2T$

6. Work done in splitting a drop of water of 1 mm radius into 10^6 droplets is (Surface tension of water $= 72\times10^{-3}\ J/m^2$) [MP PET/PMT 1988; CPMT 1989; RPET 2001]

(a) $9.58\times10^{-5}\ J$ (b) $8.95\times10^{-5}\ J$
(c) $5.89\times10^{-5}\ J$ (d) $5.98\times10^{-6}\ J$

7. A spherical liquid drop of radius *R* is divided into eight equal droplets. If surface tension is *T*, then the work done in this process will be [CPMT 1990]

(a) $2\pi R^2T$ (b) $3\pi R^2T$
(c) $4\pi R^2T$ (d) $2\pi RT^2$

8. The amount of work done in blowing a soap bubble such that its diameter increases from *d* to *D* is (*T*= surface tension of the solution) [MP PMT 1996]

(a) $4\pi(D^2 - d^2)T$ (b) $8\pi(D^2 - d^2)T$
(c) $\pi(D^2 - d^2)T$ (d) $2\pi(D^2 - d^2)T$

9. If *T* is the surface tension of soap solution, the amount of work done in blowing a soap bubble from a diameter *D* to 2*D* is

(a) $2\pi D^2T$ (b) $4\pi D^2T$
(c) $6\pi D^2T$ (d) $8\pi D^2T$

10. The radius of a soap bubble is increased from $\frac{1}{\sqrt{\pi}}$ *cm* to $\frac{2}{\sqrt{\pi}}$ *cm*. If the surface tension of water is 30 *dynes* per *cm*, then the work done will be [MP PMT 1986]

(a) 180 *ergs* (b) 360 *ergs*
(c) 720 *ergs* (d) 960 *ergs*

11. The surface tension of a liquid is 5 *N/m*. If a thin film of the area 0.02 *m* is formed on a loop, then its surface energy will be

(a) $5\times10^{2}\ J$ (b) $2.5\times10^{-2}\ J$

(c) $2\times10^{-1}\ J$ (d) $5\times10^{-1}\ J$

12. If work W is done in blowing a bubble of radius R from a soap solution, then the work done in blowing a bubble of radius $2R$ from the same solution is [MP PET 1990]

(a) W/2 (b) 2W

(c) 4W (d) $2\frac{1}{3}$W

13. A spherical drop of oil of radius 1 *cm* is broken into 1000 droplets of equal radii. If the surface tension of oil is 50 *dynes/cm*, the work done is [MP PET 1990]

(a) 18 π *ergs* (b) 180 π *ergs*

(c) 1800 π *ergs* (d) 8000 π *ergs*

14. The work done in blowing a soap bubble of radius r of the solution of surface tension T will be

[DPMT 1999; MP PMT 2003]

(a) $8\pi r^2T$ (b) $2\pi r^2T$

(c) $4\pi r^2T$ (d) $\frac{4}{3}\pi r^2T$

15. If two identical mercury drops are combined to form a single drop, then its temperature will [RPET 2000]

(a) Decrease (b) Increase

(c) Remains the same (d) None of the above

16. If the surface tension of a liquid is T, the gain in surface energy for an increase in liquid surface by A is

[MP PET 1991; RPMT 2002]

(a) AT^{-1} (b) AT

(c) A^2T (d) A^2T^2

17. The surface tension of a soap solution is $2\times10^{-2}\ N/m$. To blow a bubble of radius 1 *cm*, the work done is

[MP PMT 1989]

(a) $4\pi\times10^{-6}\ J$ (b) $8\pi\times10^{-6}\ J$

(c) $12\pi\times10^{-6}\ J$ (d) $16\pi\times10^{-6}\ J$

18. A mercury drop of 1 *cm* radius is broken into 10^6 small drops. The energy used will be (surface tension of mercury is $35\times10^{-3}\ N/cm$) [Roorkee 1984]

(a) $4.4\times10^{-3}\ J$ (b) $2.2\times10^{-4}\ J$

(c) $8.8\times10^{-4}\ J$ (d) $10^4\ J$

19. The surface tension of a liquid at its boiling point

[MP PMT 1980]

(a) Becomes zero

(b) Becomes infinity

(c) is equal to the value at room temperature

(d) is half to the value at the room temperature

20. Surface tension of a soap solution is $1.9\times10^{-2}\ N/m$.. Work done in blowing a bubble of 2.0 *cm* diameter will be

[MP PMT 1991]

(a) $7.6\times10^{-6}\pi$ *joule* (b) $15.2\times10^{-6}\pi$ *joule*

(c) $1.9\times10^{-6}\pi$ *joule* (d) 1×10^{-4} *joule*

21. The surface tension of liquid is 0.5 *N/m*. If a film is held on a ring of area 0.02 *m*, its surface energy is [CPMT 1977]

(a) 5×10^{-2} *joule* (b) 2.0×10^{-2} *joule*

(c) 4×10^{-4} *joule* (d) 0.8×10^{-1} *joule*

22. What is ratio of surface energy of 1 small drop and 1 large drop, if 1000 small drops combined to form 1 large drop

[CPMT 1990]

(a) 100 : 1 (b) 1000 : 1

(c) 10 : 1 (d) 1 : 100

23. The amount of work done in forming a soap film of size $10\,cm\times10\,cm$ is (Surface tension $T=3\times10^{-2}\ N/m$)

[MP PET 1994; MP PET 2000]

(a) $6\times10^{-4}\ J$ (b) $3\times10^{-4}\ J$

(c) $6\times10^{-3}\ J$ (d) $3\times10^{-4}\ J$

24. The work done in blowing a soap bubble of 10 *cm* radius is (Surface tension of the soap solution is $\frac{3}{100}\ N/m$)

[MP PMT 1995; MH CET 2002]

(a) 75.36×10^{-4} *joule* (b) 37.68×10^{-4} *joule*

(c) 150.72×10^{-4} *joule* (d) 75.36 *joule*

25. A liquid drop of diameter D breaks upto into 27 small drops of equal size. If the surface tension of the liquid is σ, then change in surface energy is [DCE 2005]

(a) $\pi D^2\sigma$ (b) $2\pi D^2\sigma$

(c) $3\pi D^2\sigma$ (d) $4\pi D^2\sigma$

26. One thousand small water drops of equal radii combine to form a big drop. The ratio of final surface energy to the total initial surface energy is [MP PET 1997; KCET 1999]

(a) 1000 : 1 (b) 1 : 1000

(c) 10 : 1 (d) 1 : 10

27. The work done in increasing the size of a soap film from 10 *cm* × 6 *cm* to 10 *cm* × 11 *cm* is 3×10^{-4} *joule*. The surface tension of the film is

[MP PET 1999; JIPMER 2001, 02;
MP PMT 2000; AIIMS 2000]

(a) $1.5\times10^{-2}\ N/m$ (b) $3.0\times10^{-2}\ N/m$

(c) $6.0\times10^{-2}\ N/m$ (d) $11.0\times10^{-2}\ N/m$

28. If σ be the surface tension, the work done in breaking a big drop of radius R in n drops of equal radius is

[Bihar CEET 1995]

(a) $Rn^{2/3}\sigma$ (b) $(n^{2/3}-1)R\sigma$

(c) $(n^{1/3}-1)R\sigma$ (d) $4\pi R^2(n^{1/3}-1)\sigma$

(e) $\frac{1}{n^{1/3}-1}\sigma R$

29. A big drop of radius R is formed by 1000 small droplets of water, then the radius of small drop is

[AFMC 1998; Pb. PMT 2000]

(a) $R/2$ (b) $R/5$

(c) $R/6$ (d) $R/10$

30. When 10^6 small drops coalesce to make a new larger drop then the drop [RPMT 1999]

(a) Density increases

(b) Density decreases

(c) Temperature increases

(d) Temperature decreases

31. Which of the following statements are true in case when two water drops coalesce and make a bigger drop [Roorkee 1999]

(a) Energy is released

(b) Energy is absorbed

(c) The surface area of the bigger drop is greater than the sum of the surface areas of both the drops

(d) The surface area of the bigger drop is smaller than the sum of the surface areas of both the drops

32. 8000 identical water drops are combined to form a big drop. Then the ratio of the final surface energy to the initial surface energy of all the drops together is [EAMCET (Engg.) 2000]

(a) 1 : 10 (b) 1 : 15

(c) 1 : 20 (d) 1 : 25

33. The surface energy of liquid film on a ring of area $0.15\ m^2$ is (Surface tension of liquid $= 5 Nm^{-1}$) [EAMCET (Engg.) 2000]

(a) 0.75 *J* (b) 1.5 *J*

(c) 2.25 *J* (d) 3.0 *J*

34. 8 mercury drops coalesce to form one mercury drop, the energy changes by a factor of [DCE 2000]

(a) 1 (b) 2

(c) 4 (d) 6

35. If work done in increasing the size of a soap film from $10\ cm \times 6\ cm$ to $10\ cm \times 11\ cm$ is $2 \times 10^{-4}\ J$, then the surface tension is [AIIMS 2000]

(a) $2 \times 10^{-2}\ Nm^{-1}$ (b) $2 \times 10^{-4}\ Nm^{-1}$

(c) $2 \times 10^{-6}\ Nm^{-1}$ (d) $2 \times 10^{-8}\ Nm^{-1}$

36. A mercury drop of radius 1*cm* is sprayed into 10^6 drops of equal size. The energy expended in joules is (surface tension of Mercury is $460 \times 10^{-3}\ N/m$) [EAMCET 2001]

(a) 0.057 (b) 5.7

(c) 5.7×10^{-4} (d) 5.7×10^{-6}

37. When two small bubbles join to form a bigger one, energy is [BHU 2001]

(a) Released (b) Absorbed

(c) Both (a) and (b) (d) None of these

38. A film of water is formed between two straight parallel wires of length 10*cm* each separated by 0.5 *cm*. If their separation is increased by 1 *mm* while still maintaining their parallelism, how much work will have to be done (Surface tension of water $= 7.2 \times 10^{-2}\ N/m$)

(a) 7.22×10^{-6} *Joule* (b) 1.44×10^{-5} *Joule*

(c) 2.88×10^{-5} *Joule* (d) 5.76×10^{-5} *Joule*

39. A drop of mercury of radius 2 *mm* is split into 8 identical droplets. Find the increase in surface energy. (Surface tension of mercury is $0.465\ J/m^2$) [UPSEAT 2002]

