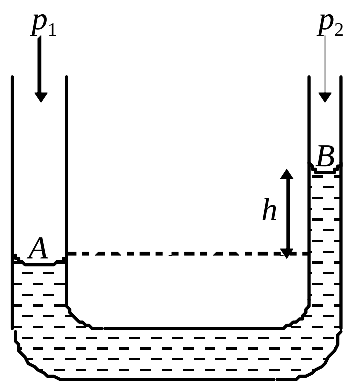
SOLVED EXAMPLES

Example 1.	Calculate the work done in blowing up a soap bubble from an initial surface area of 0.50 cm^2 to a final surface area of 1.10 cm^2. The surface tension of soap solution is 30 dyne cm^{-1}. (1) 24 erg (2) 36 erg (3) 72 erg (4) 144 erg
Solution :	Here T= 30 dyne cm^{-1} Initial surface area of the soap bubble = 0.50 cm^2 Final surface area of the soap bubble = 1.10 cm^2 Since the soap bubble has two free surfaces, effective increase in the surface area of the soap bubble. A = 2 × (1.10 – 0.50) = 1.20 cm^2 The work done in blowing up the soap bubble to the new size, W = T × A = 30 × 1.20 = 36 erg
Example 2.	What would be the gauge pressure inside an air bubble of 0.2 mm radius situated just below the surface of water? Surface tension of water is 0.07 Nm^{-1}. (1) 6.25×10^{-2} mm of Hg (2) 5.25×10^{-2} mm of Hg (3) 4.25×10^{-2} mm of Hg (4) 4.25×10^{-1} mm of Hg
Solution :	Here, T = 0.07 Nm^{-1}, R = 0.2 mm = 2×10^{-4} m The excess of pressure inside the air bubble, $p_1 - p_o = \frac{2T}{R} = \frac{2\times 0.07}{2\times 10^{-4}} = 700 Nm^2$ Let the gauge pressure inside the air bubble be equal to h cm of mercury column. If ρ is the density of the mercury. Then $h\rho g = 700$ or $h = \frac{700}{\rho g} = \frac{700}{13.6\times 10^3 \times 9.8}$ = 5.25×10^{-3} cm of Hg = 5.25×10^{-2} mm of Hg.
Example 3.	Two vertical glass plates1 mm a part are dipped into water. How high will the water rise between the plates, if the surface tension of water is 70 dyne cm^{-1}? (1) 1.43 cm (2) 1.63 cm (3) 2.86 cm (4) 3.86 cm
Solution :	$25\times 10^{-3} \times 2 \times 0.1 = m \times 10$ or $m = \frac{5\times 10^{-3}}{10}$ kg =0.05 g
Example 4.	A small hollow sphere which has a small hole in it is immersed in water to a maximum depth 20 cm before any water can penetrate into it. If the surface tension of water is 70 dyne cm^{-1}, find the radius of the hole. (1) 7.1×10^{-5} m (2) 7.1×10^{-3} m (3) 4.0×10^{-5} m (4) 4.0×10^{-3} m

