

EXERCISE # (S-1)

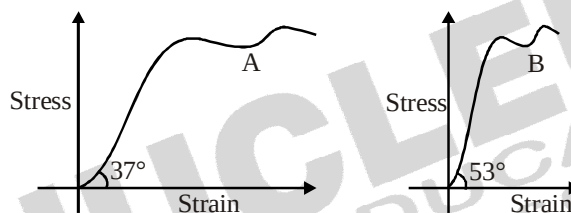
HCV Worked out Examples(Chapter No.14 - {2,3,5,7,8,10})

1. A steel wire of length 4.5 m and a copper wire of length 3.5 m are stretched same amount under a given load. If ratio of Young's moduli of steel to that of copper is $\frac{12}{7}$, then what is the ratio of cross sectional area of steel wire to copper wire?

Ans. 0.75

Sol. $Y_s = \frac{F/A_s}{\Delta\ell/\ell_s}$, $Y_c = \frac{F/A_c}{\Delta\ell/\ell_c}$
 $\frac{A_s}{A_c} = \frac{Y_c}{Y_s} \times \frac{\ell_s}{\ell_c} = \frac{7}{12} \times \frac{4.5}{3.5} = 0.75$

2. Diagram shows stress-strain graph for two material A & B. The graphs are drawn to scale.

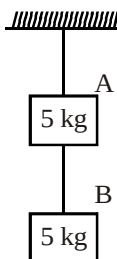


The ratio of young moduli of material A to material B is.

Ans. $\frac{9}{16}$

Sol. $\frac{Y_A}{Y_B} = \frac{(\text{Slope})_A}{(\text{Slope})_B} = \frac{\tan 37^\circ}{\tan 53^\circ} = \frac{3/4}{4/3} = \frac{9}{16}$

3. Two identical wires A & B of same material are loaded as shown in figure. If the elongation in wire B is 1.5 mm, what is the elongation in A. (Mass of A & B can be neglected)



Ans. 3 mm

Sol. $Y = \frac{F/A}{\Delta\ell/\ell}$

Identical wires means (Y, A, L) same

$\Rightarrow F \propto \Delta\ell$

$$\frac{\Delta \ell_A}{\Delta \ell_B} = \frac{F_A}{F_B}$$

$$\Delta \ell_A = \Delta \ell_B \times \frac{F_A}{F_B} = 1.5 \times \frac{10g}{5g} = 3\text{mm}$$

4. A wire of length L and radius r is clamped rigidly at one end. When the other end of the wire is pulled by a force f , its length increases by ℓ . Another wire of the same material of length $2L$ and radius $2r$, is pulled by a force $2f$. Find the increase in length of this wire.

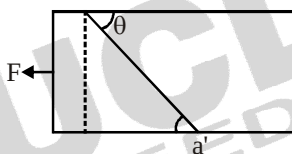
Ans. ℓ

Sol. Same material $\Rightarrow Y$ same

$$Y_1 = Y_2$$

$$\frac{f / \pi r^2}{\ell / L} = \frac{2f / 4\pi r^2}{\ell' / 2L} \Rightarrow \ell' = \ell$$

5. Consider a long steel bar under a tensile stress due to forces $\vec{F}$ acting at the edges along the length of the bar (Fig.). Consider a plane making an angle θ with the length. What are the tensile and shearing stresses on this plane?



- (a) For what angle is the tensile stress a maximum?
(b) For what angle is the shearing stress a maximum?

Ans. (a) $\theta = \frac{\pi}{2}$; (b) $\theta = \frac{\pi}{4}$

Sol. T.S = $\frac{F \sin^2 \theta}{A}$

$$S.S = \frac{F}{2A} \sin 2\theta$$

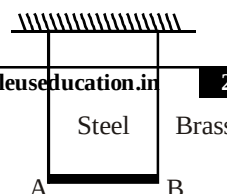
$$T.S_{\max} = \frac{F}{A} \left(\theta = \frac{\pi}{2} \right)$$

$$S.S_{\max} = \frac{F}{2A} \left(\theta = \frac{\pi}{4} \right)$$

6. A light rigid bar AB is suspended horizontally from two vertical wires, one of steel and one of brass, as shown in figure. Each wire is 2.00 m long. The diameter of the steel wire is 0.60 mm and the length of the bar AB is 0.20 m. When a mass of 10 kg is suspended from the centre of AB bar remains horizontal.

(i) What is the tension in each wire?

(ii) Calculate the extension of the steel wire and the energy stored in it.



- (iii) Calculate the diameter of the brass wire.
(iv) If the brass wire were replaced by another brass wire of diameter 1 mm, where should the mass be suspended so that AB would remain horizontal? The Young modulus for steel = 2.0×10^{11} Pa, the Young modulus for brass = 1.0×10^{11} Pa.

Ans. (i) 50 N, (ii) 0.045 J, 1.8×10^{-3} m (iii) 8.4×10^{-4} m, (iv) $x=0.12$ m

Sol. (i) $2T = 100 \Rightarrow T = 50$

(ii) $Y = \frac{T/A}{\Delta\ell/\ell}$, $U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$

(iii) $Y = \frac{T/A}{\Delta\ell/\ell}$

(iv) $T_B + T_S = mg$
 $T_B x = T_S(L - x)$
 $Y_B = \frac{T_B/A_B}{\Delta\ell/\ell}$

7. An iron bar (Young's modulus = 10^{11} N/m², $\alpha = 10^{-6}$ /°C) 1 m long and 10^{-3} m² in area is heated from 0°C to 100°C without being allowed to bend or expand. Find the compressive force developed inside the bar.

Ans. 10,000 N

Sol. $F = YA \alpha \Delta T$

HCV Exercises (Chapter No.14- {1,3,5,8,10,11,13,15})

HCV Worked out Examples(Chapter No.25 - {1,3,4,5,6})

8. One day in the morning, Ramesh filled up 1/3 bucket of hot water from geyser, to take bath. Remaining 2/3 was to be filled by cold water (at room temperature) to bring mixture to a comfortable temperature. Suddenly Ramesh had to attend to something which would take some times, say 5-10 minutes before he could take bath. Now he had two options: (i) fill the remaining bucket completely by cold water and then attend to the work, (ii) first attend to the work and fill the remaining bucket just before taking bath. Which option do you think would have kept water warmer? Explain.

Ans. The first one

Sol. $\frac{d\theta}{dt} \propto \Delta T$

9. An aluminium container of mass 100 gm contains 200 gm of ice at -20°C . Heat is added to the system at the rate of 100 cal/s. Find the temperature of the system after 4 minutes (specific heat of ice = 0.5 and $L = 80$ cal/gm, specific heat of Al = 0.2 cal/gm/°C)

Ans. 25.5°C

Sol. $Q = \left(100 \frac{\text{cal}}{\text{s}}\right)(240\text{s}) = 24000\text{cal}$

$$Q = m_{al}S_{al}(20) + m_{ice}S_{ice}(20) + m_{ice}L_{ice} + m_{al}S_{al}(T) + m_wS_wT$$

$$\Rightarrow T = 25.5^\circ\text{C}$$

10. A hot liquid contained in a container of negligible heat capacity loses temperature at rate 3 K/min, just before it begins to solidify. The temperature remains constant for 30 min. Find the ratio of specific heat capacity of liquid to specific latent heat of fusion is in K^{-1} (given that rate of losing heat is constant).

Ans. 1/90

Sol. $\frac{d\theta}{dt} = \frac{mL}{(30 \text{ min})} = ms \frac{dT}{dt}$

$$\Rightarrow \frac{S}{L} = \frac{1}{30 \times 3} = \frac{1}{90}$$

11. Two 50 gm ice cubes are dropped into 250 gm of water into a glass. If the water was initially at a temperature of 25°C and the temperature of ice -15°C . Find the final temperature of water. (specific heat of ice = $0.5 \text{ cal/gm}^\circ\text{C}$ and $L = 80 \text{ cal/gm}$). Find final amount of water and ice.

Ans. 0°C , 125/4 g ice, 1275/4 g water

Sol. 50 gm (ice) $\longrightarrow$ 50 gm (ice) $\longrightarrow$ 50 gm (water)

$(-15^\circ\text{C}) \quad Q = 50 \times \frac{1}{2} \times 15 \quad (0^\circ\text{C}) \quad Q = m.L \quad (0^\circ\text{C})$

$= 375 \text{ cal} \quad = 4000 \text{ cal}$

250 gm (water) $\longrightarrow$ 250 gm (water)

$(25^\circ\text{C}) \quad Q = 250 \times 1 \times 25 \quad (0^\circ\text{C})$

$= 6250 \text{ cal}$

Total heat required to melt both ice cube = $2 \times (375 + 400) \text{ cal}$.

Total heat provided by water when water reach to 0°C = 6250 cal.

Means, ice will not melt completely and the must be mixture of ice and water at 0°C .

Let m gm of ice melts.

$$100 \times \frac{1}{2} \times 15 + m.L. = 250 \times 1 \times 25$$

$$m.L = 6250 - 750 = 5500$$

$$m = \frac{5500}{80} \text{ gm}$$

$$\text{Final ice} = \left(100 - \frac{5500}{80}\right) \text{ gm} = \frac{125}{4} \text{ gm}$$

$$\text{Final amount of water} = \left(250 + \frac{5500}{80}\right) \text{ gm} = \frac{1275}{4} \text{ gm.}$$

12. A flow calorimeter is used to measure the specific heat of a liquid. Heat is added at a known rate to a stream of the liquid as it passes through the calorimeter at a known rate. Then a measurement of the resulting temperature difference between the inflow and the outflow points of the liquid stream enables us to compute the specific heat of the liquid. A liquid of density 0.2 g/cm^3 flows through a calorimeter at the rate of $10 \text{ cm}^3/\text{s}$. Heat is added by means of a 250-W electric heating coil, and a temperature difference of 25°C is established in steady-state conditions between the inflow and the outflow points. Find the specific heat of the liquid.

Ans. $5000 \text{ J/}^\circ\text{C kg}$

Sol. $P = RPS_\ell(T_2 - T_1) = RPS_\ell \Delta T$

$$R = 10 \text{ cm}^3/\text{s}, \quad P = 250 \text{ W}$$

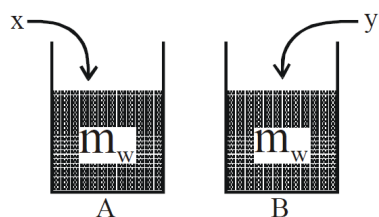
$$r = 0.2 \text{ g/cm}^3$$

$$\Delta T = 25$$

13. Two identical calorimeter A and B contain equal quantity of water at 20°C . A 5 gm piece of metal X of specific heat $0.2 \text{ cal g}^{-1} (^\circ\text{C})^{-1}$ is dropped into A and a 5 gm piece of metal Y into B. The equilibrium temperature in A is 22°C and in B 23°C . The initial temperature of both the metals is 40°C . Find the specific heat of metal Y in $\text{cal g}^{-1} (^\circ\text{C})^{-1}$.

Ans. $27/85$

Sol.



For (A)

$$m_w S_w (22 - 20) = 5 S_x (40 - 22) \quad \dots(i)$$

For (B)

$$m_w S_w (23 - 20) = 5 S_y (40 - 23) \quad \dots(ii)$$

$$\frac{\text{equation(ii)}}{\text{equation(i)}} \Rightarrow \frac{3}{2} = \frac{S_y}{S_x} \frac{17}{13} \Rightarrow S_y = \frac{27}{85}$$

14. The temperature of 100 gm of water is to be raised from 24°C to 90°C by adding steam to it. Calculate the mass of the steam required for this purpose.

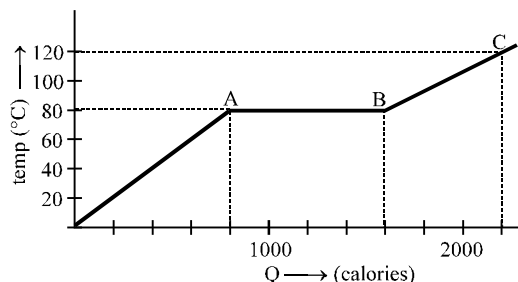
Ans. 12 gm

Sol. $100 S_w (90 - 24) = m_s L_v + m_s S_w (100 - 90)$

$$100 \times 1 \times 66 = m_s \times 540 + m_s \times 1 \times 10$$

$$m_s = 12 \text{ gm}$$

15. A substance is in the solid form at 0°C . The amount of heat added to this substance and its temperature are plotted in the following graph. If the relative specific heat capacity of the solid substance is 0.5, find from the graph



- (i) the mass of the substance;
(ii) the specific latent heat of the melting process, and
(iii) the specific heat of the substance in the liquid state.

Ans. (i) 0.02kg, (ii) 40,000 cal kg⁻¹, (iii) 750 cal kg⁻¹K⁻¹

Sol. (i) $Q = ms\Delta T$

$$m = \frac{Q}{s\Delta T} = \frac{800}{0.5 \times 80} = 20 \text{ gm} = 0.02 \text{ kg}$$

$$(ii) \quad L = \frac{800 \text{ cal}}{20 \text{ gm}} = 40 \frac{\text{cal}}{\text{gm}} = 40,000 \frac{\text{cal}}{\text{kg}}$$

$$(iii) \quad \Delta Q = mS_L\Delta T$$

$$600 = 0.02 \times S_L \times 40$$

$$S_L = 750 \frac{\text{cal}}{\text{kg} \cdot \text{K}}$$

16. A vessel containing 100 gm water at 0°C is suspended in the middle of a room. In 15 minutes the temperature of the water rises by 2°C. When an equal amount of ice is placed in the vessel, it melts in 10 hours. Calculate the specific heat of fusion of ice.

Ans. 80 k cal/kg

Sol. $\frac{d\theta}{dt} = e\sigma A(T^4 - T_s^4) = ms \frac{dT}{dt}$

HCV Exercises (Chapter No.25- {2,4,5,6,8,10,11,13,15,17,18})

HCV Worked out Examples(Chapter No.23 - {3,6,8,10,12,13,14,16})

17. 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 3 L, determine the average coefficient of linear expansion of the composite rod.

Ans. $5\alpha/3$

Sol. $L \alpha \Delta T + (2L)(2\alpha)\Delta T = 3L\alpha'\Delta T$

$$\alpha' = \frac{5}{3}\alpha$$

18. A clock pendulum made of invar has a period of 0.5 sec at 20°C. If the clock is used in a climate where average temperature is 30°C, approximately. How much fast or slow will the clock run in 10⁶sec. ($\alpha_{\text{invar}} = 1 \times 10^{-6}/^\circ\text{C}$)

Ans. 5 sec. slow

Sol. $T = 2\pi \sqrt{\frac{\ell}{g}}$

$$\frac{\Delta T}{T} = \frac{1}{2} \frac{\Delta \ell}{\ell}$$

$$\frac{\Delta T}{T} = \frac{1}{2} \alpha \Delta \theta = \text{time (lost/gained) per sec}$$

- 19.** A U-tube filled with a liquid of volumetric coefficient of $10^{-5}/^{\circ}\text{C}$ lies in a vertical plane. The height of liquid column in the left vertical limb is 100 cm. The liquid in the left vertical limb is maintained at a temperature $= 0^{\circ}\text{C}$ while the liquid in the right limb is maintained at a temperature $= 100^{\circ}\text{C}$. Find the difference in levels in the two limbs.