(a) $23.4\ \mu J$ (b) $18.5\ \mu J$

(c) $26.8\ \mu J$ (d) $16.8\ \mu J$

40. Two small drops of mercury, each of radius *R*, coalesce to form a single large drop. The ratio of the total surface energies before and after the change is [AIIMS 2003; DCE 2003]

(a) $1 : 2^{1/3}$ (b) $2^{1/3} : 1$

(c) 2 : 1 (d) 1 : 2

41. Radius of a soap bubble is increased from *R* to 2*R* work done in this process in terms of surface tension is [BHU 2003, RPET 2001; CPMT 2004]

(a) $24\pi R^2 S$ (b) $48\pi R^2 S$

(c) $12\pi R^2 S$ (d) $36\pi R^2 S$

42. The work done in blowing a soap bubble of radius 0.2 *m* is (the surface tension of soap solution being 0.06 *N/m*) [Pb. PET 2002]

(a) $192\pi \times 10^{-4}\ J$ (b) $280\pi \times 10^{-4}\ J$

(c) $200\pi \times 10^{-3}\ J$ (d) None of these

43. A liquid film is formed in a loop of area 0.05 *m*. Increase in its potential energy will be (*T* = 0.2 *N/m*) [RPMT 2002]

(a) $5 \times 10^{-2}\ J$ (b) $2 \times 10^{-2}\ J$

(c) $3 \times 10^{-2}\ J$ (d) None of these

44. In order to float a ring of area 0.04 *m* in a liquid of surface tension 75 *N/m*, the required surface energy will be [RPMT 2003]

(a) 3 *J* (b) 6.5 *J*

(c) 1.5 *J* (d) 4 *J*

45. If two soap bubbles of equal radii *r* coalesce then the radius of curvature of interface between two bubbles will be [J&K CET 2005]

(a) *r* (b) 0

(c) Infinity (d) 1/2*r*

Angle of Contact

1. A liquid does not wet the sides of a solid, if the angle of contact is [MP PAT 1990; AFMC 1988; MNR 1998; RPMT 1999, 2003; Pb. PMT 2002 KCET 2005]

(a) Zero (b) Obtuse (More than 90°)

(c) Acute (Less than 90°) (d) 90°

2. The meniscus of mercury in the capillary tube is [MP PET/PMT 1988]

(a) Convex (b) Concave

(c) Plane (d) Uncertain

3. When the temperature is increased the angle of contact of a liquid [MP PET 2001]

(a) Increases

(b) Decreases

(c) Remains the same

(d) First increases and then decreases

4. The angle of contact between glass and mercury is [MP PMT 1987]

(a) 0° (b) 30°

(c) 90° (d) 135°

5. A mercury drop does not spread on a glass plate because the angle of contact between glass and mercury is [MP PMT 1984]

(a) Acute (b) Obtuse

(c) Zero (d) 90°

6. A liquid is coming out from a vertical tube. The relation between the weight of the drop W, surface tension of the liquid T and radius of the tube r is given by, if the angle of contact is zero

(a) $W = \pi r^2 T$ (b) $W = 2\pi r T$

(c) $W = 2r^2 \pi T$ (d) $W = \frac{3}{4}\pi r^3 T$

7. The parts of motor cars are polished by chromium because the angle of contact between water and chromium is

(a) 0° (b) 90°

(c) Less than 90° (d) Greater than 90°

8. A glass plate is partly dipped vertically in the mercury and the angle of contact is measured. If the plate is inclined, then the angle of contact will

(a) Increase (b) Remain unchanged

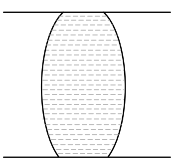
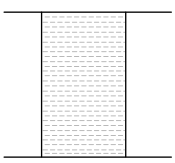
(c) Increase or decrease (d) Decrease

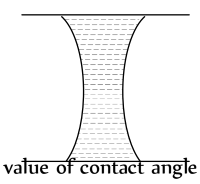
9. The liquid meniscus in capillary tube will be convex, if the angle of contact is [EAMCET (Med.) 1995; KCET 2001; Pb. PET 2000]

(a) Greater than 90° (b) Less than 90°

(c) Equal to 90° (d) Equal to 0°

10. If a water drop is kept between two glass plates, then its shape is

(a)  (b) 

(c)  (d) None of these

11. The value of contact angle for kerosene with solid surface. [RPMT 2000]

(a) 0° (b) 90^o

(c) 45^o (d) 33^o

12. Nature of meniscus for liquid of 0^o angle of contact [RPET 2001]

(a) Plane (b) Parabolic

(c) Semi-spherical (d) Cylindrical

13. A liquid wets a solid completely. The meniscus of the liquid in a sufficiently long tube is [Kerala (Engg.) 2002]

(a) Flat (b) Concave

(c) Convex (d) Cylindrical

14. What is the shape when a non-wetting liquid is placed in a capillary tube [AFMC 2004]

(a) Concave upward (b) Convex upward

(c) Concave downward (d) Convex downward

15. For which of the two pairs, the angle of contact is same [J & K CET 2004]

(a) Water and glass; glass and mercury

(b) Pure water and glass; glass and alcohol

(c) Silver and water; mercury and glass

(d) Silver and chromium; water and chromium

16. If the surface of a liquid is plane, then the angle of contact of the liquid with the walls of container is [MH CET 2004]

(a) Acute angle (b) Obtuse angle

(c) 90° (d) 0°

Pressure Difference

1. A soap bubble assumes a spherical surface. Which of the following statement is wrong [NCERT 1976]

(a) The soap film consists of two surface layers of molecules back to back

(b) The bubble encloses air inside it

(c) The pressure of air inside the bubble is less than the atmospheric pressure; that is why the atmospheric pressure has compressed it equally from all sides to give it a spherical shape

(d) Because of the elastic property of the film, it will tend to shrink to as small a surface area as possible for the volume it has enclosed

2. If two soap bubbles of different radii are in communication with each other [NCERT 1980; MP PMT/PET 1988; AIEEE 2004]

(a) Air flows from larger bubble into the smaller one

(b) The size of the bubbles remains the same

(c) Air flows from the smaller bubble into the large one and the larger bubble grows at the expense of the smaller one [CPMT 1997]

(d) The air flows from the larger

3. The surface tension of soap solution is $25 \times 10^{-3}\ Nm^{-1}$. The excess pressure inside a soap bubble of diameter 1 *cm* is

(a) 10 *Pa* (b) 20 *Pa*

(c) 5 *Pa* (d) None of the above

4. When two soap bubbles of radius r_1 and r_2 $(r_2 > r_1)$ coalesce, the radius of curvature of common surface is [MP PMT 1996]

(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) $r_2 + r_1$

5. The excess pressure due to surface tension in a spherical liquid drop of radius r is directly proportional to [MP PMT 1987; KCET 2000]

(a) r (b) r^2

(c) r^{-1} (d) r^{-2}

6. A long cylindrical glass vessel has a small hole of radius '*r*' at its bottom. The depth to which the vessel can be lowered vertically in the deep water bath (surface tension *T*) without any water entering inside is [MP PMT 1990]

(a) $4T/\rho rg$ (b) $3T/\rho rg$

(c) $2T/\rho rg$ (d) $T/\rho rg$

7. If the surface tension of a soap solution is 0.03 *MKS* units, then the excess of pressure inside a soap bubble of diameter 6 mm over the atmospheric pressure will be

(a) Less than 40 *N/m* (b) Greater than 40 *N/m*

(c) Less than 20 *N/m* (d) Greater than 20 *N/m*

8. The excess of pressure inside a soap bubble than that of the outer pressure is

[MP PMT 1989; BHU 1995; MH CET 2002; RPET 2003; AMU (Engg.) 2000]

(a) $\frac{2T}{r}$ (b) $\frac{4T}{r}$

(c) $\frac{T}{2r}$ (d) $\frac{T}{r}$

9. The pressure of air in a soap bubble of 0.7*cm* diameter is 8 *mm* of water above the pressure outside. The surface tension of the soap solution is

[MP PET 1991; MP PMT 1997]

(a) $100 dyne/cm$ (b) $68.66 dyne/cm$

(c) $137 dyne/cm$ (d) $150 dyne/cm$

10. Pressure inside two soap bubbles are 1.01 and 1.02 atmospheres. Ratio between their volumes is

[MP PMT 1991]

(a) 102 : 101 (b) $(102)^3 : (101)^3$

(c) 8 : 1 (d) 2 : 1

11. A capillary tube of radius *r* is dipped in a liquid of density ρ and surface tension *S*. If the angle of contact is θ, the pressure difference between the two surfaces in the beaker and the capillary

(a) $\frac{S}{r}\cos\theta$ (b) $\frac{2S}{r}\cos\theta$

(c) $\frac{S}{r\cos\theta}$ (d) $\frac{2S}{r\cos\theta}$

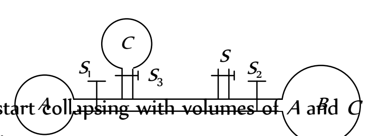
12. The radii of two soap bubbles are r_1 and r_2. In isothermal conditions, two meet together in vaccum. Then the radius of the resultant bubble is given by

[MP PMT 2001; RPET 1999; EAMCET 2003]

(a) $R = (r_1 + r_2)/2$ (b) $R = r_1(r_1 r_2 + r_2)$

(c) $R^2 = r_1^2 + r_2^2$ (d) $R = r_1 + r_2$

13. The adjoining diagram shows three soap bubbles *A*, *B* and *C* prepared by blowing the capillary tube fitted with stop cocks, S_1, S_2 and S_3. With stop cock *S* closed and stop cocks S_1, S_2 and S_3 opened



(a) *B* will start collapsing with volumes of *A* and *C* increasing

(b) *C* will start collapsing with volumes of *A* and *B* increasing

(c) *C* and *A* both will start collapsing with the volume of *B* increasing

(d) Volumes of *A*, *B* and *C* will become equal at equilibrium

14. When a large bubble rises from the bottom of a lake to the surface, its radius doubles. If atmospheric pressure is equal to that of column of water height *H*, then the depth of lake is