Solution :	Pressure exerted by 20 cm column of water = $h\rho g$ = 20 × 1 × 980 = 19600 dyne cm^{-2} Excess pressure inside air bubble = $\frac{2T}{r} = \frac{2\times 70}{r} = \frac{140}{r}$ dyne cm^{-2} So, 19600 = $\frac{140}{r}$; r = $\frac{140}{19600}$ = 0.00714 cm
Example 5.	Drops of liquid of density d are floating half immersed in a liquid of density ρ. If the surface tension of liquid is T then what is the radius of the drop? (1) $\sqrt{\frac{T}{g(2d-\rho)}}$ (2) $\sqrt{\frac{3T}{2g(2d-\rho)}}$ (3) $\sqrt{\frac{3T}{g(2d-\rho)}}$ (4) $\sqrt{\frac{5T}{2g(2d-\rho)}}$
Solution :	Force due to surface tension + force of buoyancy = weight of drop $2\pi rT + \frac{1}{2}\times\frac{4}{3}\pi r^3\rho g = \frac{4}{3}\pi r^3 dg$ Solving for r $r = \sqrt{\frac{3T}{g\left(2d-\rho\right)}}$
Example 6.	A paper disc of radius R from which a hole of radius r is cut out, is floating in a liquid of surface tension T. The force on the disc due to surface tension will be (1) $2\pi RT$ (2) $2\pi(R-r)T$ (3) $2\pi(R+r)T$ (4) $4\pi(R-r)T$
Solution :	$T = \frac{F}{L}$ $T = \frac{F}{2\pi\left(R+r\right)}$ $\therefore$ $F = 2\pi\left(R+r\right)T$
Example 7.	The lower end of a capillary tube of diameter 2.00 mm is dipped 8.00 cm below the surface of water in a beaker. What is the pressure required in the tube to blow a bubble at its end in water? Also calculate the excess pressure. [Surface tension of water = 73 × 10^{-3} N/m, density of water = 10^{3} kg/m^{3}, 1 atmosphere = 1.01 × 10^{5} Pa and g = 9.8 m/s^{2}]? (1) 1.02 × 10^{5} Pa (2) 1.02 × 10^{7} Pa (3) 1.02 × 10^{7} Pa (4) 1.02 × 10^{6} Pa
Solution :	As the bubble is in water, it has only one surface So $p = p_{in} - p_{out} = \frac{2T}{r} = \frac{2\times 7.3\times 10^{-2}}{10^{-3}} = 146$ Pa Now as bubble is at a depth of 8 cm in water, $p_{out} = p_{at} + h\rho g$ so that $p_{in} = p + p_{out} = p + p_{at} + h\rho g$ i.e. $p_{in} = 146 + 1.01 + 10^5 + 8\times 10^{-2}\times 10^3 \times 9.8$ = 1.02 ×10^{5} Pa

Example 8.	The limbs of a manometer consist of uniform capillary tubes of radii 1.4×10^{-3} m and 7.2×10^{-4} m. Find out the correct pressure difference if the level of the liquid (density 10^3 kg/m^3, surface tension 72×10^{-3} N/m) in narrower tube stands 0.2 m above that in the broader tube. (1) 1863 Pa (2) 1445 Pa (3) 1369 Pa (4) 2079 Pa
Solution :	If p_1 and p_2 are the pressure in the broader and narrower tubes of radii r_1 and r_2 respectively, the pressure just below the meniscus in the respective tubes will be $p_1 - \frac{2T}{r_1}$ and $p_2 - \frac{2T}{r_2}$ so that $\left[p_1 - \frac{2T}{r_1}\right] - \left[p_2 - \frac{2T}{r_2}\right] = h\rho g$ or $p_1 - p_2 = h\rho g - 2T\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$  [Assuming the angle of contact to be zero, i.e., radius of meniscus equal to that of capillary] $p_1 - p_2 = 0.2 \times 10^3 \times 9.8 - 2 \times 72 \times 10^{-3}\left[\frac{1}{72 \times 10^{-4}} - \frac{1}{14 \times 10^{-4}}\right]$ $p_1 - p_2 = 1960 - 97 = 1863\,\text{Pa}$

MULTIPLE CHOICE QUESTIONS

LEVEL – I

1. A soap bubble assumes a spherical surface. Which of the following statements is wrong?
   (1) The soap film consists of two surfaces.
   (2) The bubble encloses air inside it
   (3) The pressure of air inside the bubble is less than the atmospheric pressure, that is why atmospheric pressure has compressed it equally from all sides to give it a spherical shape
   (4) Because of the elastic property of the film, it will tend to shrink to as small surface area as possible for the volume it has enclosed

2. With rise of temperature the surface tension of a liquid
   (1) decreases (2) increases
   (3) remains constant (4) none of these

3. 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
   (1) water will come as a fountain from the capillary tube
   (2) water will stay at a height of 12 cm in the capillary tube
   (3) the height of water in the capillary will be 10.3 cm
   (4) water will flow down the sides of the capillary tube