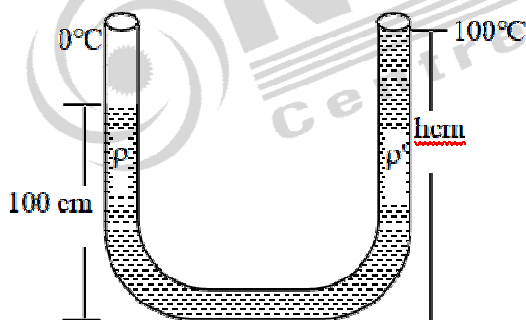
Ans. 0.1 cm

Sol. $\rho' = \frac{\rho}{1 + \gamma \Delta T}$

$$\rho' \cdot g \cdot 100 \text{ cm} = \frac{\rho}{(1 + \gamma \Delta T)} \cdot g \cdot h \text{ cm}$$

$$h = 100(1 + \gamma \Delta T)$$

$$\begin{aligned} \text{Height difference} &= (h - 100) \text{ cm} \\ &= 100 \gamma \Delta T \\ &= 100 \times 10^{-5} \times 100 = 0.1 \text{ cm} \end{aligned}$$



HCV Exercises (Chapter No.23- {8,10,12,14,17,19,21,23,27,30,31,32,33,34})

HCV Worked out Examples(Chapter No.28 - {2,3,6,8,10,12,16,18,19,20})

- 20.** A solid receives heat by radiation over its surface at the rate of 4 kW. The heat convection rate from the surface of solid to the surrounding is 5.2 kW, and heat is generated at a rate of 1.7 kW over the volume of the solid. The rate of change of the average temperature of the solid is $0.5^{\circ}\text{C s}^{-1}$. Find the heat capacity of the solid.

Ans. $1000 \text{ J } (^{\circ}\text{C})^{-1}$

Sol. $\frac{d\theta}{dt} = ms \frac{dT}{dt}$

ms = Heat capacity

$$\frac{d\theta}{dt} = (4 + 1.7 - 5.2)kW$$

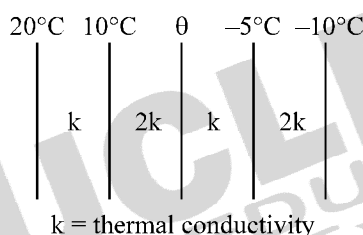
$$\frac{dT}{dt} = 0.5Cs^{-1}$$

21. A thin walled metal tank of surface area $5m^2$ is filled with water and contains an immersion heater dissipating 1 kW. The tank is covered with 4 cm thick layer of insulation whose thermal conductivity is 0.2 W/m/K. The outer face of the insulation is $25^\circ C$. Find the temperature of the tank in the steady state

Ans. $65^\circ C$

Sol. $\frac{dQ}{dt} = \frac{kA}{\ell} \Delta T$

22. The figure shows the face and interface temperature of a composite slab containing of four layers of two materials having identical thickness. Under steady state condition, find the value of temperature θ .



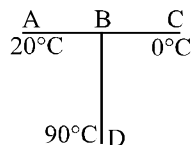
Ans. $5^\circ C$

Sol. $\frac{dQ}{dt} = \text{const. at steady state}$

$$\frac{kA}{\ell} (20 - 10) = \frac{2kA}{\ell} (10 - \theta)$$

$$\theta = 5^\circ C$$

23. Three conducting rods of same material and cross-section are shown in figure. Temperature of A, D and C are maintained at $20^\circ C$, $90^\circ C$ and $0^\circ C$. Find the ratio of length BD and BC if there is no heat flow in AB



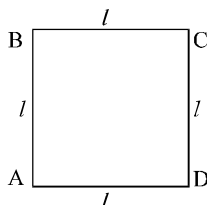
Ans. AB

Sol. Temp of B = $20^\circ C$

$$\frac{dQ}{dt} = \frac{kA}{\ell_{BD}} (90 - 20) = \frac{kA}{\ell_{BC}} (20 - 0)$$

$$\frac{\ell_{BD}}{\ell_{BC}} = \frac{7}{2}$$

24. In the square frame of side l of metallic rods, the corners A and C are maintained at T_1 and T_2 respectively. The rate of heat flow from A to C is ω . If A and D are instead maintained T_1 & T_2 respectively find, find the total rate of heat flow.



Ans. $(4/3) \omega$

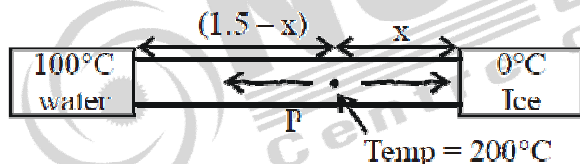
Sol. $\frac{dQ}{dt} = \omega = \frac{(T_1 - T_2)}{(R_{th})_{eq}}$

$$R_1 = R_2 = R_3 = R_4 = \frac{l}{kA} = R$$

25. One end of copper rod of uniform cross-section and of length 1.5 meters is in contact with melting ice and the other end with boiling water. At what point along its length should a temperature of 200°C be maintained, so that in steady state, the mass of ice melting is equal to that of steam produced in the same interval of time? Assume that the whole system is insulated from the surroundings.

Ans. 10.34 cm

Sol.



$$\frac{kA}{x} (200^\circ - 0^\circ) = 80 \left(\frac{dm}{dt} \right)_{ice} \quad \dots(i)$$

$$\frac{kA}{(1.5 - x)} (200^\circ - 100^\circ) = 540 \left(\frac{dm}{dt} \right)_{vapour} \quad \dots(ii)$$

$$\left(\frac{dm}{dt} \right)_{ice} = \left(\frac{dm}{dt} \right)_{vapour}$$

26. Two spheres of same radius R have their densities in the ratio $8 : 1$ and the ratio of their specific heats are $1 : 4$. If by radiation their rates of fall of temperature are same, then find the ratio of their rates of losing heat.

Ans. $2 : 1$

Sol. $\frac{dQ}{dt} = e\sigma A (T^4 - T_s^4) = ms \frac{dT}{dt}$

$$\frac{\left(\frac{dQ}{dt}\right)_1}{\left(\frac{dQ}{dt}\right)_2} = \frac{(\rho_1 V) S_1}{(\rho_2 V) S_2} = \frac{\rho_1 S_1}{\rho_2 S_2} = \frac{8}{1} \times \frac{1}{4} = 2$$

as $\frac{dT}{dt}$ = same

27. A solid copper cube and sphere, both of same mass & emissivity are heated to same initial temperature and kept under identical conditions. What is the ratio of their initial rate of fall of temperature?

Ans. $\left(\frac{6}{\pi}\right)^{1/3}$

Sol. $m \rightarrow$ same
 $e \rightarrow$ same
 $\rho \rightarrow$ same
 $\Rightarrow$ volume same

$$\frac{4}{3}\pi R^3 = a^3 \Rightarrow a = \left(\frac{4}{3}\pi\right)^{1/3} R \quad \dots(i)$$

$$(4\pi R^2)R = 6a^2\left(\frac{a}{2}\right) \text{ from (i)}$$

$$\frac{dT}{dt} \propto A$$

$$\frac{\left(\frac{dT}{dt}\right)_{\text{cube}}}{\left(\frac{dT}{dt}\right)_{\text{sphere}}} = \frac{A_1}{A_2} = \frac{6a^2}{4\pi R^2} = \frac{2R}{a} = \left(\frac{6}{\pi}\right)^{1/3}$$

28. The maximum in the energy distribution spectrum of the sun is at $4753 \text{ \AA}$ and its temperature is 6050 K . What will be the temperature of the star whose energy distribution shows a maximum at $9506 \text{ \AA}$.

Ans. 3025 K

Sol. $\lambda_m T = \text{constant}$

29. A pan filled with hot food cools from 50.1°C to 49.9°C in 5 sec. How long will it take to cool from 40.1°C to 39.9°C if room temperature is 30°C ?

Ans. 10 sec.

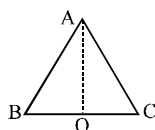
Sol. $\frac{(T_2 - T_1)}{t} = k \left[\frac{T_1 + T_2}{2} - T_s \right]$

HCV Exercises (Chapter No.28 - {2,4,6,9,13,16,18,20,22,23,26,30-33,36,42,44,46,48,50,53,54,55})

EXERCISE # (S-2)

1. Three aluminium rods of equal length form an equilateral triangle ABC. Taking O (mid point of rod BC) as the origin. Find the increase in Y-coordinate of center of mass per unit change in temperature of the system. Assume the length of the each rod is 2m, and

$$\alpha_{al} = 4\sqrt{3} \times 10^{-6} / ^\circ\text{C}$$



Ans. $4 \times 10^{-6} \text{ m}/^\circ\text{C}$

Sol.
$$\Delta y = \frac{1}{3} \left(\frac{\sqrt{3}}{2} \ell \right) \alpha \Delta \theta$$

$$\frac{\Delta y}{\Delta \theta} = \frac{1}{3} \left(\frac{\sqrt{3}}{2} \ell \right) \alpha$$

2. A metal rod A of 25cm lengths expands by 0.050cm. When its temperature is raised from 0°C to 100°C . Another rod B of a different metal of length 40cm expands by 0.040 cm for the same rise in temperature. A third rod C of 50cm length is made up of pieces of rods A and B placed end to end expands by 0.03 cm on heating from 0°C to 50°C . Find the lengths of each portion of the composite rod.

Ans. 10cm , 40cm

Sol. $25\alpha_1 \times 100 = 0.05$

$$40\alpha_2 \times 100 = 0.04$$

$$(\ell_1\alpha_1 + \ell_2\alpha_2) \times 50 = 0.03$$

$$\ell_1 + \ell_2 = 50$$

3. A wire of cross-sectional area $4 \times 10^{-4} \text{ m}^2$ modulus of elasticity $2 \times 10^{11} \text{ N/m}^2$ and length 1 m is stretched between two vertical rigid poles. A mass of 1 kg is suspended at its middle. Calculate the angle it makes with the horizontal.

Ans. $1/200 \text{ rad}$



$$2T \sin \theta = mg$$

$$T = \frac{mg}{2 \sin \theta} \quad \dots(i)$$

$$\frac{T}{A} = Y \frac{\Delta \ell}{\ell} \quad \dots(ii)$$

$$\cos \theta = \frac{\ell/2}{x} \Rightarrow x = \frac{\ell}{2} \sec \theta \quad \dots(iii)$$

$$\Delta \ell = 2x - \ell \quad \dots(iv)$$

4. A copper calorimeter of mass 100 gm contains 200 gm of a mixture of ice and water. Steam at 100°C under normal pressure is passed into the calorimeter and the temperature of the mixture is allowed to rise to 50°C . If the mass of the calorimeter and its contents is now 330 gm, what was the ratio of ice and water in the beginning? Neglect heat losses.

Given : Specific heat capacity of copper = $0.42 \times 10^3 \text{ J kg}^{-1}\text{K}^{-1}$,

Specific heat capacity of water = $4.2 \times 10^3 \text{ J kg}^{-1}\text{K}^{-1}$,

Specific heat of fusion of ice = $3.36 \times 10^5 \text{ J kg}^{-1}$

Latent heat of condensation of steam = $22.5 \times 10^5 \text{ J kg}^{-1}$

Ans. 1 : 1.26

Sol. Let ice = x gm

water = $(200 - x)$ gm

Heat lost = Heat gain

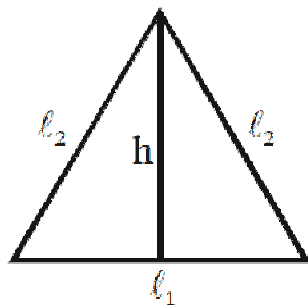
$$\frac{30}{1000} (22.5 \times 10^5) + \frac{30}{1000} \times 50 \times 4200 = \frac{200}{1000} \times 50 \times 4200 + \frac{100}{1000} \times 50 \times 420 + \frac{x}{10000} \times (3.36 \times 10^5)$$

5. An isosceles triangle is formed with a rod of length l_1 and coefficient of linear expansion α_1 for the base and two thin rods each of length l_2 and coefficient of linear expansion α_2 for the two pieces, if the distance between the apex and the midpoint of the base remain unchanged as the

temperatures varied show that $\frac{l_1}{l_2} = 2 \sqrt{\frac{\alpha_2}{\alpha_1}}$.

Ans.

Sol.



$$\ell_2^2 = h^2 + \frac{\ell_1^2}{4}$$

$$2\ell_2 d\ell_2 = \frac{\ell_1}{2} d\ell_1 \quad \dots(i)$$

Put $d\ell_2 = \ell_2 \alpha_2 \Delta\theta$ & $d\ell_1 = \ell_1 \alpha_1 \Delta\theta$ in equation (i)

6. A steel drill making 180 rpm is used to drill a hole in a block of steel. The mass of the steel block and the drill is 180 gm. If the entire mechanical work is used up in producing heat and the rate of raise in temperature of the block and the drill is 0.5°C/s . Find

- (a) the rate of working of the drill in watts, and
(b) the torque required to drive the drill.

Specific heat of steel = 0.1 and $J = 4.2 \text{ J/cal}$. Use : $P = \tau \omega$

Ans. (a) 37.8 J/s (Watts), (b) 2.005 N-m

Sol. (a) $P = ms \frac{dT}{dt} = 180 \times 0.1 \times 4.2 \times 0.5 = 37.8 \text{ J/s}$

- (b) 1 min $\rightarrow$ 180 revolutions
1 sec $\rightarrow$ 3 revolution
 $\omega = 2\pi(3) = 6\pi \text{ rad/sec}$
 $\tau = P/\omega$

7. Ice at -20°C is filled upto height $h = 10 \text{ cm}$ in a uniform cylindrical vessel. Water at temperature $\theta^\circ\text{C}$ is filled in another identical vessel upto the same height $h = 10 \text{ cm}$. Now, water from second vessel is poured into first vessel and it is found that level of upper surface falls through $\Delta h = 0.5 \text{ cm}$ when thermal equilibrium is reached. Neglecting thermal capacity of vessels, change in density of water due to change in temperature and loss of heat due to radiation, calculate initial temperature θ of water.

