7 Properties of solid and liquid

Elasticity : The inherent property of a body due to which, body trines to restore the normal shape or to oppose the change in shape is known as elasticity.

Perfect elastic body : It a body can completely regains its original stape after removal of the deforming force, it is called a perfect elastic body.
In practice it is impossible to have a perfect elastic body.
The object which can be considerd as the nearest to perfect elastic body is quartz.

Non elastic body : (plastic body) : If a body remains in the deformed state and does not even partially regain its original shape after removal of deforming force, it is called a perfect non elastic body. e.g. Wax

Rigid Body : If the relative positions of the particles of the body remain invarient even resultant force acts on it, the body is called rigid.

Stress : The restoring force arising per unit cross sectional area of a deformed body is called stress.

Stress $\sigma = \frac{F}{A} \quad \frac{\text{Force (F)}}{\text{Area (A)}}$

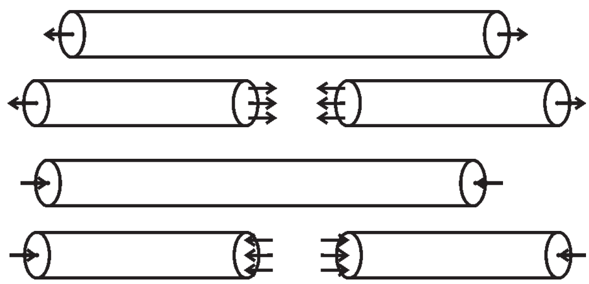
unit : Nm^{-2}

Dimenssional formula : $M^1L^{-1}T^{-2}$

Types of Stress :

(1) **Longitudinal Stress (σ_l) :** The stress due to which the length of the body changes is called longitudinal stress.

Types of longitudinal stress :



- **Tensile Stress :** The stress which causes increase in the length of the body is called tensile stress.
- **Compressive stress :** If due to the application of external forces length of the rod decreases, the resulting stress is called compressive stress.

(2) **Volume Stress or Hydraulic Stress (σ_V) :** The stress produces due to the forces which are perpendicular to the entire surface of the body is called volume stress. Application of such forces cause change in the volume of the body.

(3) **Shearing Stress or Tengential Stress (σ_s) :** If the force acting on a body is tangential to a surface of the body it causes shearing strain in the body is called shearing stress.

Note : In the normal position of the body the intermolecular distance $r = r_0$. When external force acts on it,

- If the body is compressed ($r < r_0$) $\rightarrow$ intermolecular forces are repulsive
- If the body expand ($r > r_0$) $\rightarrow$ intermolecular forces are attractive.

The Difference between pressure and stress :

Pressure	Stress
• Vector • The whole body is acted upon by forces, acting perpendicularly every where on the body. • It is same on all surface.	• Tensor • The forces should not be perpendicular to the surface. • It can be different on diffrent surfaces. It is also possible that there is stress on one surface and there is no stress on the other surface.

Thermal Stress : When both the ends of a rod is fixed in the rigid support and its temperature is reduced, the stress induced in the rod is called thermal stress.

Thermal Stress $\sigma = Y\,\alpha\,\Delta T$

Y = Young's modulus α = linear co-efficient of expansion ΔT = decrease in the temperature.

Strain : (ε)

- When an external force is applied on a body its length, volume or shape change is called strain.
- It is ratio of change in body when deforming force is applied to the original body.
- Strain is unitless and dimensionless physical quantity.

Types of strain

(1) **Longitudinal Strain (ε_l) :** The ratio of change in length of a body (Δl) when deforming force is applied to the original length (l) is called longitudinal Strain.

$$\varepsilon_l = \frac{\Delta l}{l}$$

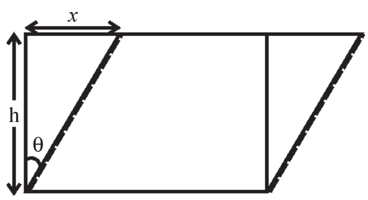
- Tensile Strain $\rightarrow$ increase in length
- Compressive Strain $\rightarrow$ decrease in length

(2) **Volume Strain (ε_V) :** It is ratio of when a body is acted upon by the forces everywhere on its surface in direction perpendicular to the sarface, the volume of the body change to original volume.

$$\varepsilon_v = \frac{\Delta V}{V}$$

(3) **Shearing Strain (ε_s) :** A force tangential to a cross-section of a body produce the change in shape, it is called shearing Strain.

$$\varepsilon_s = \frac{x}{h}$$

Types	**Stress**	**Strain**
Longitudinal	$\sigma_l = \dfrac{\text{Force perpendicular to cross-section}}{\text{cross- sectional area}}$ $\sigma_l = \dfrac{F}{A}$	$\varepsilon_l = \dfrac{\text{Change in length}}{\text{original length}}$ $\varepsilon_l = \dfrac{\Delta l}{l}$
Volume	$\sigma_V = \dfrac{\text{Force perpendicular at every point of surface}}{\text{area of surface}}$ $\sigma_V = \dfrac{F}{A} = \dfrac{PA}{A} = P$ (Where P = Pressure)	$\varepsilon_V = \dfrac{\text{Change in volume}}{\text{original volume}}$ $\varepsilon_V = \dfrac{\Delta V}{V}$
Shearing	$\sigma_s = \dfrac{\text{Tengential force}}{\text{area}}$ $= \dfrac{F_s}{A}$ Unit : Nm^{-2}	$\varepsilon_s = \dfrac{x}{h} = \tan\theta$  Unitless

(1) The length of a string is l_1 when the tension force of 3 N is applied on the string. The length becomes l_2 when force becomes 4N. What would be the length to the string if the force is made 7 N.

(A) $4l_2 - 5l_1$ (B) $7l_2 - l_1$ (C) $4l_2 - 3l_1$ (D) $3l_2 - 4l_1$

(2) One horizontal rod of length 1 m is rotating about an axis passing through its edge and perpendicular to its plane. With what revolution per second it should be rotated so that it breaks ? (breaking stress = 3×10^9 Nm^{-2}, density ot the material of the rod = 6000 kgm^{-3}.)

(A) 1000 rps (B) 318.2 rps (C) 159 rps (D) 259 rps

(3) A rod of length 2m, mass 1 kg and. Cross-sectional area 10^{-4} m^2 is hanged vertically. 1 kg mass is suspended at its lower end calculate the stress at the midpoint of the rod. (g = 10 ms^{-2})

(A) 20×10^4 Nm^{-2} (B) 10^5 Nm^{-2} (C) Zero (D) 15×10^4 Nm^{-2}

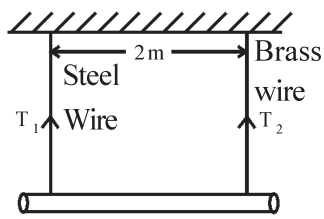
(4) When a mass more than 27 kg is suspended from a wire, it breaks. Another wire is having radius equal to one third of the first wire, which is made up of the same material. Calculate the maximum mass which can be loaded using this wire.

(A) 9 kg (B) 3 kg (C) 27 kg (D) 81 kg

(5) Length of a metallic rod of mass m and cross-sectional area A is L. If mass M is suspended at the lower end of this rod suspended vertically. Stress at the cross-section situated at $\frac{L}{4}$ distance from its upper end is ......

(A) $\frac{Mg}{A}$ (B) $\left(M + \frac{m}{4}\right)\frac{g}{A}$ (C) $\left(M + \frac{3m}{4}\right)\frac{g}{A}$ (D) $(M + m)\ \frac{g}{A}$

(6) A rod of length 100 cm and negligible weight is hanged using steel wire and brass wire in such a way that it remains horizontal as shown in the figure. A_{steel} = 0.2 cm^2 and A_{brass} = 0.4 cm^2. Both steel and brass wires are of equal length. At what distance on the rod a mass (W) must be suspended so that the tension produced in steel wire is same as that in brass wire.



(A) $\frac{2}{3}$ m from steel wire (B) $\frac{4}{3}$ m from the brass wire

(C) 1 m from the steel wire (D) $\frac{1}{4}$ m from the brass wire

Ans. : 1 (C), 2 (C), 3 (D), 4 (B), 5 (C), 6 (A)

Hooke's Law and Elastic Moduli

"For small deformations the stress and strain are directly proportional to each other."

$\sigma_l \propto \varepsilon_l \Rightarrow \sigma_l = Y\varepsilon_l$

$\therefore\ Y = \frac{\sigma_l}{\varepsilon_l} = \frac{FL}{A\Delta L}$

Bulk Modulus : $B = \frac{\sigma_V}{\varepsilon_V}$

Comperssibility $K = \frac{1}{B}$

Modulus of rigidity (Shear Modulus)

$$\eta = \frac{\sigma_s}{\varepsilon_s} = \frac{F/A}{x/h} = \frac{Fh}{Ax}$$

(7) The density of sea-water on its surface is ρ. Find the density of water where the pressure is α Pa. Where Pa = atomspheric pressure and α is a constant. The Bulk modulus of the water is B.

(A) $\frac{\rho B}{B \alpha P_a}$ (B) $\frac{\rho B}{B - \alpha P_a}$ (C) $\frac{\rho B}{B + (\alpha - 1) P_a}$ (D) $\frac{\rho B}{B - (\alpha - 1) P_a}$

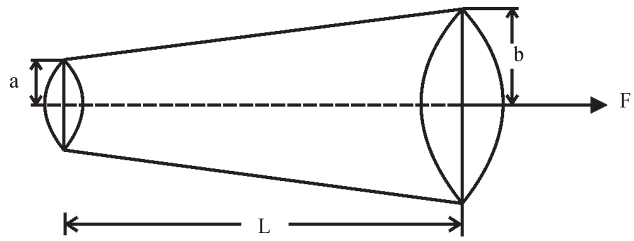
(8) A solid sphere of radius R and made up from the meterial having bulk modulus B is placed in a cylindrical container having cross-sectional area A and filled with some liquid. A piston of cross-section A is kept floating on the surface of the liquid. Calculate the relative change in the radius of the sphere when mass M is kept on the piston.

(A) $\frac{Mg}{3AB}$ (B) $\frac{Mg}{2AB}$ (C) $\frac{Mg}{AB}$ (D) $\frac{3Mg}{AB}$

(9) A wire of length 0.5 m, redius 0.1 m rotates about an axis passing through its edge and perpendicular to its plane with an angular speed of 400 rad s^{-1}. Calculate the increase in the length of the spring. The density of the material of the wire is 10^4 kgm^{-3}. Young's modulus $Y = 2 \times 10^{11}$ Nm^{-2}.

(A) $\frac{1}{6}$ mm (B) $\frac{1}{3}$ mm (C) $\frac{1}{2}$ mm (D) 1 mm

(10) Find the tension force produced in the wire when a force F is applied as shown in the figure. ($Y = 2 \times 10^{11}$ Nm^{-2})



(A) $\frac{F}{\pi(b^2 - a^2)Y}$ (B) $\frac{F}{\pi\left(\frac{a+b}{2}\right)^2 Y}$

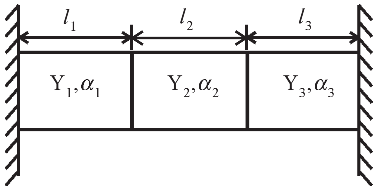
(C) $\frac{F}{\pi\left(\frac{a^2+b^2}{2}\right)Y}$ (D) $\frac{F}{\pi ab Y}$

(11) A solid sphere of radius (r) made up from the material having bulk modulus (B), placed in a cylindrical container filled with liquid. A piston having cross-sectional area (a) is placed in a container. When a mass (m) is placed on the piston than find fractional increases in radius $\frac{\Delta r}{r}$ ....