4. A liquid will not wet the surface of a solid if the angle of contact is
   (1) 0° (2) 45°
   (3) 60° (4) > 90°

5. With the rise in temperature the angle of contact
   (1) increases
   (2) decreases
   (3) remains constant
   (4) sometimes increases and sometimes decreases

6. When two capillary tubes of different diameters are dipped vertically, the rise of the liquid is
   (1) same in both the tubes
   (2) more in tube of larger diameter
   (3) less in tube of smaller diameter
   (4) more in the tube of smaller diameter

7. A drop of water breaks into two droplets of equal size. In this process which of the following statements is correct?
   (1) The sum of the temperatures of the two droplets together is equal to the original temperature of the drop
   (2) The sum of the masses of the two droplets is equal to the original mass of the drop
   (3) The sum of the radii of the two droplets is equal to the radius of the original drop
   (4) The sum of the surface areas of the two droplets is equal to the surface area of the original drop

8. Two water droplets combine to form a large drop. In this process energy is
   (1) liberated
   (2) absorbed
   (3) neither liberated nor absorbed
   (4) sometimes liberated and sometimes absorbed

9. Two soap bubbles are blown. In the first bubble excess pressure is 4 times of 2^{nd} soap bubble. The ratio of radii of first to second soap bubble is
   (1) 1 : 4 (2) 1 : 2
   (3) 2 : 1 (4) 4 : 1

10. The lower end of a capillary tube touches a liquid whose angle of contact is 90°, the liquid
    (1) rises into the tube
    (2) falls in the tube
    (3) may rise or fall inside the tube
    (4) neither rises nor falls inside the tube

11. When a capillary tube is dipped in a liquid, the capillary rise is h_1, when the inner surface is coated with wax, the capillary rise is h_2, then

(1) $h_1 = h_2$ (2) $h_1 < h_2$

(3) $h_1 > h_2$ (4) none of these

12. Two unequal soap bubbles are formed one on each side of a tube closed in the middle by a tap. What happens when the tap is opened to put the two bubbles in communication?

(1) No air passes in any direction as the pressures are the same on two sides of the tap

(2) Larger bubble shrinks and smaller bubble increases in size till they become equal in size

(3) Smaller bubble gradually collapses and the bigger one increases in size

(4) None of these

13. A capillary is immersed in water in a state of weightlessness. The water will

(1) not rise in the tube

(2) rise to the maximum available height

(3) rise to height normally observed under gravity

(4) rise to a height lesser than that observed under gravity

14. The radius of the bore of a capillary tube is r and the angle of contact is θ. When the tube is dipped in the liquid, the radius of curvature of the meniscus of liquid rising in the tube is

(1) $r\sin\theta$ (2) $r/\sin\theta$

(3) $r\cos\theta$ (4) $r/\cos\theta$

15. 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 tube is

(1) 1 : 2 (2) 2 : 1

(3) 1 : 4 (4) 4 : 1

16. The shape of a liquid drop becomes spherical due to its

(1) surface tension (2) density

(3) viscosity (4) temperature

17. A capillary tube is filled with liquid upto a height of 50 cm. The reading when the capillary tube is tilted to an angle of 45° is

(1) 50 cm (2) $50\sqrt{2}$ cm

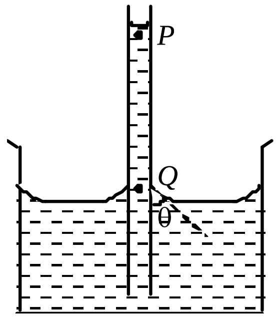
(3) zero (4) none of these

18. Water rises to a height of 10 cm in a capillary tube. If the apparatus is taken to a gas chamber having pressure half of atmosphere, then the height would be

(1) 5 cm (2) 20 cm

(3) 10cm (4) 15cm

19. Liquid reaches an equilibrium as shown, in a capillary tube of internal radius r. If the surface tension of the liquid is T, the angle of contact θ and density of liquid ρ, then the pressure difference between P and Q is



(1) $\left(\frac{2T}{r}\right)\cos\theta$ (2) $\frac{T}{r\cos\theta}$

(3) $\frac{2T}{r\cos\theta}$ (4) $\left(\frac{4T}{r}\right)\cos\theta$

20. A spherical liquid drop of radius R is divided into 8 equal droplets. If the surface tension is T, then work done in the process will be