[AIIMS 1995; AFMC 1997]

(a) *H* (b) 2*H*

(c) 7*H* (d) 8*H*

15. A soap bubble in vacuum has a radius of 3 *cm* and another soap bubble in vacuum has a radius of 4 *cm*. If the two bubbles coalesce under isothermal condition, then the radius of the new bubble is [MP PMT/PE

(a) 2.3 *cm* (b) 4.5 *cm*

(c) 5 *cm* (d) 7 *cm*

16. The volume of an air bubble becomes three times as it rises from the bottom of a lake to its surface. Assuming atmospheric pressure to be 75 *cm* of *Hg* and the density of water to be 1/10 of the density of mercury, the depth of the lake is

(a) 5 *m* (b) 10 *m*

(c) 15 *m* (d) 20 *m*

17. Excess pressure of one soap bubble is four times more than the other. Then the ratio of volume of first bubble to another one is [CPMT 1997; M

(a) 1 : 64 (b) 1 : 4

(c) 64 : 1 (d) 1 : 2

18. There are two liquid drops of different radii. The excess pressure inside over the outside is [JIPMER 1999]

(a) More in the big drop

(b) More in the small drop

(c) Equal in both drops

(d) There is no excess pressure inside the drops

19. If pressure at half the depth of a lake is equal to 2/3 pressure at the bottom of the lake then what is the depth of the lake

[RPET 2000]

(a) 10*m* (b) 20*m*

(c) 60*m* (d) 30*m*

20. If the radius of a soap bubble is four times that of another, then the ratio of their pressures will be [AIIMS 2000]

(a) 1 : 4 (b) 4 : 1

(c) 16 : 1 (d) 1 : 16

21. A spherical drop of water has radius 1 *mm* If surface tension of water is 70×10^{-3} *N/m* difference of pressures between inside and out side of the spherical drop is

[CPMT 2000; AIIMS 2000]

(a) $35\ N/m^{-2}$ (b) $70\ N/m^2$

(c) $140\ N/m^2$ (d) Zero

[CPMT 1988]

22. The pressure at the bottom of a tank containing a liquid does not depend on [Kerala (Engg.) 2001]

(a) Acceleration due to gravity

(b) Height of the liquid column

(c) Area of the bottom surface

(d) Nature of the liquid

23. In capillary pressure below the curved surface of water will be

(a) Equal to atmospheric

(b) Equal to upper side pressure

(c) More than upper side pressure

(d) Lesser than upper side pressure

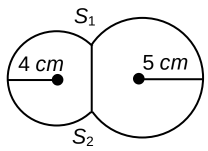
24. Two soap bubbles of radii r_1 and r_2 equal to 4 *cm* and 5 *cm* are touching each other over a common surface S_1S_2 (shown in figure). Its radius will be [MP PMT 2002]

(a) 4 *cm*

(b) 20 *cm*

(c) 5 *cm*

(d) 4.5 *cm*



25. The pressure inside a small air bubble of radius 0.1 *mm* situated just below the surface of water will be equal to

[Take surface tension of water $70 \times 10^{-3}\, Nm^{-1}$ and atmospheric pressure = $1.013 \times 10^5\, Nm^{-2}$]

[AMU (Med.) 2002]

(a) $2.054 \times 10^3\, Pa$ (b) $1.027 \times 10^3\, Pa$

(c) $1.027 \times 10^5\, Pa$ (d) $2.054 \times 10^5\, Pa$

26. Two bubbles A and B $(A > B)$ are joined through a narrow tube. Then [UPSEAT 2001; Kerala (Med.) 2002]

(a) The size of A will increase

(b) The size of B will increase

(c) The size of B will increase until the pressure equals

(d) None of these

27. Two soap bubbles have different radii but their surface tension is the same. Mark the correct statement

[MP PMT 2004]

(a) Internal pressure of the smaller bubble is higher than the internal pressure of the larger bubble

(b) Pressure of the larger bubble is higher than the smaller bubble

(c) Both bubbles have the same internal pressure

(d) None of the above

28. If the excess pressure inside a soap bubble is balanced by oil column of height 2 *mm*, then the surface tension of soap solution will be (r = 1 *cm* and density d = 0.8 *gm/cc*)

[J & K CET 2004]

(a) 3.9 *N/m* (b) 3.9×10^{-2} *N/m*

(c) 3.9×10^{-3} *N/m* (d) 3.9 *dyne/m*

29. In Jager's method, at the time of bursting of the bubble

[RPET 2002]

(a) The internal pressure of the bubble is always greater than external pressure

(b) The internal pressure of the bubble is always equal to external pressure

(c) The internal pressure of the bubble is always less than external pressure

(d) The internal pressure of the bubble is always slightly greater than external pressure

30. The excess pressure in a soap bubble is thrice that in other one. Then the ratio of their volume is

[RPMT 2003; CPMT 2001]

(a) 1 : 3 (b) 1 : 9

(c) 27 : 1 (d) 1 : 27

Capillarity

1. When two capillary tubes of different diameters are dipped vertically, the rise of the liquid is [NCERT 1978]

(a) Same in both the tubes

(b) More in the tube of larger diameter

(c) Less in the tube of smaller diameter

(d) More in the tube of smaller diameter

2. Due to capillary action, a liquid will rise in a tube, if the angle of contact is [DPMT 1984; AFMC 1988; BHU 2001]

(a) Acute (b) Obtuse

(c) 90° (d) Zero

3. In the state of weightlessness, a capillary tube is dipped in water, then water

(a) Will not rise at all

(b) Will rise to same height as at atmospheric pressure

(c) Will rise to less height than at atmospheric pressure

(d) Will rise up to the upper end of the capillary tube of any length

4. Two parallel glass plates are dipped partly in the liquid of density 'd' keeping them vertical. If the distance between the plates is 'x', surface tension for liquids is T and angle of contact is θ, then rise of liquid between the plates due to capillary will be

(a) $\frac{T\cos\theta}{xd}$ (b) $\frac{2T\cos\theta}{xdg}$

(c) $\frac{2T}{xdg\cos\theta}$ (d) $\frac{T\cos\theta}{xdg}$

5. Water rises in a capillary tube to a certain height such that the upward force due to surface tension is balanced by $75 \times 10^{-4}\, N$ force due to the weight of the liquid. If the surface tension of water is $6 \times 10^{-2}\, Nm^{-1}$, the inner circumference of the capillary must be [CPMT 19

(a) $1.25 \times 10^{-2} m$ (b) $0.50 \times 10^{-2} m$

(c) $6.5 \times 10^{-2} m$ (d) $12.5 \times 10^{-2} m$

6. It is not possible to write directly on blotting paper or newspaper with ink pen

(a) Because of viscosity (b) Because of inertia

(c) Because of friction (d) Because of capillarity

7. Two capillary tubes P and Q are dipped in water. The height of water level in capillary P is 2/3 to the height in Q capillary. The ratio of their diameters is [MP PMT 1985]

(a) 2 : 3 (b) 3 : 2

(c) 3 : 4 (d) 4 : 3

8. Two capillaries made of same material but of different radii are dipped in a liquid. The rise of liquid in one capillary is 2.2 *cm* and that in the other is 6.6 *cm*. The ratio of their radii is

(a) 9 : 1 (b) 1 : 9

(c) 3 : 1 (d) 1 : 3

9. Two capillaries made of the same material with radii $r_1 = 1mm$ and $r_2 = 2mm$. The rise of the liquid in one capillary ($r_1 = mm$) is 30 *cm*, then the rise in the other will be

(a) 7.5 *cm* (b) 60 *cm*

(c) 15 *cm* (d) 120 *cm*

10. When a capillary is dipped in water, water rises to a heig ht h. If the length of the capillary is made less than h, then

(a) The water will come out

(b) The water will not come out

(c) The water will not rise

(d) The water will rise but less than height of capillary

11. Water rises upto 10 *cm* height in a long capillary tube. If this tube is immersed in water so that the height above the water surface is only 8 *cm*, then [MP PMT 1991]

(a) Water flows out continuously from the upper end

(b) Water rises upto upper end and forms a spherical surface

(c) Water only rises upto 6 *cm* height

(d) Water does not rise at all

12. A vessel, whose bottom has round holes with diameter of 0.1*mm*, is filled with water. The maximum height to which the water can be filled without leakage is

(S.T. of water =75 *dyne/cm*, g =1000 *cm/s*)

[CPMT 1989; J&K CET 2004]

(a) 100 *cm* (b) 75 *cm*

(c) 50 *cm* (d) 30 *cm*

13. Water rises in a capillary tube when its one end is dipped vertically in it, is 3 *cm*. If the surface tension of water is 75×10^{-3} *N/m*, then the diameter of capillary will be

[MP PET 1989]

(a) 0.1 *mm* (b) 0.5 *mm*

(c) 1.0 *mm* (d) 2.0 *mm*

14. A capillary tube made of glass is dipped into mercury. Then

[MP PET 1996]

(a) Mercury rises in the capillary tube

(b) Mercury rises and flows out of the capillary tube

(c) Mercury descends in the capillary tube

(d) Mercury neither rises nor descends in the capillary tube

15. By inserting a capillary tube upto a depth *l* in water, the water rises to a height *h*. If the lower end of the capillary is closed inside water and the capillary is taken out and closed end opened, to what height the water will remain in the tube

[RPET 1996; DPMT 2000]

(a) Zero (b) $l + h$

(c) $2h$ (d) h

16. If the diameter of a capillary tube is doubled, then the height of the liquid that will rise is [CPMT 1997]

(a) Twice [MP PET 1990] (b) Half

(c) Same as earlier (d) None of these

17. If the surface tension of water is 0.06 *Nm*, then the capillary rise in a tube of diameter 1 *mm* is (θ =0°)

[AFMC 1998]

(a) 1.22 *cm* (b) 2.44 *cm*

(c) 3.12 *cm* [MP PET 1991] (d) 3.86 *cm*

18. Two capillary tubes of radii 0.2 *cm* and 0.4 *cm* are dipped in the same liquid. The ratio of heights through which liquid will rise in the tubes is [MNR 1998]

