KD EDUCATION ACADEMY [9582701166]

Time : 7 Hour | STD 11 Science Physics | Total Marks : 350

kd 90+ ch- 9 mechanical properties of fluid

*** Choose The Right Answer From The Given Options.[1 Marks Each] [29]**

1. A gale blows over the house. The force due to gale on the roof is:
   (A) In the downward direction. (B) In the upward direction.
   (C) Zero. (D) None of the above.

   Ans. :
   b. In the upward direction.
   Explanation:
   There will be less pressure on the roof and more below the roof due to gale blowing. Hence thrust acts upwards.

2. What change in surface energy will be noticed when a drop of radius R splits up into 1000 droplets of radius r, surface tension is T.
   (A) $4\pi R^2T$ (B) $7\pi R^2T$ (C) $16\pi R^2T$ (D) $36\pi R^2T$

   Ans. :
   d. $36\pi R^2T$
   Explanation:
   As, $\frac{4}{3}\pi R^3 = 1000 \times \frac{4}{3}\pi r^3$ or $r = \frac{R}{10}$
   $\therefore$ Energy spet = S.T. × Increase in surface area.

3. Application of Bernaull's Theorem can be seen in:
   (A) Dynamic lift of aeroplane. (B) Hydraullic press. (C) Helicopter. (D) None of the above.

   Ans. :
   a. Dynamic lift of aeroplane.

4. The angle of contact at the interface of water-glass is 0°, Ethylalcohol-glass is 0°, Mercury-glass is 140° and Methyliodideglass is 30°. A glass capillary is put in a trough containing one of these four liquids. It is observed that the meniscus is convex. The liquid in the trough is:
   (A) Water (B) Ethylalcohol (C) Mercury (D) Methyliodide

   Ans. :
   c. Mercury
   Explanation:
   Meniscus of liquid is convex so angle of contact will be obtuse angle which happens in case of mercury-glass.

5. A spherical liquid drop of radius R is divided into eight equal droplets. If surface tension is T, then work done in the process will be:
   (A) $2\pi R^2T$ (B) $3\pi R^2T$ (C) $4\pi R^2T$ (D) $2\pi RT^2$

Ans. :

c. $4\pi R^2 T$

Explanation:

Volume of 8 small droplets each of radius r = Volume of big drop of radius R i.e.

$8 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$r = \frac{R}{2}$

Work done = Surface tension × Increase in surface area

$= T \times [8 \times 4\pi r^3 - 4\pi R^3]$

$= T\left[32\pi\left(\frac{R}{2}\right)^2 - 4\pi R^2\right] = 4\pi R^2 T$

6. An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5cm and 3.75cm. The ratio of the velocities in the two pipes is:

(A) $9 : 4$ (B) $3 : 2$ (C) $\sqrt{3} : \sqrt{2}$ (D) $\sqrt{2} : \sqrt{3}$

Ans. :

a. $9 : 4$

Explanation:

According to continuity equation (Law of Conservation of mass)

$a_1 v_1 = a_2 v_2$

$\frac{v_1}{v_2} = \frac{a_2}{a_1} = \frac{\pi\left(\frac{d_2}{2}\right)^2}{\pi\left(\frac{d_1}{2}\right)^2} = \frac{d_2^2}{4} \cdot \frac{4}{d_1^2} = \frac{d_2^2}{d_1^2}$

$\frac{v_1}{v_2} = \frac{(3.75)^2}{(2.50)^2} = \left[\frac{3}{2}\right]^2$

$\frac{v_1}{v_2} = \frac{9}{4}$

or $v_1 : v_2 : 9 : 4$

7. Why are drops and bubbles spherical?

(A) Surface with minimum energy.

(B) Surface with maximum energy.

(C) High pressure.

(D) Low pressure.

Ans. :

a. Surface with minimum energy.

8. Pressure is a scalar quantity because:

(A) it is the ratio of force to area and both force and area are vectors.

(B) It is the ratio of the magnitude of the force to area.

(C) It is the ratio of the component of the force normal to the area.

(D) It does not depend on the size of the area chosen.

Ans. :

c. It is the ratio of the component of the force normal to the area.

Explanation:

What makes pressure a scalar quantity is the fact that it is the component of force along the direction of area that is taken into account while defining pressure. Thus the direction of quantities involved remain fixed and pressure becomes a scalar quantity.

9. Three liquids of densities d, 2d and 3d are mixed in equal proportion of weights. If density of water is d, then the specific gravity of the mixture is:

(A) $\frac{11}{7}$ (B) $\frac{18}{11}$ (C) $\frac{13}{9}$ (D) $\frac{23}{18}$

Ans. :

b. $\frac{18}{11}$

Explanation:

$w_1 = w_2 = w_3$

$\Rightarrow m = m_2 = m_3 = m(\text{say})$

Then $V_1 = \frac{m}{d}, V_2 = \frac{m}{2d}, V_3 = \frac{m}{3d}$

$\therefore d_{mix} = \frac{\text{Mass}}{\text{Volume}}$

$= \frac{3m}{V_1+V_2+V_3} = \frac{18}{11}d$

So, specific gravity of mixture $= \frac{d_{mix}}{d_{water}} = \frac{18}{11}$

10. Two water pipes of diameters 2cm and 4cm are connected with the main supply line. The velocity of flow of water in the pipe of 2cm diameter is:

(A) 4 times that in the other pipe. (B) $\frac{1}{4}$ times that in the other pipe.

(C) 2 times that in the other pipe. (D) $\frac{1}{2}$ times that in the other pipe.

Ans. :

a. 4 times that in the other pipe.

Explanation:

From equation of continuity, av = constant

d_A = 2cm and d_B = 4cm

$\therefore r_A = 1\text{cm}$ and $r_B = 2\text{cm}$

$\therefore \frac{v_A}{v_B} = \frac{a_B}{a_A} = \frac{\pi(r_B)^2}{\pi(r_A)^2} = \left(\frac{2}{1}\right)^2$

$\Rightarrow v - A = 4v_B$

11. Radius of a soap bubble is increased from R to 2R. Work done in this process in terms of surface tension is:

(A) $24\pi R^2 S$ (B) $48\pi R^2 S$ (C) $12\pi R^2 S$ (D) $36\pi R^2 S$

Ans. :

a. $24\pi R^2 S$

Explanation:

$W = 8\pi T(R_2^2 - R_1^2)$

$= 8\pi S[(2R)^2 - (R^2)]$

$= 24\pi R^2 S$

12. Streamline flow is more likely for liquids with:

(A) High density. (B) High viscosity.

(C) Low density. (D) Low viscosity.

Ans. :

b. High viscosity.

c. Low density.

Explanation:

Streamline flow is more likely for liquids having low density. We know that greater the coefficient of viscosity of a liquid more will be the velocity gradient, hence each line of flow can be easily differentiated. Streamline flow is related with critical velocity. The critical velocity is that velocity of liquid flow up to which its flow is streamlined and above which its flow becomes turbulent.

As the critical velocity is related to viscosity (η) and density (ρ) of the liquid as,

$(\mathrm{V_c})\ \alpha\ \frac{\eta}{\rho}$

Hence if the density will be low and viscosity will be high, the value of critical velocity will be more.

13. What is the shape when a non-wetting liquid in displaced in a capillary tube?

(A) Concave upwards. (B) Convex upwards.

(C) Concave downwards. (D) Convex downwards.

Ans. :

c. Concave downwards.

14. The value of surface tension of water is minimum at:

(A) 4°C. (B) 25°C. (C) 50°C. (D) 75°C.

Ans. :

d. 75°C.

Explanation:

Value of surface tension decreases with increase in temperature. So, it is minimum at 75°C.

15. When a large bubble rises from the bottom of a lake to the surface, its radius doubles. One atmosphere is equal to that of a column of water of height H. The depth of the lake is:

(A) H. (B) 2H. (C) 7H. (D) 8H

Ans. :

c. 7H.

Explanation:

Since the radius of the bubble becomes double on reaching surface, its volume $\left[\frac{4}{3}\pi(2\mathrm{r})^3\right]$ becomes 8 times. It means the pressure at the bottom of the lake is 8 times the pressure at the surface.

Therefore the pressure due to depth of lake.

= 8H - H = 7H

16. A capillary tube of radius R is immersed in water and water rises in it to a height H. Mass of water in capillary tube is M. If the radius of the tube is doubled, mass of water that will rise in capillary will be:

(A) 2M. (B) M. (C) $\frac{M}{2}$ (D) 4M.

Ans. :

a. 2M

Explanation:

Since, $h = 2T\cos\frac{\theta}{r\rho g}$ i.e., $h \propto \frac{1}{r}$;

Therefore if r becomes 2r, h becomes $\frac{h}{2}$.

Mass of the water in tube = Volume × Density

$= \pi(2r0^2\frac{h}{2}\rho = 2\pi r^2 h\rho = 2M$

17. At which of the following temperatures the value of surface tension of water is minimum?

(A) 4°C. (B) 25°C. (C) 50°C. (D) 75°C.

Ans. :

d. 75°C.

Explanation:

The surface tension of water decreases with rise of temperature.

Therefore, the surface tension of water is minimum at 75°C.

18. The coefficient of viscosity for hot air is:

(A) Greater than the coefficient of viscosity for cold air.

(B) Smaller than the coefficient of viscosity for cold air.

(C) Same as the coefficient of viscosity for cold air.

(D) Increases or decreases depending on the external pressure.

Ans. :

a. Greater than the coefficient of viscosity for cold air.

Explanation:

For gases, viscosity increases with temperature.

19. 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 a deep water bath (surface tension T) without any water entering inside is:

(A) $\frac{4T}{r\rho g}$ (B) $\frac{2T}{r\rho g}$ (C) $\frac{3T}{r\rho g}$ (D) $\frac{T}{r\rho g}$

Ans. :

b. $\frac{2T}{r\rho g}$

Explanation:

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

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

20. Let W be the work done, when a bubble of volume V is formed from a given solution. How much work is required to be done to form a bubble of volume 2V?

(A) W (B) $2\mathrm{W}$ (C) $2^{\frac{1}{3}}\mathrm{W}$ (D) $4^{\frac{1}{3}}\mathrm{W}$

Ans. :

d. $4^{\frac{1}{3}}\mathrm{W}$

Explanation:

Let R and R' be the radius of bubble of volume V and 2V respectively.

Then,

$\frac{4}{3}\pi\mathrm{R}^3=\mathrm{V}$ and $\frac{4}{3}\pi\mathrm{R}'^3=2\mathrm{V}$

So, $\frac{\mathrm{R}'^3}{\mathrm{R}^3}=2$ or $\mathrm{R}'=(2)^{\frac{1}{3}}\mathrm{R}$

$\mathrm{W}=\mathrm{S}\times\left(4\pi\mathrm{R}'^2\right)\times 2$

As, $\mathrm{W}'=\mathrm{S}\times\left(4\pi\mathrm{R}^2\right)\times 2$

$\mathrm{W}'=(4)^{\frac{1}{3}}\mathrm{W}$

21. An incompressible fluid flows steadily through a cylindrical pipe which has radius 2R at point A and Radius R at point B farther along the flow direction. If the velocity at point A is v, its velocity at point B is:

(A) 2v. (B) v. (C) $\frac{\mathrm{v}}{2}$ (D) 4v.

Ans. :

d. 4v.

Explanation:

From equation of continuity.

$\pi(2\mathrm{R})^2\mathrm{v}=\pi\mathrm{r}^2\times\mathrm{v}$ or $\mathrm{v}_1=4\mathrm{v}$

22. With increase in temperature, the viscosity of:

(A) Gases decreases. (B) Liquids increases.

(C) Gases increases. (D) liquids decreases.

Ans. :

c. Gases increases.

d. liquids decreases.

Explanation:

The viscosity of gases increases with increase of temperature, because on increasing temperature the rate of diffusion increases.

The viscosity of liquid decreases with increase of temperature, because the cohesive force between the liquid molecules decreases with increase of temperature.

Relation between coefficient of viscosity and temperature (Andrade formula)

$\eta=\frac{\mathrm{Ae}^{\frac{\mathrm{C}\rho}{\mathrm{T}}}}{\rho^{\frac{-1}{3}}}$

where T = Absolute temperature of liquid, p = density of liquid, A and C are constants.

Important point: With increase in temperature, the coefficient of viscosity of liquids decreases but that of gases increases. The reason is that as temperature rises, the atoms of the liquid become more mobile, whereas in case of a gas, the collision frequency of atoms increases as their motion becomes more random.

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

(A) 1.5×10^{-2} N/m.
(B) 3.0×10^{-2} N/m.
(C) 6.0×10^{-2} N/m.
(D) 11.0×10^{-2} N/m.

Ans. :

b. 3.0×10^{-2} N/m.

24. 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 75cm of mercury and density of water to be $\frac{1}{10}$ of the density of mercury, the depth of the lake is:

(A) 4m.
(B) 10m.
(C) 15m.
(D) 20m.

Ans. :

c. 15m.

Explanation:

$$3\mathrm{V} \times \mathrm{P} = \mathrm{V}(\mathrm{P} + \mathrm{P}_1) \text{ or } 2\mathrm{P} = \mathrm{P}_1$$

$$2 \times 75 \times \rho \times \mathrm{g} = \mathrm{h} \times \frac{\rho}{10} \times \mathrm{g}$$

$$\mathrm{h} = 1500\mathrm{cm} = 15\mathrm{m}$$

25. Water stands upto a height h behind the vertical wall of a dam. What is the net horizontal force pushing the dam down by the stream, if width of the dam is σ? (ρ = density of water).

(A) $2\mathrm{h}\sigma\mathrm{g}$
(B) $\frac{\mathrm{h}^2\sigma\rho\mathrm{g}}{2}$
(C) $\frac{\mathrm{h}^2\sigma\rho\mathrm{g}}{4}$
(D) $\frac{\mathrm{h}\sigma\rho\mathrm{g}}{4}$

Ans. :

b. $\frac{\mathrm{h}^2\sigma\rho\mathrm{g}}{2}$

Explanation:

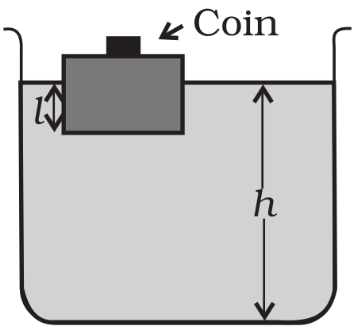
Mean pressure on vertical wall due to water

$$\mathrm{P} = \left(\frac{0+\mathrm{h}\rho\mathrm{g}}{2}\right) = \frac{1}{2}\mathrm{g}\rho\mathrm{g}$$

Horizontal force, $\mathrm{F} = \mathrm{P} \times (\mathrm{h} \times \sigma)$

$$= \left(\frac{1}{2}\mathrm{h}\rho\mathrm{g}\right) \times \mathrm{h}\sigma = \frac{1}{2}\mathrm{h}^2\sigma\rho\mathrm{g}$$

26. A wooden block with a coin placed on its top, floats in water as shown in the distance l and h are shown in the figure. After some time the coin falls into the water. Then:



(A) l decreases. (B) h decreases. (C) l increases. (D) h increase.

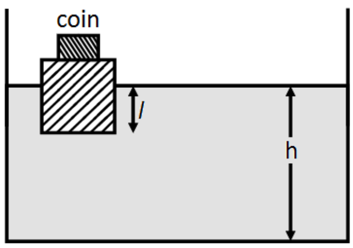
Ans. :

a. l decreases.

b. h decreases.

Explanation:

According to law of floatation weight of floating body is equal to weight of displaced fluid. When coin falls into the water, net weight of floating body is decreased so the floating body will displace less amount of water so block rises up and l will decreases. But height h of water will decrease as less water is displaced now.



27. Pascal's law states that pressure in a fluid at rest is the same at all points, if:

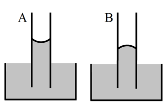
(A) They are at the same height.
(B) They are along same plane.
(C) They are along same line.
(D) Both (a) and (b).

Ans. :

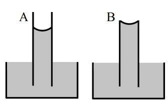
a. They are at the same height.

28. A capillary tube A is dipped in water. Another identical tube B is dipped in soap-water solution. Which of the following shows the relative nature of the liquid columns in the two tubes?