Given, Density of water, $\rho_w = 1 \text{ gm cm}^{-3}$
Density of ice, $\rho_i = 0.9 \text{ gm/cm}^3$
Specific heat of water, $s_w = 1 \text{ cal/gm}^\circ\text{C}$
Specific heat of ice, $s_i = 0.5 \text{ cal/gm}^\circ\text{C}$
Specific latent heat of ice, $L = 80 \text{ cal/gm}$

Ans. 45°C

Sol. Let 1cm ice converts to $h \text{ cm}$ water

Ice $\rightarrow$ Water

$$1 \times 0.9 = h \times 1$$

$$\Rightarrow h = 0.9 \text{ cm}$$

$$\Delta h = 0.1 \text{ m}$$

$$\text{so if Ice is } 10 \text{ cm} \Rightarrow \Delta h = 1 \text{ cm}$$

$$\text{so if Ice is } 5 \text{ cm} \Rightarrow \Delta h = 0.5 \text{ cm}$$

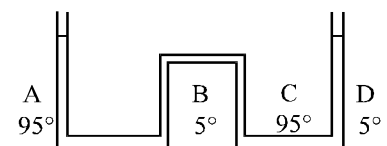
$$\text{final temperature} = 0^\circ\text{C}$$

Heat gain = Heat lost

$$(10 \times 0.9) \times (0.5) \times 20 + 80 \times 5 \times 0.9 = (1 \times 10) \times 1 \times \theta$$

$$\theta = 45^\circ\text{C}$$

8. The apparatus shown in the figure consists of four glass columns connected by horizontal sections. The height of two central columns B & C are 49 cm each. The two outer columns A & D are open to the atmosphere. A & C are maintained at a temperature of 95°C while the columns B & D are maintained at 5°C . The height of the liquid in A & D measured from the base line are 52.8 cm & 51 cm respectively. Determine the coefficient of thermal expansion of the liquid.



Ans. $2 \times 10^{-4} \text{ } ^\circ\text{C}$

Sol. Let ρ and ρ' be the densities of the liquid at 5°C and 95°C .

If h_A , h_B , h_C and h_D are the heights of liquid columns in A, B, C, D respectively.

Therefore,

$$h_A \rho' g - h_B \rho g = h_D \rho g - h_C \rho' g$$

$$52.8 \rho' - 49 \rho = 51 \rho - 49 \rho'$$

$$\rho' = \left(\frac{51 + 49}{52.8 + 49} \right) \rho \Rightarrow \rho' = \frac{100}{101.8} \rho$$

But we know

$$\rho' = \frac{\rho}{1 + \gamma \Delta T}$$

$$\frac{100}{101.8} \rho = \frac{\rho}{1 + \gamma \Delta T}$$

$$1 + \gamma \Delta T = \frac{101.8}{100} \Rightarrow \gamma = \frac{1.8}{100 \times 90} = 2 \times 10^{-4} / ^\circ\text{C}$$

9. Toluene liquid of volume 300 cm^3 at 0°C is contained in a beaker and another quantity of toluene of volume 110 cm^3 at 100°C is in another beaker. (The combined volume is 410 cm^3). Determine the total volume of the mixture of the toluene liquids when they are mixed together. Given the coefficient of volume expansion $\gamma = 0.001 / ^\circ\text{C}$ and all forms of heat losses can be ignored. Also find the final temperature of the mixture.

Ans. Decrease by 0.75 cm^3 , 25°C

Sol. Let the density at $0^\circ\text{C} = \rho_0$

$$\text{Density at } 100^\circ\text{C} = \frac{\rho_0}{1 + \gamma \Delta T} = \frac{\rho_0}{1.1}$$

$$\text{Density at temperature } T = \frac{\rho_0}{1 + \gamma \Delta T}$$

From heat transfer,

$$300\rho_0 S(T-0) = \frac{110\rho_0}{1.1} S(100-T)$$

$$300 T = 100 (100 - T)$$

$$400 T = 100 \times 100$$

$$\Rightarrow T = 25^\circ\text{C}$$

Now from the expansion and contraction we have

$$V = V_{0_1}(1 + \alpha \Delta T_1) + V_{0_2}(1 + \alpha \Delta T_2)$$

$$V = V_{0_1} + V_{0_2}$$

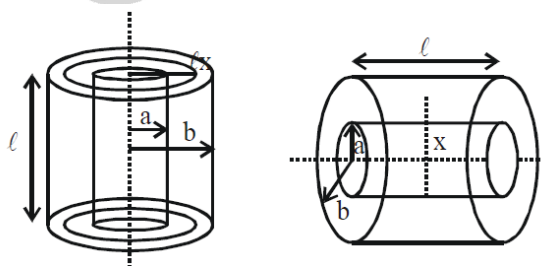
$$\begin{aligned} \Rightarrow V - V_0 &= \Delta V = V_{0_1} \alpha \Delta T_1 + V_{0_2} \alpha \Delta T_2 \\ &= 300 \times 0.001 \times 25 + 110 \times 0.001 \times (-75) \\ &= -0.75 \text{ cm}^3 \end{aligned}$$

So, the volume is decreased by 0.75 cm^3 .

10. A highly conducting solid cylinder of radius a and length l is surrounded by a co-axial layer of a material having thermal conductivity K and negligible heat capacity. Temperature of surrounding space (out side the layer) is T_0 , which is higher than temperature of the cylinder. If heat capacity per unit volume of cylinder material is s and outer radius of the layer is b , calculate time required to increase temperature of the cylinder from T_1 to T_2 . Assume end faces to be thermally insulated.

Ans. $\frac{a^2 s}{2K} \log_e \left(\frac{b}{a} \right) \log_e \left(\frac{T_0 - T_1}{T_0 - T_2} \right)$

Sol.



take element of width dx at a radial distance x from axis of cylinder

$$H = k2\pi x \ell \frac{dT}{dx}$$

$$H \int_a^b \frac{dx}{x} = k2\pi \ell \int_T^{T_0} dT$$

$$H \ell \ln \frac{b}{a} = k 2 \pi \ell (T_0 - T) \quad \dots(i)$$

$$H = S \left(\pi a^2 \ell \right) \frac{dT}{dt} \quad \dots(ii)$$

from (i) & (ii)

$$S \pi a^2 \ell \int_{T_1}^{T_2} \frac{dT}{(T_0 - T)} = \frac{k 2 \pi \ell}{\ell \ln \left(\frac{b}{a} \right)} \int_0^t dt$$

$$t = \frac{a^2 s}{2k} \ln \left(\frac{b}{a} \right) \ln \left(\frac{T_0 - T_1}{T_0 - T_2} \right)$$

11. A vertical brick duct (tube) is filled with cast iron. The lower end of the duct is maintained at a temperature T_1 which is greater than the melting point T_m of cast iron and the upper end at a temperature T_2 which is less than the temperature of the melting point of cast iron. It is given that the conductivity of liquid cast iron is equal to k times the conductivity of solid cast iron. Determine the fraction of the duct filled with molten metal.

Ans. $\frac{l_1}{l} = \frac{k(T_1 - T_m)}{k(T_1 - T_m) + (T_m - T_2)}$

12. A lagged stick of cross section area 1 cm^2 and length 1 m is initially at a temperature of 0°C . It is then kept between 2 reservoirs of temperature 100°C and 0°C . Specific heat capacity is $10 \text{ J/kg}^\circ\text{C}$ and linear mass density is 2 kg/m . Find



- (a) temperature gradient along the rod in steady state.
(b) total heat absorbed by the rod to reach steady state.

Ans. (a) -100°C/m , (b) 1000 J

Sol. (i) Temperature gradient $= \frac{(T_2 - T_1)}{1} = \frac{(0 - 100)}{1} = -100^\circ\text{C/m}$

(ii) Steady state temp of element dx is $= T = 100(1 - x)$

Heat absorbed by the element to reach steady state is dQ

$$dQ = (dm)s\Delta T = (\lambda dx)s(T - 0)$$

$$\Rightarrow dQ = 20[100(1 - x)]dx$$

Total heat absorbed by the rod

$$Q = \int dQ = 2000 \int_0^1 (1 - x)dx = 1000 \text{ J}$$

13. A cylindrical block of length 0.4 m and an area of cross-section 0.04m^2 is placed coaxially on a thin metal disc of mass 0.4 kg and of the same cross-section. The upper face of the cylinder is maintained at a constant temperature of 400K and the initial temperature of the disc is 300K. If the thermal conductivity of the material of the cylinder is 10 watt/m-K and the specific heat of the material of the disc is 600 J/kg-K, how long will it take for the temperature of the disc to increase to 350K? Assume, for purposes of calculation, the thermal conductivity of the disc to be very high and the system to be thermally insulated except for the upper face of the cylinder.

Ans. 166.3 sec

Sol. θ = temp of disc

θ_0 = constant temp

$$\text{Heat input to disc} = \frac{kA(\theta_0 - \theta)}{L}$$

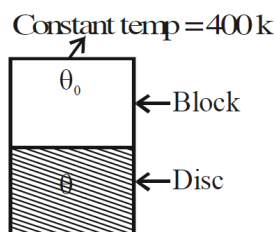
$$\text{Heat utilised by disc} = ms \frac{d\theta}{dt}$$

S = Specific heat of disc

$$ms \frac{d\theta}{dt} = \frac{kA(\theta_0 - \theta)}{L}$$

$$\Rightarrow \int_{300}^{350} \frac{d\theta}{(\theta_0 - \theta)} = \frac{kA}{msL} \int_0^t dt$$

$$\Rightarrow t = \frac{msL}{kA} \ln \left(\frac{\theta_0 - 300}{\theta_0 - 350} \right) = 166.32 \text{ sec}$$



14. A liquid takes 5 minutes to cool from 80°C to 50°C . How much time will it take to cool from 60°C to 30°C ? The temperature of surrounding is 20°C . Use exact method.

Ans. 10 Min.

Sol. $-\frac{d\theta}{dt} = k(\theta - \theta_0)$

$$\int_{80}^{50} \frac{d\theta}{\theta - \theta_0} = -k \int_0^5 dt$$

$$\ln \frac{50 - 20}{80 - 20} = -5k$$

$$k = -\frac{\ln \left(\frac{1}{2} \right)}{5} \quad \dots(i)$$

$$\text{then } \int_{60}^{30} \frac{d\theta}{(\theta - 20)} = \frac{\ln \left(\frac{1}{2} \right)}{5} \times t$$

$$\ln \frac{30-20}{60-20} = \frac{\ln\left(\frac{1}{2}\right)}{5} t$$

$$5 \ln\left(\frac{1}{4}\right) = \ln\left(\frac{1}{2}\right) t$$

$$5 \ln\left(\frac{1}{2}\right)^2 = \ln\left(\frac{1}{2}\right) t \Rightarrow t = 10 \text{ min}$$

EXERCISE # (O-1)

1. The maximum load a wire can withstand without breaking, when its length is reduced to half of its original length, will

(A) be double. (B) be half. (C) be four times. (D) remain same.

Ans. D

Sol. Stress is same

2. The temperature of a wire is doubled. The Young's modulus of elasticity

(A) will also double. (B) will become four times.
(C) will remain same. (D) will decrease.

Ans. D

Sol. $Y \propto \frac{1}{\Delta \ell} \propto \frac{1}{\Delta T}$

3. A spring is stretched by applying a load to its free end. The strain produced in the spring is

(A) volumetric. (B) shear.
(C) longitudinal and shear. (D) longitudinal.

Ans. C

Sol. When load is attached to a spring its shape and length both changes. Change in length correspond to longitudinal strain, where change in shape corresponds to shear strain.

4. Overall changes in volume and radii of a uniform cylindrical steel wire are 0.2% and 0.002% respectively when subjected to some suitable force. Longitudinal tensile stress acting on the wire is ($Y = 2.0 \times 10^{11} \text{ Nm}^{-2}$)

(A) $3.2 \times 10^9 \text{ Nm}^{-2}$ (B) $3.2 \times 10^7 \text{ Nm}^{-2}$ (C) $3.6 \times 10^9 \text{ Nm}^{-2}$ (D) $3.9 \times 10^8 \text{ Nm}^{-2}$

Ans. D

Sol. $V = \pi r^2 \ell$

$$\frac{\Delta V}{V} \times 100 = 2 \frac{\Delta r}{r} \times 100 + \frac{\Delta \ell}{\ell} \times 100$$

$$\text{stress} = Y \frac{\Delta \ell}{\ell}$$

5. A solid sphere of radius R made of material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. When a

mass m is placed on the piston to compress the liquid, the fractional change in the radius of the sphere $\delta R/R$ is

- (A) mg/AK (B) $mg/3AK$ (C) mg/A (D) $mg/3AR$

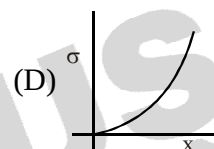
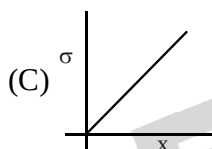
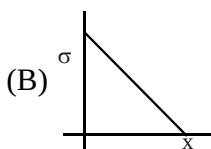
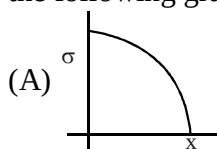
Ans. B

Sol. $V = \frac{4}{3}\pi R^3$

$$\frac{\Delta V}{V} = 3 \frac{\Delta R}{R}$$

$$B = K = \frac{P}{\Delta V/V} \Rightarrow \frac{\Delta V}{V} = \frac{mg}{AK} = \frac{3\Delta R}{R}$$

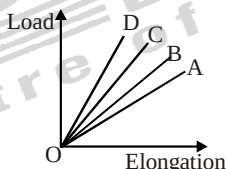
6. A uniform rod rotating in gravity free region with certain constant angular velocity. The variation of tensile stress with distance x from axis of rotation is best represented by which of the following graphs.



Ans. A

Sol. $\sigma \propto T \propto (L^2 - x^2)$

7. The load versus strain graph for four wires of the same material is shown in the figure. The thickest wire is represented by the line



(A) OB

(B) OA

(C) OD

(D) OC

Ans. C

Sol. $Y = \frac{W/A}{\Delta \ell / \ell}$

$$\frac{W}{\Delta \ell} = \frac{YA}{\ell}$$

Slope $\propto A$

8. Heat is associated with
(A) kinetic energy of random motion of molecules.
(B) kinetic energy of orderly motion of molecules.
(C) total kinetic energy of random and orderly motion of molecules.
(D) kinetic energy of random motion in some cases and kinetic energy of orderly motion in other.

Ans. A

Sol. Kinetic energy of random motion of molecules.

9. Equal amount of heat energy are transferred into equal mass of ethyl alcohol and water sample. The rise in temperature of water sample is 25°C . The temperature rise of ethyl alcohol will be. (Specific heat of ethyl alcohol is one half of the specific heat of water).

(A) 12.5°C (B) 25°C
(C) 50°C (D) It depends on the rate of energy transfer.

Ans. C

Sol. $\Delta Q = mS_1\Delta T_1 = mS_2\Delta T_2$

10. A block of mass 2.5 kg is heated to temperature of 500°C and placed on a large ice block. What is the maximum amount of ice that can melt (approx.). Specific heat for the body = $0.1 \text{ Cal/gm}^{\circ}\text{C}$.