(a) 1 : 2 (b) 2 : 1

(c) 1 : 4 (d) 4 : 1

19. A capillary tube when immersed vertically in liquid records a rise of 3 *cm*. If the tube is immersed in the liquid at an angle of 60^0 with the vertical. The length of the liquid column along the tube is

(a) 9*cm* (b) 6*cm*

(c) 3*cm* (d) 2*cm*

20. The action of a nib split at the top is explained by

[JIPMER 1999]

(a) Gravity flow (b) Diffusion of fluid

(c) Capillary action (d) Osmosis of liquid

21. The correct relation is [RPMT 2002]

(a) $r = \dfrac{2T\cos\theta}{hdg}$ (b) $r = \dfrac{hdg}{2T\cos\theta}$

(c) $r = \dfrac{2T\,dgh}{\cos\theta}$ (d) $r = \dfrac{T\cos\theta}{2hdg}$

22. Water rises upto a height *h* in a capillary on the surface of earth in stationary condition. Value of h increases if this tube is taken

(a) On sun

(b) On poles

(c) In a lift going upward with acceleration

(d) In a lift going downward with acceleration

23. During capillary rise of a liquid in a capillary tube, the surface of contact that remains constant is of

[Pb. PMT 2000]

(a) Glass and liquid (b) Air and glass

(c) Air and liquid (d) All of these

24. A shell having a hole of radius *r* is dipped in water. It holds the water upto a depth of *h* then the value of *r* is

[RPMT 2000]

(a) $r = \dfrac{2T}{hdg}$ (b) $r = \dfrac{T}{hdg}$

(c) $r = \dfrac{Tg}{hd}$ (d) None of these

25. In a capillary tube, water rises by 1.2 *mm*. The height of water that will rise in another capillary tube having half the radius of the first, is [CPMT 2001; Pb. PET 2002]

(a) 1.2 *mm* (b) 2.4 *mm*

(c) 0.6 *mm* (d) 0.4 *mm*

26. If capillary experiment is performed in vacuum then for a liquid there [RPET 2001]

(a) It will rise (b) Will remain same

(c) It will fall (d) Rise to the top

27. If liquid level falls in a capillary then radius of capillary will [RPET 2001]

(a) Increase (b) Decrease

(c) Unchanged (d) None of these

28. 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 [MP PMT 2001]

(a) $6h$ (b) $\frac{1}{6}h$

(c) h (d) Zero

29. Two capillary tubes of same diameter are put vertically one each in two liquids whose relative densities are 0.8 and 0.6 and surface tensions are 60 and 50 *dyne/cm* respectively Ratio of heights of liquids in the two tubes $\frac{h_1}{h_2}$ is [MP PMT 2002]

(a) $\frac{10}{9}$ (b) $\frac{3}{10}$

(c) $\frac{10}{3}$ (d) $\frac{9}{10}$

30. Water rises in a vertical capillary tube upto a height of 2.0 cm. If the tube is inclined at an angle of 60^o with the vertical, then upto what length the water will rise in the tube [UPSEAT 2002]

(a) 2.0 cm (b) 4.0 cm

(c) $\frac{4}{\sqrt{3}} cm$ (d) $2\sqrt{2}\, cm$

31. The surface tension for pure water in a capillary tube experiment is [MH CET 2002]

(a) $\frac{\rho g}{2hr}$ (b) $\frac{2}{hr\rho g}$

(c) $\frac{r\rho g}{2h}$ (d) $\frac{hr\rho g}{2}$

32. In a capillary tube experiment, a vertical 30 cm long capillary tube is dipped in water. The water rises up to a height of 10cm due to capillary action. If this experiment is conducted in a freely falling elevator, the length of the water column becomes [Orissa JEE 2003; AIEEE 2005]

(a) 10 cm (b) 20 cm

(c) 30 cm (d) Zero

33. Radius of a capillary is $2\times10^{-3} m$. A liquid of weight $6.28\times10^{-4} N$ may remain in the capillary then the surface tension of liquid will be [RPET 2003]

(a) $5\times10^{-3} N/m$ (b) $5\times10^{-2} N/m$

(c) $5\ N/m$ (d) $50\ N/m$

34. Two long capillary tubes A and B of radius $R_A > R_B$ dipped in same liquid. Then [Orissa PMT 2004]

(a) Water rise is more in A than B

(b) Water rises more in B than A

(c) Same water rise in both

(d) All of these according to the density of water

35. If water rises in a capillary tube upto 3 cm. What is the diameter of capillary tube (Surface tension of water = $7.2\times10^{-2}\ N/m$)

(a) $9.6\times10^{-4}\ m$ (b) $9.6\times10^{-3}\ m$

(c) $9.6\times10^{-2}\ m$ (d) $9.6\times10^{-1}\ m$

36. When a capillary is dipped in water, water rises 0.015 m in it. If the surface tension of water is $75\times10^{-3}\ N/m$, the radius of capillary is

(a) 0.1 mm (b) 0.5 mm

(c) 1 mm (d) 2 mm

37. In a capillary tube, water rises to 3 mm. The height of water that will rise in another capillary tube having one-third radius of the first is [BHU 2004]

(a) 1 mm (b) 3 mm

(c) 6 mm (d) 9 mm

38. Kerosene oil rises up the wick in a lantern [NCERT 1980; MNR 1985]

(a) Due to surface tension of the oil

(b) The wick attracts the kerosene oil

(c) Of the diffusion of the oil through the wick

(d) None of the above

39. Water rises against gravity in a capillary tube when its one end is dipped into water because

(a) Pressure below the meniscus is less than atmospheric pressure

(b) Pressure below the meniscus is more than atmospheric pressure

(c) Capillary attracts water

(d) Of viscosity

40. A capillary tube of radius R is immersed in water and water rises in it to a height H. Mass of water in the capillary tube is M. If the radius of the tube is doubled, mass of water that will rise in the capillary tube will now be [RPMT 1997; RPET 1999; CPMT 2002]

(a) M (b) $2M$

(c) $M/2$ (d) $4M$

41. Water rises up to a height h in a capillary tube of certain diameter. This capillary tube is replaced by a similar tube of half the diameter. Now the water will rise to the height of [Kerala PMT 2005]

(a) $4h$ (b) $3h$

(c) $2h$ (d) h

CT Critical Thinking

Objective Questions

1. There is a horizontal film of soap solution. On it a thread is placed in the form of a loop. The film is pierced inside the loop and the thread becomes a circular loop of radius R. If the surface tension of the loop be T, then what will be the tension in the thread

(a) $\pi R^2/T$ (b) $\pi R^2 T$

(c) $2\pi RT$ (d) $2RT$

2. A large number of water drops each of radius r combine to have a drop of radius R. If the surface tension is T and the mechanical equivalent of heat is J, then the rise in temperature will be [MP PET 1994; DPMT 2002]

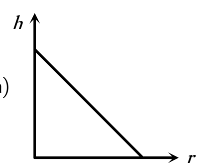
(a) $\frac{2T}{rJ}$ (b) $\frac{3T}{RJ}$

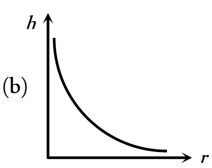
(c) $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$ (d) $\frac{2T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$

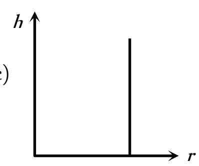
3. An air bubble in a water tank rises from the bottom to the top. Which of the following statements are true [Roorkee 2000]
   (a) Bubble rises upwards because pressure at the bottom is less than that at the top.
   (b) Bubble rises upwards because pressure at the bottom is greater than that at the top.
   (c) As the bubble rises, its size increases
   (d) As the bubble rises, its size decreases
4. In a surface tension experiment with a capillary tube water rises upto 0.1 m. If the same experiment is repeated on an artificial satellite, which is revolving around the earth, water will rise in the capillary tube upto a height of [Roorkee 1992]
   (a) 0.1 m
   (b) 0.2 m
   (c) 0.98 m
   (d) Full length of the capillary tube

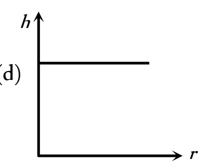
Graphical Questions

1. The correct curve between the height or depression h of liquid in a capillary tube and its radius is

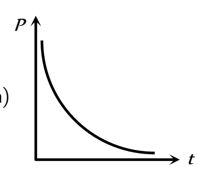
(a)


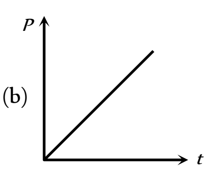
(b)


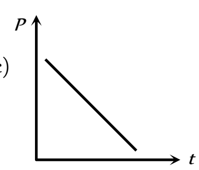
(c)


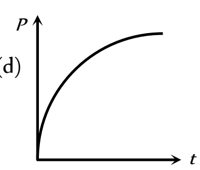
(d)


2. A soap bubble is blown with the help of a mechanical pump at the mouth of a tube. The pump produces a certain increase per minute in the volume of the bubble, irrespective of its internal pressure. The graph between the pressure inside the soap bubble and time t will be-

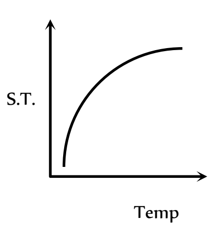
(a)


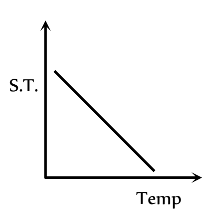
(b)


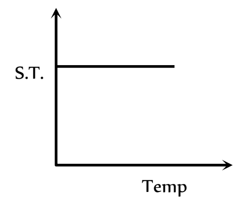
(c)


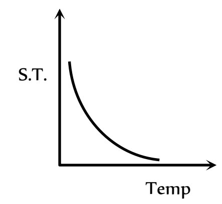
(d)


3. Which graph represents the variation of surface tension with temperature over small temperature ranges for water

(a)


(b)


(c)


(d)


Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : It is easier to spray water in which some soap is dissolved.
   Reason : Soap is easier to spread.
2. Assertion : It is better to wash the clothes in cold soap solution.
   Reason : The surface tension of cold solution is more than the surface tension of hot solution.
3. Assertion : When height of a tube is less than liquid rise in the capillary tube, the liquid does not overflow.
   Reason : Product of radius of meniscus and height of liquid in capillary tube always remains constant.
4. Assertion : A needle placed carefully on the surface of water may float, whereas a ball of the same material will always sink.
   Reason : The buoyancy of an object depends both on the material and shape of the object.
5. Assertion : A large force is required to draw apart normally two glass plates enclosing a thin water film.
   Reason : Water works as glue and sticks two glass plates.
6. Assertion : The impurities always decrease the surface tension of a liquid.
   Reason : The change in surface tension of the liquid depends upon the degree of contamination of the impurity.
7. Assertion : The angle of contact of a liquid decrease with increase in temperature.