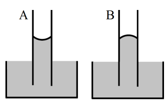
(A)



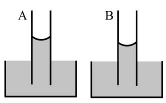
(B)



(C)

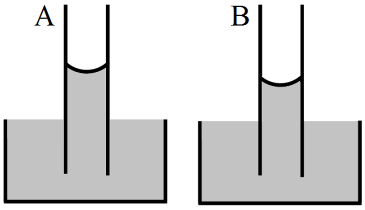


(D)



Ans. :

d.



29. A cylindrical vessel is filled with water up to height H. A hole is bored in the wall at a depth h from the free surface of water. For maximum angle h is equal to:

(A) $\frac{H}{4}$ (B) $\frac{H}{2}$ (C) $\frac{3H}{4}$ (D) H

Ans. :

b. $\frac{H}{2}$

* **Given Section consists of questions of 2 marks each.** **[48]**

30. In a car lift compressed air exerts a force F on a small piston having a radius of $5.0cm$. This pressure is transmitted to a second piston of radius $15cm$ (Fig 9.7). If the mass of the car to be lifted is $1350kg$, calculate F_1. What is the pressure necessary to accomplish this task? $\left(g = 9.8ms^2\right)$

Ans. : Since pressure is transmitted undiminished throughout the fluid,

$$F_1 = \frac{A_1}{A_2}F_2 = \frac{\pi\left(5\times10^{-2}m\right)^2}{\pi\left(15\times10^{-2}m\right)^2}\left(1350kg \times 9.8ms^{-2}\right)$$

$$= 1470N$$

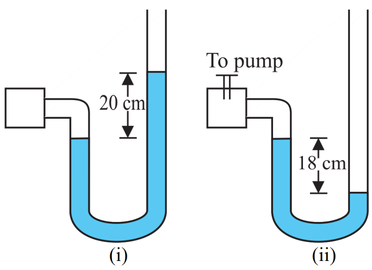
$$\approx 1.5 \times 10^3 N$$

The air pressure that will produce this force is

$$P = \frac{F_1}{A_1} = \frac{1.5\times10^3 N}{\pi\left(5\times10^{-2}\right)^2 m} = 1.9 \times 10^5 Pa$$

This is almost double the atmospheric pressure.

31. A manometer reads the pressure of a gas in an enclosure as shown in Fig.(a) When a pump removes some of the gas, the manometer reads as in Fig. (b) The liquid used in the manometers is mercury and the atmospheric pressure is 76cm of mercury. Give the absolute and gauge pressure of the gas in the enclosure for cases (i) and (ii) in units of cm of mercury. How would the levels change in case (i) if 13.6cm of water (immiscible with mercury) are poured into the right limb of the manometer? (Ignore the small change in volume of the gas.)



Ans. :

a. Given : Atmospheric pressure,

P_0 = 6cm of Hg.

In figure (i) pressure head,

h_1 = + 20cm of Hg.

Absolute pressure (P) of the gas is greater than the P_0 i.e.,

$P = P_0 + h_1 pg$

= 76cm of Hg + 20cm of Hg

= 96cm of Hg.

Gauge pressure is the difference between the absolute pressure and the atmospheric pressure. $\frac{1}{2}$ It means,

Gauge pressure = $P - P_0$

= 96cm of Hg - 76cm of Hg

= 20cm of Hg.

In figure (ii), pressure head,

h_2 = -18cm of Hg.

∴ The absolute pressure of the gas is lesser than the atmospheric pressure is given by

$P = P_0 + h_2 pg$

= 76cm of Hg + (-18cm) of Hg

= 58cm of Hg

Gauge pressure = Absolute pressure - Atmospheric pressure

= 58cm of Hg -76cm of Hg

= -18cm of Hg

It means, Gauge pressure is simply equal to h cm of Hg.

b. Given : 13.6cm of water added in the right limb is equivalent to $\frac{13.6}{13.6} = 1\mathrm{cm}$ of Hg column i.e., h = 1cm of Hg column, which can be calculated as follows

$\mathrm{h}_\omega = 13.6\mathrm{Cm}$ of water

Suppose h_m = height of Hg column equivalent to 13.6cm of water, thus equilibrium.

$$\mathrm{h_m}\rho_\mathrm{m}\mathrm{g} = \mathrm{h}_\omega\rho_\omega\mathrm{g}.$$

$$\mathrm{h_m} = \mathrm{h}_\omega\frac{\rho_\omega}{\rho_\mathrm{m}} = \frac{\mathrm{h}_\omega}{\left(\frac{\rho_\mathrm{m}}{\rho_\omega}\right)}$$

$= \frac{13.6}{13.6} = 1\mathrm{cm}$ of hg

The mercury will rise in the left limb such that the difference in the height of Hg column in the two limbs.

= 20cm - 1m

= 19 cm of Hg column.

32. Explain why Hydrostatic pressure is a scalar quantity even though pressure is force divided by area.

Ans. : When force is applied on a liquid, the pressure in the liquid is transmitted in all directions. Hence, hydrostatic pressure does not have a fixed direction and it is a scalar physical quantity.

33. Why are the wings of an aeroplane rounded outwards while flattened inwards?

Ans. : The special design of the wings increases velocity at the upper surface and decreases velocity at the lower surface. So, according to Bernoulli's theorem, the pressure on the upper side is less than the pressure on the lower side. This difference of pressure provides lift.

34. A small drop of water of surface tension T is squeezed between two clean glass plates so that a thin layer of thickness d and area A is formed between them. If the angle of contact is zero, what is the force required to pull the plates apart.

Ans. : An extremely thin layer of liquid can be considered as the collection of large number of hemispherical drops. In case of a spherical drop, the excess of pressure $= \frac{2T}{r}$.
But in case of thin layer of liquid, which is a combination of hemispherical drops, the excess pressure Force due to surface tension pushing the two plates together is
$P = \frac{T}{r}$, where $r = \frac{d}{2}$.
Therefore, $P = \frac{T}{\frac{d}{2}} = \frac{2T}{d}$

Force due to surface tenstion pushing the two plates togher is,

$F = P \times A = \frac{2TA}{d}$

35. A hydraulic automobile lift is designed to lift cars with maximum mass of 300kg. The area of cross-section of the piston carrying the load is $425cm^2$. What maximum pressure would the smaller piston have to bear?

Ans. : In hydraulic systems, $P_1 = P_2$ or $\frac{F_1}{A_1} = \frac{F_2}{A_1}$

$\therefore$ Maximum pressure on smaller piston = Maximum pressure on the larger piston

$\Rightarrow \frac{300 \times 9.8}{425 \times 10^{-4}} = 6.92 \times 10^4 N/m^2$

36. A car is lifted by a hydraulic jack that consist of two pistons. The large piston is 1m in diameter and small piston is 10cm in diameter. If W is the weight of the car, how much smaller a force is needed on the small piston to lift the car?

Ans. : Diameter of a large piston = 1m; Raduis of large piston R = 0.5m,

Diameter of a small piston = 10cm = 0.1m; Radius of small piston, r = 0.05m weight of the car = W.

As, $\frac{f}{\pi r^2} = \frac{F}{\pi r^2}$

Smaller force, $f = F \times \left(\frac{r}{R}\right)^2$

$= W\left(\frac{0.05}{0.5}\right)^2 = 0.1W \text{ Newton}$

= 1% of the weight of the car.

Hence, smaller force needed on the small piston to lift the car is 1% of the weight of the car.

37. In an artery of radius 'a' blood flows with a uniform speed v. If radius of artery becomes $'\frac{3}{4}a'$ due to the accumulation of plague on its inner walls, what will be the flow of the blood through the constriction?

Ans. : According to equation of continuity, Av = A'V'

$$\pi a^2 \times V = \pi\left(\frac{3a}{4}\right)^2 . V'$$

$$V' = \frac{a^2V}{\left(\frac{3a}{4}\right)^2} = \frac{16}{9}V$$

$$\therefore V' = 1.8V$$

38. What is the significance of:
    i. Wetting agents used by dyers.
    ii. Water proofing agents?

Ans. :

i. They are added to decrease the angle of contact between the fabric and the dye so that the dye may penetrate well.

ii. They are used to increase the angle of contact between the fabric and water to prevent the water from penetrating the cloth.

39. Two soap bubbles in vacuum having radii 3cm and 4cm respectively coalesce under isothermal conditions to form a single bubble. What is the radius of the new bubble?

Ans. : Surface energy of first bubble,

= Surface are × surface tension $= 2 \times 4\pi r_1^2 T = 8\pi r_1^2 T$

Surface energy of second bubble $= 8\pi r_2^2 T$

According to the law of conservation of energy,

$$8\pi r^2 T = 8\pi r_1^2 T + 8\pi r_2^2 T$$

$$= 8\pi(r_1^2 + r_2^2)T$$

$$\therefore r^2 = r_1^2 + r_2^2$$

$$= 3^2 + 4^2 = 9 + 16 = 25$$

$$\therefore r = 5cm.$$

40. A piece of copper having an internal cavity weight 264g in air and 221g in water. Find the volume of the cavity. The density of copper = 8.8gcm^{-3}.

Ans. : Mass of copper piece in air = 264g

Mass of copper piece in water = 221g

Apparent loss of mass = 264 - 221 = 43g

This is the mass of water displaced by the copper piece when immersed in water.

Volume of copper piece with cavity = 43cm^3

Volume of copper only $= \frac{m}{\rho} = \frac{264}{8.8} = 30cm^3$

Volume of the cavity = 43 - 30 = 13cm^3.

41. If the excess pressure inside a spherical soap bubble of radius 1cm is balanced by that due to a column of oil of specific gravity 0.9, 1.36mm high. Calculate the surface tension.

Ans. : Redius, r = 1cm; $\rho = 0.9g\ cm^{-3}$

$$h = 1.36mm = 0.136cm$$

Pressure, $P = h\rho g = 0.136 \times 0.9 \times 980$

$= 119.95 \text{ dyne cm}^{-2}$

Let T be surfac4e tension of shoap solution

$\therefore$ Excess pressure, $P = \frac{4T}{r}$ or $T = \frac{Pr}{4} = \frac{119.95 \times 1}{4}$

$= 29.988 \text{ dynecm}^{-1}$

42. Two syringes of different cross-sections (without needles) filled with water are connected with a tightly fitted rubber tube filled with water. Diameters of the smaller piston and larger piston are 1.0cm and 3.0cm respectively.
    i. Find the force exerted on the larger piston when a force of 10N is applied to the smaller piston.
    ii. If the smaller piston is pushed in through 6.0cm, how much does the larger piston move out?

Ans. : Here, d_1 = 1.0cm, d_2 = 3.0cm,

Force on smaller piston F_1 = 10N.

i. According to Pascal's law of transmission of pressure $P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$.

$\therefore \frac{F_2}{F_1} = \frac{A_2}{A_1}$

$= \frac{r_2^2}{r_1^2} = \left(\frac{d_2}{d_1}\right)^2$

$= \left(\frac{3.00\text{cm}}{1.0\text{cm}}\right)^2 = 9$

$\Rightarrow F_2 = F_1 \times 9$

$= 10 \times 9 = 90\text{N}.$

ii. Water is considered to be completely incompressible. Therefore, volume covered by the movement of smaller piston inwards is exactly equal to volume moved outwards due to movement of larger piston, distance through which smaller piston is pushed L_1 = 6.0cm. Let larger piston is pushed by a distance L_2 then,

$V = L_1 A_1 = L_2 A_2$

$\therefore L_2 = L_1 \left(\frac{A_1}{A_2}\right) = L_2 \left(\frac{d_1}{d_2}\right)^2$

$= 6.0\text{cm} \times \left(\frac{1.0\text{cm}}{3.0\text{cm}}\right)^2$

$= \frac{6}{9}\text{cm} = 0.67\text{cm}$

43. What is the excess pressure inside a soap bubble that is 5cm in diameter, assuming 0.026Nm^{-1} as the surface tension of the soap solution?

Ans. : Excess pressure inside a soap bubble is

$(P - P_a) = \frac{4T}{r}$

Here $T = 0.026\text{Nm}^{-1}$

$r = \frac{5}{2} = 2.5\text{cm} = 2.5 \times 10^{-2}\text{m}$

$\therefore P - P_a = \frac{4 \times 0.026\text{Nm}^{-1}}{2.5 \times 10^{-2}\text{m}} = 4.16\text{Nm}^{-2}$

44. In rising from the bottom of a lake to the top, the temperature of an air bubble remains unchanged, but its diameter gets doubled. What is the depth of the lake? Given h is the

barometric height in metres of mercury of relative density ρ at the surface of the lake.

Ans. : At the surface, $\mathrm{P_1 h\rho g; V_1 = \frac{4}{3}\pi(2r)^3}$

At the bottom of depth x, $\mathrm{P_2 = (h\rho + xg)}$ and $\mathrm{V_2 = \frac{4}{3}\pi r^3}$

Using Boyle's law, $\mathrm{P_1 V_1 = P_2 V_2}$

$\therefore \mathrm{h\rho g \times \frac{4}{3}\pi(2r)^3 (h\rho g + xg) \times \frac{4}{3}\pi r^3}$ or $\mathrm{x = 8h\rho - h\rho = 7h\rho\ metres.}$

45. If work required to blow a soap bubble of radius r is W, then what additional work is required to be done to blow it to a radius 3r?

Ans. : Increase in surface area $= 2[4\pi(3\mathrm{r})^2 - 4\pi \mathrm{r}^2]$

Increase in surface energy $= \sigma \times 2 \times 4\pi \times 8\mathrm{r}^2 = 8\mathrm{W}$

Addditional work done = 8W.

46. What should be the maximum average velocity of water in a tube of diameter 0.5cm. So that the flow is laminar? The viscosity of water is 0.00125Nm^{-2}s.

Ans. : Here D = 0.5cm = 0.005m

$\rho = 10^3 \mathrm{kg\ m^{-3}}$

$\eta = 0.00125 \mathrm{Nm^{-2}s}$

For laminar flow, the Reynold number for water,

N_R = 2000

Let v b the maximum average velocity,

$\therefore \mathrm{N_R} = \frac{\rho v \mathrm{D}}{\eta}$ or $\mathrm{v} = \frac{\mathrm{N_R} - \eta}{\rho - \mathrm{D}}$

$= \frac{2000 \times 0.00125}{1000 \times 0.005} = 0.5\mathrm{m/s.}$

47. A liquid drop of radius 4mm breaks into 1000 identical drops. Find the change in surface energy. S = 0.07Nm^{-1}.

Ans. : Volume of 1000 small drops = Volume of a large drop

$1000 \times \frac{4}{3}\pi \mathrm{r}^3 = \frac{4}{3}\pi \mathrm{R}^3$

$\mathrm{r} = \frac{\mathrm{R}}{10}$

Surface area of large drop $= 4\pi \mathrm{R}^2$

Surface area of 1000 drop $4\pi \times 1000\mathrm{r}^2 = 40\pi \mathrm{R}^2$

$\therefore$ Increase in surface area $= (40 - 4)\pi \mathrm{R}^2 = 36\pi \mathrm{R}^2$

The increase in surface energy = Surface tension × increase in suraface area

$= 36\pi \mathrm{R}^2 \times 0.07 = 36 \times 3.14 \times (4 \times 10^{-3})^2 \times 0.07$

$= 1.26 \times 10^{-4} \mathrm{J}$

48. A body of mass 6kg is floating in a liquid with $\frac{2}{3}$ of its volume inside the liquid. Find ratio between the density of the body and density of liquid. Take g = 10m/ s^2.

Ans. : As we know that, for a floating body

Buoyant force = Weight of liquid displaced

Let V be the volume of the body, $\frac{2}{3}\mathrm{V}\rho_l \mathrm{g} = \mathrm{V}\rho_l \mathrm{g}$

Where, $\rho_{\mathrm{b}}=$ density of floating body

and $\rho_{\mathrm{l}}=$ density of liquid

$\therefore \frac{\rho_{\mathrm{b}}}{\rho_{\mathrm{l}}}=\frac{2}{3}$

49. Explain why Water on a clean glass surface tends to spread out while mercury on the same surface tends to form drops. (Put differently, water wets glass while mercury does not.)

Ans. : Mercury molecules (which make an obtuse angle with glass) have a strong force of attraction between themselves and a weak force of attraction toward solids. Hence, they tend to form drops.

On the other hand, water molecules make acute angles with glass. They have a weak force of attraction between themselves and a strong force of attraction toward solids. Hence, they tend to spread out.

50. A piece of an alloy of mass 96gm is composed of two metals whose specific gravities are 11.4 and 7.4. If the weight of the alloy is 86gm in water, find the mass of each metal in the alloy.