(A) 1 kg (B) 1.5 kg (C) 2 kg (D) 2.5 kg

Ans. B

Sol. $m_{\text{ice}}L_f = m_bS_b\Delta T$

11. 10 gm of ice at 0°C is kept in a calorimeter of water equivalent 10 gm. How much heat should be supplied to the apparatus to evaporate the water thus formed? (Neglect loss of heat)

(A) 6200 cal (B) 7200 cal (C) 13600 cal (D) 8200 cal

Ans. D

Sol. $Q = 10 \times 30 + 20 \times 1 \times 100 + 10 \times 540 = 8200$

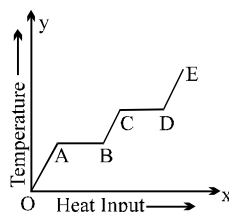
12. A continuous flow water heater (geyser) has an electrical power rating = 2 kW and efficiency of conversion of electrical power into heat = 80%. If water is flowing through the device at the rate of 100 cc/sec, and the inlet temperature is 10°C , the outlet temperature will be

(A) 12.2°C (B) 13.8°C (C) 20°C (D) 16.5°C

Ans. B

Sol. $\frac{dQ}{dt} = 2 \times 10^3 \times \frac{80}{100} = \rho \left(\frac{\Delta V}{\Delta t} \right) S \Delta T$

13. A solid material is supplied with heat at a constant rate. The temperature of material is changing with heat input as shown in the figure. What does slope DE represents?



(A) latent heat of liquid (B) latent heat of vapour
(C) heat capacity of vapour (D) inverse of heat capacity of vapour

Ans. D

Sol. $\Delta Q = mS\Delta T$

$$\frac{\Delta T}{\Delta Q} = \frac{1}{mS} = \frac{1}{\text{Heat capacity}}$$

14. A block of ice with mass m falls into a lake. After impact, a mass of ice $m/5$ melts. Both the block of ice and the lake have a temperature of 0°C . If L represents the heat of fusion, the minimum distance the ice fell before striking the surface is

(A) $\frac{L}{5g}$ (B) $\frac{5L}{g}$ (C) $\frac{gL}{5m}$ (D) $\frac{mL}{5g}$

Ans. A

Sol. $mgh = \frac{m}{5}L$

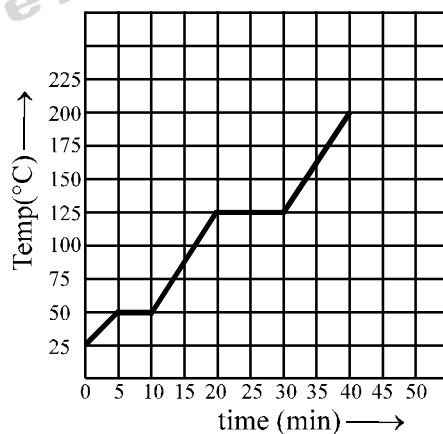
15. The specific heat of a metal at low temperatures varies according to $S = aT^3$ where a is a constant and T is the absolute temperature. The heat energy needed to raise unit mass of the metal from $T = 1\text{ K}$ to $T = 2\text{ K}$ is

(A) $3a$ (B) $\frac{15a}{4}$ (C) $\frac{2a}{3}$ (D) $\frac{12a}{5}$

Ans. B

Sol. $Q = \int dQ = \int_{T=1K}^{T=2K} msdT$

16. The graph shown in the figure represent change in the temperature of 5 kg of a substance as it absorbs heat at a constant rate of 42 kJ min^{-1} . The latent heat of vapourisation of the substance is :



(A) 630 kJ kg^{-1} (B) 126 kJ kg^{-1} (C) 84 kJ kg^{-1} (D) 12.6 kJ kg^{-1}

Ans. C

Sol. $(5\text{kg}) \times L = 42 \frac{\text{KJ}}{\text{min}} \times (10\text{ min})$

17. The density of a material A is 1500 kg/m^3 and that of another material B is 2000 kg/m^3 . It is found that the heat capacity of 8 volumes of A is equal to heat capacity of 12 volumes of B. The ratio of specific heats of A and B will be

(A) 1 : 2 (B) 3 : 1 (C) 3 : 2 (D) 2 : 1

Ans. D

Sol. $m_A S_A = m_B S_B$

$$m = \rho V$$

18. Some steam at 100°C is passed into 1.1 kg of water contained in a calorimeter of water equivalent 0.02 kg at 15°C so that the temperature of the calorimeter and its contents rises to 80°C . What is the mass of steam condensing. (in kg)

(A) 0.130 (B) 0.065 (C) 0.260 (D) 0.135

Ans. A

Sol. Let m kg of steam condenses

$$1.12 \times 1 \times 65 = 540 \times m + m \times 1 \times 20$$

$$\text{Heat gain} = \text{Heat lost}$$

19. A black body calorimeter filled with hot water cools from 60°C to 50°C in 4 min and 40°C to 30°C in 8 min. The approximate temperature of surrounding is :

(A) 10°C (B) 15°C (C) 20°C (D) 25°C

Ans. B

Sol. $\frac{(T_1 - T_2)}{t} = k \left(\frac{T_1 + T_2}{2} - T_s \right)$

20. A system S receives heat continuously from an electrical heater of power 10W. The temperature of S becomes constant at 50°C when the surrounding temperature is 20°C . After the heater is switched off, S cools from 35.1°C to 34.9°C in 1 minute. The heat capacity of S is

(A) $100 \text{ J/}^\circ\text{C}$ (B) $300 \text{ J/}^\circ\text{C}$ (C) $750 \text{ J/}^\circ\text{C}$ (D) $1500 \text{ J/}^\circ\text{C}$

Ans. D

Sol. $10 = k(50 - 20)$ (i)

$$\frac{0.2}{60} = \frac{k}{ms} (35 - 20) \quad \text{....(ii)}$$

from (i) & (ii)

$$ms = \text{heat capacity} = 1500 \text{ J/sec}$$

21. The radius of a metal sphere at room temperature T is R, and the coefficient of linear expansion of the metal is α . The sphere is heated a little by so that its new temperature is $T + \Delta T$. The increase in the volume of the sphere is approximately

(A) $2\pi R \alpha \Delta T$ (B) $\pi R^2 \alpha \Delta T$ (C) $4\pi R^3 \alpha \Delta T$ (D) $4\pi R^3 \alpha \Delta T / 3$

Ans. C

Sol. $\Delta V = \gamma V \Delta T = (3\alpha) \frac{4}{3} \pi R^3 \Delta T = 4\pi R^3 \alpha \Delta T$

22. A hole is made in a metal plate, when the temperature of metal is raised then the diameter of the hole will
(A) Decrease
(B) Increase
(C) Remain same
(D) Answer depends upon the initial temperature of the metal

Ans. B

Sol. Isotropic photographic enlargement

23. A rod of length 2m rests on smooth horizontal floor. If the rod is heated from 0°C to 20°C. Find the longitudinal strain developed? ($\alpha = 5 \times 10^{-5}/^\circ\text{C}$)
(A) 10^{-3} (B) 2×10^{-3} (C) Zero (D) None

Ans. C

Sol. Zero

no stress $\Rightarrow$ no strain

24. A steel tape gives correct measurement at 20°C. A piece of wood is being measured with the steel tape at 0°C. The reading is 25 cm on the tape, the real length of the given piece of wood must be:
(A) 25 cm (B) < 25 cm (C) > 25 cm (D) can not say

Ans. B

Sol. Length of wood at 0°C = 25 cm

Length of wood at 25°C = 25 cm $(1 + \alpha \Delta T) > 25$ cm

(α = coefficient of thermal expansion of wood)

25. The bulk modulus of copper is 1.4×10^{11} Pa and the coefficient of linear expansion is $1.7 \times 10^{-5} (^\circ\text{C})^{-1}$. What hydrostatic pressure is necessary to prevent a copper block from expanding when its temperature is increased from 20°C to 30°C?
(A) 6.0×10^5 Pa (B) 7.1×10^7 Pa (C) 5.2×10^6 Pa (D) 40 atm

Ans. B

Sol. $B = \frac{P}{\Delta V / V} \Rightarrow P = B \frac{\Delta V}{V} \dots(i)$

$\frac{\Delta V}{V} = \gamma \Delta T = 3\alpha \Delta T \dots(ii)$

26. A thin copper wire of length L increase in length by 1% when heated from temperature T_1 to T_2 . What is the percentage change in area when a thin copper plate having dimensions $2L \times L$ is heated from T_1 to T_2 ?
(A) 1% (B) 2% (C) 3% (D) 4%

Ans. B

Sol. $A \propto L^2$

$$\frac{\Delta A}{A} \propto 2 \frac{\Delta L}{L}$$

27. A metallic rod 1 cm long with a square cross-section A is heated through $t^\circ\text{C}$. If Young's modulus of elasticity of the metal is E and the mean coefficient of linear expansion is α per degree Celsius, then the compressional force required to prevent the rod from expanding along its length is : (Neglect the change of cross-sectional area)

(A) $EA\alpha t$ (B) $EA\alpha t/(1 + \alpha t)$ (C) $EA\alpha t/(1 - \alpha t)$ (D) $E/\alpha t$

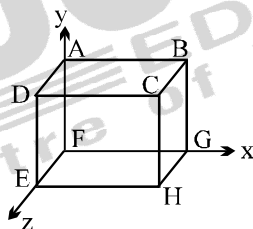
Ans. B

Sol. $E = \frac{f}{A} \cdot \frac{l_i}{\Delta l}$ $l_f = l_i + \Delta l = l_i (1 + \alpha \Delta T)$, $\Delta l = l_i \alpha \Delta T$

$$E = \frac{f}{A} \cdot \frac{l_i (1 + \alpha \Delta T)}{l_i \alpha \Delta T}$$

$$f = \frac{E_A \alpha \Delta T}{(1 + \alpha \Delta T)}$$

28. A cuboid ABCDEFGH is anisotropic with $\alpha_x = 1 \times 10^{-5}/^\circ\text{C}$, $\alpha_y = 2 \times 10^{-5}/^\circ\text{C}$, $\alpha_z = 3 \times 10^{-5}/^\circ\text{C}$. Coefficient of superficial expansion of faces can be



(A) $\beta_{ABCD} = 5 \times 10^{-5}/^\circ\text{C}$

(B) $\beta_{BCGH} = 4 \times 10^{-5}/^\circ\text{C}$

(C) $\beta_{CDEH} = 3 \times 10^{-5}/^\circ\text{C}$

(D) $\beta_{EFGH} = 2 \times 10^{-5}/^\circ\text{C}$

Ans. C

Sol. $\beta_{CDEH} = \alpha_x + \alpha_y$

29. The coefficient of apparent expansion of a liquid in a copper vessel is C and in a silver vessel is S. The coefficient of volume expansion of copper is γ_c . What is the coefficient of linear expansion of silver?

(A) $\frac{(C + \gamma_c + S)}{3}$

(B) $\frac{(C - \gamma_c + S)}{3}$

(C) $\frac{(C + \gamma_c - S)}{3}$

(D) $\frac{(C - \gamma_c - S)}{3}$

Ans. C

Sol. $C = \gamma_L - \gamma_C$ (i)

$S = \gamma_L - \gamma_S$ (ii)

$\gamma_S = 3\alpha_S$ (iii)

$$C + \gamma_C = S + \gamma_S$$

$$\gamma_s = \frac{C + \gamma_c - S}{3}$$

30. A thin walled cylindrical metal vessel of linear coefficient of expansion $10^{-3} \text{ } ^\circ\text{C}^{-1}$ contains benzene of volume expansion coefficient $10^{-3} \text{ } ^\circ\text{C}^{-1}$. If the vessel and its contents are now heated by 10°C , the pressure due to the liquid at the bottom.
(A) increases by 2% (B) decreases by 1% (C) decreases by 2% (D) remains unchanged

Ans. C

Sol. $\gamma_{\text{vessel}} = 3. \alpha_{\text{vessel}} = 3 \times 10^{-3}/^\circ\text{C}$

$$\gamma_{\text{liquid}} = 10^{-3}/^\circ\text{C}$$

When the liquid is heated, the level of liquid falls which will result in decrease of pressure.

Change in volume of liquid

$$\begin{aligned} \Delta V &= V (\gamma_{\text{vessel}} - \gamma_{\text{liquid}}) \Delta T \\ &= V \times 2 \times 10^{-3} \times 10 = 0.02 V \end{aligned}$$

$$\frac{\Delta V}{V} = 0.02$$

$$\frac{\Delta h}{h} = 0.02$$

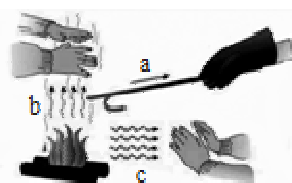
decrease in pressure in 2%.

31. An open vessel is filled completely with oil which has same coefficient of volume expansion as that of the vessel. On heating both oil and vessel,
(A) the vessel can contain more volume and more mass of oil
(B) the vessel can contain same volume and same mass of oil
(C) the vessel can contain same volume but more mass of oil
(D) the vessel can contain more volume but same mass of oil

Ans. D

Sol. Since the coefficient of expansion of both oil and vessel is same, as the temperature increases. Volume of both oil and vessel increases same amount without any overflow of oil. Hence more volume of oil is now being contained.

32. Diagram shows a heat source 'S' and three position of heat recover (hand). The main mode of heat transfer is given as 'a', 'b' & 'c'. Choose the correct matching



- (A) a-conduction ; b-convection ; c-radiation
(B) a-radiation ; b-conduction; c-convection
(C) a-convection ; b- conduction ; c- radiation

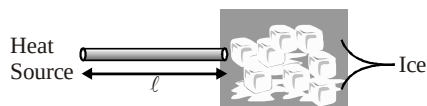
(D) a-conduction ; b-radiation ; c-convection

Ans. A

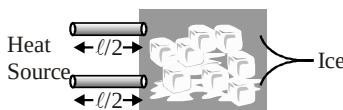
Sol. Clearly,

a → conduction, b → convection and c → radiation

33. A rod of length 'l' and cross-section 'A' is used to melt a piece of ice as shown.



Now if the rod broken into two equal parts and is arranged as shown.



Time taken to melt ice in second use becomes.