Reason : With increase in temperature, the surface tension of liquid increase.

8. Assertion : The concept of surface tension is held only for liquids.

Reason : Surface tension does not hold for gases.

9. Assertion : At critical temperature, surface tension of a liquid becomes zero.

Reason : At this temperature, intermolecular forces for liquids and gases become equal. Liquid can expand without any restriction.

10. Assertion : A large soap bubble expands while a small bubble shrinks, when they are connected to each other by a capillary tube.

Reason : The excess pressure inside bubble (or drop) is inversely proportional to the radius.

11. Assertion : Tiny drops of liquid resist deforming forces better than bigger drops.

Reason : Excess pressure inside a drop is directly proportional to surface tension.

12. Assertion : The water rises higher in a capillary tube of small diameter than in the capillary tube of large diameter.

Reason : Height through which liquid rises in a capillary tube is inversely proportional to the diameter of the capillary tube.

13. Assertion : Hot soup tastes better than the cold soup.

Reason : Hot soup has high surface tension and it does not spread properly on our tongue.

14. Assertion : The shape of a liquid drop is spherical.

Reason : The pressure inside the drop is greater than that of outside.

Answers

Surface Tension

1	a	2	b	3	b	4	a	5	d
6	a	7	b	8	b	9	b	10	cd
11	d	12	a	13	b	14	b	15	c
16	d	17	a	18	c	19	c	20	d
21	b	22	d	23	a	24	a	25	c
26	d	27	d	28	b	29	b	30	d
31	d	32	c	33	d	34	c	35	a
36	b	37	b	38	a	39	a	40	c
41	d	42	c	43	d	44	a	45	a
46	a								

Surface Energy

1	a	2	d	3	a	4	d	5	d
6	b	7	c	8	d	9	c	10	c
11	c	12	c	13	c	14	a	15	b
16	b	17	d	18	a	19	a	20	b
21	b	22	d	23	a	24	a	25	b
26	d	27	b	28	d	29	d	30	c
31	ad	32	c	33	b	34	c	35	a
36	a	37	a	38	b	39	a	40	b
41	a	42	a	43	b	44	a	45	c

Angle of Contact

1	b	2	a	3	b	4	d	5	b
6	b	7	d	8	b	9	a	10	c
11	a	12	c	13	b	14	b	15	b
16	d								

Pressure Difference

1	c	2	c	3	b	4	c	5	c
6	c	7	b	8	b	9	b	10	c
11	b	12	c	13	c	14	c	15	c
16	c	17	a	18	b	19	b	20	a
21	c	22	c	23	d	24	b	25	c
26	a	27	a	28	b	29	a	30	d

Capillarity

1	d	2	a	3	d	4	b	5	d
6	d	7	b	8	c	9	c	10	b
11	b	12	d	13	c	14	c	15	d
16	b	17	b	18	b	19	b	20	c
21	a	22	d	23	c	24	a	25	b
26	a	27	a	28	a	29	d	30	b
31	d	32	c	33	b	34	a	35	a
36	c	37	d	38	a	39	a	40	b
41	c								

Critical Thinking Questions

1	d	2	c	3	bc	4	d		

Graphical Questions

1	b	2	a	3	b				

Assertion and Reason

1	c	2	e	3	a	4	c	5	c
6	e	7	c	8	b	9	a	10	a
11	b	12	a	13	c	14	b		

Answers and Solutions

Surface Tension

1. (a)

2. (b)

3. (b)

4. (a)

5. (d) Soap helps to lower the surface tension of solution, thus soap get stick to the dust particles and grease and these are removed by action of water.

6. (a)

7. (b)

8. (b)

9. (b)

10. (c,d) At critical temperature ($T_c = 370^o C = 643\ K$), the surface tension of water is zero.

11. (d)

12. (a) Weight of spiders or insects can be balanced by vertical component of force due to surface tension.

13. (b)

14. (b)

15. (c) Force on each side $= 2TL$ (due to two surfaces)

$\therefore$ Force on the frame $= 4(2TL) = 8TL$

16. (d)

17. (a)

18. (c) This happens due to viscosity.

19. (c)

20. (d) The total length of the circular plate on which the force will act $= 2\pi R$

Force to pull $= 2\pi RT = 2 \times \pi \times 5 \times 75 = 750\pi$ *dynes*

21. (b)

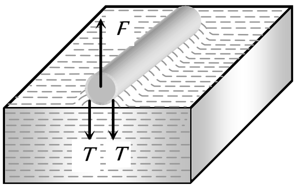
22. (d) $T = T_0(1 - \alpha t)$

23. (a) Due to force of attraction it is not easier to separate the two glass plates.

24. (a) Soluble impurities increases the surface tension.

25. (c) $T = \dfrac{F}{2l} = \dfrac{728}{2 \times 5}$

$\therefore T = 72.8\ dyne/cm$



26. (d) Cohesive force > Adhesive force, so shape of liquid surface near the solid would be convex.

For example mercury surface in glass capillary is convex.

27. (d) Surface tension decreases with increase in temperature.

28. (b)

29. (b)

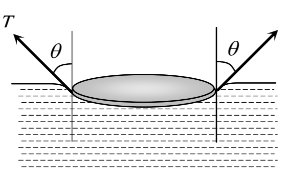
30. (d)

31. (d) Because surface tension of water > surface tension of oil

32. (c) Surface tension pulls the plates towards each other.

33. (d) Sphere has the minimum surface area for the given volume of the liquid.

34. (c)



Weight of metal disc = total upward force

= upthrust force + force due to surface tension

= weight of displaced water + $T\cos\theta\,(2\pi r)$

= $W + 2\pi rT\cos\theta$

35. (a) $T = \dfrac{F}{2l} = \dfrac{2 \times 10^{-2}}{2 \times 10 \times 10^{-2}} = 0.1\ N/m$

36. (b) Surface tension of water decrease with rise in temperature.

37. (b)

38. (a) Force required to separate the plates

$$F = \frac{2TA}{t} = \frac{2 \times 70 \times 10^{-3} \times 10^{-2}}{0.05 \times 10^{-3}} = 28N$$

39. (a)

40. (c) The cohesive force is the force of attraction between the molecules of same substance.

41. (d)

42. (c) $T = \dfrac{F}{l} = \dfrac{[MLT^{-2}]}{[L]} = [ML^0T^{-2}]$

43. (d) Net force on stick $= F_1 - F_2 = (T_1 - T_2)l$

$= (0.07 - 0.06)l = 0.01 \times 2 = 0.02N$

44. (a) Because film tries to cover minimum surface area.

45. (a) Force required, $F = 2\pi rT = 2\pi \times 2 \times 70 = 280\pi.Dyne$

46. (a)

Surface Energy

1. (a) Energy needed = Increment in surface energy

= (surface energy of n small drops) – (surface energy of one big drop)

$= n4\pi r^2T - 4\pi R^2T = 4\pi T(nr^2 - R^2)$

2. (d)

3. (a) When two droplets merge with each other, their surface energy decreases.

$W = T(\Delta A) =$ (negative) *i.e.* energy is released.

4. (d) $E = 4\pi R^2T(n^{1/3} - 1)$

$= 4 \times 3.14 \times (1.4 \times 10^{-1})^2 \times 75(125^{1/3} - 1) = 74\ erg$

5. (d) $W = 8\pi T(R_2^2 - R_1^2) = 8\pi T[(2r)^2 - (r)^2] = 24\pi r^2T$

6. (b) Work done in splitting a water drop of radius R into n drops of equal size $= 4\pi R^2T(n^{1/3} - 1)$

$= 4\pi \times (10^{-3})^2 \times 72 \times 10^{-3} \times (10^{6/3} - 1)$

$= 4\pi \times 10^{-6} \times 72 \times 10^{-3} \times 99 = 8.95 \times 10^{-5}\ J$

7. (c) $W = 4\pi R^2T(r^{1/3} - 1) = 4\pi R^2T(8^{1/3} - 1) = 4\pi R^2T$

8. (d) $W = T \times 8\pi(r_2^2 - r_1^2) = T \times 8\pi\left(\dfrac{D^2}{4} - \dfrac{d^2}{4}\right)$

$= 2\pi(D^2 - d^2)T$

9. (c) Work done to increase the diameter of bubble from d to D

$W = 2\pi(D^2 - d^2)T = 2\pi\left[(2D)^2 - (D)^2\right]T = 6\pi D^2T$

10. (c) $W = 8\pi T(r_2^2 - r_1^2) = 8\pi T\left[\left(\dfrac{2}{\sqrt{\pi}}\right)^2 - \left(\dfrac{1}{\sqrt{\pi}}\right)^2\right]$

$\therefore W = 8 \times \pi \times 30 \times \dfrac{3}{\pi} = 720\ erg$

11. (c) $W = T \times \Delta A = 5 \times 2 \times (0.02)$ (Film has two free surfaces)

$= 2 \times 10^{-1}\ J$

12. (c) $W = 8\pi R^2T \ \therefore\ W \propto R^2$ (T is constant)

If radius becomes double then work done will become four times.

13. (c) $W = 4\pi R^2T(n^{1/3} - 1) = 4\pi \times 1 \times 50(10^{3/3} - 1)$

$= 1800\pi\ erg$

14. (a)

15. (b) Surface energy of combined drop will be lowered, so excess surface energy will raise the temperature of the drop.