Ans. : Suppose the mass of the metal of specific gravity 11.4 be m. Now the mass of the second metal of specific gravity 7.4 will be (96 - m).

Volume of first metal $=\frac{\mathrm{m}}{11.4}\mathrm{cm}^3$

Volume of second metal $=\frac{96-\mathrm{m}}{7.4}\mathrm{cm}^3$

Total volume $=\frac{\mathrm{m}}{11.4}+\frac{96-\mathrm{m}}{7.4}$

Apparent loss of wt. in water $=\left(\frac{\mathrm{m}}{11.4}+\frac{96-\mathrm{m}}{7.4}\right)\mathrm{gm\ wt.}$

According wt. in water $=96-\left[\left(\frac{\mathrm{m}}{11.4}\right)+\frac{(96-\mathrm{m})}{7.4}\right]$

According to the given peoblem,

$96-\left[\left(\frac{\mathrm{m}}{11.4}\right)+\frac{(96-\mathrm{m})}{7.4}\right]=86$ or $\frac{\mathrm{m}}{11.4}+\frac{(96-\mathrm{m})}{7.4}=10$

Solving we get, m = 62.7gm.

$\therefore$ Mass of second metal = 96 - 62.7 = 33.3gm

51. These days people use steel utensils with copper bottom. This is supposed to be good for uniform heating of food. Explain this effect using the fact that copper is the better conductor.

Ans. : The copper bottom of the steel utensil gets heated quickly. Because of the reason that copper is a good conductor of heat as compared to steel. But steel does not conduct as quickly, thereby allowing food inside to get heated uniformly.

52. Is the bulb of a thermometer made of diathermic or adiabatic wall?

Ans. : Adiabatic walls does not allow to pass heat into mercury of bulb and diathermic allows to conducts heat through it. So in the bulb of thermometer diathermic walls are used.

53. A copper wire of cross-sectional area $0.01\mathrm{cm}^2$ is under a tension of 20N. Find the decrease in the cross-sectional area. Young's modulus of copper = $1.1 \times 10^{11}\mathrm{N/m}^2$ and

Poisson's ratio = 0.32. $\left[\textbf{Hint: } \frac{\triangle \mathrm{A}}{\mathrm{A}}=2 \frac{\triangle \mathrm{r}}{\mathrm{r}}\right]$

Ans. :

Given:

Cross-sectional area of copper wire A = 0.01cm^2 = 10^{-6}m^2

Applied tension T = 20N

Young modulus of copper Y = 1.1 × 10^{11}N/m^2

Poisson ratio $\sigma=0.32$

We know that:

$\mathrm{Y}=\frac{\mathrm{FL}}{\mathrm{A} \triangle \mathrm{L}}$

$\Rightarrow \frac{\triangle \mathrm{L}}{\mathrm{L}}=\frac{\mathrm{F}}{\mathrm{AY}}$

$=\frac{20}{10^{-6} \times 1.1 \times 10^{11}}=18.18 \times 10^{-5}$

Poisson's ratio, $\sigma=\frac{\frac{\triangle \mathrm{d}}{\mathrm{d}}}{\frac{\triangle \mathrm{L}}{\mathrm{L}}}=0.32$

Where d is the transverve length

So, $\frac{\triangle \mathrm{d}}{\mathrm{d}}=(0.32) \times \frac{\triangle \mathrm{L}}{\mathrm{L}}$

$=0.32 \times(18.18) \times 10^{-5}=5.81 \times 10^{-5}$

Again, $\frac{\triangle \mathrm{A}}{\mathrm{A}}=\frac{2 \triangle \mathrm{r}}{\mathrm{r}}=\frac{2 \triangle \mathrm{d}}{\mathrm{d}}$

$\Rightarrow \triangle \mathrm{A}=\frac{2 \triangle \mathrm{d}}{\mathrm{d}} \mathrm{A}$

$\Rightarrow \triangle \mathrm{A}=2 \times\left(5.8 \times 10^{-5}\right) \times(0.01)$

$=1.165 \times 10^{-6} \mathrm{cm}^2$

Hence, the required decrease in the cross-sectional area is 1.164 × 10^{-6}cm^2.

*** Given Section consists of questions of 3 marks each. [117]**

54. A fully loaded Boeing aircraft has a mass of $3.3 \times 10^5 kg$. Its total wing area is $500 m^2$. It is in level flight with a speed of $960 km/h$. (a) Estimate the pressure difference between the lower and upper surfaces of the wings (b) Estimate the fractional increase in the speed of the air on the upper surface of the wing relative to the lower surface. [The density of air is $p=1.2 kgm^3 J$

Ans. : (a) The weight of the Boeing aircraft is balanced by the upward force due to the pressure difference

$$\Delta P \quad A=3.3 \times 10^5 kg \times 9.8$$

$$\Delta P=\left(3.3 \times 10^5 kg \times 9.8 ms^{-2}\right) / 500 m^2$$

$$=6.5 \times 10^3 N m^2$$

(b) We ignore the small height difference between the top and bottom sides in Eq. (9.12). The pressure difference between them is then

$\Delta P=\frac{\rho}{2}\left(v_2^2-v_1^2\right)$

where V_2 is the speed of air over the upper surface and V_1 is the speed under the bottom surface.
$(v_2 - v_1) = \frac{2\Delta P}{\rho(v_2+v_1)}$
Taking the average speed

$V_{aw} = (V_2 + V_1)/2 = 960km/h = 267ms^{-1}$,
we have
$(v_2 - v_1)/v_{av} = \frac{\Delta P}{\rho v_{av}^2} \approx 0.08$
The speed above the wing needs to be only 8 % higher than that below.

55. At a depth of $1000\ \mathrm{m}$ in an ocean (a) what is the absolute pressure? (b) What is the gauge pressure? (c) Find the force acting on the window of area $20\ \mathrm{cm} \times 20\ \mathrm{cm}$ of a submarine at this depth. the interior of which is maintained at sealevel atmospheric pressure. (The density of sea water is $1.03 \times 10^3 kgm^{-3}$, $g = 10ms^{-2}$.)

Ans. : Here $h = 1000m$ and $\rho = 1.03 \times 10^3 kgm^3$.
(a) From Eq. (9.6), absolute pressure

$$\begin{aligned} P =& P + \rho gh \\ =& 1.01 \times 10^5 Pa \\ & + 1.03 \times 10^3 kgm^{-3} \times 10ms^{-2} \times 1000m \\ =& 104.01 \times 10^5 Pa \\ \approx& 104atm \end{aligned}$$

(b) Gauge pressure is $P - P_a = \rho gh = P$
$P_g = 1.03 \times 10^3 kgm^{-3} \times 10ms^2 \times 1000m$
$= 103 \times 10^5 Pa$
$\approx 103atm$

(c) The pressure outside the submarine is $P = P_a + \rho gh$ and the pressure inside it is P_a. Hence, the net pressure acting on the window is gauge pressure, $P_{tg} = \rho gh$. Since the area of the window is $A = 0.04m^2$, the force acting on it is $F = P_g A = 103 \times 10^5 Pa \times 0.04m^2 = 4.12 \times 10^5 N$

56. Two vessels have the same base area but different shapes. The first vessel takes twice the volume of water that the second vessel requires to fill upto a particular common height. Is the force exerted by the water on the base of the vessel the same in the two cases ? If so, why do the vessels filled with water to that same height give different readings on a weighing scale?

Ans. : Two vessels having the same base area have identical force and equal pressure acting on their common base area. Since the shapes of the two vessels are different, the force exerted on the sides of the vessels has non-zero vertical components. When these vertical components are added, the total force on one vessel comes out to be greater than that on the other vessel. Hence, when these vessels are filled with water to the same height, they give different readings on a weighing scale.

57. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000kg. The area of cross-section of the piston carrying the load is 425cm^2. What maximum pressure would the smaller piston have to bear?

Ans. : The maximum mass of a car that can be lifted, m = 3000kg.

Area of cross-section of the load-carrying piston, A = 425cm^2 = 425 × 10 ^{4}m^2

The maximum force exerted by the load, F = mg

= 3000 × 9.8

= 29400N

The maximum pressure exerted on the load-carrying piston, P = F/ A

$\frac{29400}{(425 \times 10-4)}$

= 6.917 × 10^{5}Pa

Pressure is transmitted equally in all directions in a liquid. Therefore, the maximum pressure that the smaller piston would have to bear is 6.917 × 10^{5}Pa.

58. A vertical off-shore structure is built to withstand a maximum stress of 109 Pa. Is the structure suitable for putting up on top of an oil well in the ocean? Take the depth of the ocean to be roughly 3km, and ignore ocean currents.

Ans. : Yes

The maximum allowable stress for the structure, P = 109 Pa

Depth of the ocean, d = 3km = 3 × 10^{3}m

Density of water, p = 10^{3}kg/ m^3

Acceleration due to gravity, g = 9.8m/ s^2

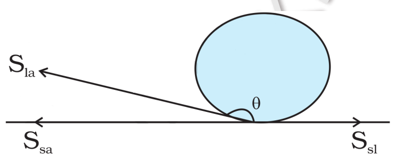
The pressure exerted because of the sea water at depth, d = pdg

= 3 × 10^3 × 10^3 × 9.8 = 2.94 × 10^{7}Pa

The maximum allowable stress for the structure (10^9 Pa) is greater than the pressure of the sea water (2.94 × 10^{7}Pa). The pressure exerted by the ocean is less than the pressure that the structure can withstand. Hence, the structure is suitable for putting up on top of an oil well in the ocean.

59. Explain why The angle of contact of mercury with glass is obtuse, while that of water with glass is acute.

Ans. : The angle between the tangent to the liquid surface at the point of contact and the surface inside the liquid is called the angle of contact (θ), as shown in the given figure.



S_{la}, S_{sa}, and S_{sl} are the respective interfacial tensions between the liquid-air, solid-air, and solid-liquid interfaces. At the line of contact, the surface forces between the three media must be in equilibrium, i.e.,

$\cos\theta = (\mathrm{Ssa} - \mathrm{Sla})/\mathrm{Sla}$

The angle of contact θ , is obtuse if $S_{sa} < S_{la}$ (as in the case of mercury on glass). This angle is acute if $S_{sl} < S_{la}$ (as in the case of water on glass).

60. A capillary tube is attached horizontally to a constant head arrangement. If the radius of the capillary tube is increased by 10% then by what percentage the rate of flow of liquid will change.

Ans. : Since, $\mathrm{V} = \frac{\pi \mathrm{pr}^4}{8\eta \mathrm{l}}$

$\mathrm{r}' = \mathrm{r} + \frac{10}{100}\mathrm{r} = \frac{110}{100}\mathrm{r} = 1.1\mathrm{r}$

$\therefore \mathrm{V}' = \frac{\pi \mathrm{p}(1.1\mathrm{r})^4}{8\eta \mathrm{l}} = \frac{1.464\pi \mathrm{pr}^4}{8\eta \mathrm{l}} = 1.464\mathrm{V}$

$\therefore$ % increase in rate of flow of liquid $= \frac{\mathrm{V}'-\mathrm{V}}{\mathrm{V}} \times 100 = \left(\frac{1.464\mathrm{V}-\mathrm{V}}{\mathrm{V}}\right) \times 100 = 46.4\%$

61. A big size balloon of mass M is held stationary in air with the help of a small block of mass M/2 tied to it by a light string such that both float in mid air. Describe the motion of the balloon and the block when the string is cut. Support your answer with calculations.

Ans. : Forces acting on balloon when held stationary are:

$\mathrm{U} \rightarrow$ the upthrust,

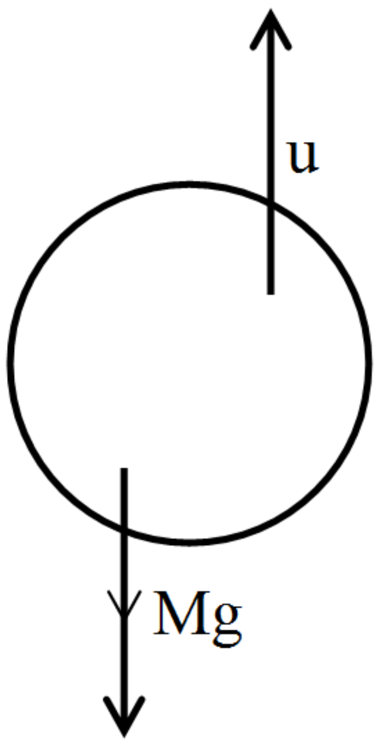
U = Mg + T ...(i)

Forces acting on small block when held stationary.

$\mathrm{T} = \left[\frac{\mathrm{M}}{2}\right]\mathrm{g} \ldots (\mathrm{ii})$

From (i) and (ii), $\mathrm{U} = \frac{3}{2}\mathrm{Mg}$

When string is cut, T = 0



Small block will have free fall.

Ballon will have acceleration 'a' such that,

U - Mg = Ma

$\frac{3}{2}\mathrm{Mg}-\mathrm{Mg}=\mathrm{Ma}$
$\Rightarrow \mathrm{a}=\frac{\mathrm{g}}{2}$ upwards

62. A piece of brass (an alloy of copper and zinc) weighs 12.9g in air. When completely immersed in water it weighs 11.3g. What is the volume of copper contained in the alloy? RD of copper and zinc are 8 : 9 and 7.1 respectively. Solving this equation, we get m = 7.61g.

Ans. : Let m be the mass of copper in the alloy.

Then the mass of zinc in the alloy = (12.9 - m)g

Volume of copper in the alloy $=\frac{\mathrm{m}}{8.9}\mathrm{cm}^3$

Volume of zinc in the alloy $=\frac{(12.9-\mathrm{m})}{7.1}\mathrm{cm}^3$

Apparent loss of weight of brass = 12.9 - 11.3 = 16g

Volume of the alloy = 1.6cm^3 (density of water = 1g cm^{-3})

Hence, $\frac{\mathrm{m}}{8.9}+\frac{12.9-\mathrm{m}}{7.1}=1.6$

Solving this equation, we get m = 7.61g.

63. A tank 5m high is half-filled with water and then filled to the top with oil of density 0.85g/cc. What is the pressure at the bottom of the tank due to these liquids?

Ans. : Here, h = 5m; $\rho_0=0.85\mathrm{g/cc}=0.85\times 10^3\mathrm{kg/m}^3$

Mean density, $\rho=\frac{\rho_{\mathrm{w}}+\rho_0}{2}$

$=\frac{10^3+0.85\times 10^3}{2}$

$=0.925\times 10^3\mathrm{kg/m}^3$

Therefore, pressure at the bottom,

$\mathrm{P}=\mathrm{h}\rho\mathrm{g}$

$=5\times 0.925\times 10^3\times 9.8$

$=4.5325\times 10^4\mathrm{N/m}^2$

64. Prove that the pressure at a depth h from the free surface of a liquid (P) in a container is $\mathrm{P}=\mathrm{P}_2+\mathrm{h}\rho\mathrm{g}$, where P, is the atmospheric pressure.

Ans. : Consider two points A and B at two levels separated by h column of a liquid of density p surrounding the points A and B. Consider an area 'a' forming a cylinder of liquid of length h.

The pressure at,

A = P_A = Atmospheric pressure = P.

Weight of the liquid at centre of gravity

$\mathrm{W}=\mathrm{Mg}=\mathrm{ha}\rho\mathrm{g}$

For equilibrium, pressure/ force at B should nullify the forces acting down.

$\therefore \mathrm{P_A}.\mathrm{a}+\mathrm{ha}\rho\mathrm{g}=\mathrm{P_B}.\mathrm{a}$

$\therefore \mathrm{P_B}=\mathrm{P_A}+\mathrm{h}\rho\mathrm{g}=\mathrm{P}_0+\mathrm{h}\rho\mathrm{g}$

65. What should be the average velocity of water in a tube of diameter 2.0cm so that the flow is laminar? The viscosity of water is 0.001N m^{-2}s.