(A) B $\frac{a}{mg}$ (B) $\frac{a}{3mg}$ (C) $\frac{mg}{3Ba}$ (D) $\frac{mg}{Ba}$

(12) A twist of 0.1 unit per cm is produced in a wire of radius 3 cm. A hollow cylinder of having internal radius 4 cm and outer radius is 5 cm is under the effect of same couple of force. Find twist in hollow cylinder per cm.

(A) 0.1 unit (B) 0.455 unit (C) 0.91 unit (D) 1.82 unit

(13) 

The Young's modulus of three rods having cross-section area and equal volume are Y_1, Y_2 and Y_3 respectively. Their coefficent of linear expansion are α_1, α_2 and α_3 respectively. A compound rod made up of these 3 rods is fixed between two walls as shown in the figure. It has been observed that the length of the central rod (l_2) remains the same even if the temperature of the system increases. Calculate original $\frac{l_1}{l_3}$.

l_1 = length of the first rod l_3 = length of the third rod.

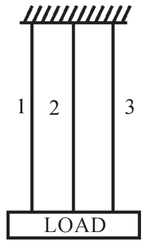
(A) $\left(\frac{Y_2\alpha_2 - Y_1\alpha_1}{Y_3\alpha_3 - Y_2\alpha_2}\right)\frac{Y_3}{Y_1}$ (B) $\left(\frac{Y_3\alpha_3 - Y_2\alpha_2}{Y_2\alpha_2 - Y_1\alpha_1}\right)\frac{Y_1}{Y_3}$

(C) $\frac{Y_1\alpha_1}{Y_3\alpha_3}$ (D) $\frac{Y_3\alpha_3}{Y_1\alpha_1}$

(14) A wooden board with uniform thickness moves on smooth surface under the influenes of constant horizontal force (F_0) its young modudus is Y. If area of cross section is A, its compressive strain in direction of force is .... (Total length of wooden board = L)

(A) $\frac{F_0}{AY}$ (B) $\frac{2F_0}{AY}$ (C) $\frac{F_0}{2AY}$ (D) $\frac{3F_0}{2AY}$

(15) Young modulus of Steel, Aluminium and Tungsten wire having same length and same area of cross-section are $Y_1 = 2\times10^{11}$ Pa, $Y_2 = 0.7 \times 10^{11}$ Pa $Y_3 = 3.6 \times 10^{11}$ Pa. They are suspended vertically us shown in figure Effective Young modulus of this arrangement is ...... Pa.

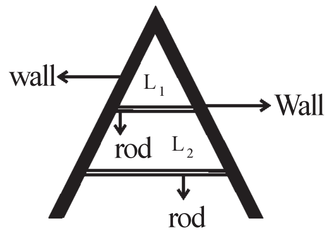


(A) 6.3×10^{11} (B) 2.1×10^{11} (C) 0.8×10^{22} (D) 7.099

(16) An average distance between two molecules of an unknown metal is 3.2×10^{-10} m. The constant of intermolecular force between them is 6 Nm^{-1}. The Young's modulus for this metal is ...... Nm^{-2}.

(A) 2.33×10^5 (B) 18.75×10^{10} (C) 0.1875×10^{10} (D) 1.875×10^{10}

(17) Two rods of length L_1 = 10 cm and L_2 = 20 cm are fixed between two walls as shown in figure. Their Young modulus are Y_1 and Y_2. Their coefficient of linear expansion are α_1 and α_2. Where $\alpha_1 : \alpha_2 = 3 : 4$. Both rods are not bend even after heating. Ratio of young modulus to obtain same value of thermal stress is $Y_1 : Y_2$ = ...

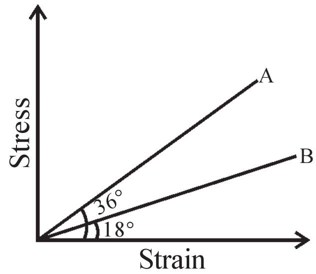


(A) 1:1 (B) 3:4 (C) 4:3 (D) 4:9

(18) A ring of radius $\frac{R}{2}$ is fixed on a wooden disc of radius R, in such a way that their centres remain the same. The area of the cross-section of the ring is 100 cm^2 and the Young's modulus of the meterial of the ring is 2×10^{11} Pa. Calculate the force required for the expansion of the ring.

(A) 4×10^9 N (B) 2×10^6 N (C) 2×10^{13} N (D) 10^{13} N

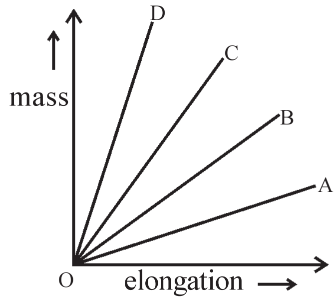
(19) A graph of stress → strain for two different material A and B is shown in the figure. If their Young modulus are Y_A and Y_B. Find $\frac{Y_A}{Y_B}$ = ... [tan 36° = 0.75, tan 18° = 0.3]



(A) $\frac{2}{5}$ (B) $\frac{2}{1}$

(C) $\frac{1}{2}$ (D) $\frac{5}{2}$

(20) The graph of mass → elongation for four wires of diffrent length but same material is as shown in the figure. Which one of the followings represent the thickest wire ?



(A) OD (B) OG

(C) OB (D) OA

Ans. : 7 (D), 8 (A), 9 (B), 10 (D), 11 (C), 12 (B), 13 (B), 14 (C), 15 (B), 16 (D), 17 (C), 18 (B), 19 (D), 20 (A)

Poisson's ratio :

- The ratio of lateral strain to longitudinal strain is known as poisson's ratio.

$\mu = \frac{\Delta D/D}{\Delta l/l}$ D = Diameter of cross-section

- $\mu < 0.5$
- For solid $\frac{1}{4} < \mu < \frac{1}{3}$
- For rubber μ is very close to 0.5

Elastic potential energy :

$U = \frac{AY}{2L}(\Delta L^2)$ | A = area of cross-section, Y = Young's modulus, L = original length, ΔL = change in length

- Energy per unit volume = $\frac{1}{2} \times Y \times \left(\frac{\Delta L}{L}\right)^2$

$\therefore \frac{U}{V} = \frac{1}{2} \times \text{Stress} \times \text{Strain}$

Note :

- for two wire If $Y_1 = Y_2$ and $F_1 = F_2$

$\therefore \Delta L \propto \frac{L}{r^2} \Rightarrow \frac{\Delta L_2}{\Delta L_1} = \frac{L_2}{L_1} \times \frac{r_1^2}{r_2^2}$

- for two wire If $Y_1 = Y_2$ and $L_1 = L_2$

$\therefore\ \Delta L \propto \frac{F}{r^2} \quad \Rightarrow \frac{\Delta L_2}{\Delta L_1} = \frac{F_2 r_1^2}{F_1 r_2^2}$

- Y, B and η decreases with the increase of temperature.
- The restoring torque produce in a wire having twist θ is,

$\tau = \frac{\pi\eta r^4\theta}{2l}$ $\qquad$ l = length of the wire.

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(21) The potential energy of the molecule of air, $U = \frac{M}{r^6} - \frac{N}{r^{12}}$ where M and N are constants. The potential energy in the equilibrium position ....

(A) 0 (B) $\frac{N^2}{4M}$ (C) $\frac{M^2}{4N}$ (D) $\frac{MN^2}{4}$

(22) The poisson's ratio of an object is 0.1. The longitudinal strain of a rod made from this object is 10^{-3} . The percentage change it its volume is ....

(A) 0.008 % (B) 0.08 % (C) 0.8 % (D) 8 %

(23) The poisson's ratio of an object is 0.5. The tensile strain is due to this force of 2×10^{-3}. The percentage change in the volume ....

(A) 2 % (B) 2.5 % (C) 5 % (D) 0 %

(24) The ratio of diameters of two wires of same length and same meterial is 2 : 3. Both are given same tension then the ratio of their potential energy per unit volume is ....

(A) 2 : 3 (B) 81 : 16 (C) 9 : 4 (D) 16 : 81

(25) What would be the potential energy per unit volume of a wire having tensile strain 20 Nm^{-2} ? Y = 2 × 10" Pa

(A) $0.5 \times 10^{-11}\ Jm^{-3}$ (B) $10^9\ Jm^{-3}$ (C) $10^{-9}\ Jm^{-3}$ (D) $2 \times 10^{-9}\ Jm^{-3}$

Ans. : 21 (C), 22 (B), 23 (D), 24 (B), 25 (C)

Fluid pressure

- fluid pressure $P = \frac{F}{A}$

1 Pa = 1 Nm^{-2}

1 atm = 1.013×10^5 Pa

1 bar = 10^5 Pa

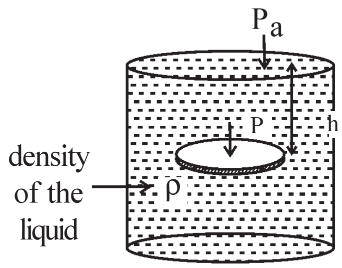
1 torr = 133.28 Pa = 1 mm-Hg

1 atm = 76 cm of Hg = 760 mm-Hg

Thrust on the Liquid :

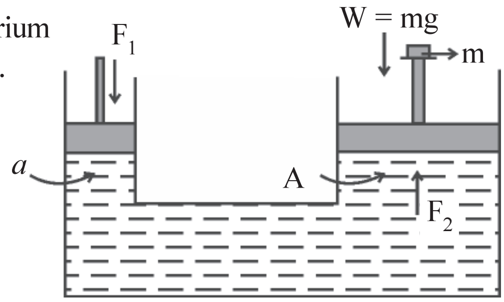
The total force acting on the surface of the liquid by the liquid is called thrust of the liquid.

- Pressure due to fluid column :
  $P - Pa = h\rho g$ (gauge pressure)
  Total Pressure $P = Pa + h\rho g$



Pascal's law : Pressure in an incompersssible fluid in equilibrium is the same everywhere, if the effect of gravity is neglected.

Principle of Hydraulic press :



$P = \frac{F_1}{a} = \frac{F_2}{A}$

but $\frac{F_1}{a} = \frac{W}{A}$

Where $A >> a$ then $F_1 << W$ and $F_2 = W$

Archimedes Principle :

When a body is partially or fully immersed in a liquid the buoyant force acting on it, is equal to the weight of the liquid displaced by it and it acts in the upward direction at the centre of mass of the displaced liquid.

$[F_b = V_f \rho_f g]$.

Law of floatation :

Weight of body W = weight of the liquid displaced by the part of body immersed.

$Mg = mg$ (M = Mass of flowting body $V_s \rho_s$,

$V_s \rho_s g = V_f \rho_f g$ m = Mass of the desplaced liquid = $V_f \rho_f$)

$\frac{\rho_s}{\rho_f} = \frac{V_f}{V_s}$

- This relation is also true for accelerated fuel
- Weight force W, F_b - buoyant force.
  $W > F_b$, the body sinks in the liquid
  $W < F_b$, the body floats on the Liquid surface.
  $W = F_b$, the body can remain in equilibrium at any depth in liquid.

Note :

- Body is sink in accelerated fluid at that point buoyant force will be upward direction is called buoancy centre.
- For the symmetrical solid body the centre of buoancy is its centre of gravity.
- When the centre of gravity and centre at buoancy are on the same line, the solid would be in the equilibrium.
- For non-symmetrical body both the centres are not lying on the same line. As a result, the resultant torque acts on the body and the body will perform rotational motion.

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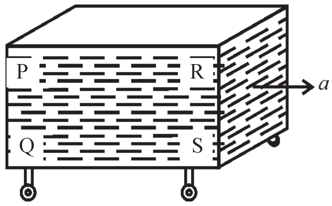
(26) Two objects having different mass are attached at both end of the balance. Where this balance immersed in the water then it is in balanced position. If mass of one object is 36g and its density is 9 g cm^{-3}. Find density of second object having mass 72 g.