(A) Half

(B) One-fourth

(C) Twice

(D) Four times

Ans. B

Sol. $R_{(eq)_1} = \frac{\ell}{kA}$

$$R_{(eq)_2} = \frac{\ell}{4kA}$$

$$\frac{dm}{dt_1} L = \frac{\Delta T}{R_{(eq)_1}}$$

$$\frac{dm}{dt_2} L = \frac{\Delta T}{R_{(eq)_2}}$$

$$\frac{dt_2}{dt_1} = \frac{R_{(eq)_2}}{R_{(eq)_1}} = \frac{1}{4}$$

34. One end of a 2.35m long and 2.0cm radius aluminium rod ($K = 235 \text{ W. m}^{-1}\text{K}^{-1}$) is held at 20°C . The other end of the rod is in contact with a block of ice at its melting point. The rate in kg.s^{-1} at which ice melts is

[Take latent heat of fusion for ice as $\frac{10}{3} \times 10^5 \text{ J.kg}^{-1}$]

(A) $48\pi \times 10^{-6}$

(B) $24\pi \times 10^{-6}$

(C) $2.4\pi \times 10^{-6}$

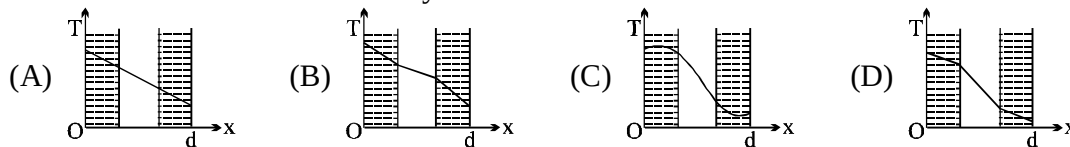
(D) $4.8\pi \times 10^{-6}$

Ans. C

Sol. $\left(\frac{dm}{dt}\right)_{\text{Ice}} \times L = \frac{\Delta T}{R}$

$$R = \frac{\ell}{kA}$$

35. The wall with a cavity consists of two layers of brick separated by a layer of air. All three layers have the same thickness and the thermal conductivity of the brick is much greater than that of air. The left layer is at a higher temperature than the right layer and steady state condition exists. Which of the following graphs predicts correctly the variation of temperature T with distance d inside the cavity?



Ans. D

Sol. $\frac{dQ}{dt} = kA \frac{dT}{dx}$

$$\frac{dT}{dx} \propto \frac{1}{kA} \Rightarrow \text{slope} \propto \frac{1}{k}$$

36. A wall has two layer A and B each made of different material, both the layers have the same thickness. The thermal conductivity of the material A is twice that of B. Under thermal equilibrium the temperature difference across the wall B is 36°C . The temperature difference across the wall A is

(A) 6°C (B) 12°C (C) 18°C (D) 72°C

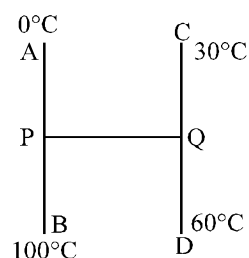
Ans. C

Sol. $\frac{dQ}{dt} = \frac{2kA}{\ell} \Delta T_A$

$$= \frac{kA}{\ell} \Delta T_B$$

37. Three identical rods AB, CD and PQ are joined as shown. P and Q are mid points of AB and CD respectively. Ends A, B, C and D are maintained at 0°C , 100°C , 30°C and 60°C respectively. The direction of heat flow in PQ is

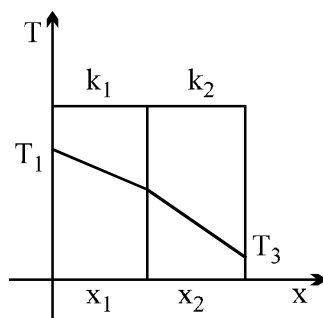
(A) from P to Q
(B) from Q to P
(C) heat does not flow in PQ
(D) data not sufficient



Ans. A

Sol. Apply kirchoff current law at P & Q to find temperature of P and Q.

38. The temperature drop through each layer of a two layer furnace wall is shown in figure. Assume that the external temperature T_1 and T_3 are maintained constant and $T_1 > T_3$. If the thickness of the layers x_1 and x_2 are the same, which of the following statements are correct.



- (A) $k_1 > k_2$
 (B) $k_1 < k_2$
 (C) $k_1 = k_2$ but heat flow through material (1) is larger than through (2)
 (D) $k_1 = k_2$ but heat flow through material (1) is less than that through (2)

Ans. A

Sol. Slope $\propto \frac{1}{k}$

39. A composite rod made of three rods of equal length and cross-section as shown in the fig. The thermal conductivities of the materials of the rods are $K/2$, $5K$ and K respectively. The end A and end B are at constant temperatures. All heat entering the face A goes out of the end B there being no loss of heat from the sides of the bar. The effective thermal conductivity of the bar is



- (A) $15K/16$ (B) $6K/13$ (C) $5K/16$ (D) $2K/13$.

Ans. A

Sol. $R_{eq} = R_1 + R_2 + R_3$

$$\frac{3L}{k_{eq}A} = \frac{2L}{kA} + \frac{L}{5kA} + \frac{L}{kA} \Rightarrow k_{eq} = \frac{15k}{16}$$

40. A black metal foil is warmed by radiation from a small sphere at temperature 'T' and at a distance 'd'. It is found that the power received by the foil is P. If both the temperature and distance are doubled, the power received by the foil will be :

- (A) 16 P (B) 4 P (C) 2 P (D) P

Ans. B

Sol. $P \propto \frac{T^4}{d^2}$

41. The rate of emission of radiation of a black body at 273°C is E , then the rate of emission of radiation of this body at 0°C will be

(A) $\frac{E}{16}$ (B) $\frac{E}{4}$ (C) $\frac{E}{8}$ (D) 0

Ans. A

Sol. $E = \sigma A(546)^4$ (i)
 $E_{0^{\circ}\text{C}} = \sigma A(273)^4$ (ii)

$$\frac{E}{E_{0^{\circ}\text{C}}} = 2^4 \Rightarrow E_{0^{\circ}\text{C}} = \frac{E}{16}$$

42. The power radiated by a black body is P and it radiates maximum energy around the wavelength λ_0 . If the temperature of the black body is now changed so that it radiates maximum energy around wavelength $3/4\lambda_0$, the power radiated by it will increase by a factor of
- (A) $4/3$ (B) $16/9$ (C) $64/27$ (D) $256/81$

Ans. D

Sol. $\lambda_0 T_0 = \frac{3}{4} \lambda_0 T_1 \Rightarrow T_1 = \frac{4}{3} T_0$ (i)

$P_0 = \sigma A T_0^4$ (ii)

$P_1 = \sigma A T_1^4$ (iii)

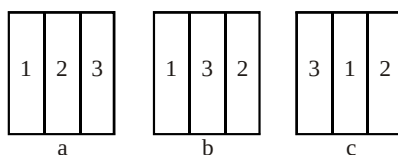
$$P_1 = \sigma A \left(\frac{4}{3} T_0 \right)^4$$

43. Spheres P and Q are uniformly constructed from the same material which is a good conductor of heat and the radius of Q is thrice the radius of P. The rate of fall of temperature of P is x times that of Q when both are at the same surface temperature. The value of x is :
- (A) $1/4$ (B) $1/3$ (C) 3 (D) 4

Ans. C

Sol. $\frac{dT}{dt} \propto \frac{A}{m} \propto \frac{A}{V} \propto \frac{1}{r}$

44. Figure shows three different arrangements of materials 1, 2 and 3 to form a wall. Thermal conductivities are $k_1 > k_2 > k_3$. The left side of the wall is 20°C higher than the right side. Temperature difference ΔT across the material 1 has following relation in three cases :



(A) $\Delta T_a > \Delta T_b > \Delta T_c$ (B) $\Delta T_a = \Delta T_b = \Delta T_c$ (C) $\Delta T_a = \Delta T_b > \Delta T_c$ (D) $\Delta T_a = \Delta T_b < \Delta T_c$

Ans. B

Sol. $\Delta T \propto \frac{1}{K}$

K same $\Rightarrow \Delta T$ same

MULTIPLE CORRECT TYPE QUESTIONS

45. A wire is suspended from the ceiling and stretched under the action of a weight F suspended from its other end. The force exerted by the ceiling on it is equal and opposite to the weight.

- (A) Tensile stress at any cross section A of the wire is F/A .
(B) Tensile stress at any cross section is zero.
(C) Tensile stress at any cross section A of the wire is $2F/A$.
(D) Tension at any cross section A of the wire is F.

Ans. AD

Sol. Stress = $\frac{F}{A}$

Tension = F

46. A copper and a steel wire of the same diameter are connected end to end. A deforming force F is applied to this composite wire which causes a total elongation of 1cm. The two wires will have

- (A) the same stress. (B) different stress. (C) the same strain. (D) different strain.

Ans. AD

Sol. Force same $\Rightarrow$ Stress same
as area is equal

$\Delta \ell_S \neq \Delta \ell_C$

47. A body of mass M is attached to the lower end of a metal wire, whose upper end is fixed. The elongation of the wire is l .

- (A) Loss in gravitational potential energy of M is Mgl
(B) The elastic potential energy stored in the wire is Mgl
(C) The elastic potential energy stored in the wire is $1/2 Mgl$
(D) Heat produced is $1/2 Mgl$.

Ans. ACD

Sol. $Wg = mg \cdot l$

$$U = \frac{1}{2} kx^2 = \frac{1}{2} mgl$$

$$Q = Wg - U = \frac{1}{2} mgl$$

48. Mark the CORRECT options:

- (A) A system X is in thermal equilibrium with Y but not with Z. System Y and Z may be in thermal equilibrium with each other.
 (B) A system X in the thermal equilibrium with Y but not with Z. Systems Y and Z are not in thermal equilibrium with each other.
 (C) A system X is neither in thermal equilibrium with Y nor with Z. The system Y and Z must be in thermal equilibrium with each other.
 (D) A system X is neither in thermal equilibrium with Y nor with Z. The system Y and Z may be in thermal equilibrium with each other.

Ans. BD

Sol. First law of thermodynamics.

49. When the temperature of a copper coin is raised by 80°C , its diameter increases by 0.2%.

- (A) Percentage rise in the area of a face is 0.4 %
 (B) Percentage rise in the thickness is 0.4 %
 (C) Percentage rise in the volume is 0.6 %
 (D) Coefficient of linear expansion of copper is $0.25 \times 10^{-4} \text{C}^{-1}$.

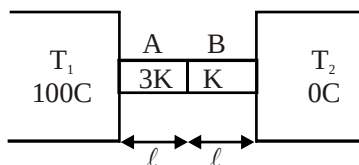
Ans. ACD

Sol. $\frac{\Delta A}{A} = \frac{2\Delta r}{r}$
 $\frac{\Delta V}{V} = \frac{3\Delta r}{r}$
 $\frac{\Delta r}{r} \times 100 = \alpha \Delta T \times 100$
 $0.2 = \alpha \times 80 \times 100$
 $\Rightarrow \alpha = 0.25 \times 10^{-4} \text{C}^{-1}$

COMPREHENSION BASED QUESTIONS

Paragraph for Question No. 50 to 52

Two rods A and B of same cross-sectional area A and length ℓ connected in series between a source ($T_1 = 100^\circ\text{C}$) and a sink ($T_2 = 0^\circ\text{C}$) as shown in figure. The rod is laterally insulated.



50. The ratio of thermal resistance of the rod is

(A) $\frac{R_A}{R_B} = \frac{1}{3}$ (B) $\frac{R_A}{R_B} = 3$ (C) $\frac{R_A}{R_B} = \frac{3}{4}$ (D) $\frac{R_A}{R_B} = \frac{4}{3}$

Ans. A

Sol. $R_A = \frac{L}{3kA} \Rightarrow R_B = \frac{L}{kA}$

51. If T_A and T_B are the temperature drop across the rod A and B then

(A) $\frac{T_A}{T_B} = \frac{1}{3}$ (B) $\frac{T_A}{T_B} = \frac{3}{1}$ (C) $\frac{T_A}{T_B} = \frac{3}{4}$ (D) $\frac{T_A}{T_B} = \frac{4}{3}$

Ans. A

Sol. $\frac{dQ}{dt} = \frac{T_A}{R_A} = \frac{T_B}{R_B} \Rightarrow \frac{T_A}{T_B} = \frac{R_A}{R_B}$

52. If G_A and G_B are the temperature gradients across the rod A and B then

(A) $\frac{G_A}{G_B} = \frac{1}{3}$ (B) $\frac{G_A}{G_B} = \frac{3}{1}$ (C) $\frac{G_A}{G_B} = \frac{3}{4}$ (D) $\frac{G_A}{G_B} = \frac{4}{3}$

Ans. A

Sol. $\frac{dQ}{dt} = 3kA \left(\frac{dT}{dx} \right)_A = kA \left(\frac{dT}{dx} \right)_B$
 $\left(\frac{dT}{dx} \right)_A = G_A \text{ \& } \left(\frac{dT}{dx} \right)_B = G_B$

EXERCISE # (O-2)

1. Consider two cylindrical rods of identical dimensions, one of rubber and the other of steel. Both the rods are fixed rigidly at one end to the roof. A mass M is attached to each of the free ends at the centre of the rods.

- (A) Both the rods will elongate but there shall be no perceptible change in shape.
 (B) The steel rod will elongate and change shape but the rubber rod will only elongate.
 (C) The steel rod will elongate without any perceptible change in shape, but the rubber rod will elongate and the shape of the bottom edge will change to an ellipse.
 (D) The steel rod will elongate, without any perceptible change in shape, but the rubber rod will elongate with the shape of the bottom edge tapered to a tip at the centre.

Ans. D

Sol. Due to different elastic properties of materials.

2. A cylindrical wire of radius 1 mm, length 1 m, Young's modulus = 2×10^{11} N/m², poisson's ratio $\mu = \pi/10$ is stretched by a force of 100 N. Its radius will become
(A) 0.99998 mm (B) 0.99999 mm (C) 0.99997 mm (D) 0.99995 mm

Ans. D

Sol.
$$\mu = -\frac{\Delta r / r}{\Delta \ell / \ell} \Rightarrow \frac{\Delta r}{r} = -\left(\frac{\pi}{10}\right) \times \frac{\Delta \ell}{\ell}$$

$$\frac{\Delta \ell}{\ell} = \frac{F}{AY}$$

$$\Delta r = -5 \times 10^{-5} \text{ mm}$$

$$r_f - r_i = -5 \times 10^{-5}$$

$$r_f = r_i - 0.00005$$

$$= 1 - 0.00005$$

$$= 0.99995 \text{ mm}$$

3. A thermally insulated vessel contains some water at 0°C. The vessel is connected to a vacuum pump to pump out water vapour. This results in some water getting frozen. It is given Latent heat of vaporization of water at 0°C = 21×10^5 J/kg and latent heat of freezing of water = 3.36×10^5 J/kg. The maximum percentage amount of water that will be solidified in this manner will be
(A) 86.2% (B) 33.6% (C) 21% (D) 24.36%

Ans. A

Sol. Let the total amount be = 100 unit

Let m solidify

$$m \times L_f = (100 - m)L_v$$

$$m = 86.2$$

4. Ice at 0°C is added to 200 g of water initially at 70°C in a vacuum flask. When 50 g of ice has been added and has all melted the temperature of the flask and contents is 40°C. When a further 80g of ice has been added and has all melted, the temperature of the whole is 10°C. Calculate the specific latent heat of fusion of ice.[Take $S_w = 1$ cal /gm °C.]