16. (b) Surface energy = surface tension × increment in area

$= T \times A$

17. (d) $W = 8\pi R^2 T = 8 \times \pi \times (10^{-2})^2 \times 2 \times 10^{-2} = 16\pi \times 10^{-6} J$

18. (a) $E = 4\pi R^2 T(n^{1/3} - 1)$

$= 4 \times 3.14 \times 10^{-4} \times 35 \times 10^{-1}(10^{6/3} - 1) = 4.4 \times 10^{-3} J$

19. (a)

20. (b) $W = 8\pi R^2 T = 8\pi \times (1 \times 10^{-2})^2 \times 1.9 \times 10^{-2} = 15.2 \times 10^{-6}\, \pi J$

21. (b) Surface energy = $T \times \Delta A = 0.5 \times 2 \times (0.02) = 2 \times 10^{-2} J$

22. (d) Volume of liquid remain same *i.e.* volume of 1000 small drops will be equal to volume of one big drop

$n\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow 1000 r^3 = R^3 \Rightarrow R = 10r \therefore \frac{r}{R} = \frac{1}{10}$

$\frac{\text{surface energy of one small drop}}{\text{surface energy of one big drop}} = \frac{4\pi r^2 T}{4\pi R^2 T} = \frac{1}{100}$

23. (a) $E = T \times \Delta A = 3 \times 10^{-2} \times 2(100 \times 10^{-4}) = 6 \times 10^{-4} J$

24. (a) $W = 8\pi R^2 T = 8 \times 3.14 \times (10 \times 10^{-2}) \times \frac{3}{100}$

$= 7.536 \times 10^{-3} J$

25. (b) Work done = $4\pi R^2 T(n^{1/3} - 1) = 4\pi\left(\frac{D}{2}\right)^2 \sigma(n^{1/3} - 1)$

$= \pi D^2 \sigma(27^{1/3} - 1) = 2\pi D^2 \sigma$

26. (d) As volume remain constant therefore $R = n^{1/3} r$

$\frac{\text{surface energy of one big drop}}{\text{surface energy of } n \text{ drop}} = \frac{4\pi R^2 T}{n \times 4\pi r^2 T}$

$\frac{R^2}{nr^2} = \frac{n^{2/3} r^2}{nr^2} = \frac{1}{n^{1/3}} = \frac{1}{(1000)^{1/3}} = \frac{1}{10}$

27. (b) $W = T \times \Delta A \;\therefore\; T = \frac{W}{\Delta A}$

$T = \frac{3 \times 10^{-4}}{2 \times (110 - 60) \times 10^{-4}}$ (Soap film has two surfaces)

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

28. (d)

29. (d) $\frac{4}{3}\pi R^3 = 1000 \times \frac{4}{3}\pi r^3$ (As volume remains constant)

$R^3 = 1000 r^3 \Rightarrow R = 10r \Rightarrow r = \frac{R}{10}$

30. (c) Because energy is liberated

31. (a,d)

32. (c) As volume remains constant $R^3 = 8000 r^3 \;\therefore R = 20r$

$\frac{\text{Surface energy of one big drop}}{\text{Surface energy of 8000 small drop}} = \frac{4\pi R^2 T}{8000\; 4\pi r^2 T}$

$= \frac{R^2}{8000 r^2} = \frac{(20r)^2}{8000 r^2} = \frac{1}{20}$

33. (b) Surface energy = $T \times A = 5 \times 2 \times (0.15) = 1.5 J$

34. (c) As volume remains constant therefore $R = n^{1/3} r$

$\frac{\text{Energy of big drop}}{\text{Energy of small drop}} = \frac{4\pi R^2 T}{4\pi r^2 T} = \frac{R^2}{r^2} = (8)^{2/3} = 4$

35. (a) $T = \frac{W}{\Delta A} = \frac{2 \times 10^{-4}}{2 \times (50 \times 10^{-4})} = 2 \times 10^{-2}\; N/m$

36. (a) $W = T\Delta A = 4\pi R^2 T(n^{1/3} - 1)$

$= 4 \times 3.14 \times (10^{-2})^2 \times 460 \times 10^{-3} \times [(10^6)^{1/3} - 1] = 0.057$

37. (a)

38. (b) Increment in area of soap film = $A_2 - A_1$

$= 2 \times [(10 \times 0.6) - (10 \times 0.5)] \times 10^{-4} = 2 \times 10^{-4} m^2$

Work done = $T \times \Delta A$

$= 7.2 \times 10^{-2} \times 2 \times 10^{-4} = 1.44 \times 10^{-5} J$

39. (a) Increase in surface energy or work done in splitting a big drop $= 4\pi R^2 T(n^{1/3} - 1)$

$\Rightarrow W = 4\pi \times (2 \times 10^{-3})^2 \times 0.465(8^{1/3} - 1) = 23.4\; \mu J$

40. (b) The ratio of the total surface energies before and after the change $= n^{1/3} : 1 = 2^{1/3} : 1$

41. (a) $W = 8\pi S(R_2^2 - R_1^2) = 8\pi S[(2R)^2 - R^2] = 24\pi R^2 S$

42. (a) $W = 8\pi r^2 \times T = 8\pi \times (0.2)^2 \times 0.06 = 192\pi \times 10^{-4} J$

43. (b) Increment in Potential energy = $T \times \Delta A$

$= 0.02 \times 2 \times 0.05 = 2 \times 10^{-2} J$

44. (a) $E = T \times \Delta A = 75 \times 0.04 = 3 J$

45. (c) $r = \frac{r_1 r_2}{r_2 - r_1} = \infty$ since $r_1 = r_2$

Angle of Contact

1. (b)

2. (a)

3. (b) Cohesive force decreases so angle of contact decreases.

4. (d)

5. (b)

6. (b)

7. (d)

8. (b)

9. (a)

10. (c) Angle of contact is acute.

11. (a)

12. (c)

13. (b)

14. (b) Since for such liquid (Non-wetting) angle of contact is obtuse.

15. (b) Both liquids water and alcohol have same nature (*i.e.* wet the solid). Hence angle of contact for both is acute.

16. (d) Tangent drawn at point of contact makes 0° with wall of container.

Pressure Difference

1. (c)

2. (c) Since $\Delta P \propto \frac{1}{R}$

3. (b) Excess pressure $\Delta P = \frac{4T}{r}$

$= \frac{4 \times 2 \times 25 \times 10^{-3}}{1 \times 10^{-2}} = 20\ N/m^2 = 20\ Pa\ (\text{as } r = d/2)$

4. (c)

5. (c)

6. (c) $hdg = \frac{2T}{r} \Rightarrow h = \frac{2T}{rdg}$

7. (b) $\Delta P = \frac{4T}{r} = 40\ N/m^2$

8. (b)

9. (b) $\Delta P = \frac{4T}{r} = hdg \Rightarrow T = \frac{rhdg}{4} = \frac{0.35 \times 0.8 \times 1 \times 10^3}{4}$

$= 70\ dyne/cm \equiv 68.66\ dyne/cm$

10. (c) Outside pressure = 1 *atm*

Pressure inside first bubble = 1.01 *atm*

Pressure inside second bubble = 1.02 *atm*

Excess pressure $\Delta P_1 = 1.01 - 1 = 0.01\ atm$

Excess pressure $\Delta P_2 = 1.02 - 1 = 0.02\ atm$

$\Delta P \propto \frac{1}{r} \Rightarrow r \propto \frac{1}{\Delta P} \Rightarrow \frac{r_1}{r_2} = \frac{\Delta P_2}{\Delta P_1} = \frac{0.02}{0.01} = \frac{2}{1}$

Since $V = \frac{4}{3}\pi r^3 \therefore \frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$

11. (b) $S = \frac{rhdg}{2\cos\theta} \Rightarrow$ Pressure difference $= hdg = \frac{2S}{r}\cos\theta$

12. (c)

13. (c) Excess pressure inside soap bubble is inversely proportional to the radius of bubble *i.e.* $\Delta P \propto \frac{1}{r}$

This means that bubbles A and C posses greater pressure inside it than B. So the air will move from A and C towards B.

14. (c) $P_1V_1 = P_2V_2 \Rightarrow (H + h)\rho g \times \frac{4}{3}\pi r^3 = H \times \frac{4}{3}\pi (2r)^3$

$\Rightarrow H + h = 8H \therefore h = 7H$

15. (c) $r = \sqrt{r_1^2 + r_2^2} = \sqrt{9 + 16} = 5\ cm$

16. (c) $P_1V_1 = P_2V_2 \Rightarrow (H_{Hg}\rho_{Hg} + H_W\rho_W)V = H_{Hg}\rho_{Hg} \times 3V$

$\Rightarrow H_{Hg}\rho_{Hg} + H_W\frac{\rho_{Hg}}{10} = 3H_{Hg}\rho_{Hg}$

$\Rightarrow H_W = 2H_{Hg} \times 10 = \frac{2 \times 75 \times 10}{100} = 15m$

17. (a) $\Delta P = \frac{4T}{r} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = 4 \therefore \frac{r_2}{r_1} = 4$ and $\frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \frac{1}{64}$

18. (b) $\Delta P \propto \frac{1}{r}$

19. (b) Pressure at half the depth $= P_0 + \frac{h}{2}dg$

Pressure at the bottom $= P_0 + hdg$

According to given condition

$P_0 + \frac{h}{2}dg = \frac{2}{3}(P_0 + hdg)$

$\Rightarrow 3P_0 + \frac{3h}{2}dg = 2P_0 + 2hdg$

$\Rightarrow h = \frac{2P_0}{dg} = \frac{2 \times 10^5}{10^3 \times 10} = 20\ m$

20. (a) $\Delta P \propto \frac{1}{r} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = \frac{r_2}{r_1} = \frac{r}{4r} = \frac{1}{4}$

21. (c) $\Delta P = \frac{2T}{R} = \frac{2 \times 70 \times 10^{-3}}{1 \times 10^{-3}} = 140\ N/m^2$

22. (c) $P = h\rho g$

23. (d)

24. (b) $r = \dfrac{r_1 r_2}{r_1 - r_2} = \dfrac{5 \times 4}{5 - 4} = 20\ cm$

25. (c) Excess pressure inside the air bubble $= \dfrac{2T}{r}$

$\Rightarrow P_{in} - P_{out} = \dfrac{2T}{r} = \dfrac{2 \times 70 \times 10^{-3}}{0.1 \times 10^{-3}} = 1400 Pa$

$\Rightarrow P_{in} = 1400 + 1.013 \times 10^5 = 1.027 \times 10^5\ Pa$

26. (a) $r_A > r_B$ and $P \propto \dfrac{1}{r}$ so $P_A < P_B$

So air will flow from B to A *i.e.* size of A will increase.

