PHYSICS

Q. 1 A liquid of cubical expansivity Y is heated in a vessel having linear expansivity $\frac{Y}{3}$.Then level of liquid -

(A) Increase (B) decrease

(C) remain same (D) all-possible **[C]**

Sol. $y_s = 3\ \alpha_s$

$\alpha_s = \frac{y}{3}$ given

So $y_s = 3 \times \frac{y}{3} = y$

Q. 2 The diameters of steel rods A and B having the same length are 2 cm and 4 cm respectively. They are heated through 100°C. What is the ratio of increase of length of A to that of B.

(A) 1 : 2 (B) 2 : 1

(C) 1 : 1 (D) 4 : 1 **[C]**

Sol. $\Delta L = L_I \propto \Delta t$

Q.3 There is a metallic rod of length L (at room temperature) and coefficient of linear expansion (α/ºC). The length of rod at 1ºC above room temperature is 102 cm and at 2ºC above room temperature is 104 cm then the values of L and α are –

(A) 101 cm, 0.02/ºC (B) 100 cm, 0.01/ºC

(C) 100 cm, 0.02/ºC (D) 99 cm, 0.02/ºC

[C]

Sol. $\ell = L\ (1 + \alpha\Delta T)$

$\therefore\ 102 = L\ (1 + \alpha)$ and $104 = L\ (1 + 2\alpha)$

Q. 4 A metallic bar is heated from 0ºC to 100ºC. The coefficient of linear expansion is 10^{-5} K^{-1} . What will be the percentage increase in length ?

(A) 0.01 % (B) 0.1 %

(C) 1 % (D) 10 % **[B]**

Sol. $\frac{\Delta\ell}{\ell} = \alpha\Delta T = 10^{-5} \times 100 = 10^{-3}$

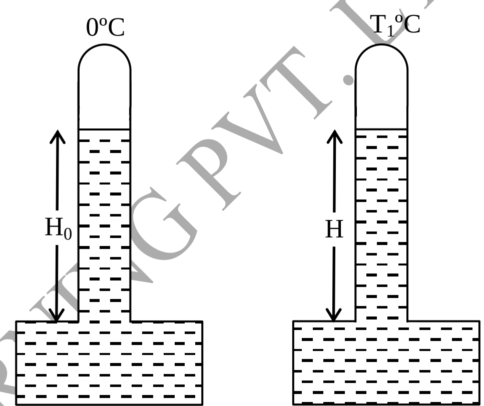
$\frac{\Delta\ell}{\ell} \times 100\% = 10^{-3} \times 100 = 10^{-1} = 0.1\%$

Q.5 The height of mercury column measured with brass scale at temperature T_0 is H_0. What height H' will the mercury column have at T = 0ºC. Coefficient of volume expansion of mercury is γ. Coefficient of linear expansion of brass is α -

(A) $H_0(1 + \alpha T_0)$ (B) $\frac{H_0(1+3\alpha T_0)}{1+\gamma T_0}$

(C) $\frac{H_0(1+3\alpha T_0)}{(1+\gamma/3)T_0}$ (D) $\frac{H_0(1+\alpha T_0)}{1+\gamma T_0}$

Sol. **[D]**



$P_{atm} = \rho_0 gH'$; $P_{atm} = \frac{\rho_0\ gH_0}{1+\gamma T_0}$

$H \rightarrow$ true reading at T_0ºC

Let H_0 be observed reading at T_0ºC

$\therefore\ H_0 = H[1 - \alpha T_1]$

$\rho_0 gH' = \frac{\rho_0 gH_0[1+\alpha T_0]}{1+\gamma T_0}$

$\Rightarrow H' = \frac{H_0[1+\alpha T_1]}{1+\gamma T_1}$

Q.6 Robin wants to shove rubber pipe up a plastic tap. The problem is that the pipe's diameter is smaller than that required to secure a tight fit. So Robin switches on a half-dryer on and pointed it towards the pipe. He found that now the pipe fitted in easily. Why is this so ?

(A) The pipe expanded due to the hot air, and then contracted back again.

(B) the tap got deformed because of the hot air.

(C) The hot air caused adhesion between rubber and plastic.

(D) None of the above.

Sol. **[A]**

Plastic tube expanded because of heat and then when one stopped applying heat, it contracted by cooling.

Q.7 A parallel plate capacitor of plate area A and separation d is provided with thin insulating spacers to keep its plates aligned in an environment of fluctuating temperature. If the coefficient of thermal expansion of material of plate is α then the coefficient of thermal expansion (α_S) of the spacers in order that the capacitance does not vary with temperature (ignore effect of spacers on capacitance)

(A) $\alpha_S = \frac{\alpha}{2}$ (B) $\alpha_S = 3\alpha$

(C) $\alpha_S = 2\alpha$ (D) $\alpha_S = \alpha$ **[C]**

Sol. $C = \frac{\varepsilon_0 A}{x}$, where x is separation between plates

$$\frac{1}{C}\frac{dC}{dT} = \frac{1}{A}\frac{dA}{dT} - \frac{1}{x}\frac{dx}{dT}$$

for $\frac{dC}{dT} = 0,\ \frac{1}{x}\frac{dx}{dT} = \frac{1}{A}\frac{dA}{dT} \Rightarrow \alpha_S = 2\alpha$