Ans. : Here, D = 2cm = 0.02m,

$\eta = 0.001\mathrm{N\ m^{-2}s}$,

$\rho = 10^3\mathrm{kg\ m^{-3}}; \mathrm{v_c} = ?$

Maximum value of Reynold's number for flow to be linear, N_R = 2000

Now, $\mathrm{v_c} = \frac{\mathrm{N_R}\eta}{\rho \mathrm{D}} = \frac{2000 \times 0.001}{10^3 \times 0.02}$

$= 0.1\mathrm{ms^{-1}}$

66. Air is streaming past a horizontal air plane wing such that its speed is 120ms^{-1} over the upper surface and 90ms^{-1} at the lower surface. If the density of air is 1.3kg m^{-3}, find the difference in pressure between the top and bottom of the wing. If wing is 10m long and has an average width of 2m, calculate the gross lift of the wing.

Ans. : According to Bernoulli's theorem,

$\frac{\mathrm{P_1}}{\rho} + \mathrm{gh_1} + \frac{1}{2}v_1^2$

$= \frac{\mathrm{P_2}}{\rho} + \mathrm{gh_2} + \frac{1}{2}v_2^2$

For the horizontal flow, $h_1 = h_2$

$\therefore \frac{\mathrm{P_1}}{\rho} + \frac{1}{2}v_1^2 = \frac{\mathrm{P_2}}{\mathrm{P}} + \frac{1}{2}v_2^2 \ldots (\mathrm{i})$

Here, $v_1 = 90\mathrm{ms^{-1}}; v_2 = 120\mathrm{ms^{-1}};$

$\rho = 1.3\mathrm{kg\ m^{-3}}$

$\therefore \frac{\mathrm{P_1} - \mathrm{P_2}}{\rho} = \frac{1}{2}\left(v_2^2 - v_1^2\right)$

$(\mathrm{P_1} - \mathrm{P_2}) = \frac{\rho\left(v_2^2 - v_1^2\right)}{2}$

$= \frac{1.3(14400 - 8100)}{2} = \frac{1.3 \times 63}{2}$

$\mathrm{P_1} - \mathrm{P_2} = 4.095 \times 10^3\mathrm{Nm^{-2}}$

Which is the pressure difference between the top and the bottom of the wing.

Now, Gross lift of the wing (i.e. force)

= (P_1 - P_2) × Area of the wing = 4.095 × 10^3 × 10 × 2

= 8.190 × 10^4N.

67. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000kg. The area of cross-section of the piston carrying the load is 425cm^2. What maximum pressure would the smaller piston have to bear?

Ans. : The maximum mass of a car that can be lifted, m = 3000kg.

Area of cross-section of the load-carrying piston, A = 425cm^2 = 425 × 10 ^{4}m^2

The maximum force exerted by the load, F = mg

= 3000 × 9.8

= 29400N

The maximum pressure exerted on the load-carrying piston, P = F/ A

$\frac{29400}{(425 \times 10 - 4)}$

= 6.917 × 10^5Pa

Pressure is transmitted equally in all directions in a liquid. Therefore, the maximum pressure that the smaller piston would have to bear is 6.917×10^5Pa.

68. An air bubble of volume 1.0cm rises from the bottom of a lake 40m deep at a temperature of 12°C. To what volume does it grow when it reaches the surface which is at a temperature of 35°C?

Ans. : When the air bubble is at 40m depth, then

$$\mathrm{V_1 = 1cm^3 = 1 \times 10^{-6} m^3}$$
$$\mathrm{T_1 = 12^\circ C = 12 + 273 = 285K}$$

Bubble rises to a height, h = 40m

Temperature at the surface of the lake,

T_2 = 35°C = 308K

The pressure on the surface of the lake:

P_2 = 1atm = 1.01×10^5Pa

The pressure at the depth of 40m

$$\mathrm{P_1 = 1atm + h\rho g}$$
$$= 1.01 \times 10^5 + 40 \times 10^3 \times 9.8$$
$$= \mathrm{493000Pa}$$

When the air bubble reaches at the surface of lake, then V_2 = ?

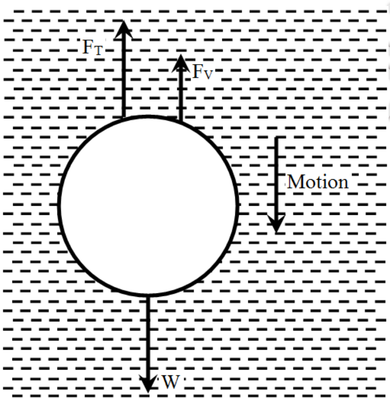
We have, $\frac{\mathrm{P_1V_1}}{\mathrm{T_1}} = \frac{\mathrm{P_2V_2}}{\mathrm{T_2}}$

$$\Rightarrow \mathrm{V_2} = \frac{\mathrm{P_1V_1T_2}}{\mathrm{T_1P_2}}$$
$$= \frac{493000 \times 1 \times 10^{-6} \times 308}{258 \times 1.01 \times 10^5}$$
$$5.263 \times 10^{-6} \mathrm{m^3 or\ 5.263cm^3}$$

69. Show that terminal velocity V of a spherical object of radius r, density ρ falling vertically through a viscous fluid of density σ and coefficient of viscosity n is given by:

$$\mathrm{V} = \frac{2}{9} \frac{(\rho - \sigma)\mathrm{r^2 g}}{\eta}$$

Ans. : Let ρ be the density of the material of the spherical body of radius r and σ be the density of the medium.



$\therefore$ True weight of the body,

$$\mathrm{W = Volume \times Density \times g} = \frac{4}{3}\pi \mathrm{r^3} \rho \mathrm{g}$$

Upward thrust due to buoyancy,

F_T = Weight of the medium desplaced

$\therefore F_T$ = Volume of the medium desplaced × Density × g

$= \frac{4}{3}\pi r^3 \sigma g$

If V is the terminal velocity of the body, then according to stoke's law, upward viscous drag,

$F_v = 6\pi\eta rv$

When body attains terminal velocity, then

$F_T + F_v = W$

$\therefore \frac{4}{3}\pi r^3 \sigma g + 6\pi\eta rV = \frac{4}{3}\pi r^3 \rho g$

$6\pi\eta rV = \frac{4}{3}\pi r^3 (\rho - \sigma) g$

$V = \frac{2r^2(\rho-\sigma)g}{9\eta}$

$\sigma =$ Density of viscous fluid,

$\eta =$ Coefficient of viscosity.

70. Water rises to a height of 10cm in a certain capillary tube. The level of mercury in the same tube is depressed by 3.42cm. Compare the surface tensions of water and mercury. Specific gravity of mercury is 13.6g/cc and angle of contact for water and mercury are zero and 135° respectively.

Ans. : Using the capillarity relation,

$\sigma = \frac{rh\rho g}{2\cos\theta}$

σ_1 (for water)

$\sigma_1 = \frac{r\times 1\times g\times 10}{2\cos 0^\circ} = 5rg$

σ_2 (for mercury)

$\sigma_2 = \frac{r\times 13.6\times g\times(-3.42)}{2\cos 135^\circ}$ [-ve refers to dip in level]

$\sigma_2 = \frac{r\times 13.6\times g\times(-3.42)}{2\times\left(\frac{1}{\sqrt{2}}\right)} = 32.9rg$

$\frac{\sigma_1}{\sigma_2} = \frac{5rg}{32.9rg} = \frac{1}{6.5} = 0.15$

71. An ice floats in water with about nine-tenths of its volume submerged. What is the fractional volume submerged for an iceberg floating on a freshwater lake of a (hypothetical) planet whose gravity is ten times that of the earth?

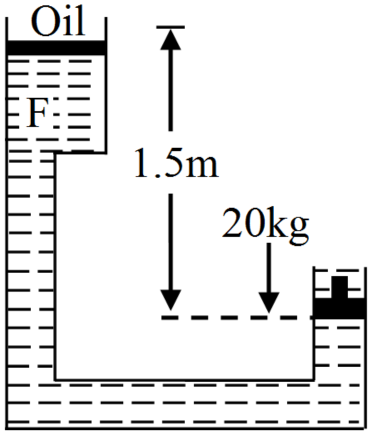
Ans. :

i. The fractional volume submerged is independent of the value of g, so it is nine-tenths on the new planet also.
ii. For free fall, g = 0

The ice cube has no weight and no thrust.

Therefore, the ice cube can float with any value for the fractional volume submerged.

72. The figure adjoining shows a hydraulic press with the larger piston of diameter 35cm at a height of 1.5m relative to the smaller piston of diameter 10cm. The mass on the smaller piston is 20kg. What is the force exerted on the load by the larger piston? The



density of oil in the press is 750kg m^{-3}.

Ans. : Pressure on the smaller piston,

$= \frac{20\times9.8}{\pi\times(5\times10^{-2})^2}\mathrm{N\ m^{-2}}$

Pressure on the larger piston,

$= \frac{\mathrm{F}}{\pi\times(17.5\times10^{-2})^2}\mathrm{N\ m^{-2}}$

The difference between these two pressures is equal to $\mathrm{h}\rho\mathrm{g}$ where

$\mathrm{h} = 1.5\mathrm{m}; \rho = 750\mathrm{kg/m^3};$

And $\mathrm{g} = 9.8\mathrm{ms^{-2}}$

$\therefore \frac{20\times9.8}{\pi\times(5\times10^{-2})^2} - \frac{\mathrm{F}}{\pi\times(17.5\times10^{-2})^2}$

$\Rightarrow 1.5\times750\times9.8$

Simplyfying, we get

$\mathrm{F} = 1.3\times10^3\mathrm{N}$

73. Pressure decreases as one ascends the atmosphere. If the density of air is ρ, what is the change in pressure dp over a differential height dh?

Ans. : consider a part (packet) of atmosphere of thickeness dh. As the pressure at a point in fluid is equal in all directions. so the pressure on upper layer is p acting downward and on lower layer is (p + dp) acting upward. Force due to pressure is balanced by Buoyant force by air,

(p + dp)A - pA = -Vpg

PA + dpA - pA = -Adhpg

dpA = -ppgdhA

dpp = -pgdh ....(i)

(image)

Negative sign shows that pressure decreases as height increases.

74. The sufrace tension and vapour pressure of water at 20°C is 7.28 × 10^{-2}N m^{-1} and 2.33 × 10^3 Pa, respectively. What is the radius of the smallest spherical water droplet which can form without evaporating at 20°C?

Ans. : The drop will evaporate if the water pressure on liquid, is greater than vapour pressure above the surface of liquid. Let a water droplet of radius R be formed without evaporation then.

Vapour pressure = Excess pressure in a drop

$\rho=\frac{2\sigma}{R}$ (onlt one surface in drop)

$R=\frac{2\times7.28\times10^{-2}}{\text{Vapour preessure}}$

$=\frac{2\times7.28\times10^{-2}}{2.33\times10^{3}}=\frac{1456\times10}{233\times10^{5}}$

$R=6.25\times10^{-5}\mathrm{m}$

75. A liquid drop of diameter 4mm breaks into 1000 droplets of equal size. Calculate the resultant change in surface energy, the surface tension of the liquid is 0.07Nm".

Ans. : $\sigma=0.17\mathrm{Nm}^{-1}, R=\frac{D}{2}=2\times10^{-3}\mathrm{m}$

$N=1000$

Change in surface energy, $W=\sigma[N4\pi r^2-4\pi R^2]$

Where $r=RN^{-\frac{1}{3}}$

$\therefore W=\sigma\left[N^{1-\frac{2}{3}}.4\neq R^2-4\neq R^2\right]$

$=\sigma4\pi R^2\left[N^{\frac{1}{3}}-1\right]$

$W=0.07\times4\times\frac{22}{7}\times(2\times10^{-3})^2\times\left[(10000)^{\frac{1}{3}}-1\right]$

$=0.07\times4\times\frac{22}{7}\times4\times10^{-6}\times9$

$W=31.68\times10^{-6}\mathrm{J}$

76. A cylindrical vessel of uniform cross-section contains liquid upto a height 'H'. At a depth $'h'=\frac{H}{2}$ below the free surface of the liquid there is an orifice. Using Bernoulli's theorem, find the velocity of efflux of liquid.

Ans. : Applying Bernoulli's theorem between two points just on either side of the hole, we get,

$\frac{P_0+\frac{H}{2}\rho g}{\rho g}+\frac{0}{2g}+\frac{H}{2}$

$=\frac{H}{2}+\frac{v^2}{2g}+\frac{P_0}{\rho g}$

$\Rightarrow v^2=\frac{H}{2}\times2g$

$\Rightarrow v=\sqrt{gH}$

77. What is the pressure inside a drop of mercury of radius 3.0mm at room temperature? Surface tension of mercury at that temperature (20°C) is $4.65\times10^{-1}\mathrm{Nm}^{-1}$. The atmospheric pressure is 1.01×10^{5} Pa. Also give the excess pressure inside the drop.

Ans. : Here, $r=3.0\mathrm{mm}=3\times10^{-3}\mathrm{m};$

$S=4.65\times10^{-1}\mathrm{N\,m}^{-1}; P=1.01\times10^{5}\mathrm{Pa}$

Excess of pressure inside the drop of mecury is given by,

$P'=\frac{2S}{r}=\frac{2\times4.65\times10^{-1}}{3\times10^{-3}}=310\mathrm{Pa}$

Total pressure inside the drop,

$=P'+P=1.01\times10^{5}+310$

$=1.0131\times10^{5}\mathrm{Pa}$

78. A U-tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10.0cm of water in one arm and 12.5cm of spirit in the other. What is the specific gravity of spirit?

Ans. : Height of the spirit column, h_1 = 12.5cm = 0.125m

Height of the water column, h_2 = 10cm = 0.1m

ρ_0 = Atmospheric pressure

ρ_1 = Density of spirit

ρ_2 = Density of water

Pressure at point $\mathrm{B} = \rho_0 + \rho_1 \mathrm{h}_1 \mathrm{g}$

Pressure at point $\mathrm{D} = \rho_0 + \rho_2 \mathrm{h}_2 \mathrm{g}$

Pressure at points B and D is the same.

$\rho + \rho_1 \mathrm{h}_1 \mathrm{g} = \rho_0 + \rho_2 \mathrm{h}_2 \mathrm{g}$

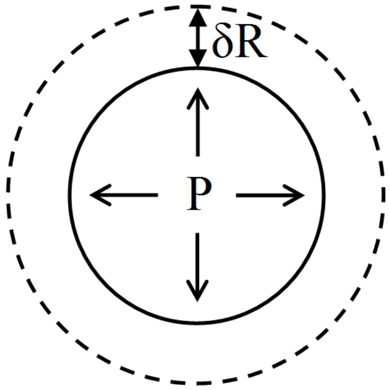
$\frac{\rho_1}{\rho_2} = \frac{\mathrm{h}_2}{\mathrm{h}_1}$

$= \frac{10}{12.5} = 0.8$

Therefore, the specific gravity of spirit is 0.8.

79. Derive an expression for the excess of pressure inside a liquid drop.

Ans. : Consider a liquid drop of radius R and σ the surface tension of liquid.



Excess pressure inside the liquid drop,

P = P_i - P_0 ($\because$ liquid drop has only one free surface)

$\delta\mathrm{R} =$ Small increase in radius of liquid drop due to excess pressure

$\therefore$ W = Force × Displacement.

W = (Excess pressure × Area) × Increase in radius

$\mathrm{W} = \mathrm{P} \times 4\pi \mathrm{R}^2 \times \delta\mathrm{R}$

Increase in surface area of liquid drop

= Final surface area - Initail surface area

$= 4\pi(\mathrm{R} + \delta\mathrm{R})^2 - 4\pi\mathrm{R}^2$

$= 8\pi\mathrm{R}(\delta\mathrm{R})(\text{Neglecting } \delta\mathrm{R}^2)$

Increase P.E.

= Increase in surface area × Surface tension

$= 8\pi\mathrm{R}(\delta\mathrm{R}) \times \sigma$

Since the drop is in equilibrium.

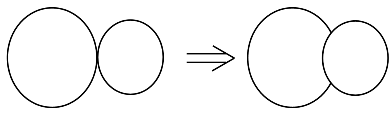
$\therefore P \times 4\pi R^2 \times \delta R = 8\pi R(\delta R) \times \sigma$

$\Rightarrow P = \frac{2\sigma}{R}$

$\Rightarrow P_i - P_o = \frac{2\sigma}{R}[\because P = P_i - P_o]$

80. Two soap bubbles of different diameters are in contact with a certain portion common to both the bubbles. What will be the shape of the common boundary as seen from inside the smaller bubble? Support your answer with a neat diagram. Give reason for your answer.

Ans. : As seen from inside the smaller bubble, the shape of the common boundary will be concave.