27. (a) $\Delta P = \dfrac{4T}{R}$ $\therefore$ $\Delta P \propto \dfrac{1}{R}$ (T = constant)

Hence, the internal pressure of smaller bubble is larger than that of larger bubble.

28. (b) $\dfrac{4T}{R} = hdg$ $\therefore$ $T = \dfrac{Rhdg}{4}$

$T = \dfrac{10^{-2} \times 2 \times 10^{-3} \times 0.8 \times 10^3 \times 9.8}{4} = 3.9 \times 10^{-2}\ N/m$

29. (a)

30. (d) $\Delta P \propto \dfrac{1}{r} \Rightarrow \dfrac{r_1}{r_2} = \dfrac{\Delta P_2}{\Delta P_1} = \dfrac{1}{3} \Rightarrow \dfrac{V_1}{V_2} = \left(\dfrac{r_1}{r_2}\right)^3 = \dfrac{1}{27}$

Capillarity

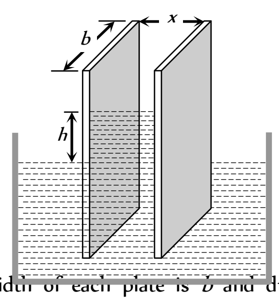
1. (d) $h = \dfrac{2T\cos\theta}{rdg}$ $\therefore h \propto \dfrac{1}{r}$ (T, θ, d and g are constant)

If r is less then h will be more.

2. (a) $h = \dfrac{2T\cos\theta}{rdg}$. If θ is less than 90° then h will be positive

3. (d) In the state of weightlessness or in gravity free space, water will rise to the upper end of the tube of any length.

4. (b)



Let the width of each plate is b and due to surface tension liquid will rise upto height h then upward force due to surface tension

$= 2Tb\cos\theta$ ...(i)

Weight of the liquid rises in between the plates

$= Vdg = (bxh)dg$ ...(ii)

Equating (i) and (ii) we get, $2T\cos\theta = bxhdg$

$\therefore h = \dfrac{2T\cos\theta}{xdg}$

5. (d) $6 \times 10^{-2} \times$ Circumference = Force

$\therefore$ Circumference $= \dfrac{75 \times 10^{-4}}{6 \times 10^{-2}} = 12.5 \times 10^{-2} m$

6. (d) Due to capillarity it absorbs the ink.

7. (b) $r \propto \dfrac{1}{h} \Rightarrow \dfrac{r_P}{r_Q} = \dfrac{h_Q}{h_P} = \dfrac{h}{\frac{2}{3}h} = \dfrac{2}{3}$

8. (c) $r \propto \dfrac{1}{h} \Rightarrow \dfrac{r_1}{r_2} = \dfrac{h_2}{h_1} = \dfrac{6.6}{2.2} = \dfrac{3}{1}$

9. (c) $\dfrac{h_2}{h_1} = \dfrac{r_1}{r_2} = \dfrac{1}{2} \Rightarrow h_2 = \dfrac{30}{2} = 15cm$

10. (b)

11. (b)

12. (d) $h = \dfrac{2T}{rdg} = \dfrac{2 \times 75}{0.005 \times 1 \times 10^3} = 30cm$

13. (c) $T = \dfrac{rh\rho g}{2} \Rightarrow 75 \times 10^{-3} = \dfrac{3 \times 10^{-2} \times r \times 10^3 \times 9.8}{2}$

$\Rightarrow r = \dfrac{1}{2}mm$ $\therefore D = 2r = 1\ mm$

14. (c) The angle of contact of mercury with glass is obtuse. So it gets depressed below the liquid level outside.

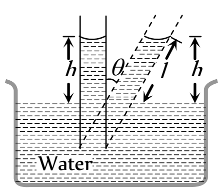
15. (d) The water rises to height h due to capilarity.

16. (b) $h \propto \dfrac{1}{r}$

17. (b) $h = \dfrac{2T}{rdg} = \dfrac{2 \times 6 \times 10^{-2}}{5 \times 10^{-4} \times 10^3 \times 10} = 2.4 \times 10^{-2} m = 2.4cm$

18. (b) $h \propto \dfrac{1}{r}$ $\therefore$ $r_1 h_1 = r_2 h_2 \Rightarrow \dfrac{h_1}{h_2} = \dfrac{r_2}{r_1} = \dfrac{0.4}{0.2} = 2:1$

19. (b)



Vertical height of the water in the tube remains constant

So, $l = \dfrac{h}{\cos\theta} = \dfrac{3}{\cos 60^o} = 6\ cm$

20. (c)

21. (a)

22. (d) If lift moves downward with some acceleration then effective g decreases, so h increases.

As $h = \frac{2T\cos\theta}{rdg}$ $\therefore h \propto \frac{1}{g}$

23. (c)

24. (a) $\frac{2T}{r} = hdg \Rightarrow r = \frac{2T}{hdg}$

25. (b) $h \propto \frac{1}{r} \therefore r_1h_1 = r_2h_2 \Rightarrow h_2 = \frac{r_1h_1}{r_2} = 2.4\ mm$

26. (a)

27. (a) $h \propto \frac{1}{r}$ $\therefore$ rh = constant

28. (a) $h = \frac{2T\cos\theta}{rdg} \therefore h \propto \frac{1}{g}$

As $g_m = \frac{g_e}{6} \therefore h_m = 6h_e$

29. (d) Ascent formula $h = \frac{2T\cos\theta}{rdg}$

$\Rightarrow \frac{h_1}{h_2} = \frac{T_1}{T_2} \times \frac{d_2}{d_1}$ (r, θ and g are constants)

$= \frac{60}{50} \times \frac{0.6}{0.8} = \frac{9}{10}$

30. (b) $l = \frac{h}{\cos\theta} = \frac{2}{\cos 60^o} = 4.0\ cm$

31. (d) $T = \frac{rhdg}{2\cos\theta}$. For pure water $\theta = 0^o$ so $T = \frac{rhdg}{2}$

32. (c) The length of the water column will be equal to full length of capillary tube.

33. (b) $T = \frac{F}{2\pi r} = \frac{6.28 \times 10^{-4}}{2 \times 3.14 \times 2 \times 10^{-3}} = 5 \times 10^{-2}\ N/m$

34. (a) $h \propto \frac{1}{R}$

35. (a) $h = \frac{2T\cos\theta}{rdg}$, for water $\theta = 0°$

$\Rightarrow r = \frac{2T}{hdg} = \frac{2 \times 7.2 \times 10^{-2}}{3 \times 10^{-2} \times 10^3 \times 10} = 4.8 \times 10^{-4}$

$\therefore\ d = 2r = 9.6 \times 10^{-4}\ m$

36. (c) $h = \frac{2T}{rdg} \Rightarrow r = \frac{2T}{hdg} = \frac{2 \times 75 \times 10^{-3}}{15 \times 10^{-3} \times 10^3 \times 10} = 1mm$

37. (d) $h \propto \frac{1}{r}$

38. (a)

39. (a)

40. (b) Mass of liquid in capillary tube

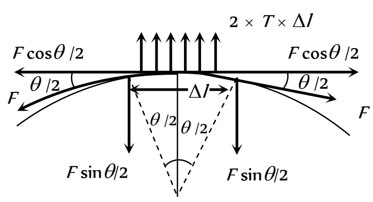
$M = \pi R^2 H \times \rho \therefore\ M \propto R^2 \times \left(\frac{1}{R}\right)$ (As $H \propto 1/R$)

$\therefore\ M \propto R$. If radius becomes double then mass will becomes twice.

41. (c) $h \propto \frac{1}{r} \Rightarrow \frac{h_2}{h_1} = \frac{r_1}{r_2} = \frac{D_1}{D_2} = 2 \Rightarrow h_2 = 2h_1$

Critical Thinking Questions

1. (d) Suppose tension in thread is F, then for small part Δl of thread



$\Delta l = R\theta$ and $2F\sin\theta/2 = 2T\Delta l = 2TR\theta$

$\Rightarrow F = \frac{TR\theta}{\sin\theta/2} = \frac{TR\theta}{\theta/2} = 2TR(\sin\theta/2 \approx \theta/2)$

2. (c) Rise in temperature, $\Delta\theta = \frac{3T}{JSd}\left(\frac{1}{r} - \frac{1}{R}\right)$

$\therefore \Delta\theta = \frac{3T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$ (For water $S = 1$ and $d = 1$)

3. (b,c) $P_{Bottom} > P_{Surface}$. So bubble rises upward.

At constant temperature $V \propto \frac{1}{P}$ (Boyle's law)

Since as the bubble rises upward, pressure decreases, then from above law volume of bubble will increase *i.e.* its size increases.

4. (d) In the satellite, the weight of the liquid column is zero. So the liquid will rise up to the top of the tube.

Graphical Questions

1. (b) $h = \frac{2T\cos\theta}{rdg}$ $\therefore$ $h \propto \frac{1}{r}$. So the graph between h and r will be rectangular hyperbola.

2. (a) $\Delta P = \frac{4T}{r} \therefore \Delta P \propto \frac{1}{r}$

As radius of soap bubble increases with time $\therefore \Delta P \propto \frac{1}{t}$

3. (b) $T_c = T_o(1 - \alpha t)$ *i.e.* surface tension decreases with increase in temperature.

Assertion and Reason

1. (c) When a liquid is sprayed, the surface area of the liquid increases. Therefore, work has to be done in spraying the liquid, which is directly proportional to the surface tension.

Because on adding soap, surface tension of water decreases, the spraying of water becomes easy.

2. (e) The soap solution, has less surface tension as compared to ordinary water and its surface tension decreases further on heating. The hot soap solution can, therefore spread over large surface area and also it has more wetting power. It is on account of this property that hot soap solution can penetrate and clean the clothes better than the ordinary water.

3. (a) $h=\frac{2T}{Rdg} \Rightarrow hR=\frac{2T}{Rdg} \quad \therefore \; hR=\text{constant}$

Hence when the tube is of insufficient length, radius of curvature of the liquid meniscus increases, so as to maintain the product hR a finite constant.

i.e. as h decreases, R increases and the liquid meniscus becomes more and more flat, but the liquid does not overflow.