(1) $2\pi R^2 T$ (2) $3\pi R^2 T$

(3) $4\pi R^2 T$ (4) $2\pi R T^2$

LEVEL – II

1. A drop of liquid pressed between two glass plates spreads into a circle of diameter 10 cm. Thickness of the liquid film is 0.5 mm and coefficient of surface tension is 70×10^{-3} N/m. The force required to pull them apart

(1) 4.4 N (2) 1.1 N

(3) 2.2 N (4) 3.6 N

2. A spherical soap bubble of radius 1 cm is formed inside another of radius 3 cm. The radius of a single soap bubble which maintains the same pressure difference as maintained between the inside of smaller and outside of larger soap bubble is

(1) 0.75 cm (2) 0.75 m

(3) 7.5 cm (4) 7.5 m

3. A ring is cut from a platinum tube 8.5 cm internal and 8.7 cm external diameter. It is supported horizontally from a pan of balance so that it comes in contact with the water in a glass vessel What is the surface tension of water if an extra 3.97 gm weight is required to pull it away from water (g = 980 cm/sec^2)

(1) 72.13 dyne/cm (2) 72.13 N/m

(3) 7.213 dyne/m (4) none of these

4. A soap film is formed on a frame of area 4×10^{-3} m^2. If the area of the film is reduced to half, what is the change in its potential energy? (Surface tension = 40×10^{-3} N/m)

(1) 32×10^{-5} J

(2) 16×10^{-5} J

(3) 8×10^{-5} J

(4) 16×10^{-3} J

5. By inserting a capillary tube upto 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 what will remain in the tube? Here l > h.

(1) zero (2) l + h

(3) 2h (4) h

6. Two vertical parallel glass plates are partially submerged in water. The distance between the plates is d and there width is l. Assume that the water between a plates does not reach the upper edges of the plates and that the wetting is complete. The water will rise to height (ρ = density of water and σ = surface tension of water)

(1) $2\sigma/\rho gd$ (2) $3\sigma/\rho gd$

(3) $4\sigma/\rho gd$ (4) $5\sigma/\rho gd$

7. A vessel, whose bottom has round holes with diameter of 1 mm is filled with water. Assuming that surface tension acts only at holes, then the maximum height to which the water can be filled in vessel without leakage is (Surface tension of water is 75×10^{-3} N/m and g = 10 m/s^2)

(1) 3 cm (2) 0.3 cm

(3) 3 mm (4) 3 m

8. 1000 drops of water all of same size join together to form a single drop and the energy released raises the temperature of the drop. Given that T is the surface tension of water, r the radius of each small drop, ρ the density of liquid, J the mechanical equivalent of heat. What is the rise in temperature?

(1) T/Jr (2) $10T/Jr$

(3) $100T/Jr$ (4) none of these

9. Liquid drops are falling slowly one by one from a vertical glass tube. Establish a relation between the weight W of a drop, the surface tension T and the radius r of the tube ($\theta = 0^o$)

(1) $W = \pi r^2 T$ (2) $W = 2\pi r T$

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

10. If a section of soap bubble (of radius R) through its centre is considered, the force on one half due to surface tension is

(1) $2\pi RT$ (2) $4\pi RT$

(3) $\pi R^2 T$ (4) $2T/R$

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

(1) 102 : 101 (2) $(102)^3 : (101)^3$

(3) 8 : 1 (4) 2 : 1

12. If the excess pressure inside a soap bubble is balanced by an 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)

(1) 3.9 N/m (2) 3.9×10^{-2} N/m

(3) 3.9×10^{-3} N/m (4) 3.9 dyne/m

13. Two soap bubbles, each with radius r, coalesce in vacuum under isothermal conditions to form a bigger bubble of radius R. Then R is equal to