(A) $\frac{4}{3}$ gcm^{-3} (B) $\frac{2}{3}$ gcm^{-3} (C) 1.8 gcm^{-3} (D) 5 gcm^{-3}

(27) An object having density 4 kg m^{-3} in a medium having density 1 kg m^{-3} is in equilibqium with an object having density 8 kg m^{-3} and weight 10 N. Find actual mass of an object. ($g = 10\ ms^{-2}$)

(A) 10 kg (B) $\frac{7}{8}$ kg (C) $\frac{3}{4}$ kg (D) $\frac{7}{6}$ kg

(28) A cubical tank is completely filled with water is fixed on *a* trolly. If this tank is acclerated with (a). then,

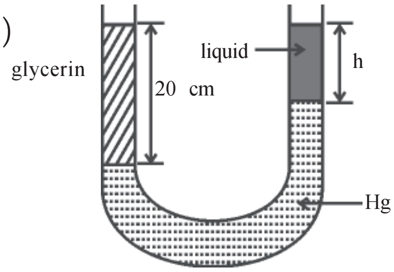


(i) Pressure at ...... point is maximum

(ii) Pressure at ...... point is minimum

(A) (i) Q (ii) R (B) (i) S (ii) R (C) (i) Q (ii) S (D) (i) Q (ii) P

(29)



Height of mercury in both arm of manometer (U tube) is same. Glycerin having density 1.3 gcm^{-3} and height of 20 cm is entered in one arm of a tube. Find the height of a liquid having density 0.8 gcm^{-3} entered in other arm of manometer so that free end of both liquid in manometer remains same.

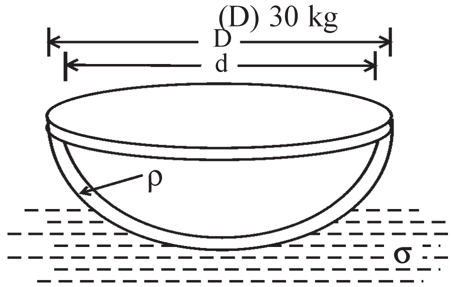
(ρ_{Hg} = 13.6 g cm^{-3})

(A) 10 cm (B) 8 cm (C) 16 cm (D) 19.2 cm

(30) A wooden raft having mass 120 kg having density 600 kgm^{-3} floats on surface of water. Find the maximum mass placed on the raft so that it sinks in the water. (g = 10 ms^{-2})

(A) 80 kg (B) 50 kg (C) 60 kg (D) 30 kg

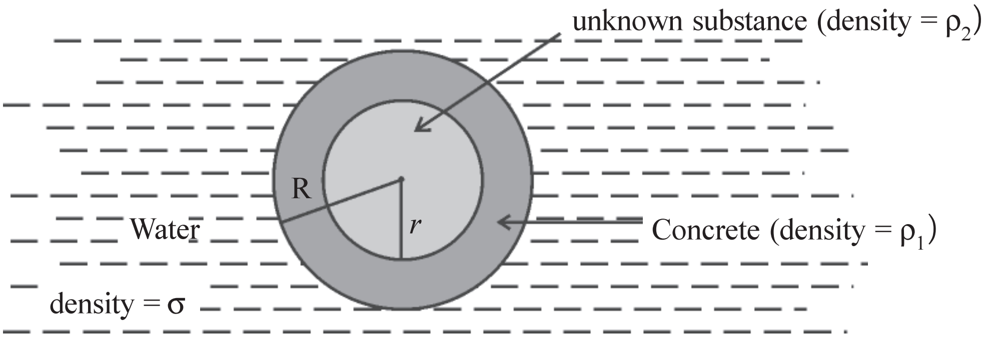
(31) A semisphere bowl having density 3×10^4 kgm^{-3} is float on the surface of liquid. Density of liquid is 1.8×10^3 kgm^{-3}. If outer diameter of a bowl (D) is 1m. Find internal diameter (d) of bowl.



(A) 0.94 m (B) 0.97 m

(C) 0.98 m (D) 0.99 m

(32) A sphere of radius (r) is filled with dust of unknown substance as shown in figure and concrete is filled in remaing part of the sphers of radius R. Specific density of concrete and unknown substance are 2.5 and 0.5 respectively. When this sphere is placed in water then it is just sink in water find the ratio of mass of concrete and unknown substance.

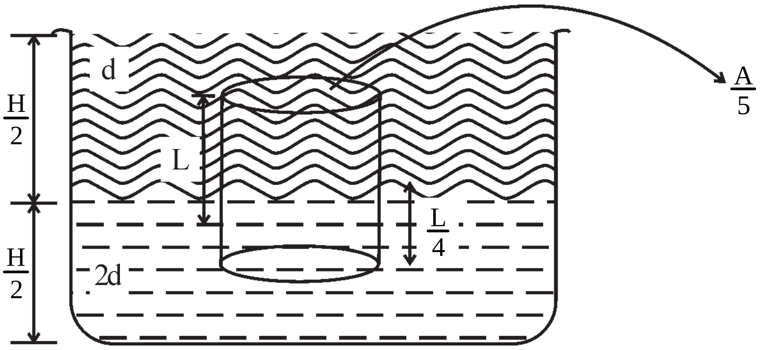


(A) $\frac{3}{5}$ (B) $\frac{5}{3}$ (C) $\frac{1}{3}$ (D) 3

(33) A cubical block floats on surface of liquid such that half of its volume is in the liquid if a container accelerated in upward direction with accelaration $\frac{g}{4}$, then ...... part of a block inside the water.

(A) $\frac{1}{2}$ (B) $\frac{3}{8}$ (C) $\frac{2}{3}$ (D) $\frac{3}{4}$

(34) As shown in the figure, a liquid of density $2d$ filled up to height $\frac{H}{2}$ and a liquid of density d filled up to height $\frac{H}{2}$. If a cylinder having crosss sectional area $\frac{A}{5}$ and length (L) (Where $L < \frac{H}{2}$) is placed in the container as shown in figure. Find density of the cylinder (D). (atmospheric pressure = P_0).



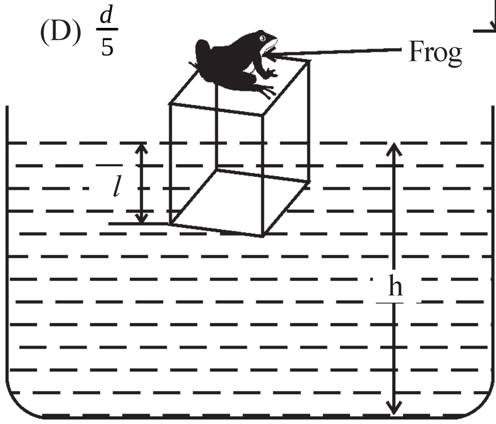
(A) $\frac{5}{4}$d

(B) $\frac{4}{5}$d

(C) d

(D) $\frac{d}{5}$

(35) A cubical block is partially immersed in water as shown in the figure. A frog is placed on the surface of block. Depth of a block in side the water is l. If a frog jumped to water than ......



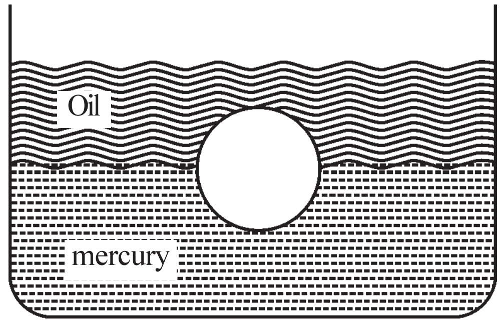
(A) l decreases and h increase

(B) l increases and h decrease

(C) l and h both increases

(D) l and h both decreases

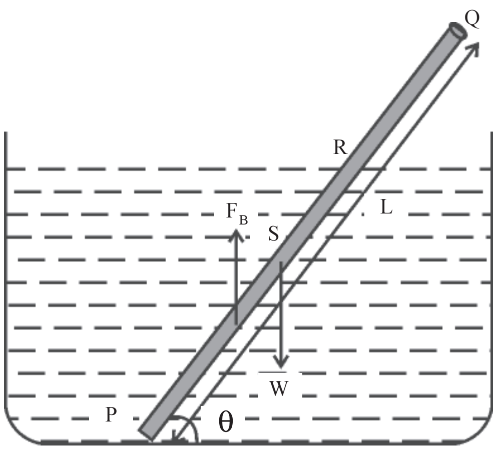
(36) An oil having density 0.8 gcm^{-3} is filled in upper part of a mercury having density 13.6 gcm^{-3} as shown in figure. If a sphere remains in equilibrium such that its half part in the liquid and half part in the mercury. Density of material of a sphere is ......



(A) 3.3 (B) 6.4

(C) 7.2 (D) 12.8

(37) A rod having density (ρ) is kept in a huge tank filled with liquid having density (ρ_0) then it remains equilibrium at an angle θ with bottom of container. If depth of liquid in a tank is $\frac{L}{2}$ then ......



(A) $\sin\theta = \frac{1}{2}\sqrt{\frac{\rho_0}{\rho}}$ (B) $\sin\theta = \frac{1}{2}\cdot\frac{\rho_0}{\rho}$

(C) $\sin\theta = \sqrt{\frac{\rho_0}{\rho}}$ (D) $\sin\theta = \frac{\rho_0}{\rho}$

(38) Weight of an object in air is 250 g, in water is 200 g and in liquid is 150 g then ......

(A) density of liquid is one forth of the density of object (B) Object will floats on surface of wator

(C) density of an object is 5 gcm^{-3} (D) density of liquid is 2 kg m^{-3}

(39) A rectangle block having mass (m) and area of cross-section A is totally immersed in liquid having density (ρ). If it is slightly displaced from its equilibrium then it starts oscillation with periodic time (T). Then ....

(A) $T \propto \frac{1}{\sqrt{A}}$ (B) $T \propto \frac{1}{\sqrt{\rho}}$ (C) $T \propto \frac{1}{\sqrt{m}}$ (D) $T \propto \sqrt{\rho}$

Ans. : 26 (C), 27 (D), 28 (A), 29 (D), 30 (A), 31 (C), 32 (B), 33 (A), 34 (A), 35 (D), 36 (C), 37 (A), 38 (C), 39 (A)

Streamlines :

- Streamlines can never intersect each other.
- The tengent drawn at any point represent the direction of velocity of the fluid at that point.

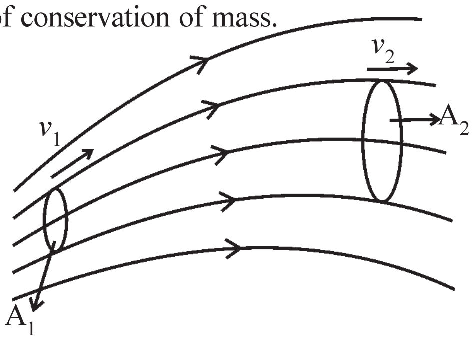
Equation of continuity :

- In fluid mechanics equation of continuity represents law of conservation of mass.

$\boxed{A_1v_1 = A_2v_2}$

$\therefore Av = \text{constant}$

$\therefore v \propto \frac{1}{A}$



Bernoulli's equation :

- Bernoulli's equation for streamline flow which is steady, irrotational, incompressible and non-viscous.