(A) 3.8×10^5 J/ kg (B) 1.2×10^5 J/ kg (C) 2.4×10^5 J/ kg (D) 3.0×10^5 J/ kg

Ans. A

Sol. $50L + 50 \times 1 \times 40 = 200 \times 1 \times 30 + m \times S \times 30$ (i)

$80L + 80 \times 1 \times 10 = 250 \times 1 \times 30 + m \times s \times 30$ (ii)

Equation (ii) – (i)

$$30L - 1200 = 1500$$

$$30L = 2700$$

$$L = 90 \text{ cal/gm}$$

$$= 90 \times 4.2 \times 1000 \text{ J/kg} = 3.8 \times 10^5 \text{ J/kg}$$

5. The coefficient of linear expansion of copper is $17 \times 10^{-6} (^{\circ}\text{C})^{-1}$. A copper statue is 93 m tall on the summer morning of temperature 25°C . What is maximum order of increase in magnitude of the height in statue (maximum temperature of day is 45°C)

(A) 0.1 mm (B) 1 mm (C) 10 mm (D) 100 mm

Ans. C

Sol. $\Delta L = L \alpha \Delta T = 93 \times 17 \times 10^{-6} \times 20\text{m} = 31.620 \text{ mm}$
i.e. 10 mm order

6. The coefficients of thermal expansion of steel and a metal X are respectively 12×10^{-6} and 2×10^{-6} per $^{\circ}\text{C}$. At 40°C , the side of a cube of metal X was measured using a steel vernier callipers. The reading was 100 mm. Assuming that the calibration of the vernier was done at 0°C , then the actual length of the side of the cube at 0°C will be

(A) $> 100 \text{ mm}$ (B) $< 100 \text{ mm}$
(C) $= 100 \text{ mm}$ (D) data insufficient to conclude

Ans. A

Sol. $> 100 \text{ mm}$

Since the coeff of thermal exp of steel is greater then metal X.

7. The volume of the bulb of a mercury thermometer at 0°C is V_0 and cross section of the capillary is A_0 . The coefficient of linear expansion of glass is α_g per $^{\circ}\text{C}$ and the cubical expansion of mercury γ_m per $^{\circ}\text{C}$. If the mercury just fills the bulb at 0°C , what is the length of mercury column in capillary at $T^{\circ}\text{C}$.

(A) $\frac{V_0 T (\gamma_m + 3\alpha_g)}{A_0 (1 + 2\alpha_g T)}$ (B) $\frac{V_0 T (\gamma_m - 3\alpha_g)}{A_0 (1 + 2\alpha_g T)}$ (C) $\frac{V_0 T (\gamma_m + 2\alpha_g)}{A_0 (1 + 3\alpha_g T)}$ (D) $\frac{V_0 T (\gamma_m - 2\alpha_g)}{A_0 (1 + 3\alpha_g T)}$

Ans. B

Sol. Volume exp. $= \Delta V = V_0 (\gamma_m - 3\alpha_g) T$

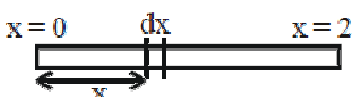
$$\Delta V = A_f \times L = A_0 (1 + 2\alpha_g T) L$$

$$\Rightarrow L = \frac{V_0 T (\gamma_m - 3\alpha_g)}{A_0 (1 + 2\alpha_g T)}$$

8. A rod of length 2m at 0°C and having expansion coefficient $\alpha = (3x + 2) \times 10^{-6} ^{\circ}\text{C}^{-1}$ where x is the distance (in cm) from one end of rod. The length of rod at 20°C is :

(A) 2.124 m (B) 3.24 m (C) 2.0120 m (D) 3.124 m

Ans. C

Sol. 

Take element of length dx at distance x from one end.

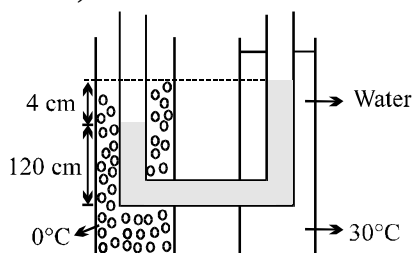
Let dy is the expansion of length dx then

$$dy = dx \alpha \Delta T$$

$$\int dy = \int_{x=0}^{x=2} \alpha dx \Delta T$$

Integrate from $x = 0$ to $x = 2$ for net expansion.

9. Two vertical glass tubes filled with a liquid are connected by a capillary tube as shown in the figure. The tube on the left is put in an ice bath at 0°C while the tube on the right is kept at 30°C in a water bath. The difference in the levels of the liquid in the two tubes is 4 cm while the height of the liquid column at 0°C is 120 cm. The coefficient of volume expansion of liquid is (Ignore expansion of glass tube)



- (A) $22 \times 10^{-4}/^\circ\text{C}$ (B) $1.1 \times 10^{-4}/^\circ\text{C}$ (C) $11 \times 10^{-4}/^\circ\text{C}$ (D) $2.2 \times 10^{-4}/^\circ\text{C}$

Ans. C

Sol. $\rho \cdot g \times 120 = \frac{\rho}{(1 + \gamma \Delta T)} g \times 124$

$$1 + \gamma \Delta T = \frac{124}{120}$$

$$\gamma \Delta T = \frac{4}{120} \Rightarrow \gamma = \frac{4}{120 \times 30} = 11.11 \times 10^{-4} / ^\circ\text{C}$$

10. A liquid is given some heat.

Statement A : Some liquid evaporates.

Statement B : The liquid starts boiling.

- (A) A implies B and B implies A (B) B implies A but, A does not imply B
(C) A implies B but B does not imply A (D) Neither A implies B nor B implies A

Ans. B

Sol. Theoretical

11. A long solid cylinder is radiating power. It is remolded into a number of smaller cylinders, each of which has the same length as original cylinder. Each small cylinder has the same temperature as the original cylinder. The total radiant power emitted by the pieces is twice that emitted by the original cylinder. How many smaller cylinders are there ? Neglect the energy emitted by the flat faces of cylinder.

- (A) 3 (B) 4 (C) 5 (D) 6

Ans. B

Sol. Since volume is constant

$$\pi R^2 L = n \pi r^2 L$$

$$R^2 = nr^2 \quad \dots(i)$$

& $P \propto A$ (Since temperature is constant)

$A = \text{Surface area}$

$$P \propto (2\pi R)L \quad \dots(ii)$$

$$2P \propto n(2\pi r)L \quad \dots(iii)$$

$$\frac{P}{2P} = \frac{2\pi RL}{n2\pi rL}$$

$$\frac{1}{2} = \frac{R}{nr} \Rightarrow \frac{1}{4} = \frac{R^2}{n^2 r^2} = \frac{nr^2}{n^2 r^2}$$

$$\Rightarrow n = 4$$

12. Four rods of same material with different radii r and length l are used to connect two reservoirs of heat at different temperatures. Which one will conduct most heat ?

(A) $r = 2\text{cm}, l = 0.5\text{m}$

(B) $r = 2\text{cm}, l = 2\text{m}$

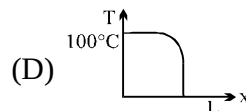
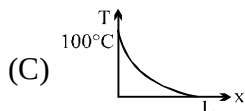
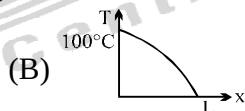
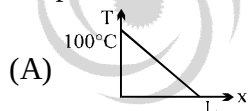
(C) $r = 0.5\text{cm}, l = 0.5\text{m}$

(D) $r = 1\text{cm}, l = 1\text{m}$

Ans. A

Sol. $\frac{dQ}{dt} \propto \frac{kA}{\ell} \propto \frac{r^2}{\ell}$

13. A rod of length L and uniform cross-sectional area has varying thermal conductivity which changes linearly from $2K$ at end A to K at the other end B. The ends A and B of the rod are maintained at constant temperature 100°C and 0°C , respectively. At steady state, the graph of temperature : $T = T(x)$ where $x = \text{distance from end A}$ will be



Ans. B

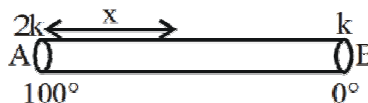
Sol. $k(x) = -\frac{k}{L}x + 2k$

$$\frac{dQ}{dt} = -k(x)A \frac{dT}{dx}$$

$$\text{Let } \frac{dQ}{dt} = P$$

$$dT = \frac{-Pdx}{k(x)A}$$

$$dT = -\frac{PL}{A} \frac{dx}{(-kx + 2kL)}$$



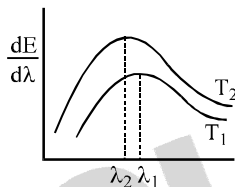
$$\int_{100}^{T(x)} dT = \frac{PL}{A} \int_0^x \frac{dx}{(kx - 2kL)}$$

$$T(x) - 100 = \frac{PL}{A} \left[\frac{\ln(kx - 2kL)}{k} \right]_0^x$$

$$= \frac{PL}{Ak} [\ln(kx - 2kL) - \ln 2kL]$$

$$T(x) - 100 = \frac{PL}{Ak} \left[\ln \frac{kx - 2kL}{2kL} \right]$$

14. The spectral emissive power E_λ for a body at temperature T_1 is plotted against the wavelength and area under the curve is found to be A. At a different temperature T_2 the area is found to be 9A. Then $\lambda_1/\lambda_2 =$



- (A) 3 (B) 1/3 (C) $1/\sqrt{3}$ (D) $\sqrt{3}$

Ans. D

Sol. $\int_0^\infty E_\lambda d\lambda = E$

$$E_1 = A \Rightarrow \sigma eA T_1^4 = A \quad \dots(i)$$

$$E_2 = 9A \Rightarrow \sigma eA T_2^4 = 9A \quad \dots(ii)$$

$$\frac{T_1}{T_2} = \left(\frac{1}{9} \right)^{1/4} \quad \text{from (i) \& (ii)}$$

$$T_1 \lambda_1 = T_2 \lambda_2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{T_2}{T_1}$$

$$\frac{\lambda_1}{\lambda_2} = \sqrt{3}$$

15. 'Gulab Jamuns' (assumed to be spherical) are to be heated in an oven. They are available in two sizes, one twice bigger (in radius) than the other. Pizzas (assumed to be discs) are also to be heated in oven. They are also in two sizes, one twice big (in radius) than the other. All four are put together to be heated to oven temperature. Choose the correct option from the following:
- (A) Both size gulab jamuns will get heated in the same time.
(B) Smaller gulab jamuns are heated before bigger ones.

- (C) Smaller pizzas are heated before bigger ones.
(D) Bigger pizzas are heated before smaller ones.

Ans. B

Sol. $\frac{dT}{dt} = \frac{\sigma e A}{ms} (T^4 - T_s^4)$

$$\frac{dT}{dt} \propto \frac{A}{m} \quad (m = \rho V)$$

for disc (pizzas) $m \propto A$ so $\frac{dT}{dt}$ is same for both

$$\left(\frac{dT}{dt} \right)_{\text{small}} < \left(\frac{dT}{dt} \right)_{\text{big}} \quad (\text{for Gulab jamun})$$

for gulab jamuns (sphere)
 small (A, m)
 big (4A, 8m)

- 16.** An experiment is performed to measure the specific heat of copper. A lump of copper is heated in an oven, then dropped into a beaker of water. To calculate the specific heat of copper, the experimenter must know or measure the value of all of the quantities below EXCEPT the
(A) heat capacity of water and beaker
(B) original temperature of the copper and the water
(C) final (equilibrium) temperature of the copper and the water
(D) time taken to achieve equilibrium, after the copper is dropped into the water

Ans. D

Sol. $\theta = ms(T_f - T_i)$

Time does not reflect in equation.

- 17.** 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 the rod is doubled
(B) the temperature is made 100°C and length of rod is made four times
(C) area of cross-section of rod is halved and length is doubled
(D) the temperature is made 100°C and the area of cross-section of rod and length both are doubled.

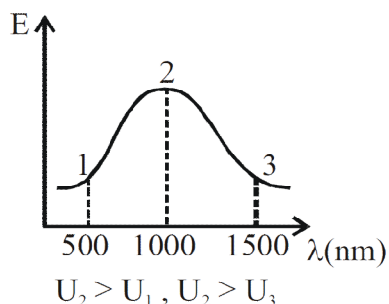
Ans. D

Sol. $\frac{dQ}{dt} = \frac{kA}{L} \Delta T$

- 18.** A black body is at a temperature of 2880 K . The energy of radiation emitted by this object with wavelength between 499 nm and 500 nm is U_1 , between 999 nm and 1000 nm is U_2 and between 1499 nm and 1500 nm is U_3 . The Wien constant $b = 2.88 \times 10^6\text{ nm K}$. Then
(A) $U_1 = 0$ (B) $U_3 = 0$ (C) $U_1 > U_2$ (D) $U_2 > U_1$

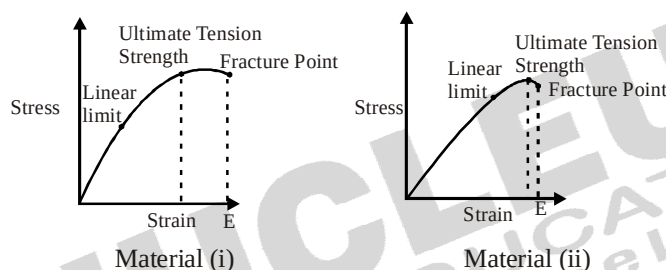
Ans. D

Sol. $\lambda_m T = b \Rightarrow \lambda = \frac{b}{T} = 1000 \text{ nm}$



MULTIPLE CORRECT TYPE QUESTIONS

19. The stress-strain graphs for two materials are shown in figure (assume same scale).



- (A) Material (ii) is more elastic than material (i) and hence material (ii) is more brittle.
 (B) Material (i) and (ii) have the same elasticity and the same brittleness.
 (C) Material (ii) is elastic over a larger region of strain as compared to (i).
 (D) Material (ii) is more brittle than material (i).

Ans. CD

Sol. Explain with stress-strain curve analysis.

20. A composite rod consists of a steel rod of length 25 cm and area $2A$ and a copper rod of length 50 cm and area A . The composite rod is subjected to an axial load F . If the Young's modulus of steel and copper are in the ratio 2 : 1.

- (A) the extension produced in copper rod will be more.
 (B) the extension in copper and steel parts will be in the ratio 2 : 1.
 (C) the stress applied to the copper rod will be more.
 (D) no extension will be produced in the steel rod.

Ans. AC

Sol. $Y_S : Y_{Cu} = 2 : 1$

i.e. $Y_{Cu} = Y$

$Y_S = 2Y$

$$\frac{\Delta \ell_S}{\ell_S} = \frac{F}{2AY_S}$$

$$\Rightarrow \Delta \ell_s = \frac{F\ell}{2AY_s} = \frac{F\ell}{2A(2Y)}$$

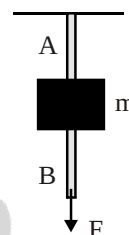
$$\Delta \ell_{Cu} = \frac{F(2\ell)}{2A}$$

$$\& \text{Stress in steel} = \frac{F}{2A}$$

$$\text{Stress in Cu} = \frac{F}{A}$$

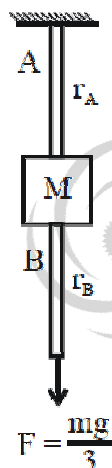
21. The wires A and B shown in the figure are made of the same material and have radii r_A and r_B respectively. The block between them has a mass m . When the force F is $mg/3$, one of the wires breaks.