(1) $2^{-1/2}r$ (2) $2^{1/3}r$

(3) $2^{1/2}r$ (4) $2r$

14. A cylindrical vessel with a circular hole of radius 0.2 mm in its bottom, is filled with water. If surface tension of water is equal to 70 dynes per cm, density of water is 1 gm per cm^3 and g is equal to 980 cm/sec^2, then the maximum height to which the vessel can be filled without water flowing out of the hole is nearly

(1) zero (2) 14.28 cm

(3) 7.14 cm (4) 0.714 cm

15. Liquid rises to a height of 2 cm in a capillary tube. The angle of contact between the solid and the liquid is zero. The tube is depressed more now so that the top of the capillary is only 1 cm above the liquid. Then the apparent angle of contact between the solid and the liquid is

(1) 0° (2) 30°

(3) 60° (4) 90°

16. An air bubble of radius r in water is at a depth h below the water surface at some instant. If P is atmospheric pressure, d and T are density and surface tension of water respectively, the pressure inside the bubble will be

(1) $P+hdg-\frac{4T}{r}$ (2) $P+hdg+\frac{2T}{r}$

(3) $P+hdg-\frac{2T}{r}$ (4) $P+hdg+\frac{4T}{r}$

17. Water rises in a capillary tube to a certain height such that the upward force due to surface tension is balanced by 75×10^{-4} N force due to the weight of the liquid. If the surface tension of water is 6×10^{-2} N/m, the inner circumference of the capillary tube must be

(1) 1.25×10^{-2} m (2) 0.50×10^{-2} m

(3) 6.5×10^{-2} m (4) 12.5×10^{-2} m

18. If h is the height of capillary rise and r be the radius of capillary tube, then which of the following relation will be correct?

(1) hr = constant (2) $\frac{h}{r^2}$ = constant

(3) hr^2 = constant (4) $\frac{h}{r}$ = constant

19. A capillary tube of radius *r* is immersed in a liquid. The liquid rises to a height *h*. The corresponding mass is *m*. What mass of water shall rise in the capillary if the radius of the tube is doubled??

(1) m (2) 2m

(3) 3m (4) 4m

20. An ice cube of edge 1 cm melts in a gravity-free container. The approximate surface area of water formed is

(1) $[36\pi]^{1/2}cm^2$ (2) $[36\pi]^{1/3}cm^2$

(3) $[36\pi]^{2/3}\ m^2$ (4) $36\pi\ m^2$

LEVEL – III

1. There is a small hole in a hollow sphere. The water enters in it when it is taken to a depth of 40 cm under water. The surface tension of water is 0.07 N/m. The diameter of hole is

(1) 7 mm (2) 0.07 mm

(3) 0.0007 mm (4) 0.7 m

2. A drop of water of volume V is pressed between the two glass plates so as to spread to an area A. If T is the surface tension, the normal force required to separate the glass plates is

(1) $\frac{TA^2}{V}$ (2) $\frac{2TA^2}{V}$

(3) $\frac{4TA^2}{V}$ (4) $\frac{TA^2}{2V}$

3. A large number of liquid drops each of radius r coalesce to form a single drop of radius R. The energy released in the process is converted into the kinetic energy of the big

drop so formed. The speed of the big drop is (given surface tension of liquid is T, density of liquid is ρ)

(1) $\sqrt{\frac{T}{\rho}\left(\frac{1}{r}-\frac{1}{R}\right)}$ (2) $\sqrt{\frac{2T}{\rho}\left(\frac{1}{r}-\frac{1}{R}\right)}$

(3) $\sqrt{\frac{4T}{\rho}\left(\frac{1}{r}-\frac{1}{R}\right)}$ (4) $\sqrt{\frac{6T}{\rho}\left(\frac{1}{r}-\frac{1}{R}\right)}$

4. In a vessel equal masses of alcohol (sp. gravity 0.8) and water are mixed together. A capillary tube of radius 1 mm is dipped vertically in it. If the mixture rises to a height 5 cm in the capillary tube, the surface tension of the mixture is

(1) 217.9 dyne/cm (2) 234.18 dyne/cm

(3) 107.9 dyne/cm (4) 10.79 dyne/cm

5. The work done in increasing the size of a rectangular soap film with dimensions 8 cm × 3.75 cm to 10 cm × 6 cm is 2×10^{-4} J. The surface tension of the film in N/m is