Q. 8 A gas is at pressure P and temperature T. Coefficient of volume expansion of one mole of gas at constant pressure is –

(A) $\frac{1}{T}$ (B) T

(C) $\frac{1}{T^2}$ (D) T^2 **[A]**

Sol. $PV = RT \Rightarrow PdV = RdT$

$\therefore$ Coefficient of volume expansion

$$= \frac{1}{V}\frac{dV}{dT} = \frac{R}{PV} = \frac{1}{T}$$

Q.9 If two rods of length L and 2 L having coefficients of linear expansion α and 2α respectively are connected so that total length becomes 3L, the average coefficient of linear expansion of the composite rod equals –

(A) $\frac{3}{2}\alpha$ (B) $\frac{5}{2}\alpha$

(C) $\frac{5}{3}\alpha$ (D) None of these

[C]

Sol. $(3L)\alpha_{eff}\Delta\theta = L\alpha\,\Delta\theta + 2L(2\alpha)(\Delta\theta)$

$\therefore \alpha_{eff} = \frac{5}{3}\alpha$

Q.10 A metal ball immersed in water weighs w_1 at 0ºC and w_2 at 50ºC. The coefficient of cubical expansion of metal is less than that of water. Then –

(A) $w_1 > w_2$ (B) $w_1 < w_2$

(C) $w_1 = w_2$ (D) data is insufficient

[B]

Sol. Apparent weight (w_a)

= actual weight (w) – upthrust (F)

Here, $F = V\rho_w g$ (ρ_w = density of water)

i.e., $F_{0^\circ C} = V_{0^\circ C}(\rho_w)_{0^\circ C}\,g$

and $F_{50^\circ C} = V_{50^\circ C}(\rho_w)_{50^\circ C}\,g$

$$\therefore \frac{F_{50^\circ C}}{F_{0^\circ C}} = \frac{V_{50^\circ C}}{V_{0^\circ C}}\cdot\frac{(\rho_w)_{50^\circ C}}{(\rho_w)_{0^\circ C}} = \frac{(1+\gamma_m\Delta\theta)}{(1+\gamma_w\Delta\theta)}$$

($\Delta\theta = 50^\circ$ C)

Given that $\gamma_m < \gamma_w \therefore F_{50^\circ C} < F_{0^\circ C}$

or apparent weight at 50º C will be more.

Q.11 The design of some physical apparatus requires that there be a constant difference in length at any temperature between iron and copper cylinder laid side by side. What should be the length of cylinders at 0ºC for difference in length to be 10 cm at all temperatures (Given: Iron $\alpha = 1.1 \times 10^{-5}$ ºC^{-1}, Copper $\alpha = 1.7 \times 10^{-5}$ ºC^{-1}) –

(A) L_{Iron} = 18.33 cm, L_{Copper} = 28.33 cm

(B) L_{Iron} = 15 cm, L_{Coper} = 25 cm

(C) L_{Iron} = 28.33 cm, L_{Copper} = 18.33 cm

(D) L_{Iron} = 25 cm, L_{Copper} = 15 cm **[C]**

Sol. For Iron

$L_t - L_0 = L_0 \times \alpha \times \Delta t$

$L_t - L_0 = (L_0)_{Iron} \times 1.1 \times 10^{-5}\,\Delta t$

For Copper

$L_t - L_0 = (L_0)_{Copper} \times 1.7 \times 10^{-5}\ \Delta t$

Since $L_t - L_0$ is equal for both metals at all temperatures.

$(L_0)_{Iron} \times 1.1 \times 10^{-5}\ \Delta t = (L_0)_{Copper} \times 1.7 \times 10^{-5}\ \Delta t$

$(L_0)_{Iron} \times 11 = (L_0)_{Copper} \times 17$

But $(L_0)_{Iron} - (L_0)_{Copper} = 10$ cm

or $(L_0)_{Iron} = (L_0)_{Copper} + 10$ cm

$((L_0)_{Copper} + 10) \times 11 = (L_0)_{Copper} \times 17$

or $6(L_0)_{copper} = 110$ cm

or $(L_0)_{copper} = 110/6$ cm $= 18.33$ cm.

$(L_0)_{copper} = 18.33$ cm.

$(L_0)_{Iron} = 28.33$ cm.

Q.12 An anisotropic material has coefficient of linear expansion α, 2α and 3α along the three co-ordinate axis. Coefficient of cubical expansion of material will be equal to –

(A) 2α (B) $\sqrt[3]{6}\,\alpha$

(C) 6α (D) None of these **[C]**

Sol. For anisotropic material

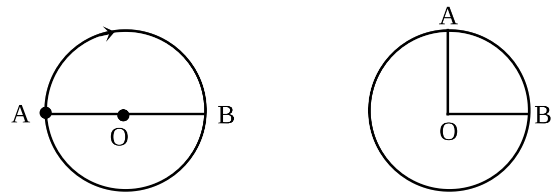
$\gamma = \alpha + 2\alpha + 3\alpha = 6\alpha$

Q.13 A and B are two points on a uniform metal ring whose centre is O. The angle AOB = θ. A and B are maintained at two different constant temperatures. When $\theta = 180°$, the rate of total heat flow from A to B is 1.2 W. When $\theta = 90°$, this rate will be -

(A) 0.6 watt (B) 0.9 watt

(C) 1.6 watt (D) 1.8 watt **[C]**

Sol.



$$1.2 = \frac{KA(T_1 - T_2)}{R/4}$$

$$\tau = \frac{KA(T_1 - T_2)}{\frac{R}{4} + \frac{3R}{4}}$$

$\tau = 1.6$ watt.