Reasons:

i. Pressure inside the smaller bubble is more as compared to that inside the larger bubble.

ii. For a liquid film, the pressure on concave side is higher.

81. Two exactly similar rain drops falling with terminal velocity of $(2)^{\frac{1}{3}} \mathrm{ms}^{-1}$ coalesce to form a bigger drop. Find the terminal velocity of the bigger drop.

Ans. : Given, Terminal valocity of two exactly similar rain drop $= (2)^{\frac{1}{3}} \mathrm{ms}^{-1}$

According to the question, we have

Volume of bigger rain drop = 2 × Volume of a smaller rain drop

$\Rightarrow \frac{4}{3}\pi R^3 = 2 \times \frac{4}{3}\pi R^3$

I.e., $\frac{R^3}{r^3} = 2$

$\Rightarrow \frac{R}{r} = (2)^{\frac{1}{3}},$

Where R = Radius of bigger drop; r = Radius of smaller drop

Terminal valocity of smaller drop, $v_1 = \frac{2}{9}\frac{r^2}{\eta}(e - e')g$

Terminal velocity of bigger drop, $v_2 = \frac{2}{9}\frac{R^2}{\eta}(e - e')g$

$\therefore \frac{v_2}{v_1} = \frac{R^2}{r^2} = (2^{\frac{1}{3}})^2 = 2^{\frac{2}{3}}$

$\Rightarrow v_2 = 2^{\frac{2}{3}} \times v_1[\because v_1 = 2^{\frac{1}{3}} \mathrm{ms}^{-1}]$

$= 2^{\frac{2}{3}} \times 2^{\frac{1}{3}} = 2\mathrm{ms}^{-1}$

Hence, the terminal velocity of the bigger drop is $2\mathrm{ms}^{-1}$.

82. The sap in trees, which consists mainly of water in summer, rises in a system of capillaries of radius r = 2.5×10^{-5}m. The surface tension of sap is T = 7.28×10^{-2}N m^{-1} and the angle of contact is 0°. Does surface tension alone account for the supply of water to the top of all trees?

Ans. : Radius of capillarity $r = 2.5 \times 10^{-5} \mathrm{m}$

$S = T = 7.8 \times 10^{-2} \mathrm{Nm}^{-1}$ $g = 9.8\mathrm{m/\ s}^2$

$\theta = 0^\circ,\ \mathrm{p} = 10^3 \mathrm{kg\ m}^3$

$\mathrm{h} = \frac{2s\cos\theta}{\mathrm{rpg}} = \frac{2\times7.28\times10^{-2}\cos0^\circ}{2.5\times10^{-5}\times10^3\times9.8} = \frac{2\times728\times10^{-2+5}}{25\times98\times10^3}$

$\mathrm{h} = \frac{104}{175}\times\frac{10^{-3}}{10^3} = \frac{104}{175} = 0.594\mathrm{m} \cong 6\mathrm{m}$

Most of trees are of more than 0.6m height. So, capillary action alone connot account for the rise of water in all other tress.

83. A cube of wood floating in water supports a 200g mass resting at the centre of its top face. When the mass is removed, the cube rises 2cm. Find the volume of the cube.

Ans. : Let A be the surface area of cube and l be the side length.

When 200g mass is taken away, the cube comes out by 2cm. Therefore, the weight of 200g should be balance by the upthrust due to 2cm volume of cube.

(i.e.) $200 \times 10^{-3} \times g = A \times 2 \times 10^{-2} \times r_{wg}$

$\mathrm{A} = \frac{200\times10^{-3}}{2\times10^{-2}\times1000} = \frac{1}{100}$

$\therefore$ side length,

$\mathrm{l} = \sqrt{\mathrm{A}} = \sqrt{\frac{1}{100}}$

$= \frac{1}{10}\mathrm{m\ or\ 10cm}$

Volume = $l^3 = (10)^3 = 1000\mathrm{cm}^3$

84. What is the pressure inside the drop of mercury of radius 3.00mm at room temperature? Surface tension of mercury at that temperature (20°C) is $4.65 \times 10^{-1}\mathrm{N\ m}^{-1}$. The atmospheric pressure is 1.01 × 105Pa. Also give the excess pressure inside the drop.

Ans. : Radius of the mercury drop, $r = 3.00\mathrm{mm} = 3 \times 10^{-3}\mathrm{m}$

Surface tension of mercury, $S = 4.65 \times 10^{-1}\mathrm{N\ m}^{-1}$

Atmospheric pressure, $P_0 = 1.01 \times 10^5$ Pa

Total pressure inside the mercury drop.

= Excess pressure inside mercury + Atmospheric pressure

= $2S/r + P_0$

$= \left[\frac{2\times4.65\times10^{-1}}{(3\times10^{-3})}\right] + 1.01\times10^5$

$= 1.0131 \times 10^5$

$= 1.01 \times 10^5\mathrm{Pa}$

Excess pressure = $2S/r$

$= \left[\frac{2\times4.65\times10^{-1}}{(3\times10^{-3})}\right] 310\mathrm{pa}$

85. Iceberg floats in water with part of it submerged. What is the fraction of the volume of iceberg submerged if the density of ice is $\rho_\mathrm{i} = 0.917\mathrm{g\ cm}^{-3}$?

Ans. : According to the problem, density of ice $(\rho_\mathrm{ice}) = 0.917\mathrm{g/\ cm}^3$, Density of water $(\rho_\mathrm{w}) = 1\mathrm{g/\ cm}^3$

Let V_i = Volume of iceberg,

V_w = Volume of water displaced by iceberg,
Weight of iceberg, $W = \rho_i V_i g$
Upthrust, $F_B = \rho_w V_w g$
At equilibrium, Weight of the iceberg = Weight of the water displaced by the submerged part by ice
$\Rightarrow \rho_w V_w g = \rho_i V_i g$
$\Rightarrow \frac{V_w}{V_i} = \frac{\rho_i}{\rho_w} = \frac{0.917}{1} = 0.917$

86. Calculate the temperature which has same numeral value on celsius and Fahrenheit scale.

Ans. : Let the required temperature is $x^0C = x^0F$
$\frac{C}{100} = \frac{F-32}{180}$
$\Rightarrow \frac{x}{5} = \frac{x-32}{9}$
$\Rightarrow 5x - 160 = 9x$
$\Rightarrow -9x + 5x = 160$
$\Rightarrow -4x = 160$
$\Rightarrow x = \frac{160}{-4} = -40^\circ$
$\therefore -40^\circ F = -40^\circ C$

87. Why does a metal bar appear hotter than a wooden bar at the same temperature? Equivalently it also appears cooler than wooden bar if they are both colder than room temperature.

Ans. :
1. It is due to facts that conductivity of metal bar is very high as of wood. So the rate of transferring the heat in metal is very large than in wood.
2. The specific heat of metal is very low as compared to wood, so metal requires very smaller quantities of heat than wood to change each degree of temperature.

So due to larger conductivity and smaller specific heat, metals become more colder when placed in colder region as compared to wood and become more hot when placed in hot region.

88. Find out the increase in moment of inertia I of a uniform rod (coefficient of linear expansion α) about its perpendicular bisector when its temperature is slightly increased by ΔT.

Ans. : I of rod its axis along perpendicular bisector $= \frac{1}{12} ML^2$
$\Delta L = \alpha L \Delta T$
$I' = \frac{1}{12} M(L + \Delta L)^2$
$= \frac{1}{12} M(L^2 + \Delta L^2 + 2L\Delta L)$
Neglecting ΔL^2 due to very small term.
$I' = \frac{M}{12}(L^2 + 2L\Delta L)$
$= \frac{ML^2}{12} + \frac{ML\Delta L}{6} \times \frac{2L}{2L}$
$I' = \frac{ML^2}{12} + \frac{ML^2}{12} \cdot \frac{2\Delta L}{L}$

$= \mathrm{I} + \mathrm{I} \cdot \frac{2\alpha \mathrm{L} \Delta \mathrm{T}}{\mathrm{L}}$

$\mathrm{I}' = \mathrm{I}(1 + 2\alpha \Delta \mathrm{T})$

So, new moment of inertia increased by $(2\mathrm{I}\alpha\Delta\mathrm{T})$.

89. 100 g of water is supercooled to -10°C. At this point, due to some disturbance mechanised or otherwise some of it suddenly freezes to ice. What will be the temperature of the resultant mixture and how much mass would freeze? [Sw = 1cal/ g/ °C and L^{W}_{Fusion} = 80cal/ g]

Ans. : Water mass = 100g

At -10°C ice and water mixture exists.

Heat required (given out) by $10^{\circ}\mathrm{C}$ ice to $0^{\circ}\mathrm{C}$ ice $= \mathrm{ms}\Delta\mathrm{t}$

$= 100 \times 1 \times [0 - (-10)]$

$\mathrm{Q} = 1000\mathrm{cal}$

Let gm ice melted Q = ml

$\mathrm{m} = \frac{\mathrm{Q}}{\mathrm{L}} = \frac{1000}{80} = 12.5\mathrm{g}$

So, there is m = 12.5g water and ice in mixture. Hence temperature of mixture remains 0°C.

90. A sphere of mass 20kg is suspended by a metal wire of unstretched length 4m and diameter 1mm. When in equilibrium, there is a clear gap of 2mm between the sphere and the floor. The sphere is gently pushed aside so that the wire makes an angle θ with the vertical and is released. Find the maximum value of θ so that the sphere does not rub the floor. Young's modulus of the metal of the wire is 2.0 × 10^{11}N/m^2. Make appropriate approximations.

Ans. : m = 20Kg

L = 4m

2r = 1mm, r = 5 × 10^{-4}m

At equilibrium T = mg

When it moves at an angle θ and released the tension T at lowest point is

$\mathrm{T} = \mathrm{mg} + \frac{\mathrm{mv}^2}{\mathrm{r}}$

The change in tension is due to centrifugal force

$\triangle \mathrm{T} = \frac{\mathrm{mv}^2}{\mathrm{r}} \ \cdots (1)$

Again by work energy principle

$\frac{1}{2}\mathrm{mv}^2 - 0 = \mathrm{mgr}(1 - \cos\theta)$

$\mathrm{v}^2 = 2\mathrm{gr}(1 - \cos\theta) \cdots (2)$

So, $\triangle \mathrm{T} = \frac{\mathrm{m}[2\mathrm{gr}(1-\cos\theta)]}{\mathrm{r}}$

$= 2\mathrm{mg}(1 - \cos\theta)$

$\Rightarrow \mathrm{F} = \triangle \mathrm{T}$

$\Rightarrow \mathrm{F} = \frac{\mathrm{Y\,A}\triangle \mathrm{L}}{\mathrm{L}}$

$= 2\mathrm{mg}\cos\theta = 2\mathrm{mg} - \frac{\mathrm{Y\,A}\triangle \mathrm{L}}{\mathrm{L}}$

$\Rightarrow \coth\eta = 1 - \frac{\mathrm{YA}\triangle \mathrm{L}}{\mathrm{L}(2\mathrm{mg})}$

$\Rightarrow \cos\theta = 1 - \left[\frac{2\times10^{11}\times4\times3.14\times(5)^2\times10^{-8}\times2\times10^{-3}}{4\text{x}2\times20\times10}\right]$

$\Rightarrow \cos\theta = 0.80$

$\theta = 36.4^\circ$

91. Water near the bed of a deep river is quiet while that near the surface flows. Give reasons.

Ans. : The motion of any liquid is dependent upon the amount of stress acting on it. The motion of one layer of liquid is resisted by the other due to the property of viscosity. A river bed remains in a static state. Therefore, any immediate layer of liquid in contact with the river bed will also remain static due to the frictional force. However, the next layer of liquid above this static layer will have a greater velocity due to lesser resistance offered by the static layer. Moving upwards, subsequent layers provide lesser and lesser resistance to the movement of the layers above it. Finally, the topmost layer acquires the maximum velocity. Therefore, for a river, the surface waters flow the fastest.

92. A steel wire of original length 1m and cross-sectional area $4.00mm^2$ is clamped at the two ends so that it lies horizontally and without tension. If a load of 2.16kg is suspended from the middle point of the wire, what would be its vertical depression? Y of the steel = $2.0 \times 10^{11} N/m^2$ Take $g = 10m/s^2$.

Ans. :

Given:

Original length of steel wire L = 1m

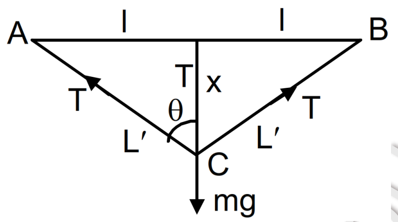
Area of cross-section $A = 4.00mm^2 = 4 \times 10^{-2} cm^2$

Load = 2.16kg

Young's modulus of steel $Y = 2 \times 10^{11} N/m^2$

Acceleration due to gravity $g = 10ms^{-2}$

Let T be the tension in the string after the load is suspended and θ be the angle made by the string with the vertical, as shown in the figure:



$\cos\theta = \frac{x}{\sqrt{x^2+l^2}} = \frac{x}{l}\left\{1 + \frac{x^2}{l^2}\right\}^{\frac{-1}{2}}$

Expanding the above equation using the binominal theorem:

$\cos\theta = \frac{x}{l}\left\{1 - \frac{1}{2}\frac{x^2}{l^2}\right\}$ (neglecting the higher order terms)

Since x << l, $\frac{x^2}{l^2}$ can be neglected.

$\Rightarrow \cos\theta = \frac{x}{l}$

increase in length:

$\triangle l = (AC + CB) - AB$

$\mathrm{AC} = \left(l^2 + x^2\right)^{\frac{1}{2}}$

$\triangle l = 2\left(l^2 + x^2\right)^{\frac{1}{2}} - 2l$

We know that:

$\mathrm{Y} = \frac{\mathrm{F}}{\mathrm{A}} \frac{\mathrm{L}}{\triangle \mathrm{L}}$

$\Rightarrow 2 \times 10^{12} = \frac{\mathrm{T} \times 100}{\left(4 \times 10^{-2}\right) \times \left[2\left(50^2 + x^2\right)^{\frac{1}{2}} - 100\right]}$

From the free body diagram:

$2\mathrm{T}\cos\theta = \mathrm{mg}$

$2\mathrm{T}\left(\frac{x}{50}\right) = 2.16 \times 10^3 \times 980$

$\Rightarrow \frac{2 \times \left(2 \times 10^{12}\right) \times \left(4 \times 10^{-2}\right) \times \left[2\left(50^2 + x^2 \frac{1}{2}\right) - 100\right] x}{100 \times 50} = (2.16) \times 10^3 \times 980$

On solving the above equation, we get x = 1.5cm

Hence, the required vertical depression is 1.5cm.

*** Given Section consists of questions of 5 marks each. [140]**

93. In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius 2.0 × 10^{-5}m and density 1.2 × 10^3 kg m^{-3}. Take the viscosity of air at the temperature of the experiment to be 1.8 × 10^{-5} Pa s. How much is the viscous force on the drop at that speed ? Neglect buoyancy of the drop due to air.

Ans. : Terminal speed = 5.8cm/ s; Viscous force = 3.9 × 10^{-10} N

Radius of the given uncharged drop, r = 2.0 × 10^{-5}m

Density of the uncharged drop, $\rho = 1.2 \times 10^3 \mathrm{kg\ m}^{-3}$

Viscosity of air, = 1.8 x 10^{-5}Pa/ s

Density of air (P_o) can be taken as zero in order to neglect buoyancy of air.

Acceleration due to gravity, g = 9.8m/ s^2

Terminal velocity (v) is given by the relation:

$\mathrm{v} = \frac{2r^2 \times (\rho - \rho_0) g}{9\eta}$

$= \frac{2 \times (2.0 \times 10^{-5})^2 (.2 \times 10^3 - 0) \times 9.8}{9 \times 1.8 \times 10^{-5}}$

$= 5.807 \times 10^{-2} \mathrm{m/\ s}^{-1}$

$= 5.8 \mathrm{cm/\ s}^{-1}$

Hence, the terminal speed of the drop is 5.8cm s^{-1}

The viscous force on the drop is given by:

$\mathrm{F} = 6\pi\eta \mathrm{rv}$

$\therefore \mathrm{F} = 6 \times 3.14 \times 1.8 \times 10^{-5} \times 2.0 \times 10^{-5} \times 5.8 \times 10^{-2}$

$= 3.9 \times 10^{-10} \mathrm{N}$

Hence, the various force on the drop is $3.9 \times 10^{-10} \mathrm{N}$

94. Mercury has an angle of contact equal to 140° with soda lime glass. A narrow tube of radius 1.00mm made of this glass is dipped in a trough containing mercury. By what amount does the mercury dip down in the tube relative to the liquid surface outside? Surface tension of mercury at the temperature of the experiment is 0.465N m^{-1}. Density of mercury = 13.6×10^3kg m^{-3}.