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$\boxed{P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}}$$

- The first term is known as "Pressure head"

  The second term is known as "Velocity head" and

  The third term is called "Elevation"

Venturie meter :

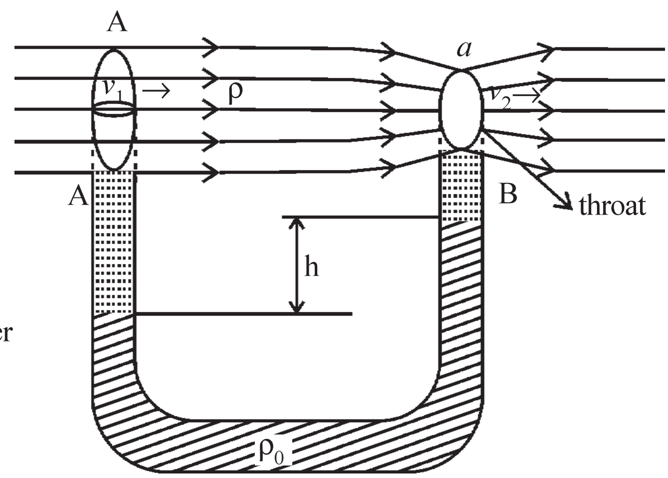
- It is used to measure the velocity of the fluid.

  ρ = density of the fluid

  ρ_0 = density of the liquid in the manometer

  A = Area of the big cross-section

  a = Area of throat



- Velocity at big cross section

$$v_1 = a\sqrt{\frac{2(\rho-\rho_0)gh}{\rho(A^2-a^2)}}$$

- velocity at throat,

$$v_2 = A\sqrt{\frac{2(\rho-\rho_0)gh}{\rho(A^2-a^2)}}$$

Torricelli's law :

- The velocity of the liquid coming out of hole at a depth h from the sarface of the liquid is equal to the terminal velocity of the freely falling particle from the same height.

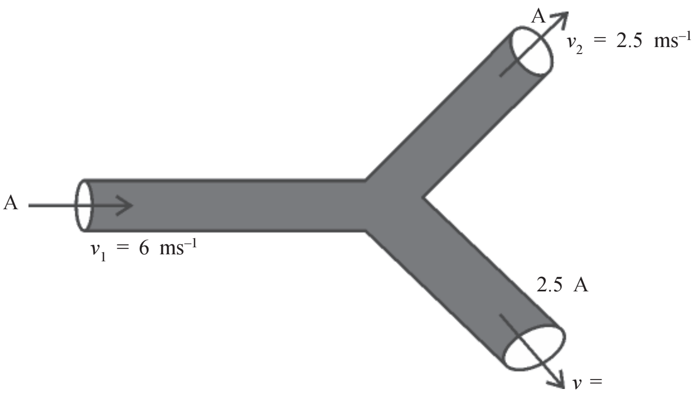
$$v = \sqrt{\frac{2gh}{1-\left(\frac{A_2}{A_1}\right)^2}} \approx \sqrt{2gh} \quad (\because A_2 << A_1)$$

where,
A_1 = Area of the free surface of the liquid
A_2 = Area of the hole

Note :

- A person standing close to the moving train may pulled towards the train because the air which is in contact with the train also move with large velocity. As a result pressure of the air decreases. Due to the pressure difference the person may pulled towards the train.
- Blowing off roots by wind storms.
- During a tornado, when a high speed wind blows over a straw, it creates a low pressure. The pressure below the roof is high. As a result, the roof is lifted up and is then blown off by the wind.

(40) An incompressible liquid flows in the horizontal plane, in Y shape joint of a pipe. What would be the velocity of the liquid at crossectional area 2.5 A, as shown in the figure ?



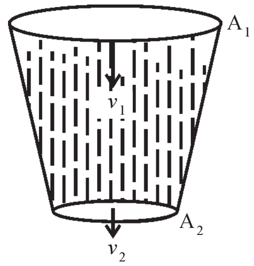
(A) $\frac{5}{7}$ ms^{-1} (B) 1.5 ms^{-1}

(C) $\frac{7}{5}$ ms^{-1} (D) 2.25 ms^{-1}

(41) A square hole of side L is sitauted at depth (y) from the top of water tank and a circular hole of radius R is at depth (4y). When a tank is completely filled with water then the amount of a water comes out per second in both holes. Radius R = ...

(A) L (B) 2 π L (C) $\frac{L}{2\pi}$ (D) $\frac{L}{\sqrt{2\pi}}$

(42) Water flows in downward direction in a tabe as shown in figure. Internel diameter at top is 12×10^{-3} m. Speed of water at bottom is 0.6 ms^{-1}. Find internal diameter of that at a distance 2×10^{-1} m from the top. ($g = 10$ m s^{-2})



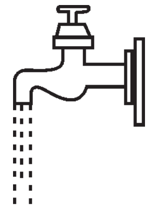
(A) 5×10^{-3} m (B) 7.5×10^{-3} m

(C) 9.6×10^{-3} m (D) 6.4×10^{-3} m

(43) A liquid flows in a tube having length (l) and radius (r) under the plessure difference P, at a rate of constant volume. (V = volume of liquid). Volume of liquid in a tube having redius $\frac{r}{2}$ is joined with this tube is ...... (Pressure at series connection both tube is P = constant)

(A) $\frac{V}{16}$ (B) $\frac{V}{17}$ (C) $\frac{16\,V}{17}$ (D) $\frac{17\,V}{16}$

(44) Streamline flow of water comes out from the tap, makes a coloum with continously decrease in cross-sectional area. True explanation of this statement is ....



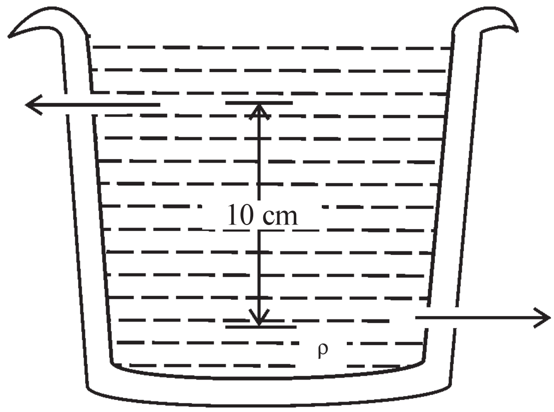
(A) As the water is coming down its speed is increase so due to decrease in pressure the atmospheric pressure decreases hence the coloumn of water decreases.

(B) To achive terminal velocity, water comes out reduces its area of coloumn and balance upward and downward force.

(C) Mass of water at any cross-section is same and water is incompressible. Thus rate of its volume remains same volume V = Av = constant therefore area dereases due to increares in speed.

(D) Water beam becomes nerrow due to surface tension.

(45) A container filled with water is placed on frictionless horizontal surface. Two holes having same diameter are in opposite side. If height difference between the holes is 10 cm and area of cross-section is 0.2 cm^2 find the horizontal froce required to keep container in equilibrium .... ($g = 1000$ cms^{-2})



(A) 2000 dyne (B) 10^5 dyne (C) 4000 dyne (D) 5×10^4 dyne

(46) A cylinder filled with liquid perform rotational motion about a vertical rotational axis passing through its base. Liquid experience upward force near to the wall. If radius of a cylinder is 5 cm and angular speed is 1 rotation/sec. find the height difference of liquid at the centre and at the wall. ($g = 1000$ cms^{-2})

(A) $5\ \pi^2$ (B) $0.05\ \pi^2$ (C) $0.5\ \pi$ (D) $10\ \pi$

(47) A cylinder filled with liquid performs motion about its axis then liquid experience upward force near to the wall. If the height difference of liquid near the wall and at the centre is 2.0 cm then ...... is correct. ($r = 0.04$ m , $\omega = 2$ rps, $g = 10\ ms^{-2}$, $\pi^2 = 10$)

(A) liquid comes out from the cylinder (B) a liquid does not cames out from the cylinder

(C) liquid just comes out time the cylirder (D) None of these.

(48) Two capillary having same radius and same length are kept on horizontal table. when same pressure difference is applied at both end then rate of flows of fluid is x. If both tubes are joined in series and same pressure difference is applied then rate of flow in this combination is ....

(A) $\frac{x}{2}$ (B) x (C) $2x$ (D) non of these

Ans. : 40 (C), 41 (D), 42 (D), 43 (B), 44 (C), 45 (C), 46 (B), 47 (B), 48 (A)

Viscosity :

Laminar flow : Different layers slide over each other with out getting mixed up in a steady flow, such flow is known as laminar flow.

Viscous force :

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

$\therefore F \propto A \frac{dv}{dx}$

- $\eta_{liquid} > \eta_{gas}$
- $\eta_{liquid} \rightarrow$ decrases with increase in temperature

$\rightarrow \eta_{gas}$ increase with increase in temperature.

So,

A = area of contact

$\frac{dv}{dx}$ = velocity gradient

η = Co-efficient of viscousity

Stokel's law : A resistive force on a small smooth, spherical, solid body of radius (r) moving with velocity (v) through a viscous medium of large dimention having co-efficient of viscousity (η) is given by $F(v) = 6\pi\eta rv$.

$F(v) \propto v$

- This force is velocity dependent force.

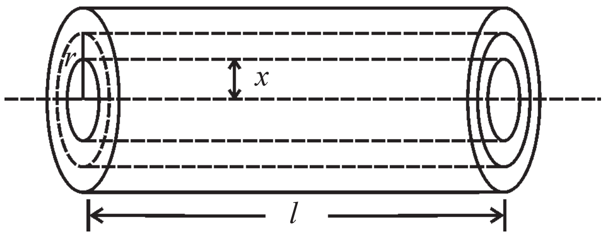
Terminal velocity (v_t) : When weight (W) = buoyort fore (F_b) + viscous force (Fv), the resultant force on the sphere is zero and sphere travels with constant velocity. This velocity is known as terminal velocity (v_t).

terminal velocity $v_t = \frac{2}{9}\frac{r^2 g}{\eta}(\rho - \rho_0)$ ρ = density of sphere, ρ_0 = dencity of liquid

Poiseiulle's law : Volume of the liquid passing through the tube in one second is

$V = \frac{\pi P r^4}{8\eta l}$

● Velocity of a layer situated at distance (x)



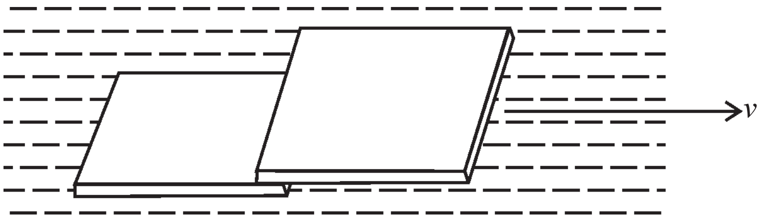
from the axis of tube is $v = \frac{P}{4\eta l}(r^2 - x^2)$

Where P = Pressure difference

η = co-efficient of viscousity

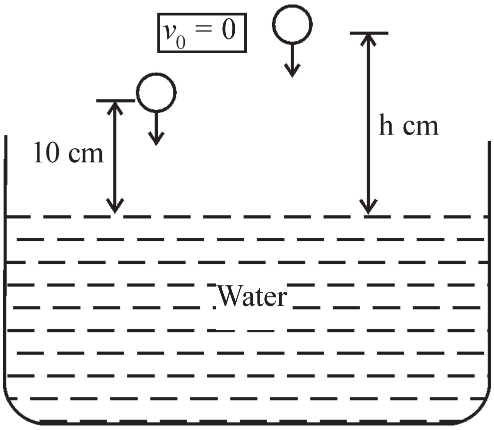
Reynold's Number $N_R = \frac{\rho v D}{\eta}$	where ρ = density v = velocity η = co-efficient of vescousity D = diameter of a b tube	Here, N_R is dimension less. If, $N_R < 2000 \Rightarrow$ Streomline flow $2000 < N_R < 3000 \Rightarrow$ flow is unstable $N_R > 3000 \Rightarrow$ flow is turbulent

(49) A square plate of length 0.1 m slides on other plate with speed 0.1 ms^{-1}. If viscous force is 0.002 N and co-efficient of viscosity is 0.01 poise. The thickness of a liquid layer between two plates is ...... m.