Q.14 A parallel-sided slab is made of two different materials. The upper half of the slab is made of material X, of thermal conductivity λ; the lower half is made of material Y, of thermal conductivity 2λ. In the steady state, the left hand face of the composite slab is at a higher, uniform temperature than the right-hand face, What fraction of the total heat flow through the slab passes through material X ?

(A) $\frac{1}{4}$ (B) $\frac{1}{3}$

(C) $\frac{1}{2}$ (D) $\frac{2}{3}$ **[B]**

Sol. $$\tau = \frac{(T_1 - T_2)\ 3\lambda A}{L}$$

$$\tau_1 = \frac{(T_1 - T_2)\ \lambda A}{L}$$

$$\frac{\tau}{\tau_1} = 3 \Rightarrow \tau_1 = \tau/3$$

Q.15 The thermal conductivity of two materials are in the ratio 1 : 2. What will be the ratio of thermal resistances of rods of these materials having length in the ratio 1 : 2 and area of cross-section in the ratio 1 : 2:

(A) 1 : 2 (B) 1 : 4

(C) 1 : 8 (D) 1 : 16 **[A]**

Sol. $$\frac{K_1A(T_h - T_j)}{L} = \frac{K_2A(T_j - T_c)}{L}$$

Q.16 The co-efficient of thermal expansion of a rod is temperature dependent and is given by the formula α = aT, where a is a positive constant and T in ºC. If the length of the rod is ℓ at temperature 0ºC, then the temperature at which the length will be 2ℓ is -

(A) $\sqrt{\frac{\ell n2}{\alpha}}$ (B) $\sqrt{\frac{\ell n4}{a}}$

(C) $\frac{1}{\alpha}$ (D) $\frac{2}{\alpha}$ **[B]**

Sol. As; $d\ell = \alpha\, \ell dT$ $\therefore \int_0^{2\ell} \frac{d\ell}{\ell} = a\int_0^T TdT$

$\ell n2 = a\,\frac{T^2}{2}$ $\therefore T = \left[\frac{\ell n4}{a}\right]^{1/2}$

Q.17 Three rods A, B and C have the same dimensions. Their thermal conductivities are k_A, k_B, and k_C respectively. A and B are placed end to end, with their free ends kept at certain temperature difference. C is placed separately with its ends kept at same temperature difference. The two arrangements conduct heat at the same rate. k_C must be equal to -

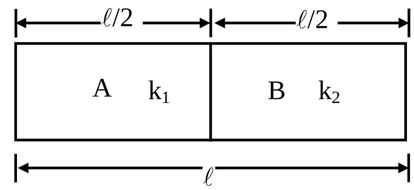
(A) $k_A + k_B$ (B) $\frac{k_A k_B}{k_A + k_B}$

(C) $\frac{1}{2}(k_A + k_B)$ (D) $\frac{2k_A k_B}{k_A + k_B}$ **[B]**

Sol. $\frac{T_1 - T_2}{\frac{L}{k_A A} + \frac{L}{k_B A}} = \frac{T_1 - T_2}{\frac{L}{k_C A}}$

$\frac{k_A k_B}{k_A + k_B} = k_C$

Q.18 A composite slab consists of two slabs A and B of different materials but of the same thickness placed one on top of the other. The thermal conductivities of A and B are k_1 and k_2 respectively. A steady temperature difference of 12ºC is maintained across the composite slab. If $k_1 = k_2/2$, the temperature difference across slab A will be :

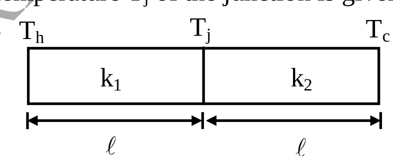


(A) 4ºC (B) 8ºC (C) 12º (D) 16º **[B]**

Sol. $R = \frac{L}{KA}$

$\frac{R_1}{R_2} = \frac{L_1}{L_2} \times \frac{K_2}{K_1} \times \frac{A_2}{A_1}$

Q.19 Two bars of equal length and the same cross-sectional area but of different thermal conductivities, k_1 and k_2, are joined end to end as shown in figure. One end of the composite bar is maintained at temperature T_h where as the opposite end is held at T_c . If there are no heat losses from the sides of the bars, the temperature T_j of the junction is given by -



(A) $\frac{k_2}{k_1}\frac{(T_h + T_c)}{2}$

(B $\frac{k_2}{k_1 + k_2}(T_h + T_c)$

(C) $\frac{k_1 + k_2}{k_2}\frac{(T_h + T_c)}{2}$

(D) $\frac{1}{k_1 + k_2}(k_1T_h + k_2T_c)$ **[D]**

Sol. $\tau \propto \frac{Kr^2}{\ell}$

$\therefore$ $\tau_1 = \tau_2$

$\frac{K_1 r_1^2}{\ell_1} = \frac{K_2 r_2^2}{\ell_2}$

Q.20 A rectangular block is heated from 0ºC to 100ºC. The percentage increase in its length is 0.10%. What will be the percentage increase in its volume ?