Ans. : Terminal speed = 5.8 cm/ s

Viscous force = 3.9×10^{-10}N

Radius of the given uncharged drop, r = 2.0×10^{-5}m

Density of the uncharged drop, $\rho = 1.2 \times 10^3 \mathrm{kg\ m^{-3}}$

Viscosity of air, $\eta = 1.8 \times 10^{-5} \mathrm{pa}$

Density of air (ρ_0) can be taken as zero in order to neglect buoyancy of air.

Acceleration due to gravity, g = 9.8 m/ s^2

Terminal velocity (v) is given by the relation:

$$\mathrm{v} = 2\mathrm{r}^2 \times (\rho - \rho_0)\mathrm{g}/\ 9\eta$$

$$= \frac{2 \times (2 \times 10^{-5})^2 (1.2 \times 10^3 - 0) \times 9.8}{(9 \times 1.8 \times 10^{-5})}$$

= 5.8×10^{-2} m/ s

= 5.8cm s^{-1}

Hence, the terminal speed of the drop is 5.8cm/ s^{-1}.

The viscous force on the drop is given by:

$$\mathrm{F} = 6\pi\eta\mathrm{rv}$$

$\therefore$ F = $6 \times 3.14 \times 1.8 \times 10^{-5} \times 2 \times 10^{-5} \times 5.8 \times 10^{-2}$

= 3.9×10^{-10} N

Hence, the viscous force on the drop is 3.9×10^{-10} N.

95. In the previous problem, if 15.0cm of water and spirit each are further poured into the respective arms of the tube, what is the difference in the levels of mercury in the two arms? (Specific gravity of mercury = 13.6)

Ans. : Height of the water column, h_1 = 10 + 15 = 25cm

Height of the spirit column, h_2 = 12.5 + 15 = 27.5cm

Density of water,$\rho_1 = 1 \mathrm{g\ cm^{-3}}$

Density of spirit, $\rho_2 = 0.8 \mathrm{g\ cm^{-3}}$

Density of mercury = 13.6g cm^{-3}

Let h be the difference between the levels of mercury in the two arms.

Pressure exerted by height h, of the mercury column:

$$= \mathrm{h}\rho\mathrm{g} = \mathrm{h} \times 13.6\mathrm{g} \ldots (1)$$

Difference between the pressures exerted by water and spirit:

$$= \mathrm{h}_1\rho_1\mathrm{g} - \mathrm{h}_1\rho_1\mathrm{g}$$

= g(25 × 1 – 27.5 × 0.8) = 3g …… (ii)

Equating equations (i) and (ii), we get:

13.6hg = 3g h

= 0.220588 = 0.221cm

Hence, the difference between the levels of mercury in the two arms is 0.221cm.

96. Two narrow bores of diameters 3.0mm and 6.0mm are joined together to form a U-tube open at both ends. If the U-tube contains water, what is the difference in its levels in the two limbs of the tube ? Surface tension of water at the temperature of the experiment is 7.3×10^{-2}N m^{-1}. Take the angle of contact to be zero and density of water to be 1.0 × 103kg/ m^{-3} (g = 9.8m/ s^{-2}) .

Ans. : Diameter of the first bore, d_1 = 3.0mm = 3×10^{-3}m

Hence, the radius of the first bore, $\mathrm{r}_1 = \frac{\mathrm{d}_1}{2} = 1.5 \times 10^{-3}\mathrm{m}$

Diameter of the first bore, d_2 = 6.0mm = 6×10^{-3}mm

Hence, the radius of the first bore, $\mathrm{r}_2 = \frac{\mathrm{d}_2}{2} = 3 \times^{-3} \mathrm{m}$

Surface tension of water, s = 7.3×10^{-2}N m^{-1}

Angle of contact between the bore surface and water, $\upsilon = 0$

Density of water, $\rho = 1.0 \times 10^3 \mathrm{kg}/ \mathrm{m}^{-3}$

Acceleration due to gravity, g = 9.8m/ s^2

Let h_1 and h_2 be the heights to which water rises in the first and second tubes respectively. These heights are given by the relations:

$$\mathrm{h}_1 = 2\mathrm{s}\cos\theta/\mathrm{r}_1\rho\mathrm{g} \ldots (1)$$

$$\mathrm{h}_2 = 2\mathrm{s}\cos\theta/\mathrm{r}_2\rho\mathrm{g} \ldots (2)$$

The difference between the levels of water in the two limbs of the tube can be calculated as:

$$= \frac{2\mathrm{s}\cos\theta}{\mathrm{r}_1\rho\mathrm{g}} - \frac{2\mathrm{s}\cos\theta}{\mathrm{r}_2\rho\mathrm{g}}$$

$$= \frac{2\cos\theta}{\rho\mathrm{g}}\left[\frac{1}{\mathrm{r}_1} - \frac{1}{\mathrm{r}_2}\right]$$

= 4.966×10^{-3}m

= 4.97mm

Hence, the difference between levels of water in the two bores is 4.97mm.

97. In deriving Bernoulli’s equation, we equated the work done on the fluid in the tube to its change in the potential and kinetic energy.

a. What is the largest average velocity of blood flow in an artery of diameter 2 × 10–3m if the flow must remain laminar?

b. Do the dissipative forces become more important as the fluid velocity increases? Discuss qualitatively.

Ans. :

a. Diameter of the artery, d = 2×10^{-3}m

Viscosity of blood, n = 2.084×10^{-3} kg/ m^3

Density of blood, p = 1.06×10^3 kg/ m^3

Reynolds' number for laminar flow, N_R = 2000

The largest average velocity of blood is given as:

$V_{arg} = N_R n/ pd$

$= \frac{2000 \times 2.084 \times 10^{-3}}{1.06 \times 10^{3} \times 2 \times 10^{-3}}$

= 1.966 m/ s

Therefore, the largest average velocity of blood is 1.966 m/ s.

b. As the fluid velocity increases, the dissipative forces become more important. This is because of the rise of turbulence. Turbulent flow causes dissipative loss in a fluid.

98. The cylindrical tube of a spray pump has a cross-section of 8.0cm^2 one end of which has 40 fine holes each of diameter 1.0mm. If the liquid flow inside the tube is 1.5m min^{-1}, what is the speed of ejection of the liquid through the holes?

Ans. : Area of cross-section of the spray pump, A_1 = 8cm^2

= 8 × 10^{-4}m^2

Number of holes, n = 40

Diameter of each hole, d = 1mm = 1 × 10^{-3}m

Radius of each hole, $\mathrm{r} = \frac{\mathrm{d}}{2} = 0.5 \times^{-3} \mathrm{m}$

Area of cross-section of each hole, $\mathrm{a} = \pi \mathrm{r}^2 = \pi(0.5 \times 10^{-3})^2 \mathrm{m}^2$

Total area of 40 holes, A_2 = n × a

$= 40 \times \pi(0.5 \times 10^{-3})^2 \mathrm{m}^2$

$= 31.41 \times 10^{-6} \mathrm{m}^2$

Speed of flow of liquid inside the tube, V_1 = 1.5m/ min = 0.025m/ s

Speed of ejection of liquid through the holes = V_2

According to the law of continuity, we have:

$A_1V_1 = A_2V_2$

$\mathrm{V}_2 = \frac{\mathrm{A}_1\mathrm{V}_1}{\mathrm{A}_2}$

$= 8 \times 10^{-4} \times \frac{0.025}{(31.61 \times 10^{-6})}$

$= 0.633 \mathrm{m/s}$

99.

a. What is the largest average velocity of blood flow in an artery of radius 2×10 –3m if the flow must remain lanimar?

b. What is the corresponding flow rate ? (Take viscosity of blood to be 2.084 × 10–3 Pa/ s).

Ans. : Radius of the artery, r = 2 × 10^{-3}m

Diameter of the artery, d = 2 × 2 × 10^{-3}m = 4 × 10^{-3}m

Viscosity of blood, n = 2.084 X 10^{-3} Pa/ s

Density of blood, ρ = 1.06 × 10^{3} kg/ m^{3}

Reynolds' number for laminar flow, N_R = 2000

The largest average velocity of blood is given by the relation:

$\mathrm{V}_{\mathrm{arg}} = \mathrm{N}_{\mathrm{R}}\eta/\rho \mathrm{d}$

$= \frac{2000 \times 2.084 \times 10^{-3}}{(1.06 \times 10^{3} \times 4 \times 10^{-3})}$

= 0.983 m/ s

Therefore, the largest average velocity of blood is 0.983 m/ s.

(b) Flow rate is given by the relation:

$$R = \pi r^2 V_{avg}$$

$= 3.14 \times (2 \times 10^{-3})^2 \times 0.983$

$= 1.235 \times 10^{-5}\ m^3 s^{-1}$

Therefore, the corresponding flow rate is $1.235 \times 10^{-5}\ m^3 s^{-1}$.

100. What is the excess pressure inside a bubble of soap solution of radius 5.00mm, given that the surface tension of soap solution at the temperature (20°C) is 2.50 × 10–2 Nm^{-1}? If an air bubble of the same dimension were formed at depth of 40.0cm inside a container containing the soap solution (of relative density 1.20), what would be the pressure inside the bubble? (1 atmospheric pressure is 1.01 × 105Pa).

Ans. : Excess pressure inside the soap bubble is 20Pa;

Pressure inside the air bubble is 1.06×10^5Pa

Soap bubble is of radius, r = 5.00mm = 5×10^{-3}m

Surface tension of the soap solution, S = $2.50 \times 10^{-2} Nm^{-1}$

Relative density of the soap solution = 1.20

∴ Density of the soap solution, $\rho = 1.2 \times 10^3 kg/m^3$

Air bubble formed at a depth, h = 40cm = 0.4m

Radius of the air bubble, r = 5mm = 5×10^{-3}m

1 atmospheric pressure = 1.01×10^5Pa

Acceleration due to gravity, g = 9.8m/ s^2

Hence, the excess pressure inside the soap bubble is given by the relation:

$$p = \frac{2}{r}$$

$$= \frac{2 \times 2.5 \times 10^{-2}}{(5 \times 10^{-3}}$$

$$= 10pa$$

Therefore, the excess pressure inside the air bubble is 10Pa. At a depth of 0.4 m, the total pressure inside the air bubble

= Atmospheric pressure + hρg + P

$= 1.01 \times 10^5 + 0.4 \times 1.2 \times 10^3 \times 9.8 + 10$

$= 1.06 \times 10^5$Pa

Therefore, the pressure inside the air bubble is 1.06×10^5Pa.

101. A venturimeter is connected to two points in the mains where its radii are 20cm and 10cm, respectively, and the levels of water column in the tubes differ by 10cm. How much water flows through the pipe per minute?

Ans. : As we know that,

The volume of water flowing per second,

$$V = a_1 a_2 \sqrt{\frac{2h\rho_m g}{\rho(a_1^2 - a_2^2)}}$$

$\because V = a_1 a_2 \sqrt{\frac{2gh}{a_1^2 - a_2^2}}$

$\because r = 20cm, a_1 = \pi r_1^2 = \pi(20)^2 cm^2$

$r_2 = 10cm, a_2 \pi r_2^2 = \pi(10)^2 cm^2$

$r_1 = 10cm, g = 980 cm/s^2$

$\therefore V = \pi^2 (20)^2 . (10)^2 \sqrt{\frac{2 \times 10 \times 980}{\pi^2 \left((20)^4 - (10^4)\right)}} c.c./ \sec$

$= \frac{175.93 \times 10^3}{\sqrt{15}} c.c./ \sec$

$= \frac{175.93 \times 10^3}{\sqrt{15}} \times 60 c.c./min$

$= 2728.7$ literes/min

102. Show that if n equal rain droplets falling through air with equal steady velocity of $10cm\ s^{-1}$ coalesce, the resultant drop attains a new terminal velocity of $10n^{2/3} cm\ s^{-1}$.

Ans. : Volume of a bigger drop = n × Volume of a smaller drop

$\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$ or $R^3 = nr^3$ or $R = n^{\frac{1}{3}} r$

Terminal velocity of a small droplet is given by,

$v_s = \frac{2}{9} \frac{r^2}{\eta} (\rho - \rho') g \ldots (i)$

Terminal velocity of a bigger drop is given by,

$v_b = \frac{2}{9} \frac{R^2}{\eta} (\rho - \rho') g \ldots (ii)$

Divinding equation (ii) by equation (i) we get $\frac{v_b}{v_s} = \frac{R^2}{r^2}$

But $R = n^{\frac{1}{3}} r$ and $v_s = 10 cm/s$

$v_b = v_s \times \left(\frac{R^2}{r^2}\right) = 10 \times \frac{n^{\frac{2}{3}} r^2}{r^2}$

$v_b = 10 n^{\frac{2}{3}} cm/s$

103. If a number of little droplets of water of surface tension S, all of the same radius r combine to form a single drop of radius R and the energy released is converted into K.E. Find the velocity acquired by the bigger drop. If the energy released is converted into heat, find the rise in temperature.

Ans. : Volume of bigger drop = n × volume of a smaller drop

So, $\frac{4}{3}\pi R^3 = n \times \frac{4}{3}$ or $n = \frac{R^3}{r^3} \ldots (i)$

Mass of the bigger drop,

$m = \frac{4}{3}\pi R^3 \times 1 = \frac{4}{3}\pi R^3 \ldots (ii)$

The energy released,

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

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

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

$$= 3S \times \frac{4}{3}\pi R^3\left[\frac{1}{r}-\frac{1}{R}\right]$$

$$= 3Sm\left[\frac{1}{r}-\frac{1}{R}\right]\left(\because \frac{4}{3}\pi R^3 = m\right)$$

As, per equation,

$$\Delta W = \frac{1}{2}m\,v^2 = 3Sm\left[\frac{1}{r}-\frac{1}{R}\right]$$

Or $v = \sqrt{6S\left[\frac{1}{r}-\frac{1}{R}\right]} = \sqrt{\frac{6S(R-r)}{r\,R}}$

Quantity of heat produced,

$$dH = \frac{\Delta W}{J} = \frac{3S}{J}m\left(\frac{1}{r}-\frac{1}{R}\right)$$

Heat taken by water,

Where J = Joules Mechanical equivalent of heat.

dH = Mass × Specific heat Rise in temp.

$$= m \times 1 \times \Delta\theta$$

$$\therefore m\Delta\theta = \frac{3Sm}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$$

$$\Delta\theta = \frac{3S}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$$

104. The manual of a car instructs the owner to inflate the tyres to a pressure of 200k Pa:

i. What is the recommended gauge pressure?

ii. What is the recommended absolute pressure?

iii. If, after the required inflation of the tyres, the car is driven to a mountain peak, where the atmospheric pressure is 10% below that at sea level. What will the tire gauge read?

Ans. :

i. Manual reads gauge pressure,

$$\therefore P_g = 200k\ Pa$$

ii. Absolute pressure, $P = Pa + P_g$

$$= 101k\ Pa + 200k\ Pa$$

$$= 301k\ P_a$$

iii. At the peak of the mountain, P_a is only 90k Pa. If the absolute pressure is not altered, then gauge pressure,

$$= P - P_a$$

$$= 301k\ Pa - 90k\ Pa$$

$$= 211k\ Pa$$

105. If a number of little droplets of water, each of radius r, coalesce to form a single drop of radius R, and the energy released is converted into kinetic energy then find out the velocity acquired by the bigger drop.

Ans. : Let n be the number of little droplets which coalesce to form single drop. Then,

Volume of n little droplets = Volume of single drop

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

Decrease in surface area

$$= n \times 4\pi r^2 - 4\pi R^2$$

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

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

The energy released,

E = Surface tension × decrease in surface area

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

The mass of bigger drop,

$$M = \frac{4}{3}\pi R^3 \times 1$$

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

$$\therefore E = \frac{4}{3}\pi SR^3 4.3\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$= 3SM\left[\frac{1}{r} - \frac{1}{R}\right] \ \left[\because M = \frac{4}{3}\pi R^3\right]$$

∵ K.E. of bigger drop = Energy released

$$\frac{1}{2}MV^2 = 3SM\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\therefore V = \sqrt{6S\left(\frac{R-r}{Rr}\right)}$$

106. What is viscosity? What are the factors affecting viscous force in a liquid flowing in a tube? Derive the relation for the velocity upto which the liquid can have streamlined flow.