(A) 0.1
(B) 0.05
(C) 0.005
(D) 0.0005

(50) A sphere of radius r and density ρ falls freely from height 10 cm. Another sphere of same material falls freely from height h. Radius of other sphere is 2r. If both sphere maintain their velocity in water then h = ...



(A) 80 cm (B) 40 cm

(C) 160 cm (D) Insufficient Information

(51) A small solid sphere acquires terminal velocity in viscous medium match the colour :

A	B
(a) Buoyant force acts on sphere	(i) Increares
(b) viscous force on sphere	(ii) decreases
(c) Resultant force on the sphere	(iii) constant
(d) acceleration of a sphere	(iv) zero

(A) (a) → (iii), (b) → (i), (c) → (ii), (d) → (iv) (B) (a) → (i), (b) → (ii), (c) → (iii), (d) → (iv)

(C) (a) → (ii), (b) → (i), (c) → (iii), (d) → (iv) (D) (a) → (iv), (b) → (ii), (c) → (iii), (d) → (i)

(52) A small sphere of radius r moving with terminal velocity in liquid having viscous co-efficient η the ...... is true.

(A) $v_r \propto \frac{mgr}{\eta}$ (B) $v_r \propto mgr\eta$ (C) $v_r \propto \frac{mg}{r\eta}$ (D) $v_r \propto \frac{\eta mg}{r}$

Ans. : 49 (D), 50 (C), 51 (A), 52 (C)

Surface tension, surface energy and capillarity

Cohesive force : The inter molecular attractive force between the molecules of same substance is called cohesive force.

Example :

(1) It is difficult to seperat two glass plate stic with water

(2) It is difficult to divided a mercury drop in many droplets.

Adhesive force :

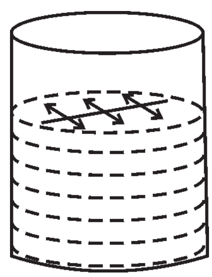
- The attractive force between the molecules of different substance is known as adhesive force.

(1) We can write on board

(2) Adhesive force between brick and cement.

Surface tension :

- 'The force exerted by the molecule lying on one side of an imaginary line of unit length, on the molecules lying on other side of the line which is perpendicular to the line and parallel to the surface is define as the surface tension (T) of a liquid.'
- Surface of liquid has a tendency to contrac due to surface tension.



Some interesting phenomencn based on surface tension :

Example :

- Water droplets are spherical
- When shaving brush or painting brush is dipped within the water hairs are well seperated, but when the brush is taken out of the water, hairs get stick with each other.
- some insects can walk on water sarface.

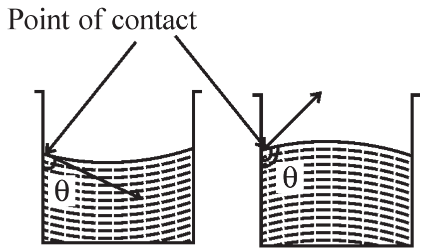
Surface energy :

- The potential energy stored per unit area in free surface of liquid is known as surface energy
- unit : J m^{-2} or erg cm^{-2}

Surface tension :

- $T = \frac{W}{\Delta A}$
- Work done to increase the unit surface area is equal to the measure of surface tension.

Angle of contact :



- The angle between the tangent to the liquid surface at the point of contact and solid surface inside the liquid is called angle of contact.

  θ = angle of contact

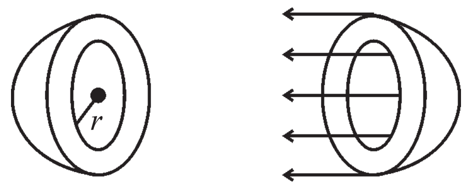
Water drops and bubbles :

(1) **A bubble in air.**

- Pressure differce = $P_i - P_0$.

  ∴ P_i = pressure in side the bubble

  P_0 = pressure out side the bubble



- Suppose the bubble is devided into two semi spheres as shown in the figure.
- Here there are two free surface (inside and outside)

  Force $F = T \times 2\,(2\pi r)$ .... (1) (bubble has two free surface)
- and force due to excess pressure is

  $F = (P_i - P_0)\,\pi r^2$ .... (2)
- compare (1) and (2)

  $(P_i - P_0) = \frac{4T}{r}$

(2) **bubble inside the liquid**

$(P_i - P_0) = \frac{2T}{r}$ (It has one free surface)

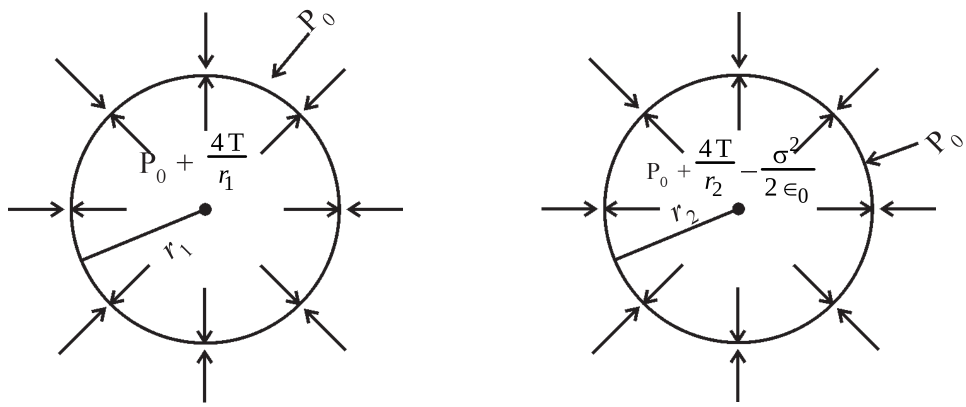
(3) **For water drop :**

$P_i - P_0 = \frac{2T}{r}$ (It has one free surface)

(4) **bubble having charge**

- Radius of a bubble increase when charge deposite on its surface.
- Initial pressure inside the bubble

  $P_i = P_0 + \frac{4T}{r_1}$



- final pressure inside the bubble

$$P_i = P_0 + \frac{4T}{r_2} - \frac{\sigma^2}{2\epsilon_0} \quad (\sigma = \text{surface charge density})$$

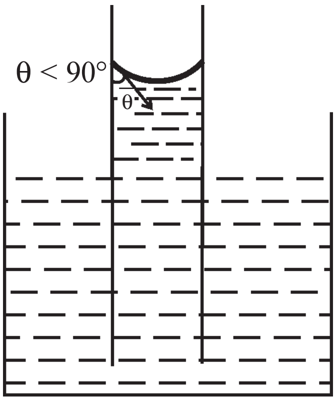
- If tempereture remains constant according to Boyle's law

$$\left(P_0 + \frac{4T}{r_1}\right)\frac{4}{3}\pi r_1^3 = \left(P_0 + \frac{4T}{r_2} - \frac{\sigma^2}{2\epsilon_0}\right)\frac{4}{3}\pi r_2^3$$

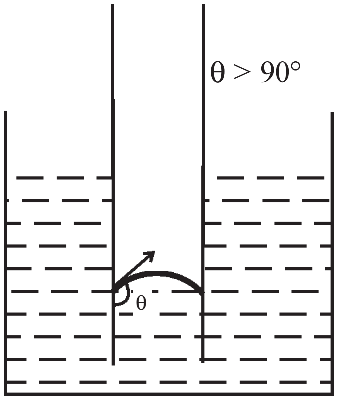
- radius (r_2) can be calculated from alove equation.

Capillarity

- The phenomenon of rise or fall of a liquid in a capillary held vertically in a liquid is called capillarity.
- Angle of contact $\theta < 90°$, meniscus – concave, water wets the surface, water rise in capillary.



(fig. A)



(fig. B)

- Angle of contact $\theta > 90°$, Meniscus – convex, liquid (mercury) doesnot wet the surface liquid falls in the capillary.

Equation of height :

- Excess Pressure = Pressure due to liquid coloum.

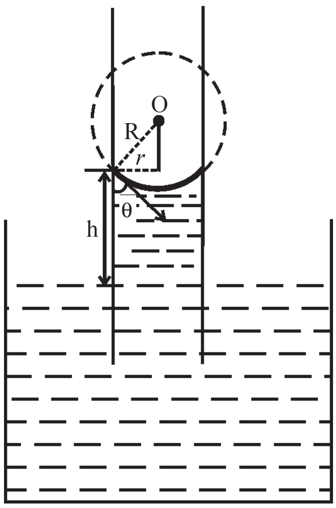
$$\frac{2T}{R} = h\rho g$$

(but $\cos\theta = \frac{r}{R}$)

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

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

T = =Surface tension
R = radius of meniscus
r = radius of capillary
h = height of the liquid column
ρ = density of liqnid
θ = angle of contact



(1) $\theta < 90° \rightarrow$ h is positive
liquid will rise up.

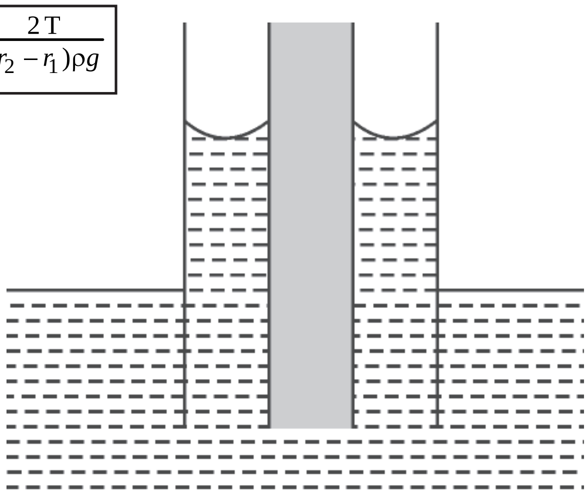
(2) $\theta > 90° \rightarrow$ h is negative.
liquid will fall down

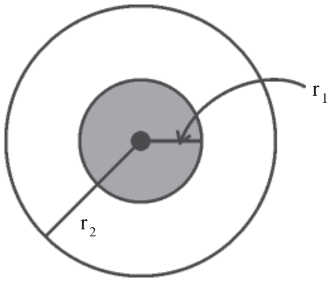
(3) If θ, T, ρ is constant

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

(4) For two coaxial tubes having radius r_1 and r_2 (Inner tube is solid)

$$\boxed{h = \frac{2T}{(r_2 - r_1)\rho g}}$$



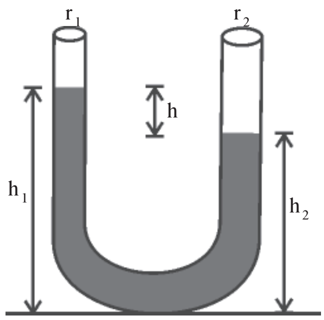


Cross-section of the tube

(53) n water droplets of radious (r) are unite to form a big drop of radious (R) then increase in tempereture is ...... (T = Surface tension, specific density of water = 1 unit)

(A) $\frac{2T}{rJ}$ (B) $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$ (C) $\frac{-3T}{rJ}$ (D) $\frac{3T}{J}\left(\frac{1}{r}+\frac{1}{R}\right)$

(54) Radins of the arms of U-tabe are r_1 and r_2. The height difference of a liquid having density (ρ) filled in the tube is h. If angle of contact θ = o, then surface tension T = ...



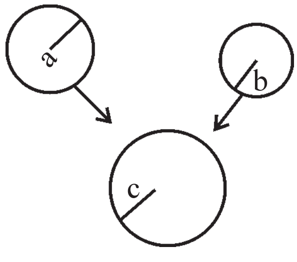
(A) $\frac{\rho g h r_1 r_2}{2(r_2 - r_1)}$ (B) $\frac{\rho g h (r_2 - r_1)}{2 r_1 r_2}$

(C) $\frac{2(r_2 - r_1)}{\rho g h\, r_1 r_2}$ (D) $\frac{\rho g h}{2(r_2 - r_1)}$

(55) Surface energy of a liquid drop is u. If it divided in to 512 equal droplets, then total surface energy of all droplets are ......