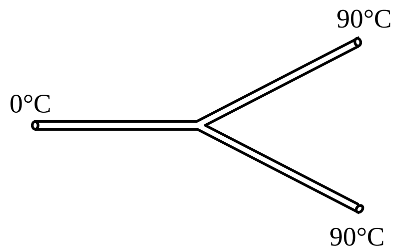
(A) 0.03 % (B) 0.10 %

(C) 0.30 % (D) None of these **[C]**

Sol. $\alpha = 10^{-5}$/ºC $\frac{\Delta\ell}{\ell}$ = 0.10%, ΔT = 100ºC

$\therefore \frac{\Delta \ell}{\ell} = \alpha\, \Delta\theta$ and $\frac{\Delta V}{V} = \gamma.\, \Delta\theta = 3\alpha.\Delta\theta$

Q.21 Three rods made of the same material and having the same cross-section have been joined as shown in the figure. Each rod is of the same length.The left and right ends are kept at 0°C and 90°C respectively. The temperature of the junction of the three rods will be –



(A) 45°C (B) 60°C
(C) 30°C (D) 20°C **[B]**

Sol. $\tau = \tau_1 + \tau_2 =$

$$\frac{KA\,(T-0)}{L} = \frac{KA\,(90-T)}{L} + \frac{KA\,(90-T)}{L}$$

Q.22 Two metallic rods are connected in series. Both are of same material of same length and same area of cross-section. If the conductivity of each rod be k, then what will be the conductivity of the combination ?

(A) 4 k (B) 2 k (C) k (D) k/2 **[C]**

Sol. $$\frac{2L}{k_{eq.}A} = \frac{L}{kA} + \frac{L}{kA}$$

$$\frac{2}{k_{eq.}} = \frac{2}{k} \Rightarrow k_{eq.} = k$$

For parallel

$$k_{eq.} = \frac{k_1A_1 + k_2A_2}{A_1 + A_2} = k$$

Q.23 The ratio of thermal conductivities of two rods of different material is 5 : 4. The two rods of same area of cross-section and same thermal resistance will have the lengths in the ratio -

(A) 4 : 5 (B) 9 : 1
(C) 1 : 9 (D) 5 : 4 **[D]**

Sol. $$\frac{L_1}{K_1A} = \frac{L_2}{K_2A}$$

$$\frac{K_1}{K_2} = \frac{L_1}{L_2}$$

Q.24 Two vessels A and B of different materials are similar in shape and size. The same quantity of ice filled in them melts in times t_1 and t_2 respectively. The ratio of the thermal conductivities of A and B is -

(A) $t_1 : t_2$ (B) $t_2 : t_1$
(C) $t_1^2 : t_2^2$ (D) $t_2^2 ; t_1^2$ **[B]**

Sol. $$\frac{mL}{t_1} = \frac{K_1A\,(T_1 - T_2)}{L}$$

$$\frac{mL}{t_2} = \frac{K_2A\,(T_1 - T_2)}{L}$$

$$\frac{K_1}{K_2} = \frac{t_2}{t_1}$$

Q.25 One end of a conducting rod is maintained at temperature 50°C and at the other end ice is melting at 0°C. The rate of melting of ice is doubled if -

(A) The temperature is made 200°C and the area of cross-section of rod is doubled

(B) The temperature is made 100°C and length of the rod is made of four times

(C) Area of cross section of rod is halved and length is doubled

(D) The temperature is made 100°C and area of cross-section of rod and length both are doubled. **[D]**

Sol. $$\frac{\Delta Q}{\Delta t} \propto \frac{A(\Delta T)}{\ell}$$

If A is double the rate of flow of heat is double.

Q.26 Wires A and B have identical lengths and have circular cross-sections. The radius of A is twice the radius of B i.e. $R_A = 2R_B$. For a given temperature difference between the two ends, both wires conduct heat at the same rate. The relation between the thermal conductivities is given by -

(A) $K_A = 4\,K_B$ (B) $K_A = 2\,K_B$
(C) $K_A = K_B/2$ (D) $K_A = K_B/4$ **[D]**

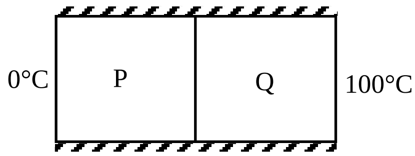
Sol. $$\tau_1 = \frac{K_A\pi(2R_B)^2(T_1 - T_2)}{L}$$

$$\tau_2 = \frac{K_B\pi R_B^2(T_1 - T_2)}{L}$$

$\therefore$ $\tau_1 = \tau_2$

$K_B = 4\,K_A$

Q.27 The diagram below shows rods of the same size of two different materials P and Q placed end to end in thermal contact and heavily lagged at their sides. The outer ends of P and Q are kept at 0°C and 100°C, respectively. The thermal conductivity of P is four times that of Q. What is the steady-state temperature of the interface ?