Ans. : Viscosity: The opposing force that exists between the layers of a liquid and the inner walls of the tube in which it flows is called viscous drag or viscous force and the property is called viscosity. The viscous force directly depends on the area of the layer and the velocity gradient.

$$F = -\eta A \frac{dv}{dx}$$

-ve sign shows the opposing nature n refers to coefficient of viscosity.

Factors affecting viscosity:

i. Increase in temperature decreases viscosity.
ii. Increase in pressure increases viscosity in liquids. In water, it decreases while in gases it remains same.

Expression for velocity of streamlined flow: The net force on the sphere becomes zero as the viscous force equals the apparent weight (weight in air-upthrust).

Consider a lengthy column of a dense liquid like glycerine. As the ball or spherical ball is dropped in it, the forces experienced are,

i. Weight $= mg = \frac{4}{3}\pi r^3 \rho g$

 where $\rho-$ density of ball

ii. Upthrust, $U = \frac{4}{3}\pi r^3 \rho_l g$

 Where ρ_l- densicy of liquid

iii. Viscous force, $F_v = 6\pi\eta\, rv$

Where v - terminal velocity

When terminal velocity is attained, acceleration should be zero and the ner force should be zero.

$\therefore \mathrm{mg} - \mathrm{U} - \mathrm{F_v} = 0$

$\Rightarrow \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \rho_l g - 6\pi\eta\, rv = 0$

$\therefore v = \frac{\frac{4}{3}\pi r^3 g(\rho - \rho_l)}{6\pi\eta r} = \frac{2}{9}\frac{r^2 g(\rho-\rho_l)}{\eta}$

107. If a liquid is flowing through a horizontal tube, write down the formula for the volume of the liquid flowing per second through it. Water is flowing through a horizontal tube of radius 2r and length 1m at a rate of 60L/s, when connected to a pressure difference of h cm of water. Another tube of same length but radius is connected in series with this tube and the combination is connected to the same pressure head. Find out the pressure difference across each tube and the rate of flow of water through the combination.

Ans. : The volume of the liquid flowing per second through a horizontal tube, $V = \frac{\pi}{8}.\frac{pr^4}{\eta l}$

Where,

r = radius of the tube,

l = lenghth of the tube,

P = pressure difference acreoss the two ends of the tube and

$\eta =$ coefficient of vilosity of the liquid

$\because V = \frac{\pi}{8} \cdot \frac{pr^4}{\eta l}$

In first case,

$= \frac{\pi}{8} \cdot \frac{h\rho g(2r)^4}{\eta l}[\because p = h\rho g]$

$\frac{\pi}{8} \cdot \frac{h\rho g(2r)^4}{\eta l} = 60 \ldots (i)$

In IInd case, the volume of liquid flowing per second V_1 through each tube is equal

$V_1 = \frac{\pi\rho_1}{8}\frac{\rho_1(2r)^4}{\eta l} = \frac{\pi\rho_2(r)^4}{8\eta l} \ldots (ii)$

$\because \rho_1 + \rho_2 = h\rho g \ldots (iii)[\text{given}]$

From equation (ii),

$\rho_1 = \frac{\rho_2}{16}$

Putting this value of ρ_2 into equation (ii)

$V_1 = \frac{\pi}{8} \cdot \frac{16h\rho g}{17} \cdot \frac{r^4}{\eta l}$

$= \frac{1}{17} \cdot \frac{\pi}{8} \cdot \frac{h\rho g}{\eta l}(2r)^4$

$= \frac{1}{17} \times 60$ [using equation (i)]

$= 3.53 L/s$

108. Define surface tension and surface energy. Write units and dimensions of surface tension. Also prove that surface energy numerically equal to the surface tension.

Ans. : Surface Tension : Force on unit length of an imaginary line drawn on the surface of the liquid is called surface tension. Its S.I. unit is Nm^{-1} and its dimension is $[ML^0T^2]$.

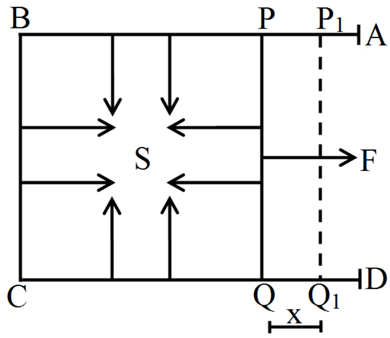
Surface Energy: Energy possessed by the surface of the liquid is called surface energy. Change in surface energy is the product of surface tension and change in surface area under constant temperature.

Let

S = Surface tension of soap solution

d = Length of the wire PQ

l = length of wire PQ



Surface tension acts on both the free surfaces of film.

Hence, total inward force on wire PQ

F = S × 2l

Increase in area of the film PQ Q_1P_1

$= \Delta A = 2 = (l \times x)$

Work done in stretching film is,

W = Force applied × Distance moved

$= (S \times 2l) \times x = S \times (2l\, x)$

$= S \times \Delta A (\because 2l\, x = \Delta A)$

This work done is stored in the film as this surface energy.

$E = W = S \times \Delta A$

$\Rightarrow S = \frac{W}{\Delta A}$

If increase in area is unity then, $\Delta A = 1$

$S = W$

$\therefore$ Surface tension of a liquid is numerically equal to surface energy of the liquid surface.

109. A plane is in level flight at constant speed and each of its two wings has an area of $25 m^2$. If the speed of the air is 180km/ h over the lower wing and 234km/ h over the upper wing surface, determine the plane's mass. (Take air density to be 1kg m^{-3}).

Ans. : The area of the wings of the plane, A = 2 × 25 = $50 m^2$

Speed of air over the lower wing, V_1 = 180 km/ h = 50m/ s

Speed of air over the upper wing, V_2 = 234km/ h = 65m/ s

Density of air, $\rho = 1 \text{kg m}^{-3}$

Pressure of air over the lower wing = P_1

Pressure of air over the upper wing= P_2

The upward force on the plane can be obtained using Bernoulli's equation as:

$p_1 + \left(\frac{1}{2}\right)\rho v_1^2 = p_2 + \left(\frac{1}{2}\right)\rho v_2^2$

$$p_1 - p_2 = \left(\frac{1}{2}\right) \rho \left(V_2^2 - V_1^2\right) \ldots (1)$$

The upward force (F) on the plane can be calculated as:

$$(p_1 - p_2)A = \left(\frac{1}{2}\right) \rho \left(V_2^2 - V_1^2\right)A$$

$$= \left(\frac{1}{2}\right) \times 1 \times (65^2 - 50^2) \times 50$$

$$= 43125N$$

Using Newton’s force equation, we can obtain the mass (m) of the plane as: F =

$$\therefore m = \frac{43125}{9.8} = 4400.51kg$$

$$\sim 4400kg$$

Hence, the mass of the plane is about 4400kg.

110. Air is streaming past a horizontal air plane wing such that its speed is $120ms^{-1}$ over the upper surface and $90ms^{-1}$ at the lower surface. If the density of air is $1.3kg\ m^{-3}$, find the difference in pressure between the top and bottom of the wing. If wing is 10m long and has an average width of 2m, calculate the gross lift of the wing.

Ans. : Given, v_2 = 120m/ s, v_1 = 90m/ s, $\rho_a = 1.3kg/m^3$,

$$h_1 = 10m, a_1 = 10 \times 2 = 20m^2$$

According to Bernoulli's theorem,

$$\frac{P_1}{\rho} + gh_1 + \frac{1}{2}v_1^2 = \frac{P_2}{\rho} + gh_2 + \frac{1}{2}v_2^2$$

For the horizontal flow, $h_1 = h_2$

$$\therefore \frac{P_1}{\rho} + \frac{1}{2}v_1^2 = \frac{P_2}{\rho} + \frac{1}{2}v_2^2$$

Given, $v_1 = 90m/s,\ v_2 = 120m/s,\ \rho = 1.3kg/m^3$

$$\therefore \frac{P_1 - P_2}{\rho} = \frac{1}{2}(v_2^2 - v_1^2)$$

$$(P_1 - P_2) = \frac{\rho(v_2^2 - v_1^2)}{2}$$

$$= 1.3 \times \frac{(14400 - 8100)}{2} = \frac{1.3 \times 6300}{2}$$

$$P_1 - P_2 = 4.095 \times 10^3 N/m^2$$

It is the pressure difference between the top and the bottom of the wing.

Gross lift of wing = (P_1 - P_1) × Area of the wing

= $4.095 \times 10^3 \times 10 \times 2$

= 8.190×10^4N

111.

i. What is the phenomenon of capillarity? Derive an expression for the rise of liquid in a capillary tube.
ii. What will happen if the length of the capillary tube is smaller than the height to which the liquid rises? Explain briefly.

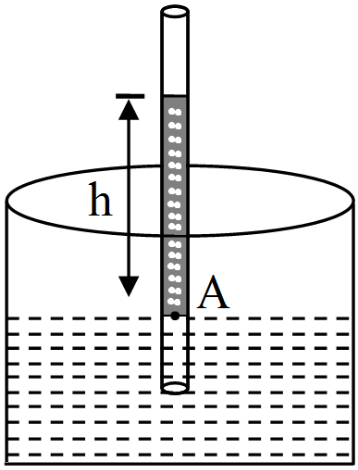
Ans. :

i. **Phenomenon of Capillarity:** Any liquid rises in a capillary tube to compensate for the excess pressure. The height gained in a tube of radius r by a liquid of density p and angle of contact θ is,

$h = \frac{2\sigma\cos\theta}{r\rho g}$

For mercury, θ being obtuse there is a drop in the level. In a capillary tube of insufficient length, the liquid rises to the level available and then forms a meniscus of higher radius.

A liquid rises in a capillary tube to compensate for the excess pressure in level with the liquid in the container (A). Let R be the radius of the meniscus at A. Then excess pressure will be $\frac{2\sigma}{R}$ where σ is the surface tension. If the pressure is compensated by h column of liquid rise, then,



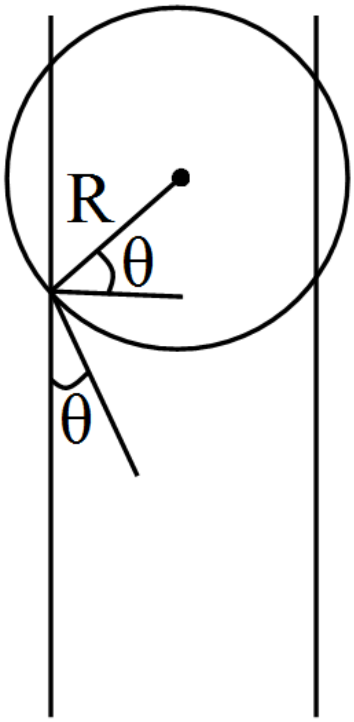
$h\rho g = \frac{2\sigma}{R}$

$\therefore h = \frac{2\sigma}{R\rho g}$

From figure (ii), $\frac{r}{R} = \cos\theta$

$\Rightarrow R = \frac{r}{\cos\theta}$

$\therefore h = \frac{2\sigma\cos\theta}{r\rho g}$



ii. The liquid will rise to the level available and form a meniscus of larger radius due to lesser uncompensated excess pressure.

112. The cylindrical tube of a spray pump has a cross-section of $8.0 cm^2$ one end of which has 40 fine holes each of diameter 1.0mm. If the liquid flow inside the tube is $1.5 m\ min^{-1}$, what is the speed of ejection of the liquid through the holes?

Ans. : Area of cross-section of the spray pump, $A_1 = 8 cm^2$

$= 8 \times 10^{-4} m^2$

Number of holes, n = 40

Diameter of each hole, $d = 1mm = 1 \times 10^{-3} m$

Radius of each hole, $\mathrm{r} = \frac{\mathrm{d}}{2} = 0.5 \times^{-3} \mathrm{~m}$

Area of cross-section of each hole, $\mathrm{a} = \pi \mathrm{r}^2 = \pi(0.5 \times 10^{-3})^2 \mathrm{m}^2$

Total area of 40 holes, $A_2 = n \times a$

$= 40 \times \pi(0.5 \times 10^{-3})^2 \mathrm{m}^2$

$= 31.41 \times 10^{-6} \mathrm{m}^2$

Speed of flow of liquid inside the tube, $V_1 = 1.5 m/ min = 0.025 m/ s$

Speed of ejection of liquid through the holes = V_2

According to the law of continuity, we have:

$A_1 V_1 = A_2 V_2$

$\mathrm{V}_2 = \frac{\mathrm{A}_1 \mathrm{V}_1}{\mathrm{A}_2}$

$= 8 \times 10^{-4} \times \frac{0.025}{(31.61 \times 10^{-6})}$

$= 0.633 \mathrm{m/s}$

113. A 50kg girl wearing high heel shoes balances on a single heel. The heel is circular with a diameter 1.0cm. What is the pressure exerted by the heel on the horizontal floor?

Ans. : Given,

Weight of the girl = 50kg = 490N

Circular diameter of the heel = 1.0cm = 10^{-2}m

Area of the heel is given by,

$\mathrm{A} = \frac{1}{4} \pi \mathrm{D}^2 = \frac{1}{4} \pi \times 10^{-4} \mathrm{m}^2$

Therefore, the pressure exerted by the heel on the ground is given by,

$\mathrm{P} = \frac{\mathrm{W}}{\mathrm{A}} = \frac{490}{\frac{1}{4} \pi \times 10^{-4}} = 6.2 \times 10^6 \mathrm{N/m}^2$

114.

a. What is the largest average velocity of blood flow in an artery of radius 2×10 –3m if the flow must remain lanimar?

b. What is the corresponding flow rate ? (Take viscosity of blood to be 2.084 × 10–3 Pa/ s).

Ans. : Radius of the artery, $r = 2 \times 10^{-3} m$

Diameter of the artery, $d = 2 \times 2 \times 10^{-3} m = 4 \times 10^{-3} m$

Viscosity of blood, $n = 2.084 X 10^{-3}$ Pa/ s

Density of blood, $\rho = 1.06 \times 10^3\ kg/ m^3$

Reynolds' number for laminar flow, $N_R = 2000$

The largest average velocity of blood is given by the relation:

$\mathrm{V_{arg}} = \mathrm{N_R}\eta/\rho\mathrm{d}$

$= \frac{2000\times2.084\times10^{-3}}{(1.06\times10^{3}\times4\times10^{-3})}$

= 0.983 m/ s

Therefore, the largest average velocity of blood is 0.983 m/ s.

(b) Flow rate is given by the relation:

$\mathrm{R} = \pi\mathrm{r}^2\mathrm{V_{avg}}$

= 3.14 × (2 × 10^{-3})^2 × 0.983

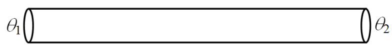
= 1.235 × 10^{-5} m^3s^{-1}

Therefore, the corresponding flow rate is 1.235 × 10^{-5} m^3s^{-1}.

115. A thin rod having length L_0 at 0°C and coefficient of linear expansion α has its two ends maintained at temperatures θ_1 and θ_2, respectively. Find its new length.

Ans. : When temperature of a rod varies linearly, then average temperature of the middle point of the rod can be taken as mean of temperatures at the two ends. According to the diagram,

According to the diagram,



$\theta = \frac{\theta_1+\theta_2}{2}$

Let temperature varies linearly in the rod from its one end tp other end from θ_1 to θ_2 Let θ be the temperature of the mid-point of the rod.

Therefore, average temperature of the mid-point of the rod is,

$\Rightarrow \theta = \frac{\theta_1+\theta_2}{2}$

Using relation, $\mathrm{L} = \mathrm{L_0}(1+\alpha\theta)$

Or $\mathrm{L} = \mathrm{L_0}\left[1+\alpha\left(\frac{\theta_1+\theta_2}{2}\right)\right]$

116. One day in the morning, Ramesh filled up 1/ 3 bucket of hot water from geyser, to take bath. Remaining 2/ 3 was to be filled by cold water (at room temperature) to bring mixture to a comfortable temperature. Suddenly Ramesh had to attend to something which would take some times, say 5-10 minutes before he could take bath. Now he had two options:

i. Fill the remaining bucket completely by cold water and then attend to the work.

ii. First attend to the work and fill the remaining bucket just before taking bath.