(A) u (B) 8u (C) 64 u (D) 512 u

(56) Two bubble of soap solution are combine and form a big bubble. If V = change in volume inside the bubble, S = change in area then which of the following is true. (P_0 = atmospheric pressure, T = Surface tension.)



(A) $3P_0V + 4ST = 0$

(B) $4P_0V + 3ST = 0$

(C) $P_0V + 4ST = 0$

(D) $4P_0V + ST = 0$

(57) Find the work required to be done to double the diameter, of the bubble of soap solution form in air, T = surface tension = 30 dyne cm^{-1}

(A) 360 π (B) 720 π (C) 90 π (D) 180 π

(58) 1000 mercury droplets are unite to form a big drop of radius R. The ratio of total surface energy of all droplets to the surface energy of big drop is ......

(A) 1 : 10 (B) 10 : 1 (C) 100 : 1 (D) 1 : 100

(59) Two soap bubble of radius 1 cm and 2 cm are combine and form a big bubble. If tempereture remains constaund during this process. than radius of big drop is ....

(A) 2.4 cm (B) 1.5 cm (C) 1.1 cm (D) 0.66 cm

(60) A capillary of radius 0.2 mm held vertical in a container filled with water. Find the pressure applied on a capillary so that water level in capillary is same as the water surface in cantainer (T = 0.07 Nm^{-1}, atmospheric pressure P = 10^5 Nm^{-2}).

(A) 10^3 (B) 99×10^3 (C) 100×10^3 (D) 101.4×10^3

(61) When an air bubble rises from bottom of a lake to surface of lake, its volume increases by four times. If 75 cm of mercury coloum producer atmosphere depth of a lake is ...... m. (density of water is one tenth of that of mercury)

(A) 45 m (B) 7.5 m (C) 22.5 m (D) 12.5 m

(62) When an air bubble rises from bottom of a lake to surface of a lake, its diameter becomers three times. Tempereture of a bubble remains same. Barometric height at the surface with respect to relative density of mercury is ......

(A) $26\,\sigma\,H$ (B) $\frac{H}{26\sigma}$ (C) $9\,\sigma\,H$ (D) $\frac{H}{9\sigma}$

Ans. : 53 (B), 54 (A), 55 (B), 56 (A), 57 (D), 58 (B), 59 (C), 60 (D), 61 (C), 62 (B)

Heat transfer :

- **Type of heat transfer**

  (i) Heat conduction (ii) Heat convection (iii) Thermal radiation

Heat (Thermal) conduction :

- 'The flow of heat energy between the adjacent past of a body due to temperaturs difference between them is called thermal or heat conduction.
- The constituent particles in solid vibrate about their mean position, depending on their temperature and not perfom real linear motion.

Non steady state :

- Temperature at every cross section changes with time.

Steady state :

- Thermal steady state temperature at every cross-section remain same. Temperature ture decrease from hot end to cold end.

  Remember, temperature of each parts becomes constant but not equal but it is gradually decresing from hot end to cold end.

Iso - thermal surface :

- A surface perpendicular to heat conduction maintain at constant temperature is known as isothermal surface.
- Two isothermal surfaces do not intersect each other.
- Shape of isothermal surface depends upon type of heat conduction and shape of a conductor.
- Such isothermal surfaces are perpendicular to the heat conduction.

Temperature gradient :

- Rate of change of temperature in direction of heat conduction is known as temperature gradient.

  Temperature gradient $= \frac{-\Delta T}{\Delta x} = \lim_{\Delta x \to 0}\left(\frac{-\Delta T}{\Delta x}\right) = \frac{-dT}{dx}$

- (negative sign indicate that temperature decrease with distance).

unit : C°/m^{-1} or Km^{-1}

- Heat current

  $H = \frac{dQ}{dt} = -kA\frac{dT}{dx}$

  $H = -kA\left[\frac{T_2 - T_1}{L}\right]$

  $H = \frac{Q}{t} = kA\left[\frac{T_1 - T_2}{L}\right]$

- Amount of heat flows through the conductor in time (t).

  $Q = kA\left[\frac{T_1 - T_2}{L}\right]t$

  k = thermal conductivity, A = area of cross-section, T_1 = Temperature at hot end

  T_2 = Temperature at cold end, L = length of a conductor = Thickness of bottom of a container.

Thermal conductivity (k) :

- Amount of heat flowing per unit time perpendicularly between the planes having unit temperature gradient between then per unit area is known as thermal conductivity.

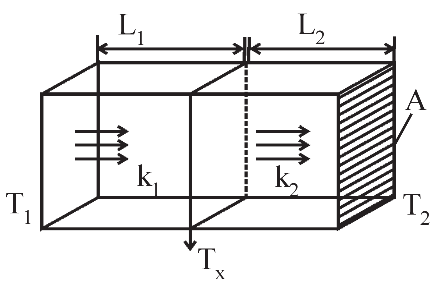
MKS unit : cal s^{-1} m^{-1} K^{-1} or Wm^{-1} K^{-1}. Dimensional formula : $M^1L^1T^{-3}K^{-1}$

Thermal resistance $R = \frac{L}{kA} = \frac{T_1 - T_2}{H}$

MKS unit : KsJ^{-1} or K watt^{-1}. Dimensional formula : $M^{-1}L^{-2}T^3K^1$

- A compound slab can be obtained by fusing two slabs having different thermal condctirity.
- Following two types of connections are possible.

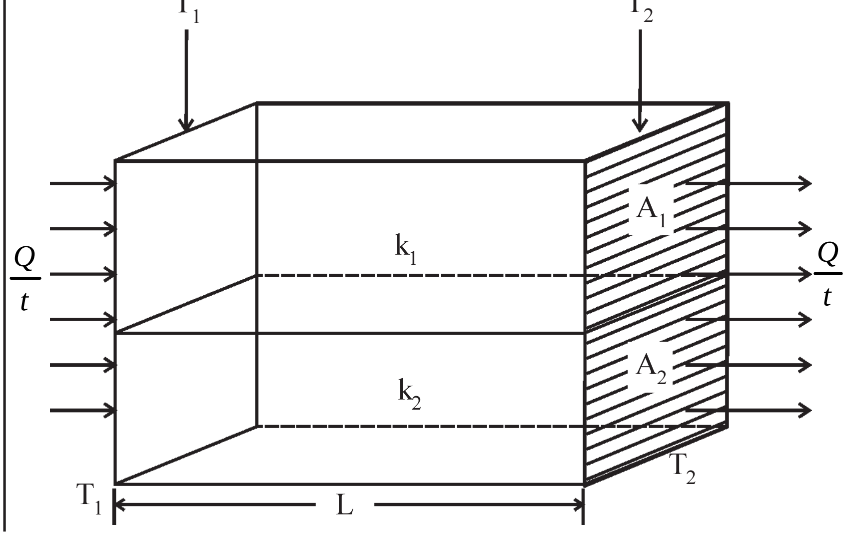
(1) **Series connection :**



$R_s = R_1 + R_2$

$= \frac{1}{A}\left(\frac{L_1}{k_1} + \frac{L_2}{k_2}\right)$

Parallel connection



For series connection $R_s = R_1 + R_2$

$$\left(\frac{L_1 + L_2}{k_s\,A}\right) = \frac{L_1}{k_1\,A} + \frac{L_2}{k_2\,A}$$

$$\therefore\ k_s = \frac{L_1 + L_2}{\frac{L_1}{k_1} + \frac{L_2}{k_2}}$$

If : $L_1 = L_2 = L$

$$k_s = \frac{2k_1k_2}{k_1 + k_2}$$

For n slabs

$$k_s = \frac{L_1 + L_2 + \ldots\ldots + L_n}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \ldots\ldots + \frac{L_n}{k_n}}$$

For parallel connection R_p

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{k_1 A_1}{L_1} + \frac{k_2 A_2}{L_2}$$

$$\frac{1}{R_p} = \frac{1}{L}(k_1A_1 + k_2A_2) \quad (\therefore\ L_1 = L_2 = L)$$

$$\therefore\ R_p = \frac{L}{k_1 A_1 + k_2 A_2}$$

$$\frac{L}{k_p (A_1 + A_2)} = \frac{L}{k_1 A_1 + k_2 A_2}$$

$$\therefore\ k_p = \frac{k_1 A_1 + k_2 A_2}{A_1 + A_2}$$

If $A_1 = A_2 = A$

$$k_p = \frac{k_1 A + k_2 A}{2A}$$

$$k_p = \frac{k_1 + k_2}{2}$$

For n - slabs

$$k_p = \frac{k_1 A_1 + k_2 A_2 + \ldots\ldots + k_n A_n}{A_1 + A_2 + \ldots\ldots + A_n}$$

Phenomeon of formation of ice in a lake :

- Thickness of ice level increase from x_1 to x_2 time

$$t = \frac{1}{2}\frac{\rho L}{kT}(x_2^2 - x_1^2)$$

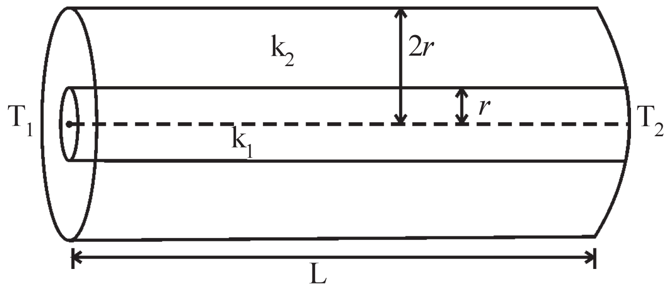
$$\therefore\ t \propto (x_2^2 - x_1^2)$$

where, ρ = density of water
L = latent heat of water
k = thermal conuctivity
T = negative temp of atmosphere

Remember :

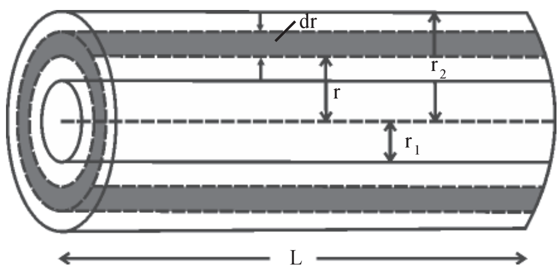
- A compound slab can be divided in series connection and parallel connection.
- If every point on the contact surface are at same temperature then they are connected in series.
- If temperature at every point on the contact surface continosly decreases from hot end to cold end then they are connected in parallel.

(63) A cylindrical shell having thermal conductivity (k) is fixed on a cylinder having radius r and thermal condutivity 2k. Internal and outer radius of shell is r_1 and r_2 respectively. Temperature at both ends are T_1 and T_2 (Where $T_1 > T_2$). Find equivailent thermal conductivity ?



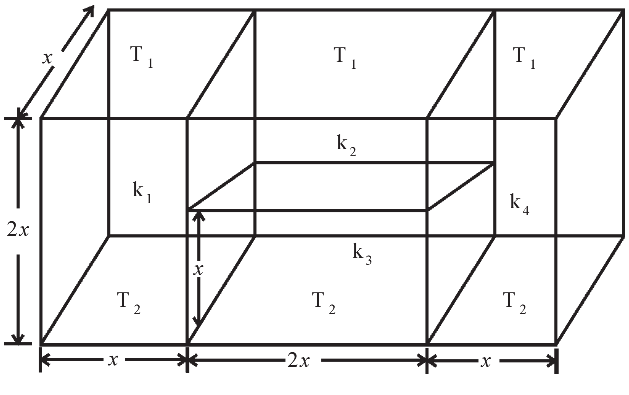
(A) $\frac{4k}{5}$ (B) $\frac{5k}{4}$ (C) $\frac{3k}{4}$ (D) $\frac{4k}{3}$

(64) Internal and outer radius of a cylindrical shell are 2 cm and 4 cm respectively. Length of a cylinder is 50 cm. Temperature at internal surface and outer surface are T_1 = 0°C and T_2 = 200°C remains constant. Thermal conductivity is 69.3 $Wm^{-1}K^{-1}$. Calculate the rate of heat flow perpendicular to outer and inner surface.