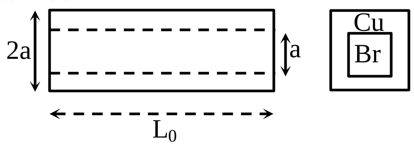


(A) 20°C (B) 75°

(C) 25°C (D) 80°C **[A]**

Sol. $\frac{4K(T-0)}{L} = \frac{K(100-T)}{L}$

Q.28 There is a copper rod of square cross-section, the dimension of each side being 2a, but having a square hole through out the rod, dimension of each side of hole being a. A brass rod exactly fitting inside the hole is inserted in the hole. Now, both sides of the rod are welded together. The temperature is elevated by θ. Neglecting any lateral expansion or stresses developed, the composite length of the system at temperature θ will be -



(A) $L_0\left[1+\frac{\alpha_{Br}Y_{Br}+\alpha_{Cu}Y_{Cu}}{Y_{Br}+Y_{Cu}}(\theta)\right]$

(B) $L_0\left[1+\frac{\alpha_{Br}Y_{Br}-\alpha_{Cu}Y_{Cu}}{Y_{Br}-Y_{Cu}}(\theta)\right]$

(C) $L_0\left[1+\frac{3\alpha_{Br}Y_{Br}+\alpha_{Cu}Y_{Cu}}{3Y_{Br}+Y_{Cu}}(\theta)\right]$

(D) $L_0\left[1+\frac{\alpha_{Br}Y_{Br}+3\alpha_{Cu}Y_{Cu}}{Y_{Br}+3Y_{Cu}}(\theta)\right]$

Sol. **[D]**

$F_1 = F_2$

$\frac{Y_{Cu}(3a^2)(x-L_0\alpha_{Cu}\theta)}{L_0}$

$= \frac{Y_{Br}(a^2)(L_0\alpha_{Br}\theta-x)}{L_0}$

Composite length = $L_0 + x$

$= L_0\left[1+\frac{\alpha_{Br}Y_{Br}+3Y_{Cu}\alpha_{Cu}}{3Y_{Cu}+Y_{Br}}(\theta)\right]$

Q.29 Two rods made of same material having same length and diameter are joined in series. The thermal power dissipated through then is 2W. If they are joined in parallel, the thermal power dissipated under the same conditions on the two ends of the rods, will be -

(A) 16 W (B) 8 W

(C) 4 W (D) 2 W **[B]**

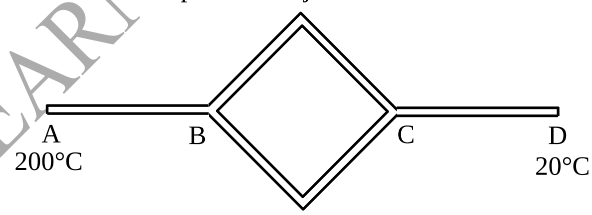
Sol. $2W = \frac{T_1-T_2}{2R}$

$\tau = \frac{T_1-T_2}{R/2}$

$\frac{2\text{ watt}}{\tau} = \frac{T_1-T_2}{2R}\times\frac{R}{2(T_1-T_2)}$

τ = 8 watt

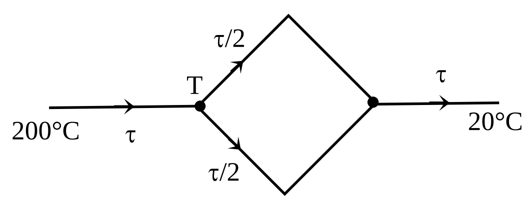
Q.30 Six identical conducting rods are joined as shown in figure. Points A and D are maintained at temperatures 200°C and 20°C respectively. The temperature of junction B will be –



(A) 120°C (B) 100°C

(C) 140° C (D) 80°C **[C]**

Sol.



$\frac{200-T_B}{R} = \frac{T_C-20}{R}$

$200 - T_B = T_C - 20$

$220 = T_B + T_C$

$T_B + T_C = 220$ …….(i)

$\frac{\tau}{2} = \frac{T_B-T_C}{2R}$

$\frac{200-T_B}{R} = \frac{T_B-T_C}{R}$

$200 - T_B = T_B - T_C$

$200 - T_B = T_B - (220 - T_B)$

$420 = 3\,T_B$

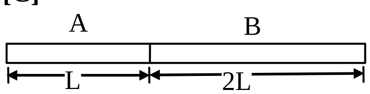
T_B = 140 ° C

Q.31 If two rods of length L and 2L having coefficient of linear expansion α and 2α respectively are connected so that total length becomes 3L, the average coefficient of linear expansion of the composition rods equals -

(A) $\frac{3}{2}\alpha$ (B) $\frac{5}{2}\alpha$

(C) $\frac{5}{3}\alpha$ (D) None of these

Sol. **[C]**



$\therefore \alpha = \frac{\Delta\ell}{L\Delta T}$

for A : $\alpha = \frac{\Delta\ell_1}{L\Delta T} \Rightarrow \Delta\ell_1 = L\,\alpha\,\Delta T$

for B : $2\alpha = \frac{\Delta\ell_2}{2L\Delta T} \Rightarrow \Delta\ell_2 = 4L\,\alpha\,\Delta T$

For composition

$\alpha_{avg.} = \frac{\Delta\ell_1 + \Delta\ell_2}{3L\Delta T} = \frac{\alpha L\Delta T + 4L\alpha\Delta T}{3L\Delta T} = \frac{5}{3}\alpha$

Q.32 A thin copper wire of length L increase in length by 1% when heated from temp T_1 to T_2. What is the percentage change in area when a thin copper plate having dimensions 2L × L is heated from T_1 to T_2 ?