(1) 1.65×10^{-2} (2) 3.3×10^{-2}

(3) 6.6×10^{-2} (4) 8.25×10^{-2}

6. The radii of the two columns in U-tube are r_1 and r_2. When a liquid of density ρ (angle of contact is 0°) is filled in it the level difference of liquid in two arms is h. The surface tension of liquid is (g = acceleration due to gravity)

(1) $\frac{\rho g h r_1 r_2}{2(r_2 - r_1)}$ (2) $\frac{\rho g h (r_2 - r_1)}{2 r_1 r_2}$

(3) $\frac{2(r_2 - r_1)}{\rho g h r_1 r_2}$ (4) $\frac{\rho g h}{2(r_2 - r_1)}$

7. Two spherical soap bubbles of radii r_1 and r_2 in vacuum combine under isothermal conditions. The resulting bubble has a radius equal to

(1) $\frac{r_1 + r_2}{2}$ (2) $\sqrt{r_1 r_2}$

(3) $\frac{r_1 r_2}{r_1 + r_2}$ (4) $\sqrt{r_1^2 + r_2^2}$

8. A number of water droplets each of radius r coalesce to form a drop of radius R. Assuming the whole of the energy liberated due to coalescence goes into heating the drop, the rise in the temperature $d\theta$ is

(1) $\frac{2T}{rJ}$ (2) $\frac{3T}{rJ}$

(3) $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$ (4) $\frac{3T}{J}\left(\frac{1}{r}+\frac{1}{R}\right)$

9. A U-tube is such that the diameter of one limb is 0.4 mm and that of other is d mm. If the surface tension of water contained in the tube is 0.07 N/m and the difference in the levels of liquid in the limbs is 3.6 cm, then the value of d is

(1) 1.6×10^{-3} m (2) 0.4×10^{-3} m

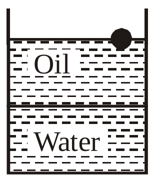
(3) 8×10^{-3} m (4) 4×10^{-3} m

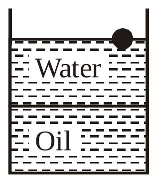
10. There is a horizontal film of soap solution. On it a thread is placed in the form of loop. The film is pierced inside the loop and thread becomes a circular loop of radius R. If the surface tension of the solution be T, then what will be the tension in the thread?

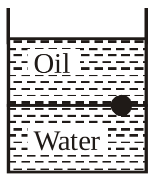
(1) $\frac{\pi R^2}{T}$ (2) $\pi R^2 T$

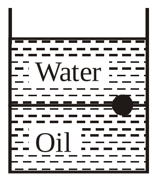
(3) $2\pi RT$ (4) $2\,RT$

11. A ball is made of a material of density ρ where $\rho_{oil} < \rho < \rho_{water}$ with ρ_{oil} and ρ_{water} representing the densities of oil and water, respectively. The oil and water are immiscible. If the above ball is in equilibrium in a mixture of this oil and water, which of the following pictures represents its equilibrium position ?

(1) 

(2) 

(3) 

(4) 

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ANSWERS (FLUIDS)

LEVEL - I

1. (3)	5. (2)	9. (1)	13. (2)	17. (2)
2. (1)	6. (4)	10. (4)	14. (4)	18. (3)
3. (2)	7. (2)	11. (3)	15. (2)	19. (1)
4. (4)	8. (1)	12. (3)	16. (1)	20. (2)

LEVEL - II

1. (3)	5. (4)	9. (2)	13. (3)	17. (4)
2. (1)	6. (1)	10. (2)	14. (3)	18. (1)
3. (1)	7. (1)	11. (3)	15. (3)	19. (2)
4. (2)	8. (4)	12. (2)	16. (2)	20. (2)

LEVEL - III

1. (1)	3. (4)	5. (2)	7. (4)	9. (3)
2. (2)	4. (1)	6. (1)	8. (3)	10. (4)
				11. (3)