(A) 2.72×10^4 Js^{-1} (B) 2.72×10^7 Js^{-1} (C) 6.28×10^4 Js^{-1} (D) 6.28×10^7 Js^{-1}

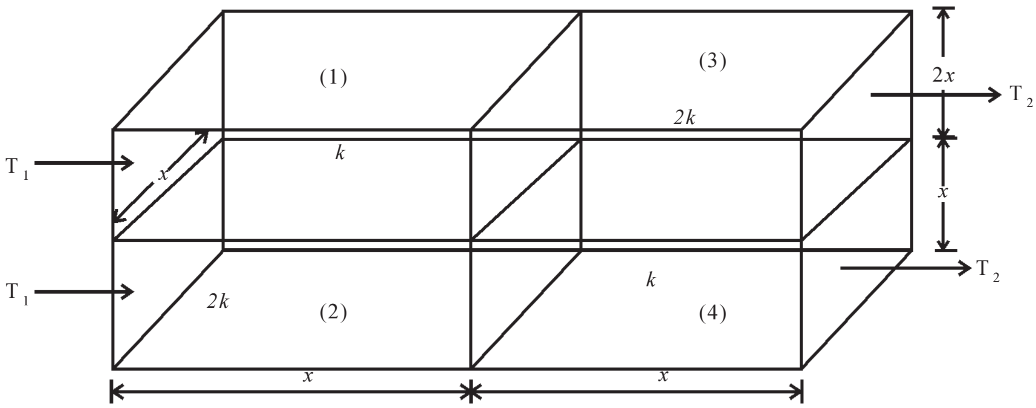
(65) A compound slab is shown in figure. Temperature at top and botton are T_1 and T_2 respectively. Find equivalant thermal conduetivity k (Where $T_1 > T_2$) Dimensions of each block are show in figure.



(A) $\frac{(k_1 + k_4)(k_2 + k_3) + 4k_2k_3}{4(k_2 + k_3)}$ (B) $\frac{k_1 + k_2\ k_3 + k_4}{3}$

(C) $\frac{4k_1k_4 + (k_2 + k_3)(k_1 + k_4)}{2k_2k_3}$ (D) non of the above

(66) Calculate the equivalent thormal conductivity of a compound slab shown in figure (Where $T_1 > T_2$)



(A) 3k (B) $\frac{20k}{27}$ (C) $\frac{40k}{27}$ (D) $\frac{3k}{2}$

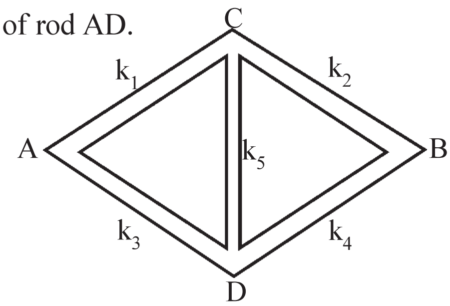
(67) A spherical thermocol container contains 10 kg ice. Internal and outer radius of a container are 25m and 30m respectively. 335 kJ heat energy is required to melt 1 kg of ice. Thermal conductivity of thermocol is 0.028 $Jm^{-1}K^{-1}s^{-1}$. Consider walls of container in thermal steady state. Calculate the time in which half of the ice melts ?

(A) 90 h (B) 3800 s. (C) 9000 s. (D) 20 h.

(68) The dimensions of the celling of a room are 5 m×5 m×10 cm. Thermel conductivity of concrete is 1.26 W/m°C. At one moment, the temperature outside and inside the room are 44°C and 32°C respectively. A layer of thermocol of thickness 5 cm and thermal conductivity 0.0275 W m^{-1}°C^{-1} is laid on the ceiling. A layer of bricks of thickness 7.5 cm and thermal conductivity 0.65 W m^{-1}°C^{-1} laid on the ceiling. Find new rate of heat flow.

(A) 155.8 Js^{-1} (B) 20.337 Js^{-1} (C) 0.924 Js^{-1} (D) 0.0064 Js^{-1}

(69) Five rods of different material but having same dimensions are connected as shown in figure. If heat current in rod CD is zero find thermal conductivity of rod AD.



k_1 = 370 $Wm^{-1}K^{-1}$ (Copper)

k_2 = 320 $Wm^{-1}K^{-1}$ (Gold)

k_4 = 16 $Wm^{-1}K^{-1}$ (Steel)

k_3 = ?

(A) 74.00 (B) 13.83 (C) 18.5 (D) 185

(70) The thickness of ice layer on the surface of lake is 8 cm. Temperature of environment is –12°C find the time require for the thickness of ice layer becomes 15 cm. Thermal conductivity of ice 0.004 cal $K^{-1}cm^{-1}s^{-1}$, density of ice 0.92 g cm^{-3}, latent heat of fusion is 80 cal g^{-1}.)

(A) 21.4 h (B) 34.3 h (C) 27.7 h (D) 4.4 h

Ans. : 63 (B), 64 (C), 65 (A), 66 (C), 67 (D), 68 (A), 69 (C), 70 (B)

Heat convection

- The transfer of heat, due to the difference in the density of fluid is callled heat convection.
- Here, the constituent particles actually move from one place to the other.
- In heat transfer occurs on the earth, the maximum contribution is of heat convection only.

Natural heat Convection

- **Langmuir - Lorentz law**

$$-\frac{dT}{dt} = k' (T-T_s)^{\frac{5}{4}}$$

Where, T = temperature of the system
T_s = temperature of surrounding
k' = proportionality constant

Forced heat Convection

- **Newton's Law of cooling**

$$-\frac{dT}{dt} = k' (T-T_s)$$

k' = propertionality Constant

Thermal Radiation

- Every substance emitts electromagnetic radiation of difinate frequencies in accordance with its temperature.
- Thermal radiations are electromagnetic waves only, they travel with the speed of light, in free space.
- The medium is not required for their propagation.

Perfect Black Body :

- The body which absorbs all the radiant energy incident on it is called a perfect black body. e.g. Sun.
- The good absorber of heat is also good reflector of heat.
- When a black body is heated upto certain high temperature it emitts all wave lengths.

Total emissive Power

- The amount of radient energy emitted per unit area per second, at a given temperatue, is called total emissive power (W)

Its unit is : Wm^{-2}

- absorptivity (a) = $\dfrac{\text{radient energy absorbed}}{\text{radient energy incident}}$
- emissivity (e) = $\dfrac{\text{Total emissive power of the body}}{\text{emissive power of the black body at the same temp.}}$
- For perfect black body a = 1 and e = 1

Kirchhoff's law :

The values of emissivity and absorptivity are equal for every surface.

Steafan - Boltzman's law

- The total emissive power of the body is directly propotional of forth power of its absolute temperature.

  $W \propto T^4$

  $\therefore W = e\,\sigma\,T^4$

Where $\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

σ = Steafan Boltzman's constant

dimenssional formula = $M^1L^0T^{-3}K^{-4}$

The rate of loss of heat due to radiation

- $\frac{dQ}{dt} = e\,\sigma\,A\,(T^4 - T_s^{\,4})$

Where T = temperature of the system

T_s = temp of the surrounding

Wien's Displacement Law

- With the increase in temperature, the wavelength λ_m corresponding to maximum value W_λ decreases.

  $\therefore \lambda_m T$ = constant (k)

Where k = wien's constant

$k = 2.89 \times 10^{-3}$ mK

The D.F. of the constant : $M^0L^1T^0K^1$

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(71) The temperature of the body decreases from 90°C to 74°C in 4 min. The temperature becomes 62°C in 8 min. What would be the tempereture of the body at the end of 20 min ?

(A) 36.4 °C (B) 42.4 °C (C) 38.4 °C (D) 40.4 °C

(72) The temperature of a liquid at 100 °C is in contact with the atmosphere having temperature 10 °C. What would be the time require to decrease the temperature of the liquid to 82 °C. Constant k' = 0.01234567 $°C^{-1/4}\ min^{-1}$.

(A) 18 min (B) 9 min (C) 6 min (D) 12 min

(73) Calculate the change in the wavelength corrosponding to the maximum energy for the perfect black body whose temperature is increased by 30 %.

(A) 8100 % increase (B) 8100 % decrease (C) 30 % decrease (D) 30 % increase

(74) On decreasing the temperature of a perfect black body, the decrease in the wavelength corresponding to its maximum energy is 20 %. What would be the percentage change in the power emitted ?

(A) increases by 316 % (B) decreases by 316 % (C) increases by 416 % (D) decreases by 416 %

(75) What would be the percentage change in the temperature of a perfect black body to decrease its emissive power by 25 %.

(A) decrease by 30 % (B) decrease by 7 % (C) increase by 7 % (D) increase by 30 %

(76) What would be the percentage change in the emissive power of a perfect black body on increasing its temperature by 3 times ?

(A) 8100 % (B) 800 % (C) 81 % (D) 8000 %

(77) The temperature of a cup of hot milk decreases 3.65 times faster at temp 360 K than at 320 K by 1°C. Consider milk as a perfect black body and calculate the temperature of the room.

(A) 310 K (B) 273 K (C) 285 K (D) 300 K

Ans. : 71 (D), 72 (C), 73 (C), 74 (A), 75 (B), 76 (D), 77 (D)

Assertion - Reason type Question :

Instruction : Read assertion and reason carefully, select proper option from given below.

(a) Both assertion and reason are true and reason explains the assertion.

(b) Both assertion and reason are true but reason does not explain the assertion.

(c) Assertion is true but reason is false.

(d) Assertion is false and reason is true.

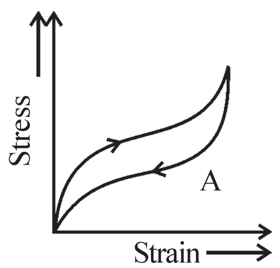
(78) **Assertion :** The length of a rubber string is L. On appling the tensile force of 5N and 6N the length becomes a and b respectively. When 9N force is applied the length becomes (a + b – L) m.

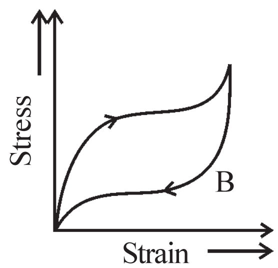
Reason : Increase in the length of the string is directly proportional to its original length

(A) a (B) b (C) c (D) d

(79) **Assertion :** The graph of stress $\rightarrow$ strain for two different type of rubbers are as shown in the figure. Rubber A is more useful as car tyre than ruber B.

Reason : Ruber A releases more energy than B.





(A) a (B) b (C) c (D) d

(80) **Assertion :** Two wires A and B are of equal material and are also of equal cross-section. The length of the wire A is double than that of B. The increase in the length of wire A is double than of B.

Reason : Increasing in the length is directly proportional to the original length.

(A) a (B) b (C) c (D) d

(81) **Assertion :** Two wires A and B are of equal material and are also of equal length. The diameter of wire A is double than that of B. Now increase in the length of wire B is 4 times than that of A.

Reason : Increase in the length of the wire is inversely proportional to its cross-sectional area.

(A) a (B) b (C) c (D) d

(82) **Assertion :** When a tension force is applied on an object, the restoring force is produced due to the inter molecular force of attraction.