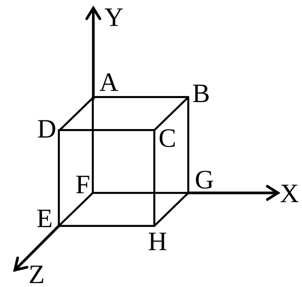
(A) 1% (B) 2%

(C) 3% (D) 4%

Sol. **[B]**

$\frac{\%\text{change in length}}{\%\text{change in Area}} = \frac{\alpha}{\beta}$

Q.33 A cuboid ABCDEFGH is anisotropic with $\alpha_x = 1 \times 10^{-5}$/ºC, $\alpha_y = 2 \times 10^{-5}$/ºC, $\alpha_z = 3 \times 10^{-5}$/ºC. Coefficient of superficial expansion (β) of faces can be (Take approximation)



(A) $\beta_{ABCD} = 5 \times 10^{-5}$/ºC (B) $\beta_{BCGH} = 4 \times 10^{-5}$/ºC

(C) $\beta_{CDEH} = 3 \times 10^{-5}$/ºC (D) $\beta_{EFGH} = 2 \times 10^{-5}$/ºC

Sol. **[C]**

$\ell_x = \ell_{x_0}(1 + \alpha_x T)$, $\ell_y = \ell_{y_0}(1 + \alpha_y T)$

$\ell_x\ell_y = \ell_{x_0}\ell_{y_0}[1 + (\alpha_x + \alpha_y + \alpha_x\alpha_y)T]$

$A_x = A_{x_0}[1 + (\alpha_x + \alpha_y + \alpha_x\alpha_y)T]$

$A_x = A_{x_0}[1 + (1 \times 10^{-5} + 2 \times 10^{-5} + 1 \times 2 \times 10^{-10})T]$

$A_x = A_{x_0}[1 + 3 \times 10^{-5}T]$, $\beta_{CDEH} = 3 \times 10^{-5}$/ºC

Q.34 A clock which keeps correct time at 25ºC has a pendulum made of a metal. The temperature falls to 0ºC. If the coefficient of linear expansion of the metal is 1.9×10^{-5} per ºC, then number of second the clock gains per day is -

(A) 10.25 s (B) 20.52 s

(C) 30.75 s (D) 41 s

Sol. **[B]**

$\frac{\Delta T}{T} = \frac{1}{2}\alpha(\theta_2 - \theta_1)$

$\Delta T = \frac{1}{2} \times 1.9 \times 10^{-5}(25 - 0) \times 24 \times 3600$

Q.35 Equation of a gas is given by $(T^7/P^2)^{1/5}$ = constant. Coefficient of volume expansion of that gas in isobaric process is -

(A) $-\frac{1}{T}$ (B) $-\frac{1.5}{T}$

(C) $-\frac{2.5}{T}$ (D) $-\frac{3.5}{T}$

Sol. **[C]**

$$T^{\frac{7}{5}} P^{-\frac{2}{5}} = C \; ; \; T^{\frac{7}{5}} \left(\frac{nRT}{V}\right)^{-\frac{2}{5}} = C$$

$$T^{\frac{7}{5}-\frac{2}{5}} \; V^{\frac{2}{5}} = C \; ; \; TV^{\frac{2}{5}} = C$$

$$\ln T + \frac{2}{5} \ln V = \ln C$$

$$\frac{\Delta T}{T} + \frac{2}{5}\frac{\Delta V}{V} = 0 \; ; \; -\frac{5}{2T} = \frac{\Delta V}{V\Delta T} = \gamma$$

$$\gamma = -\frac{2.5}{T}$$

Q.36 The temperature of a thin uniform circular disc, of diameter 1m is increased by 10ºC. The percentage increase in its moment of inertia about an axis passing through its centre and perpendicular to its surface is - ($\alpha = 11 \times 10^{-6}$ / ºC)

(A) 0.0055% (B) 0.011%

(C) 0.022% (D) 0.044%

Sol. **[C]**

$$I = \frac{1}{2} mr^2$$

$$\ln I = \ln \frac{1}{2} m + \ln r^2$$

$$\ln I = 2\ln r + \ln \frac{1}{2} m$$

$$\frac{\Delta I}{I} = 2\frac{\Delta r}{r} = 2\,\alpha\,\Delta\theta$$

$= 2 \times 11 \times 10^{-6} \times 10$

$= 22 \times 10^{-5} = 22 \times 10^{-3}\,\% = 0.022\%$

Q.37 A glass flask of volume one litre at 0ºC is filled, level full of mercury at this temperature. The flask and mercury are now heated at 100ºC. How much mercury will spill out, if coefficient of volume expansion of mercury is 1.82×10^{-4}/ºC and linear expansion of glass is 0.1×10^{-4}/ºC respectively -

(A) 21.2 cc (B) 15.2 cc

(C) 1.52 cc (D) 2.12 cc

Sol.[B] $\Delta V_A = \Delta V_R - \Delta V_s$

$= V (r_A - r_s)\, \Delta\theta$

$= 10^3$ c.c. $(1.82 \times 10^{-4} - 0.3 \times 10^{-4}) \times 100$

$= 1.52 \times 10$ cc $= 15.2$ cc

Q.38 A crystal has a coefficient of expansion 13×10^{-7} in one direction and 231×10^{-7} in every other direction at right angles to it. Then the cubical coefficient of expansion is -