- (A) A breaks if $r_A = r_B$
(B) A breaks if $r_A < 2r_B$
(C) Either A or B may break if $r_A = 2r_B$
(D) The lengths of A and B must be known to predict which wire will break



Ans. ABC

Sol.



$$\sigma_A = \frac{4mg}{3\pi r_A^2}$$

$$\sigma_B = \frac{mg}{3(\pi r_B^2)}$$

22. 50 gm ice at -10°C is mixed with 20 gm steam at 100°C . When the mixture finally reaches its steady state inside a calorimeter of water equivalent 1.5 gm then : [Assume calorimeter was initially at 0°C , Take latent heat of vaporization of water = 540 cal/gm, Latent heat of fusion of water = 80 cal/gm, specific heat capacity of water = 1 cal/gm- $^\circ\text{C}$, specific heat capacity of ice = 0.5 cal/gm- $^\circ\text{C}$]

- (A) Mass of water remaining is : 67.4 gm (B) Mass of steam remaining is : 2.6 gm

(C) Mass of water remaining is : 67.87 gm (D) Mass of steam remaining is : 2.13 gm

Ans. AB

Sol. Let m amount of steam will convert into water.

$$50 \times \frac{1}{2} \times 10 + 50 \times 80 + (51.5) \times 1 \times 100 = m \times 540$$

$$m \times 540 = 9400$$

$$m = 17.40 \text{ gm}$$

$$\text{Mass of steam remaining} = (20 - 17.40) \text{ gm} = 2.6 \text{ gm}$$

$$\text{Mass of water remaining} = (50 + 17.40) \text{ gm} = 67.40 \text{ gm}$$

23. Two metallic sphere A and B are made of same material and have got identical surface finish. The mass of sphere A is four times that of B. Both the spheres are heated to the same temperature and placed in a room having lower temperature but thermally insulated from each other.

(A) The ratio of heat loss of A to that of B is $2^{4/3}$.

(B) The ratio of heat loss of A to that of B is $2^{2/3}$.

(C) The ratio of the initial rate of cooling of A to that of B is $2^{-2/3}$.

(D) The ratio of the initial rate of cooling of A to that of B is $2^{-4/3}$.

Ans. AC

Sol. $m \propto V$

$$\frac{m_A}{m_B} = \frac{\frac{4}{3}\pi r_A^3}{\frac{4}{3}\pi r_B^3} = 4 = 2^2$$

$$\Rightarrow \frac{r_A}{r_B} = 2^{2/3}$$

e & σ is same for both

$$\frac{dQ}{dt} \propto \text{Area} \propto r^2$$

$$\frac{\left(\frac{dQ}{dt}\right)_A}{\left(\frac{dQ}{dt}\right)_B} = \left(\frac{r_A}{r_B}\right)^2 = 2^{4/3}$$

$$-\frac{dT}{dt} \propto \frac{\text{Area}}{\text{mass}}$$

$$\frac{\left|\left(\frac{dT}{dt}\right)_A\right|}{\left|\left(\frac{dT}{dt}\right)_B\right|} = \frac{2^{4/3}}{2^2} = 2^{-2/3}$$

24. Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies radiate energy at the same rate. The wavelength λ_B , corresponding to the maximum spectral radiance in the radiation from B, is shifted from the wavelength corresponding to the maximum spectral radiance in the radiation from A by $1.00 \mu\text{m}$. If the temperature of A is 5802 K,
(A) the temperature of B is 1934 K (B) $\lambda_B = 1.5 \mu\text{m}$
(C) the temperature of B is 11604 K (D) the temperature of B is 2901 K

Ans. AB

Sol. $e_A = 0.01, e_B = 0.81$

Area = same for both

$$\frac{dQ}{dt} = e\sigma AT^4 = \text{same for both}$$

$$\sigma e_A AT_A^4 = \sigma e_B AT_B^4$$

$$\left(\frac{T_A}{T_B}\right)^4 = \frac{e_B}{e_A} = 81 = 3^4$$

$$\frac{T_A}{T_B} = 3 \Rightarrow T_B = \frac{T_A}{3} = 1934$$

also

$$\lambda_B T_B = \lambda_A T_A$$

$$\lambda_B \times 1934 = (\lambda_A - 1)5802$$

$$\lambda_B = 3\lambda_A - 3$$

$$2\lambda_B = 3$$

$$\Rightarrow \lambda_B = 1.5 \mu\text{m}$$

25. A bimetallic strip is formed out of two identical strips one of copper and the other of brass. The coefficient of linear expansion of the two metals are α_C and α_B . On heating, the temperature of the strip goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is
(A) proportional to ΔT (B) inversely proportional to ΔT
(C) proportional to $|\alpha_B - \alpha_C|$ (D) inversely proportional to $|\alpha_B - \alpha_C|$

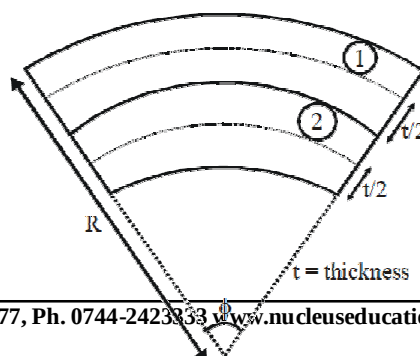
Ans. BD

Sol. $L_1 = L_0(1 + \alpha_1 \Delta T)$

$$\left(R + \frac{t}{2}\right)\phi = L_0(1 + \alpha_1 \Delta T) \quad \dots(i)$$

$$\left(R - \frac{t}{2}\right)\phi = L_0(1 + \alpha_2 \Delta T) \quad \dots(ii)$$

solving



$$R \approx \frac{\tau}{(\alpha_1 - \alpha_2) \Delta T}$$

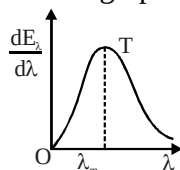
$$\alpha_1 = \alpha_B$$

$$\alpha_2 = \alpha_C$$

COMPREHENSION BASED QUESTIONS

Paragraph for Question No. 26 & 27

The figure shows a radiant energy spectrum graph for a black body at a temperature T .



26. Choose the **CORRECT** statement(s)
- (A) The radiant energy is not equally distributed among all the possible wavelengths
 - (B) For a particular wavelength the spectral intensity is maximum
 - (C) The area under the curve is equal to the total rate at which heat is radiated by the body at that temperature
 - (D) None of these

Ans. ABC

27. If the temperature of the body is raised to a higher temperature T' , then choose the correct statement(s)
- (A) The intensity of radiation for every wavelength increases
 - (B) The maximum intensity occurs at a shorter wavelength
 - (C) The area under the graph increases
 - (D) The area under the graph is proportional to the fourth power of temperature

Ans. ABCD

Sol. (26 & 27)

Explained by Planks radiation law

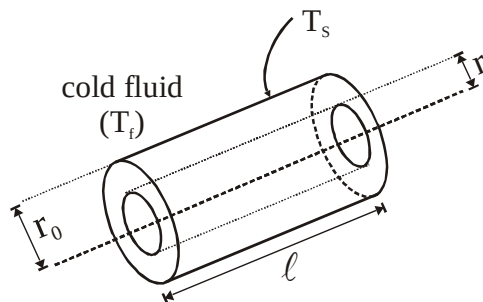
for all λ , if $T \uparrow \Rightarrow E \uparrow$

area of curve = $\int E d\lambda = \sigma T^4$ (stefans law)

= Total intensity of radiation at a particular time

Paragraph for Question No. 28 & 30

Heat generation may occur in a variety of radial geometries. Consider a long, solid cylinder as shown in the figure, which could represent a current-carrying wire or a fuel element in a nuclear reactor. For steady state conditions, the rate at which heat is generated within the cylinder must equal the rate at which heat is convected from the surface of the cylinder to a moving fluid.



This condition allows the surface temperature to be maintained at a fixed value of T_s . To determine the temperature distribution in the cylinder, we begin with energy conservation principle. Consider a cylindrical section of radius r . The energy is generated within the volume and is conducted radially outwards.

$$q \pi r^2 \ell = -K 2\pi r \ell \left(-\frac{dT}{dr} \right)$$

where q is the energy generated per unit time per unit volume, K is the thermal conductivity and $\frac{dT}{dr}$ is the temperature gradient at radius r . If q is constant $T(r) = -\frac{q}{4k} r^2 + C$

$$\text{At } r = r_0, T(r_0) = T_s. \text{ Therefore, } T(r) = \frac{q}{4k} r_0^2 \left(1 - \frac{r^2}{r_0^2} \right) + T_s$$

The rate of heat convected to the surrounding fluid (at temperature T_f) by the surface at temperature T_s is proportional to the temperature difference $(T_s - T_f)$ and the surface area in contact with the fluid. Thus, rate of heat convection = $h(2\pi r_0 \ell) (T_s - T_f)$ where h is a constant called heat convection coefficient. By overall energy balance, $q (\pi r_0^2 \ell) = h(2\pi r_0 \ell) (T_s - T_f)$

$$\Rightarrow T_s = T_f + \frac{q r_0}{2h}$$

28. The dimension of heat convection coefficient is-

- (A) $[ML^2 T^{-1} \theta^{-1}]$ (B) $[ML^0 T^{-3} \theta^{-1}]$ (C) $[ML^0 T^{-2} \theta^{-1}]$ (D) $[ML^4 T^{-2} \theta^{-1}]$

Ans. B

Sol. $h \rightarrow$ heat convection

$$h = \frac{q r_0}{2\Delta T}, \quad q = \frac{\Delta V}{\Delta T \cdot \Delta V} = \frac{M \cdot L}{T^2} \cdot \frac{L}{T \cdot L^3}$$

$$\text{Dimension of } h = [ML^0 T^{-3} \theta^{-1}]$$

29. In the given passage, the difference in temperature at the axis and surface of the cylinder is-

- (A) $\frac{q r_0^2}{4k}$ (B) $\frac{q r_0^2}{k}$ (C) $\frac{q r_0^2}{2k}$ (D) $\frac{2q r_0}{k}$

Ans. A

$$\text{Sol. } T_{(r)} = \frac{q}{4k} r_0^2 \left(1 - \frac{r^2}{r_0^2} \right) + T_s$$

at $r = 0$

$$T_{(r)} - T_s = \frac{qr_0^2}{4k}$$

30. In the above passage, the ratio of temperature gradient at $r = r_0/2$ and $r = r_0$ is

- (A) 1 (B) 1/4 (C) 1/2 (D) 1/8

Ans. C

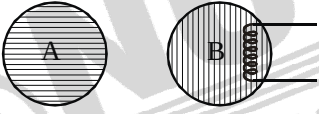
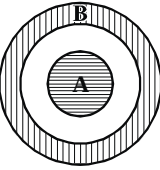
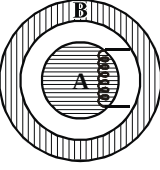
Sol. $\frac{dT}{dr} = \frac{q\pi r^2 l}{k \cdot 2\pi r l} = \frac{qr}{2k}$

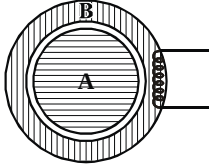
$$\left(\frac{dT}{dr}\right)_{r=\frac{r_0}{2}} = \frac{1}{2}$$

$$\left(\frac{dT}{dr}\right)_{r=r_0} = 1$$

MATRIX MATCH BASED QUESTIONS

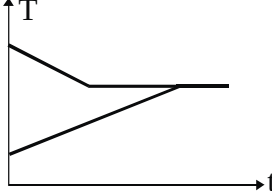
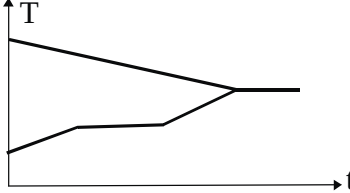
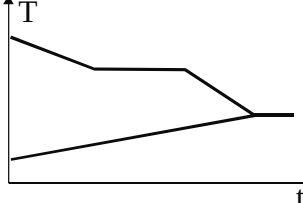
31. A & B are two black bodies of radii r_A and r_B respectively, placed in surrounding of temperature T_0 . At steady state the temperature of A & B is T_A & T_B respectively.

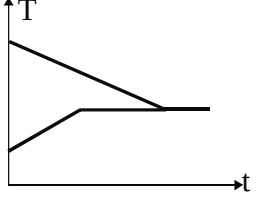
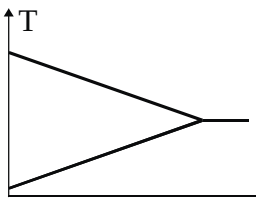
	Column I		Column II
(A)	 • A & B are solid sphere • $r_A = r_B$ • Body 'B' is being heated by a heater of constant power 'P'	(P)	$T_A = T_B$
(B)	 • B is thin spherical shell • A is a solid sphere • $r_A < r_B$	(Q)	$T_A < T_B$
(C)	 • B is thin spherical shell • A is a solid sphere	(R)	Heat received by A is more than heat radiated by it at steady state.

	• $r_A < r_B$ • Body A is being heated by a heater of constant power 'P'		
(D)	 • B is thin spherical shell • A is a solid sphere • $r_A \approx r_B$ • Body B is being heated by a heater of constant power 'P'	(S) (T)	Radiation spectrum of A & B is distinguishable Steady state can't be achieved

Ans. (A)→ QS; (B)→ P; (C)→ S; (D)→ QS

32. A sample 'A' of liquid water and a sample B of ice of equal mass are kept in 2 nearby containers so that they can exchange heat with each other but are thermally insulated from the surroundings. The graphs in column-II show the sketch of temperature T of samples versus time t. Match with appropriate description in column-I.

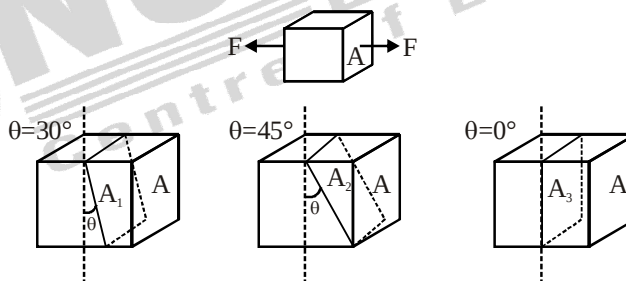
Column I		Column II	
(A)	Equilibrium temperature is above melting point of ice.	(P)	
(B)	At least some of water freezes.	(Q)	
(C)	At least some of ice melts.	(R)	

(D)	Equilibrium temperature is below freezing point of water	(S)	
		(T)	

Ans. (A) → Q; (B) → PR; (C) → QS; (D) → R

Sol. (A) Only in Q equilibrium temperature is greater than melting point of ice.
 (B) In P and R some water freezes.
 (C) In Q and S ice melts
 (D) Only in Q equilibrium temperature is below freezing point of water.