Reason : The restoring force produced is due to the internal property of the object and not due to intermolecular force of attraction.

(A) a (B) b (C) c (D) d

(83) **Assertion :** To maintain a piece of paper floating horizontally in air, we must blow air above the paper and not below.

Reason : In a steady flow of a fluid, for a given mass, the total energy is conserved.

(A) a (B) b (C) c (D) d

(84) **Assertion :** When a fluid is flowing through a small hole of a vessel than the backforce acts on the vessel.

Reason : For a given mass of fluid the total energy is fully in the form of kinetic energy.

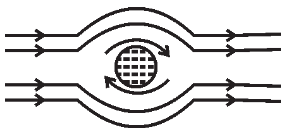
(A) a (B) b (C) c (D) d

(85) **Assertion :** The critical velocity of a fluid passing through a tube is inversly proportional to the radius of the tube.

Reason : The velocity ot the fluid passing through a tube is inversly proportional to the area of the cross section.

(A) a (B) b (C) c (D) d

(86) **Assertion :** To keep a light ball rotating about its own axis in air, the blow of air must be as shown in the figure.



Reason : Due to the viscosity of air there exsist upward thrust.

(A) a (B) b (C) c (D) d

(87) **Assertion :** The upward lift of an aeroplane when it moves horizontally, is due to the pressure difference between over and below the wings.

Reason : The velocity of the air over the wings is more than that below the wings.

(A) a (B) b (C) c (D) d

(88) **Assertion :** No force is acting on an object freely falling with its terminal velocity.

Reason : The weight of the object is balanced by the upward buoyant force.

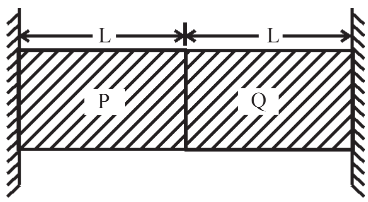
(A) a (B) b (C) c (D) d

Ans. : 78 (D), 79 (C), 80 (A), 81 (A), 82 (C), 83 (A), 84 (C), 85 (C), 86 (C), 87 (A), 88 (C)

Comprehension Type Questions

Passage-1

Two conducting rods P and Q are of equal cross-section area (A) and length (L) are kept between two rigid walls as shown in the figure. Their linear coefficient of expansion are α_1 and α_2 and Young's modulus are Y_1 and Y_2 respectively. The temperature of both the rod increases by T.



(89) The force exerted by any one rod, on the other is ....

(A) $F = \dfrac{TA(\alpha_1 + \alpha_2)}{\left(\dfrac{1}{Y_1} + \dfrac{1}{Y_2}\right)}$ (B) $F = TAY_1Y_2(\alpha_1 + \alpha_2)$

(C) $F = TA(Y_1 + Y_2)\alpha_1\alpha_2$ (D) None of the above

(90) The new length of the rod P

(A) $L_1 = L\left[1+\alpha_1 T+\frac{F}{AY_1}\right]$ (B) $L_1 = L\left[1+\alpha_1 T+\frac{F}{AY_1}\right]$

(C) $L_1 = L\left[1+\alpha_1 T-\frac{F}{AY_1}\right]$ (D) $L_1 = L\left[1+\alpha_1 T-\frac{F}{AY_1}\right]$

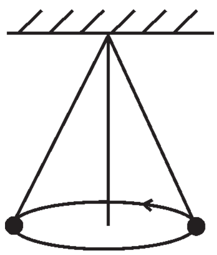
(91) The new length of the rod Q

(A) $L_2 = L\left[1+\alpha_2 T+\frac{F}{AY_2}\right]$ (B) $L_2 = L\left[1+\alpha_2 T+\frac{F}{AY_2}\right]$

(C) $L_2 = L\left[1+\alpha_2 T-\frac{F}{AY_2}\right]$ (D) $L_2 = L\left[1-\alpha_2 T-\frac{F}{AY_2}\right]$

Passage-2

One end of a steel rod of length 1m and cross-section area 0.01 cm^2 is fixed with a rigid support and a sphere of 2 kg is attached at the other end. Now as shown in the figure the sphere is given rotation on the circular path of radius 0.2 m with a constant angular speed ω in such a way that the wire makes an angle θ with vertical line. ($\theta = 30°$)



(92) Angular speed ω = ...

(A) 5 rad s^{-1} (B) 6.58 rad s^{-1} (C) 5.37 rad s^{-1} (D) 9.30 rad s^{-1}

(93) The tension force porduced in the wire is = ...

(A) 23.12 N (B) 40 N (C) 34.6 N (D) 266.5 N

(94) Increase in the length of the wire ΔL = ...

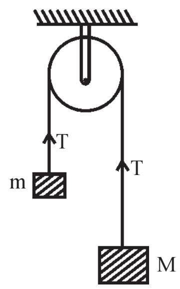
(A) 4.62×10^{18} m (B) 1.156×10^{-4} m (C) 2×10^{-4} m (D) 1×10^{-4} m

(95) The stress produced in the wire = ...

(A) 20×10^6 N m^{-2} (B) 16×10^6 N m^{-2} (C) 24×10^6 N m^{-2} (D) 4×10^6 N m^{-2}

Passage-3

As shown in the figure mass m and M = 2m are tied to two ends of a wire of cross - sectional area A passed over a frictionless pulley. Now the system is made free from the equilibriam.



(96) The common acceleration of the blocks is = ...

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

(97) The stress produced in the wire = ...

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

(98) If m = 1 kg, $A = 8 \times 10^{-9}\ m^2$, Braking Stress = $2 \times 10^9\ Nm^{-2}$ and $g = 10\ ms^{-2}$. The maximum value of M for which the wire does not break is ....

(A) 4 kg (B) 6 kg (C) 8 kg (D) 20 kg

Passage-4

When a fluid passes through a tube, there exsist relative velocity between fluid layers. As a result, resistive force is produced at the surface of layers in contact. This force is called viscous force. According to Newton's law for Viscous flow, the frictional force $F = -\eta A \cdot \frac{dv}{dx}$.

Where A is area of contact between two layers. η is co-efficient of viscocity and $\frac{dv}{dx}$ is velocity gradient.

(99) If f is the frictional force required for one solid object to move over another solid object and F is the frictional force acting between two consecutive layers of the liquid then...

(A) f is indepent of the area of contanct between the surfaces of the solids.

(B) f depends on the relative velocity between the solids.

(C) f depends on the area of the liquid layer.

(D) f is independent to the relative velocity between the liquid layers.

(100) The dimenssional formula for the co-efficient of viscosity.

(A) $M^1L^{-1}T^{-1}$ (B) $M^1L^1T^{-1}$ (C) $M^1L^{-2}T^{-2}$ (D) $M^1L^{-1}T^{-2}$

(101) The depth of a river is 5 m. The velocity of the water at the uppermost layer is $2\ ms^{-1}$. The co-efficient of viscosity is 10^{-3} SI unit. Calculate the viscous force acting per unit area of contact ?

(A) $10^{-4}\ Nm^{-2}$ (B) $2 \times 10^{-4}\ Nm^{-2}$ (C) $4 \times 10^{-4}\ Nm^{-2}$ (D) $5 \times 10^{-4}\ Nm^{-2}$

Passage-5

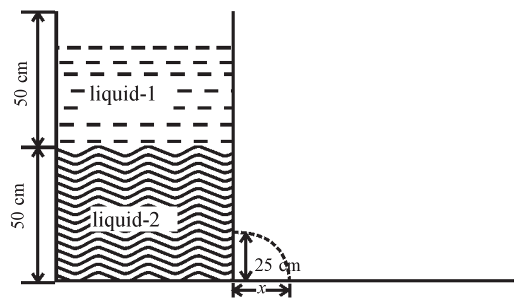


Figure shows a cylindrical vessel having cross-sectional area A. Two non viscous liquid which do not get mixed are filled in this vessel. The density of the liquids are $0.6\ g\ cm^{-3}$ and $1.2\ g\ cm^{-3}$ respectively. The height of both of the liquid is 50 cm. A small hole is bored on the Surface of the Vessel, at a height of 25 cm from the bottom. The cross-section area of the hole a (<<<A).

(102) The initial speed of the liquid coming out of the hole is ....

(A) $88.54\ cm\ s^{-1}$ (B) $62.60\ cm\ s^{-1}$ (C) $44.27\ cm\ s^{-1}$ (D) $31.30\ cm\ s^{-}$

(103) The initial horizontal range x of the liquid = ...

(A) 100 cm (B) 70.71 cm (C) 50 cm (D) 35.35 cm

(104) The height of the hole required to have maximum range x is ...... cm from the bottom.

(A) 66.66 (B) 150 (C) 75 (D) 50

Passage-6

A cylindrical water-tank of cross-sectional area a_1 is open at the top. The height of the water level in the tank is h. A small hole having cross-section area a_2 is at the bottom of this tank, where $a_1 = 3a_2$.

(105) The initial speed of the water falling from the tank.

(A) $\sqrt{2gh}$ (B) $\sqrt{gh}$ (C) $\sqrt{\frac{gh}{2}}$ (D) $\frac{1}{2}\sqrt{gh}$

(106) The initial speed of the water coming out at the hole ....

(A) $\frac{1}{2}\sqrt{gh}$ (B) $\sqrt{2gh}$ (C) $\frac{3}{2}\sqrt{gh}$ (D) $2\sqrt{2gh}$

(107) The time consumed to empty the tank is ....

(A) $\sqrt{\frac{2h}{g}}$ (B) $4\sqrt{\frac{h}{g}}$ (C) $6\sqrt{\frac{2h}{g}}$ (D) $g\sqrt{\frac{2h}{g}}$

Passage-7

Every substance emits electromagnetic rodiation of definate frequency in accordance with its temperature. This radiation is known as thermal radiation. The energy associated with this radiations is called radient energy. The thermal radiation propagates in the frce space or air with the speed of light. The thermal radiation also experiences reflection and refraction same as those of light and also produce phenomenons like interference, diffraction and polarization.

The body which absorbs all the radient energy incident on it is called perfect black body.

The radient energy emitted per second through the unit area is

$W = \sigma T^4$ Where, T = temperature of the black body, σ = Slefan-Boltzman constant

If the body is not perfect black

$W = e\sigma T^4$

e = emissivity of the surface.

(108) The dimenssional formula for σ.

(A) $M^1L^{-2}T^{-2}K^{-4}$ (B) $M^1L^{-1}T^{-2}K^{-4}$ (C) $M^1L^1T^{-3}K^{-4}$ (D) $M^1L^0T^{-3}K^{-4}$

(109) What is the SI unit of σ ?

(A) $Js^{-1}K^{-4}$ (B) $Wm^{-1}K^{-4}$ (C) $Wm^{-2}K^{-4}$ (D) $Jm^{-2}K^{-4}$

(110) In which part of the electromagnetic wave the thermal radiations are laying ?

(A) Visible light (B) Infrared (C) Ultraviolet (D) microwave

(111) Which appratus is used to detect thermal radiation.

(A) Constant gas thermometer (B) Platinum resistance thermometer

(C) Thermostate (D) Thermopile

(112) An object B of temp T_2 is wound on object A having higher temperature T_1. ($T_2 < T_1$). The rate of heat loss for object A is ....

(A) T_1^4 (B) $(T_1 - T_2)^4$ (C) $T_1 - T_2$ (D) $T_1^4 - T_2^4$

Ans. : 89 (A), 90 (C), 91 (C), 92 (C), 93 (A), 94 (B), 95 (A), 96 (B), 97 (D), 98 (D), 99 (A) & (C), 100 (A), 101 (C), 102 (D), 103 (B), 104 (C), 105 (D), 106 (C), 107 (B), 108 (D), 109 (C), 110 (B), 111 (D), 112 (D)

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