(A) 462×10^{-7} (B) 244×10^{-7}

(C) 475×10^{-7} (D) 257×10^{-7}

Sol.[C] $\gamma = \alpha_1 + 2\alpha_2 = (13 + 2 \times 231) \times 10^{-7} = 475 \times 10^{-7}$

Q.39 An iron tyre of diameter 2 m is to be fitted on to a wooden wheel of diameter 2.01 m. The temperature to which the tyre must be heated, if $\alpha = 11 \times 10^{-6}$/ºC and room temperature is 20ºC, will be -

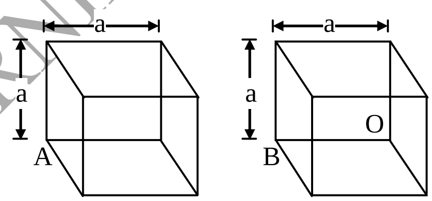
(A) 474.5ºC (B) 490.5ºC

(C) 440.5ºC (D) 460.5ºC

Sol.[A] $\Delta\theta = \frac{\Delta \ell}{\ell \alpha} = \frac{0.01}{2 \times 11 \times 10^{-6}} = \frac{10^4}{22} = 454.5$

$\theta = 454.5 + 20 = 474.5$ºC

Q.40 A and B are made up of an isotropic medium. Both A and B are of equal volume. Body B has cavity as shown in Fig.(b). Which of the following statements is true?



(a) (b)

(A) Expansion in volume of A > expansion in B

(B) Expansion in volume of B > expansion in A

(C) Expansion in A = expansion in B

(D) None of these

Sol. **[C]** Thermal expansion in isotropic bodies is independent of shape size & availability of cavity.

Q. 41 A piece of metal floats on Hg. The coefficient of expansion of metal and Hg are γ_1 and γ_2 respectively. If the temperature of both Hg and metal are increased by an amount ΔT, by what factor the fraction of the volume of metal submerged in mercury changes?

(A) $(\gamma_2 - \gamma_1)\,\Delta T$ (B) $\left(\frac{\gamma_2 + \gamma_1}{2}\right) \Delta T$

(C) $\frac{2\gamma_1\gamma_2}{\gamma_1 + \gamma_2}\,\Delta T$ (D) $\frac{\gamma_1\gamma_2}{\gamma_1 + \gamma_2}\,\Delta T$

Sol. **[A]**

$f_{in} = \frac{V_{in}}{V} = \frac{\rho}{\sigma}$ $\rho \rightarrow$ density of metal, $\sigma \rightarrow$ density of Hg

$$\frac{\Delta f}{f} = \frac{f'_{in} - f_{in}}{f_{in}} = \frac{f'_{in}}{f_{in}} - 1$$

$$= \frac{\frac{\rho}{\sigma}\left(\frac{1+\gamma_2\Delta T}{1+\gamma_1\Delta T}\right) - 1}{\rho/\sigma}$$

$= (\gamma_2 - \gamma_1)\,\Delta T$ (using Binomial theorem)

Q.42 A Cu rod and a steel rod maintain a difference in their lengths constant = 10 cm at all temperatures. If their coefficients of expansion are $1.6 \times 10^{-5}\ K^{-1}$ and $1.2 \times 10^{-5}\ K^{-1}$, then the length of the Cu rod is -

(A) 40 cm (B) 30 cm

(C) 32 cm (D) 24 cm

Sol. **[B]**

$\Delta\ell_1 = \Delta\ell_2 \Rightarrow \ell_1\alpha_1\,\Delta T = \ell_2\alpha_2\Delta T$

$\Rightarrow \ell_1\alpha_1 = \ell_2\alpha_2 \Rightarrow \frac{\ell_2}{\ell_1} = \frac{\alpha_1}{\alpha_2} \Rightarrow \frac{\ell_2}{\ell_1} - 1 = \frac{\alpha_1}{\alpha_2} - 1$

$\frac{\ell_2 - \ell_1}{\ell_1} = \frac{\alpha_1 - \alpha_2}{\alpha_1} \Rightarrow \ell_1 = \frac{\alpha_1(\ell_2 - \ell_1)}{(\alpha_1 - \alpha_2)}$

Q.43 A clock which keeps correct time at 20ºC has a pendulum rod made of brass. How many seconds will it gain or lose per day when temperature falls to 0ºC ($\alpha = 18 \times 10^{-6}$/ºC) ?