Which option do you think would have kept water warmer? Explain.

Ans. : According to the Newton’s law o‘f cooling, the rate of loss of heat is directly proportional to the difference of temperature. Or we can say which gives a consequence about rate of fall of temperature of a body with respect to the difference of temperature of body and surroundings. The first option would have kept water warmer because by adding hot water to cold water, the temperature of the mixture decreases. Due to this temperature difference between the mixed water in the bucket and the surrounding decreases, thereby the decrease in the rate of loss of the heat by the water.

In second option, the hot water in the bucket will lose heat quickly. So if he first attend to the work and fill the remaining bucket with cold water which already lose much heat in 5-10 minutes then the water become more colder as comparison with first case.

117. Calculate the stress developed inside a tooth cavity filled with copper when hot tea at temperature of 57°C is drunk. You can take body (tooth) temperature to be 37°C and a = 1.7×10^{-5}/°C bulk modulus for copper = 140×10^{9}N/ m^2

Ans. : According to the problem, decrease in temperature

$(\Delta \mathrm{t}) = 57 - 37 = 20^{\circ}\mathrm{C}$

Coefficient of linear expansion

$(\alpha) = 1.7 \times^{-5} /^{\circ}\mathrm{C}$

Bulk modulus for copper $(\mathrm{B}) = 140 \times 10^{9} \mathrm{N/\ m^{2}}$

Coefficient of cubical expansion,

$(\gamma) = 3\alpha = 5.1 \times 10^{-5} /^{\circ}\mathrm{C}$

Let initial volume of the cavity be V and its volume increases by $\Delta \mathrm{V}$ due to increase in temperature.

$\therefore\ \Delta \mathrm{V} = \gamma \mathrm{V} \Delta \mathrm{t}$

$\Rightarrow\ \frac{\Delta \mathrm{V}}{\mathrm{V}} = \gamma \Delta \mathrm{t}$

We know, $\mathrm{B} = \frac{\text{stress}}{\text{volume strain}}$

$\therefore$ Thermal stress $= \mathrm{B} \times \left(\frac{\Delta \mathrm{V}}{\mathrm{V}}\right) = \mathrm{B}(\gamma \Delta \mathrm{T})$

$= \mathrm{B}(3\alpha \Delta \mathrm{T})\ \ (\because \gamma = 3\alpha)$

$= 140 \times 10^{9} \times 3 \times 1.7 \times 10^{-5} \times 20$

$= 1.428 \times 10^{8} \mathrm{Nm}^{-2}$

This is about 10^3 times of atmospheric pressure.

118. According to Stefan's law of radiation, a black body radiates energy $\sigma = \mathrm{T}^4$ from its unit surface area every second where T is the surface temperature of the black body and $\sigma = 5.67 \times 10^{-8} \mathrm{w/m^2K^4}$ is known as Stefan's constant. A nuclear weapon may be thought of as a ball of radius 0.5m. When detonated, it reaches temperature of 106K and can be treated as a black body.

a. Estimate the power it radiates.

b. If surrounding has water at 30C°, how much water can 10% of the energy produced evaporate in 1s?

$\left[\mathrm{s}_w = 4186.0 \mathrm{J/\ kgK} \text{ and } \mathrm{L}_v = 22.6 \times 10^{5} \mathrm{J/\ kg}\right]$

c. If all this energy U is in the form of radiation, corresponding momentum is $\rho = \frac{\mathrm{U}}{\mathrm{c}}$ How much momentum per unit time does it impart on unit area at a distance of 1km?

Ans. :

a. $\mathrm{E} = \sigma \mathrm{T}^4$ per second per sq. m

Total E = radiated from all surface area A per will be power radiated by nuclear weapon, $\mathrm{P} = \sigma \mathrm{A} \mathrm{T}^4$

$\sigma = 5.67 \times 10^{-8} \mathrm{W/m^2/\ K^4},\ \mathrm{R} = 0.5\mathrm{m},\ \mathrm{T} = 10^{6}\mathrm{K}$

$$P = 5.67 \times 10^{-8} \times (4 \times \pi R^2)(10^6)^4$$
$$= 5.67 \times 4 \times 3.14 \times 0.5 \times 0.5 \times 10^{-8} \times 10^{24}$$
$$= 5.67 \times 4 \times 3.14 \times 10^{24-8} \times 1.00$$
$$P \cong 18 \times 10^{16} \text{ Watt} = 1.8 \times 10^{17} \text{J/s} \ldots \text{(i)}$$

b. $\therefore\ P = 18 \times 10^{16}\text{watt}$

10% of this power is required to evaporate water

$$E = \frac{10}{100} \times 18 \times 10^{16} \text{ Watt } = 1.8 \times 10^{16} \text{J/ s}$$

Energy required by mkg water at 30°C to evaporate 100°C.

E required to heat up water from 30°C to 100°C

+E required to evaporate water into vapour

$$= mS_w(T_2 - T_1) + mL = m(S_w(T_2 - T_1) + L)$$
$$1.8 \times 10^{16} = m\left[4180(100 - 30) + 22.6 \times 10^5\right]$$
$$= m\left[4186 \times 70 + 22.6 \times 10^5\right]$$
$$m(2.93020 + 22.6) \times 10^5 = 1.8 \times 10^{16}$$
$$m25.5 \times 10^5 = 1.8 \times 10^{16}$$
$$m = \frac{1.8 \times 10^{16}}{25.5 \times 10^5} \cong 7 \times 10^9 \text{kg}$$

c. Momentum per unit time $p' = \frac{U}{c} = \frac{1.8 \times 10^{17}}{3 \times 10^8} = 0.6 \times 10^9$

From (i) $P' = 6 \times 10^8 \text{kg ms}^{-2}$

P per unit time per unit at a distance 1km $= \frac{6 \times 10^8}{4\pi R^2}$

$$\therefore\ p = \frac{6 \times 10^8}{4 \times 3.14 \times (10^3)^2}$$
$$\frac{6 \times 10^8}{4 \times 3.14 \times 10^6} = \frac{6 \times 100}{12.56}$$
$$= 47.77 \text{kg ms}^{-2}/\text{m}^2$$

P per sec at 1km away on m^2 = 47.8N/ m^2

119. We would like to make a vessel whose volume does not change with temperature (take a hint from the problem above). We can use brass and iron $\left(\beta_{\text{ubrass}} = 6 \times 10^{-5}/\text{K and } \beta_{\text{uiron}} = 3.55 \times 10^{-5}\text{K}\right)$ to create a volume of 100cc. How do you think you can achieve this.

Ans. : Volume of vessel, V_0 = 100cm^3

= 10^{-4} = constant

Volume of iron vessel (V_I) - Volume of brass rod (V_B) = 10^{-4}m^3

⇒ V_I - V_B = 10^{-4}m^3

This condition is possible if

$$\beta_I V_I \Delta T = \beta_B V_B \Delta T$$
$$\therefore\ V_I = \left(\frac{\beta_B}{\beta_I}\right) V_B$$
$$= \left(\frac{6 \times 100^{-5}}{3.55 \times 10^{-5}}\right) V_B$$
$$= 1.69 V_B$$

From equation (i),

$$1.69V_B - V_B = 10^{-4}$$

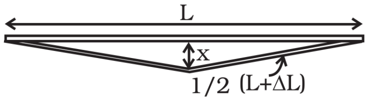
$$\Rightarrow V_B = \frac{10^{-4}}{0.69} = 1.449 \times 10^{-4} m^3$$

$$\Rightarrow V_B = \frac{10^{-4}}{0.69} = 1449 \times 10^{-4} m^3$$

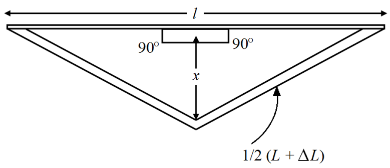
$$\Rightarrow V_I = 1.69V_B = 1.69 \times 144.9 = 244.9 cm^3$$

Therefore, an iron vessel with a volume of 249.9cm^3 fitted with a brass rod of volume 144.9cm^3 will serve as a vessel of volume 100cm^3, which will not change with temperature.

120. A rail track made of steel having length 10m is clamped on a railway line at its two ends. On a summer day due to rise in temperature by 20°C , it is deformed as shown in figure. Find x(displacement of the centre) if $\alpha_{steel} = 1.2 \times 10^{-5} /^\circ C$.



Ans. : Diagram shows the deformation of a railway track due to rise in temperature.



Applying Pythagoras theorem in right angled triangle,

$$x^2 = \left(\frac{L+\Delta L}{2}\right)^2 - \left(\frac{L}{2}\right)^2$$

$$x = \sqrt{\left(\frac{L+\Delta L}{2}\right)^2 - \left(\frac{L}{2}\right)^2}$$

$$= \sqrt{\left(\frac{L}{2}\right)^2 + \frac{2L\Delta L}{4} + \left(\frac{\Delta L}{2}\right)^2 - \left(\frac{L}{2}\right)^2}$$

$$= \frac{1}{2}\sqrt{\left(L^2 + \Delta L^2 + 2L\Delta L\right) - L^2}$$

$$= \frac{1}{2}\sqrt{\left(\Delta L^2 + 2L\Delta L\right)}$$

As increase in length ΔL is very small, therefore, neglecting $(\Delta L)^2$, we get

$$x = \frac{\sqrt{2L\Delta L}}{2}$$

But $\Delta L = L\alpha\Delta t$

According to the problem, L = 10m

$$\alpha = 1.2 \times 10^{-5}{}^\circ C^{-1}, \Delta T = 20^\circ C$$

Substituting value of ΔL in Eq. (i) from Eq. (ii)

$$x = \frac{1}{2}\sqrt{2L \times L\alpha\Delta t} = \frac{1}{2}L\sqrt{2\alpha\Delta t}$$

$$= \frac{10}{2} \times \sqrt{2 \times 1.2 \times 10^{-5} \times 20}$$

$$= 5 \times \sqrt{4 \times 1.2 \times 10^{-4}}$$

$$= 5 \times 2 \times 1.1 \times 10^{-2}$$

$= 0.11\mathrm{m} = 11\mathrm{cm}$

* Case study based questions [16]

121. Read the passage given below and answer the following questions from 1 to 5. Surface Tension The property due to which the free surface of liquid tends to have minimum surface area and behaves like a stretched membrane is called surface tension. It is a force per unit length acting in the plane of interface between the liquid and the bounding surface i.e., $\mathrm{S} = \frac{\mathrm{F}}{\mathrm{L}}$, where F = force acting on either side of imaginary line on surface and L = length of imaginary line. Surface tension decreases with rise in temperature. Highly soluble impurities increases surface tension and sparingly soluble impurities decreases surface tension.

i. The excess pressure inside a soap bubble is three times than excess pressure inside a second soap bubble, then the ratio of their surface area is:
   a. 9 : 1
   b. 1 : 3
   c. 1 : 9
   d. 3 : 1

ii. Which of the following statements is not true about surface tension?
   a. A small liquid drop takes spherical shape due to surface tension.
   b. Surface tension is a vector quantity.
   c. Surface tension of liquid is a molecular phenomenon.
   d. Surface tension of liquid depends on length but not on the area.

iii. Which of the following statement is not true about angle of contact?
   a. The value of angle of contact for pure water and glass is zero.
   b. Angle of contact increases with increase in temperature of liquid.
   c. If the angle of contact of a liquid anda solid surface is less than 90°, then the liquid spreads on the surface of solid.
   d. Angle of contact depend upon the inclination of the solid surface to the liquid surface.

iv. Which of the following statements is correct?
   a. Viscosity is a vector quantity.
   b. Surface tension is a vector quantity.
   c. Reynolds number is a dimensionless quantity.
   d. Angle of contact is a vector quantity.

v. A liquid does not wet the solid surface if the angle of contact is:
   a. 0°
   b. Equal to 90°
   c. Equal to 45°
   d. Greater than 90°

Ans. :

i. (c) 1 : 9

Explanation:

Piecare, $\mathrm{P} = \frac{4\mathrm{S}}{\mathrm{r}}$ or $\mathrm{P} \propto \frac{1}{\mathrm{r}}$

$\therefore \frac{\mathrm{P}_1}{\mathrm{p}_2} = \frac{\mathrm{r}_2}{\mathrm{r}_1} = \frac{3}{1} \ldots (\mathrm{i})$ or $r_2 = 3r_1$

Also $\frac{A_1}{A_2} = \frac{4\pi r_1^2}{4\pi r_2^2} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{r_1}{3r_1}\right)^2 = \frac{1}{9}$ (Using (i))

ii. (b) Surface tension is a vector quantity.

Explanation:

Surface tension is a scalar quantity because it has no specific direction for a given liquid.

iii. (b) Angle of contact depend upon the inclination of the solid surface to the liquid surface.

Explanation:

Angle of contact does not depend upon the inclination of the solid surface to the liquid surface.

iv. (c) Reynolds number is a dimensionless quantity.

Explanation:

Viscosity is a scalar quantity. Surface tension is a scalar quantity.

Reynolds number is a dimensionless quantity.

v. (d) Greater than 90°

Explanation:

A liquid does not wet the solid surface if the angle of contact is obtuse (i.e. 8 > 90°).

122. Read the passage given below and answer the following questions from 1 to 3.

Bernoulli's Theorem It states that for the streamline flow of an ideal liquid through a tube, the total energy (the sum of pressure energy, the potential energy and kinetic energy) per unit volume remains constant at every cross-section throughout the tube. $P + pgh + \frac{1}{2}pv^2$ = constant or $\frac{P}{pg} + h + \frac{1}{2}\frac{v^2}{g}$ = another constant Here, $\frac{P}{pg}$ = pressure head; h = potential head and $\frac{1}{2}\frac{v^2}{g}$ velocity head. If the liquid is flowing through a horizontal tube, then h is constant, then according to Bernoulli's theorem, $\frac{P}{pg} + \frac{1}{2}\frac{v^2}{g}$ constant Bernoulli's theorem is based on law of conser - vation of energy.

i. Bernoulli's equation for steady, non-viscous, incompressible flow expresses the:
   a. Conservation of linear momentum
   b. Conservation of angular momentum
   c. Conservation of energy
   d. Conservation of mass

ii. Applications of Bernoulli's theorem can be seen in:
   a. Dynamic lift of aeroplane
   b. Hydraulic press
   c. Helicopter
   d. None of these

iii. A tank filled with fresh water has a hole in its bottom and water is flowing out of it. If the size of the hole is increased, then:
   a. The volume of water flowing out per second will decrease.
   b. The velocity of outflow of water remains unchanged.
   c. The volume of water flowing out per second remains zero.
   d. Both (b) and (c)

Ans. :

i. (c) Conservation of energy

Explanation:

Bernoullis equation for steady, non-viscous, in compressible flow express the conservation of energy.

ii. (a) Dynamic lift of aeroplane

Explanation:

The shape of the aeroplane wings is such that when it moves forward, the air molecules at the top of the wings have a greater velocity (relative to the wings) compared to the air molecules at the bottom.

Therefore in accordance with Bernoulli's principle, the pressure at the top of the wings is less than that at the bottom.

This results in a dynamic lift of the wings which balances the weight of the plane.

iii. (b) The velocity of outflow of water remains unchanged.

Explanation:

The velocity of outflow of water remains unchanged because it depends upon the height of water level and is independent of the size of the hole.

The volume depends directly on the size of the hole.

123. When some wax is rubbed on a cloth, it becomes waterproof. Explain.

Ans. : A liquid wets a surface when the angle of contact of the liquid with the surface is small or zero. Due to its fibrous nature, cloth produces capillary action when in contact with water. This makes clothes have very small contact angles with water. When wax is rubbed over cloth, the water does not wet the cloth because wax has a high contact angle with water.

124. When a glass capillary tube is dipped at one end in water, water rises in the tube. The gravitational potential energy is thus increased. Is it a violation of conservation of energy?

Ans. : No, it does not violate the principle of conservation of energy.

There is a force of attraction between glass and water, which is why the liquid rises in the tube. However, when water and glass are not in contact, there exists a potential energy in the system. When they are brought into contact, this potential energy is first converted into kinetic energy, which lets the liquid rush upwards in the tube, and then into gravitational potential energy. Therefore, energy is not created in the process.

----- मनुष्य को हमेशा मौका नही ढूंढना चाहिये,क्योंकि जो आज है वही सबसे अच्छा मौका है। -----