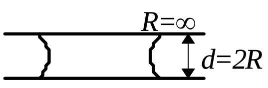
SOLUTIONS (LEVEL - III)

2. Excess pressure

$$p = T\left(\frac{1}{R}-\frac{1}{\infty}\right)=\frac{T}{R}=\frac{T}{d/2}=\frac{2T}{d}$$

Volume, $V = Ad$ and $p=\frac{2TA}{V}$

F = force = $pA=\frac{2TA^2}{V}$



3. Work done, $W = T\Delta A$

or $W=T\left[\left(4\pi r^2\right)_n-4\pi R^2\right]=T.4\pi\left[nr^2-R^2\right]$

where $n\times\frac{4}{3}\pi r^3=\frac{4}{3}\pi R^3$ and $W=\frac{1}{2}mv^2$

$\therefore\ \frac{1}{2}mv^2=T.4\pi\left(nr^2-R^2\right)$

or $\frac{1}{2}\times\frac{4}{3}\pi r^3\rho v^2=T.4\pi\left(nr^2-R^2\right)$

or $v=\sqrt{\frac{6T}{\rho}\left(\frac{nr^2}{R^3}-\frac{R^2}{R^3}\right)}=\sqrt{\frac{6T}{\rho}\left(\frac{nr^2}{nr^3}-\frac{1}{R}\right)}$

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

5. Change in surface energy = 2×10^{-4} J

$\Delta A=10\times6-8\times3.75=30\,\text{cm}^2=30\times10^{-4}\,\text{m}^2$

Work done W = T × 2 × (Change in area)

Now, Change in surface energy = Work done

$2\times10^{-4}=T\times2\times30\times10^{-4}$

$\therefore\ T=3.3\times10^{-2}$ N/m

7. Since the bubbles coalesce in vacuum and there not change in temperature, hence its surface energy does not change. This means that the surface area remains unchanged.

Hence, $4\pi r_1^2+4\pi r_2^2=4\pi R^2$

$\therefore\ R=\sqrt{r_1^2+r_2^2}$

8. When n droplets combine to form one big drop of radius R, there occurs a release of energy. Let energy released be ΔW.

Then

$$\Delta W = T\left[A_i - A_f\right] = T\left(n.4\pi r^2 - 4\pi R^2\right)$$

Heat equivalent

$$\Delta Q = \frac{\Delta W}{J} = \frac{T}{J}\left[n4\pi r^2 - 4\pi R^2\right] \quad ...(1)$$

If ΔQ be the increase in temperature, then

$$\Delta Q = msd\theta$$

$$= \left(\frac{4}{3}\pi R^3 \times 1\right)\times 1 \times d\theta = \frac{4}{3}\pi R^3 d\theta \quad ...(2)$$

$\left(\because \ d = 1\text{g/cc}, \ s = 1\text{cal/gm/}^{o}\text{C}\right)$

From (1) and (2),

$$\frac{4}{3}\pi R^3 d\theta = \frac{T}{J}4\pi R^2\left[\frac{nr^2}{R^2} - 1\right]$$

$$\therefore \quad d\theta = \frac{3T}{JR}\left[\frac{nr^2}{R^2} - 1\right] = \frac{3T}{J}\left[\frac{nr^2}{R^3} - \frac{1}{R}\right]$$

Now, volume of n droplets is equal to the volume of the big drop;

So $\quad n.\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

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

$$\therefore \quad d\theta = \frac{3T}{J}\left[\frac{nr^2}{nr^3} - \frac{1}{R}\right] = \frac{3T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

hr = constant

9.

$$h_1 - h_2 = \frac{2T}{dg}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$10^{-2} \times 3.6 = \frac{2 \times 0.07}{10^3 \times 9.8}\left(\frac{1}{4 \times 10^{-3}} - \frac{1}{d}\right)$$

Solving, we get, d = 8 × 10^{-3} m

10. Here, the force on semicircle is to be considered. So surface energy of film considered

= tension × length of the threads in semi-circle

$\therefore \quad T \times \pi R^2 = F \times \pi R$

$\therefore \quad F = 2TR$