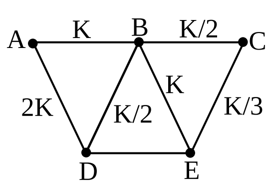
(A) 155.5 s (B) 15.55 s

(C) 25.55 s (D) 18.55 s

Sol.[B] $\Delta T = \frac{1}{2} \propto T\Delta\theta = \frac{1}{2} \times 18 \times 10^{-6} \times 86400\ s \times 20$

$= 1.8 \times 8.64\ s = 15.55\ s$

Q.44 Five rods of identical geometries are arranged as shown in figure. Temperatures are maintained at points A, C, D and E as 100ºC, 0ºC, 40ºC and 60ºC respectively. Thermal conductivities of rods are shown in the figure. Heat current in the branch BE is - [Take length of each rod ℓ = 1m and A = 1m^2, K = 0.5 W/m-K]



(A) 10 W (B) 20 W

(C) zero (D) None of these

Sol.[C] Net heat current at B must be zero so T_B = 60ºC

Q.45 A clock with a metal pendulum beating seconds keeps correct time at 0ºC. If it loses 12.5 seconds a day at 25ºC, the coefficient of linear expansion of metal of pendulum is -

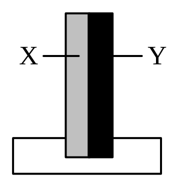
(A) $\frac{1}{86400}$/ºC (B) $\frac{1}{43200}$/ºC

(C) $\frac{1}{14400}$/ºC (D) $\frac{1}{28800}$/ºC

Sol. [A] $\Delta t = \frac{1}{2}\alpha t\,\Delta\theta$

$\alpha = \frac{2\Delta t}{t\Delta\theta} = \frac{2 \times 12.5}{86400 \times 25} = \frac{1}{86400}$/ºC

Q.46 A bimetallic strip consists of metals X and Y. It is mounted rigidly at the base as shown in the figure. The metal X has a higher coefficient of expansion as compared to that for metal Y. When the bimetallic strip is placed in a cold bath ?



(A) It will bend towards the right

(B) It will bend towards the left

(C) It will not bend but shrink

(D) It will neither bend nor shrink

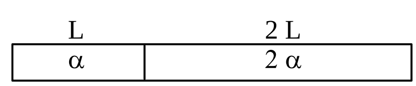
Sol.[B] As, $\alpha_x > \alpha_y$ then on colling X contracts more than Y. So, the strip bends towards X, i.e., towards left.

Q.47 If two rods of length L and 2L having coefficients of linear expansion α and 2α respectively are connected so that total length becomes 3L, the average coefficient of linear expansion of the composition rod equals -

(A) $\frac{3}{2}\alpha$ (B) $\frac{5}{2}\alpha$

(C) $\frac{5}{3}\alpha$ (D) none of these

Sol.[C]



$\Delta\ell = \Delta\ell_1 + \Delta\ell_2$

$\alpha_{eq} 3L\Delta T = \alpha L\Delta T + 2\alpha \times 2\ L\Delta T$

$3\alpha_{eq} = 5\alpha \Rightarrow \alpha_{eq} = \frac{5}{3}\alpha$

Q.48 At 4ºC, 0.98 of the volume of a body is immersed in water. The temperature at which the entire body gets immersed in water ($\gamma_w = 3.3 \times 10^{-4} K^{-1}$) is (neglect the expansion of the body)–

(A) 40.8ºC (B) 65.8ºC

(C) 60.6ºC (D) 58.8ºC **[B]**

Q.49 A solid ball of metal has a spherical cavity inside it. If the ball is heated, the volume of the cavity will–

(A) Increase

(B) Decrease

(C) Remains unchanged

(D) Have its shape changed **[A]**

Q.50 A beaker is completely filled with water at 4°C. It must overflow -

(A) when heated but not when cooled

(B) when cooled but not when heated

(C) both when heated or cooled

(D) neither when heated nor when cooled **[C]**

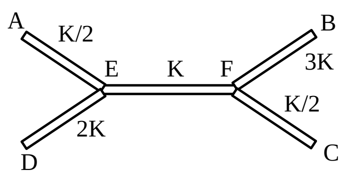
Q.1 A bar measured with a Vernier Caliper is found to be 1800 mm long. The temperature during the measurement is 10ºC.

The measurement error if the scale of the Vernier Caliper has been graduated at a temperature of 20ºC is found to $x \times 10^{-2}$ mm. Find x.

Sol.[2] $x = \ell_0 \alpha t$

$x = 2$

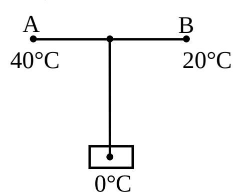
Q.2 Five rods with identical geometries are arranged as shown. Their thermal conductivity are shown. Only A and C are maintained at 100°C and 0°C respectively. If temperature difference between ends B and C can be writted as 10x °C where x is an integer. Then find x .



Sol. [2] $\frac{d\theta}{dt} = \frac{100-0}{R_{eq}}$; $T_B = 40°C$, $T_D = 60°C$

Q.2 In the figure shown AB is a rod of length L and thermal resistance $R_H = 10$ SI unit and end A and B are maintained by 20°C and 40°C. At mid point of rod another rod of thermal resistance $R'_H = R_H/4$ SI unit connected and other end of rod is inserted into ice.

After steady state reach, we start counting of time, and find the amount of ice (in kg) melt in 5.6×10^4 s. ($L_f = 3.36 \times 10^5$ J/kg)



Sol. [1] $\frac{40-T}{R_H/2} = \frac{T-20}{R_H/2} + \frac{T-0}{R_H/4}$

$T = 15°C$

$\frac{T-0}{R_H/4} = i_H \Rightarrow i_H = 6$ J/s

Heat supplied $= 6 \times 5.6 \times 10^4 = 3.36 \times 10^5$ J In 5.6×10^4s. amount of ice $mL_f = 3.36 \times 10^5$