4. (c) Needle floats due to surface tension there is no role of buoyant force in its floating

Buoyant force = $V\sigma g$

Where V = volume of body submerged in liquid

σ = density of liquid.

i.e. the buoyancy of an object depends on the shape of the object.

5. (c) The two glass plates stick together due to surface tension.

6. (e) The presence of impurities either on the liquid surface or dissolved in it, considerably affect the force of surface tension, depending upon the degree of contamination. A highly soluble substance like sodium chloride when dissolved in water increase the surface tension. But the sparing soluble or substance like phenol when dissolved in water reduces the surface tension of water.

7. (c) With increase in temperature surface tension of the liquid decreases and angle of contact also decreases.

8. (b) We know that the intermolecular distance between the gas molecules is large as compared to that of liquid. Due to it the forces of cohesion in the gas molecules are very small and these are quite large for liquids. Therefore, the concept of surface tension is applicable to liquid but not to gases.

9. (a) Zero surface tension means no opposition to expansion.

10. (a) Since the excess pressure due to surface tension is inversely proportional to its radius, it follows that smaller the bubble, greater is the excess pressure. Thus, when the larger and the smaller bubbles are put in communication, air starts passing from the smaller into the large bubble because excess pressure inside the former is greater than inside the latter. As a result, the smaller bubble shrinks and the larger one swells.

11. (b) When a drop of liquid is poured on a glass plate, the shape of the drop is governed by two forces, the force of gravity. For very small drops, the potential energy due to gravity is insignificant compared to that due to surface tension. Hence, in this case the shape of the drop is determined by surface tension alone and drop becomes spherical.

12. (a) The height of capillary rise is inversely proportional to radius (or diameter) of capillary tube *i.e.* $h \propto \frac{1}{r}$

So for smaller r the value of h is higher.

13. (c) With increase in temperature of liquid its surface tension decreases so that it tends to acquire larger area. Hence hot soup having low value of surface tension spread properly on our tongue & provides better taste than cold soup.

14. (b) The free surface of liquid tries to acquire a minimum area due to surface tension, hence liquid drop is spherical because sphere has minimum area than other shape.

Surface Tension

SET Self Evaluation Test -10

1. A soap film of surface tension $3\times10^{-2}\ Nm^{-1}$ formed in rectangular frame, can support a straw. The length of the film is 10 *cm*. Mass of the straw the film can support is

(a) 0.06 *gm* (b) 0.6 *gm*

(c) 6 *gm* (d) 60 *gm*

2. Energy required to form a soap bubble of diameter 20 *cm* will be (Surface tension for soap solution is 30 *dynes/cm*)

(a) 12000 π *ergs* (b) 1200 π *ergs*

(c) 2400 π *ergs* (d) 24000 π *ergs*

3. If the work done in blowing a bubble of volume *V* is *W*, then the work done in blowing the bubble of volume 2*V* from the same soap solution will be [MP PET 1989]

(a) *W*/2 (b) $\sqrt{2}\ W$

(c) $\sqrt[3]{2}\ W$ (d) $\sqrt[3]{4}\ W$

4. Surface tension of soap solution is 2×10^{-2} *N/m*. The work done in producing a soap bubble of radius 2 *cm* is

(a) $64\pi\times10^{-6}\ J$ (b) $32\pi\times10^{-6}\ J$

(c) $16\pi\times10^{-6}\ J$ (d) $8\pi\times10^{-6}\ J$

5. Excess pressure inside a soap bubble is three times that of the other bubble, then the ratio of their volumes will be

(a) 1 : 3 (b) 1 : 9

(c) 1 : 27 (d) 1 : 81

6. When a capillary tube is dipped in water it rises upto 8 *cm* in the tube. What happens when the tube is pushed down such that its end is only 5 *cm* above the outside water level

(a) The radius of the meniscus increases and therefore water does not overflow

(b) The radius of the meniscus decreases and therefore water does not overflow

(c) The water forms a droplet on top of the tube but does not overflow

(d) The water start overflowing

7. A bubble of 8 mm diameter is formed in the air. The surface tension of soap solution is 30 *dynes/cm*. The excess pressure inside the bubble is [MP PET 1990]

(a) 150 $dynes/cm^2$ (b) 300 $dynes/cm^2$

(c) 3×10^{-3} *dynes/cm* (d) 12 $dynes/cm^2$

8. The height upto which water will rise in a capillary tube will be

(a) Maximum when water temperature is $4°C$

(b) Maximum when water temperature is $0°C$

(c) Minimum when water temperature is $4°C$

(d) Same at all temperatures

9. Water rises to a height of 10 *cm* in capillary tube and mercury falls to a depth of 3.112 *cm* in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the ratio of surface tension of water and mercury is

(a) 1 : 0.15 (b) 1 : 3

(c) 1 : 6 (d) 1.5 : 1

10. The angle of contact between glass and water is 0° and it rises in a capillary upto 6 *cm* when its surface tension is 70 *dynes/cm*. Another liquid of surface tension 140 *dynes/cm*, angle of contact 60° and relative density 2 will rise in the same capillary by

(a) 12 *cm* (b) 24 *cm*

(c) 3 *cm* (d) 6 *cm*

11. A drop of water breaks into two droplets of equal size. In this process, which of the following statement is correct [NCERT 1976]

(a) The sum of temperature of the two droplets together is equal to the original temperature of the drop

(b) The sum of masses of the two droplets is equal to the original mass of the drop

(c) The sum of the radii of two droplets is equal to the radius of the original drop

(d) The sum of the surface areas of the two droplets is equal to the surface area of the original drop

12. A soap bubble of radius *R* is blown. After heating the solution a second bubble of radius 2*R* is blown. The work required to blow the second bubble in comparison to that required for the first bubble is

(a) Double

(b) Slightly less than double

(c) Slightly less than four times

(d) Slightly more than four times

13. A false statement is

(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

14. The diameter of rain-drop is 0.02 *cm*. If surface tension of water be 72×10^{-3} *newton* per *metre*, then the pressure difference of external and internal surfaces of the drop will be

(a) $1.44\times10^{4}\ dyne-cm^{-2}$

(b) $1.44\times10^{4}\ newton-m^{-2}$

(c) $1.44 \times 10^3\ dyne - cm^{-2}$

(d) $1.44 \times 10^5\ newton - m^{-2}$

15. Water rises to a height of 16.3 *cm* in a capillary of height 18 *cm* above the water level. If the tube is cut at a height of 12 *cm*

(a) Water will come as a fountain from the capillary tube

(b) Water will stay at a height of 12 *cm* in the capillary tube

(c) The height of the water in the capillary will be 10.3 *cm*

(d) Water will flow down the sides of the capillary tube

[CPMT 1974]

Answers and Solutions

(SET - 10)

1. (b) The weight of straw will be balanced by the force of surface tension $\therefore\ mg = 2Tl \Rightarrow m = \frac{2Tl}{g}$

$= \frac{2 \times 3 \times 10^{-2} \times 10 \times 10^{-2}}{9.8} kg = 0.6 gm$

2. (d) $E = 8\pi r^2 T = 8\pi (10)^2 \times 30 = 24000\ \pi\ erg$

3. (d) Work done to form a soap bubble

$W = 8\pi R^2 T$ (As $V \propto R^3 \ \therefore\ R \propto V^{1/3}$)

$\therefore\ W \propto V^{2/3}$

$\frac{W_2}{W_1} = \left(\frac{V_2}{V_1}\right)^{2/3} = (2)^{2/3} \Rightarrow W_2 = (4)^{1/3} W$

4. (a) $W = 8\pi R^2 T = 8 \times \pi \times (2 \times 10^{-2})^2 \times 2 \times 10^{-2} = 64\pi \times 10^{-6} J$

5. (c) $\Delta P \propto \frac{1}{r} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = \frac{r_2}{r_1} \Rightarrow \frac{r_2}{r_1} = \frac{3}{1}$

$\therefore \frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{3}\right)^3 = \frac{1}{27}$

6. (a) $h = \frac{2T}{Rdg} \Rightarrow hR = \frac{2T}{dg} = \text{constant}$

When h decreases, R increases.

7. (b) $\Delta P = \frac{4T}{r} = \frac{4 \times 30}{0.4} = 300\ dyne/cm^2$.

8. (c) $h = \frac{2T\cos\theta}{rdg}$. For water, density is maximum at 4^oC, so the height is minimum at 4^oC.

***

9. (c) $h = \frac{2T\cos\theta}{rdg} \therefore T = \frac{hrdg}{2\cos\theta}$

$\Rightarrow \frac{T_1}{T_2} = \frac{h_1}{h_2} \times \frac{r_1}{r_2} \times \frac{d_1}{d_2} \times \frac{\cos\theta_2}{\cos\theta_1} = \frac{1}{6}$

10. (c) $h = \frac{2T\cos\theta}{rdg} \therefore \frac{h_2}{h_1} = \frac{T_2}{T_1} \times \frac{\cos\theta_2}{\cos\theta_1} \times \frac{d_1}{d_2} \times \frac{r_1}{r_2}$

$\frac{h_2}{h_1} = \frac{140}{70} \times \frac{\cos 60°}{\cos 0°} \times \frac{1}{2} \times 1 = \frac{1}{2} \Rightarrow h_2 = \frac{h_1}{2} = 3cm.$

11. (b)

12. (c) Work done to form a bubble of radius R

$W_1 = 8\pi R^2 T_1$

Work done to form a bubble of radius $2R$

$W_2 = 8\pi(2R)^2 T_2 = 32\pi R^2 T_2 \ \therefore \frac{W_1}{W_2} = \frac{T_1}{4T_2}$

If surface tension of soap solution is same then

$W_2 = 4W_1$

But in the problem temperature of solution is increased so its surface tension decreases.

$\therefore W_2 < 4W_1$

13. (d) If radius of capillary is reduced to half, the rise of liquid column will be two times. as $h \propto 1/r$

14. (a) $\Delta P = \frac{2T}{r} = \frac{2 \times 72 \times 10^{-3}}{0.01 \times 10^{-2}} = 1440\ N/m^2$

$= 1.44 \times 10^4\ dyne/cm^2$

15. (b) Because if the length available is less than required, then water will rise upto available height and adjust its radius of curvature.