33. The square block of cross section area A is subjected to two equal and opposite forces F as shown in figure, the block is in equilibrium. Consider the planes A_1 , A_2 and A_3 which are passing through the square block and making angle 30° , 45° and 0° respectively with eplane at right angle to the block.



Match the following based on the information given above

Column-I

- (A) Maximum shear stress
 (B) Minimum shear stress
 (C) Maximum Normal stress
 (D) Minimum Normal stress

Column-II

- (P) Plane A_1
 (Q) Plane A_2
 (R) Plane A_3
 (S) $\frac{F}{2A}$
 (T) $\frac{F}{A}$

Ans. (A) → QS; (B) → R; (C) → RT; (D) → QS

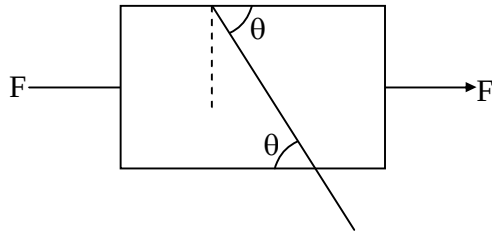
Sol. Normal stress = $\frac{F \sin^2 \theta}{A}$

$$\text{Shear stress} = \frac{F}{2A} \sin 2\theta$$

Maximum shear stress $\rightarrow$ in plane A_2

Minimum shear stress $\rightarrow$ in plane A_1

Maximum normal stress $\rightarrow$ in plane A_1



EXERCISE # (JM)

1. A wire elongates by ℓ mm when a load W is hanged from it. If the wire goes over a pulley and two weights W each are hung at the two ends, the elongation of the wire will be (in mm)

[AIEEE 2006]

- (1) ℓ (2) 2ℓ (3) zero (4) $\ell/2$

Ans. (1)

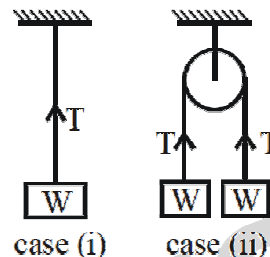
Sol. Case (i) at equilibrium, ($T = W$)

$$Y = \frac{W/A}{\ell/L}$$

case (ii) at equilibrium, ($T = W$)

$$Y = \frac{W/A}{\ell/L}$$

$\Rightarrow$ Elongation is same



2. Assuming the sun to be a spherical body of radius R at a temperature of T K, evaluate the total radiant power, incident on Earth, at a distance r from the Sun. (earth radius = r_0)

[AIEEE-2006]

- (1) $\frac{R^2 \sigma T^4}{r^2}$ (2) $\frac{4\pi r_0^2 R^2 \sigma T^4}{r^2}$ (3) $\frac{\pi r_0^2 R^2 \sigma T^4}{r^2}$ (4) $\frac{r_0^2 R^2 \sigma T^4}{4\pi r^2}$

Ans. (3)

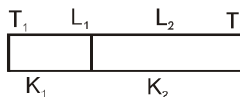
Sol. Total power radiated by Sun = $\sigma T^4 (4\pi R^2)$

$$\text{The intensity of power at earth's surface} = \frac{\sigma T^4 \times 4\pi R^2}{4\pi r^2}$$

$$\text{Total power received by Earth} = \frac{\sigma T^4 R^2}{r^2} [\pi r_0^2]$$

3. One end of a thermally insulated rod is kept at a temperature T_1 and the other at T_2 . The rod is composed of two sections of lengths L_1 and L_2 and thermal conductivities k_1 and k_2 respectively. The temperature at the interface of the sections is

[AIEEE-2007]



- (1) $\frac{(K_2 L_2 T_1 + K_1 L_1 T_2)}{(K_1 L_1 + K_2 L_2)}$ (2) $\frac{(K_2 L_1 T_1 + K_1 L_2 T_2)}{(K_2 L_1 + K_1 L_2)}$
(3) $\frac{(K_1 L_2 T_1 + K_2 L_1 T_2)}{(K_1 L_2 + K_2 L_1)}$ (4) $\frac{(K_1 L_1 T_1 + K_2 L_2 T_2)}{(K_1 L_1 + K_2 L_2)}$

Ans. (3)

Sol. $\frac{k_1 A (T_1 - T)}{\ell_1} = \frac{k_2 A (T - T_2)}{\ell_2}$

4. Two wires are made of the same material and have the same volume. However wire 1 has cross-sectional area A and wire 2 has cross-sectional area $3A$. If the length of wire 1 increases by Δx on applying force F , how much force is needed to stretch wire 2 by the same amount?

[AIEEE-2009]

- (1) $4F$ (2) $6F$ (3) $9F$ (4) F

Ans. (3)

Sol. $A\ell_1 = 3A\ell_2$

$$\Rightarrow \ell_2 = \frac{\ell_1}{3}$$

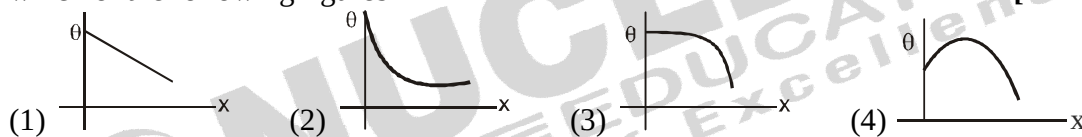
$$\text{For wire 1 : } Y = \frac{F/A}{\Delta x / \ell_1}$$

$$\text{For wire 2 : } Y = \frac{F'/3A}{\Delta x / \ell_2}$$

$$\Rightarrow F' = 9F$$

5. A long metallic bar is carrying heat from one of its ends to the other end under steady-state. The variation of temperature θ along the length x of the bar from its hot end is best described by which of the following figures

[AIEEE-2009]



Ans. (1)

Sol. The heat flow rate is given by

$$\frac{dQ}{dt} = \frac{kA(\theta_1 - \theta)}{x}$$

$$\Rightarrow \theta = \theta_1 - \frac{x}{kA} \frac{dQ}{dt}$$

where θ_1 is the temp of hot end and θ is temp at a distance x from hot end.

6. The specific heat capacity of a metal at low temperature (T) is given as : [AIEEE 2011]

$$C_p (\text{kJK}^{-1} \text{kg}^{-1}) = 32 \left(\frac{T}{400} \right)^3$$

A 100 gram vessel of this metal is to be cooled from 20°K to 4°K by a special refrigerator operating at room temperature (27°C). The amount of work required to cool the vessel is :

- (1) greater than 0.148 kJ (2) between 0.148 kJ and 0.028 kJ
(3) less than 0.028 kJ (4) equal to 0.002 kJ

Ans. (4)

Sol. $Q = \int mcdT$

$$= \int_{20}^4 0.1 \times 32 \times \left(\frac{T^3}{400^3} \right) dT$$

$$\approx 0.002 \text{ k J.}$$

7. A metal rod of Young's modulus Y and coefficient of thermal expansion α is held at its two ends such that its length remains invariant. If its temperature is raised by $t^\circ\text{C}$, the linear stress developed in its is : **[AIEEE 2011]**

(1) $\frac{Y}{\alpha t}$ (2) $Y\alpha t$ (3) $\frac{1}{(Y\alpha t)}$ (4) $\frac{\alpha t}{Y}$

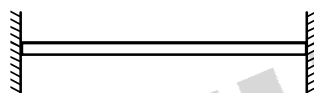
Ans. (2)

Sol. $\frac{\Delta \ell}{\ell} = \alpha \Delta T$

and $Y = \frac{F/A}{\Delta \ell / \ell}$

So, $F = AY\alpha t$

Thermal stress $\left(\frac{F}{A} \right) = Y\alpha t$.



8. An aluminium sphere of 20 cm diameter is heated from 0°C to 100°C . Its volume changes by (given that coefficient of linear expansion for aluminium $\alpha_{\text{Al}} = 23 \times 10^{-6}/^\circ\text{C}$) **[AIEEE 2011]**

(1) 2.89 cc (2) 9.28 cc (3) 49.8 cc (4) 28.9 cc

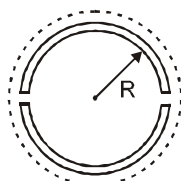
Ans. (4)

Sol. $\Delta v = v_0(3\alpha) \Delta T$

$$= \frac{4}{3} \pi (10)^3 \times 3 \times 23 \times 10^{-6} \times 100$$

$\Delta v = 28.9 \text{ cc.}$

9. A wooden wheel of radius R is made of two semicircular parts (see figure). The two parts are held together by a ring made of a metal strip of cross sectional area S and length L . L is slightly less than $2\pi R$. To fit the ring on the wheel, it is heated so that its temperature rises by ΔT and it just steps over the wheel. As it cools down to surrounding temperature, it presses the semicircular parts together. If the coefficient of linear expansion of the metal is α , and its Young's modulus is Y , the force that one part of the wheel applies on the other part is : **[AIEEE 2012]**



(1) $2\pi SY\alpha\Delta T$ (2) $SY\alpha\Delta T$ (3) $\pi SY\alpha\Delta T$ (4) $2SY\alpha\Delta T$

Ans. (4)

Sol. $Y = \frac{F/S}{\Delta L/L}$

$$\frac{\Delta L}{L} = \frac{\Delta R}{R} = \alpha \Delta T \quad [L = 2\pi R]$$

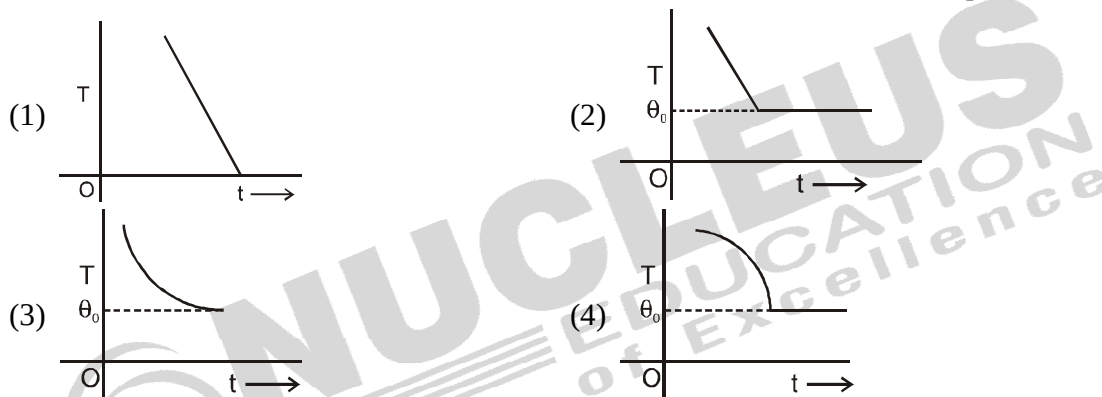
$$\Rightarrow F = YS\alpha\Delta T$$

$\therefore$ The ring is pressing the wheel
from both sides, thus

$$F_{\text{net}} = 2F = 2YS\alpha\Delta T$$

10. If a piece of metal is heated to temperature θ and then allowed to cool in a room which is at temperature θ_0 , the graph between the temperature T of the metal and time t will be closest to :

[JEE-Mains 2013]



Ans. (3)

Sol. According to Newton's law of cooling, The temp goes on decreasing with time non-linearly.

11. The pressure that has to be applied to the ends of a steel wire of length 10 cm to keep its length constant when its temperature is raised by 100°C is : [JEE-Main 2014]

(For steel Young's modulus is $2 \times 10^{11} \text{ N m}^{-2}$ and coefficient of thermal expansion is $1.1 \times 10^{-5} \text{ K}^{-1}$)

- (1) $2.2 \times 10^8 \text{ Pa}$ (2) $2.2 \times 10^9 \text{ Pa}$ (3) $2.2 \times 10^7 \text{ Pa}$ (4) $2.2 \times 10^6 \text{ Pa}$

Ans. (1)

Sol. Thermal strain $= \alpha \Delta T$

$$(\text{by } \ell = \ell_0 (1 + \alpha \Delta T))$$

$\Rightarrow$ Thermal stress in Rod (Pressure due to

$$\text{Thermal strain}) = Y \alpha \Delta T$$

$$= 2 \times 10^{11} \times 1.1 \times 10^{-5} \times 100$$

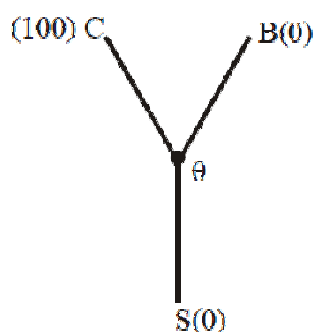
$$= 2.2 \times 10^8 \text{ Pa}$$

12. Three rods of Copper, brass and steel are welded together to form a Y-shaped structure. Area of cross-section of each rod = 4 cm^2 . End of copper rod is maintained at 100°C where as ends of brass and steel are kept at 0°C . Lengths of the copper, brass and steel rods are 46, 13 and 12 cms respectively. The rods are thermally insulated from surroundings except at ends. Thermal conductivities of copper, brass and steel are 0.92, 0.26 and 0.12 CGS units respectively. Rate of heat flow through copper rod is : **[JEE-Mains 2014]**

(1) 1.2 cal/s (2) 2.4 cal/s (3) 4.8 cal/s (4) 6.0 cal/s

Ans. (3)

Sol.



$$\frac{100 - \theta}{R_C} = \frac{\theta - 0}{R_B} + \frac{\theta - 0}{R_S}$$

$$\text{where } R = \frac{\ell}{KA}$$

on solving we get $\theta = 40$

Heat flow per unit time through copper rod

$$= \frac{(100 - 40)}{\ell_C} (K_C A_C)$$

$$= \frac{60}{46} \times 0.92 \times 4 = 4.8 \text{ cal/s}$$

13. A pendulum made of a uniform wire of cross sectional area A has time period T . When an additional mass M is added to its bob, the time period changes to T_M . If the Young's modulus of the material of the wire is Y then $\frac{1}{Y}$ is equal to : (g = fravitational acceleration)

[JEE-Mains 2015]

(1) $\left[\left(\frac{T_M}{T} \right)^2 - 1 \right] \frac{Mg}{A}$ (2) $\left[1 - \left(\frac{T_M}{T} \right)^2 \right] \frac{A}{Mg}$ (3) $\left[1 - \left(\frac{T}{T_M} \right)^2 \right] \frac{A}{Mg}$ (4) $\left[\left(\frac{T_M}{T} \right)^2 - 1 \right] \frac{A}{Mg}$

Ans. (4)

Sol. $T = 2\pi \sqrt{\frac{L}{g}}$ (1)

$$T_M = 2\pi \sqrt{\frac{L + \Delta L}{g}} \quad \dots(2)$$

$$Y = \frac{F/A}{\Delta L/L}$$

$$\Delta L = \frac{FL}{AY} \quad \dots(3)$$

Putting (3) in (2)

solving the equation we get the value of $\frac{1}{Y}$ as

$$\left[\left(\frac{T_M}{T} \right)^2 - 1 \right] \frac{A}{mg}$$

14. A pendulum clock loses 12 s a day if the temperature is 40° C and gains 4 s day if the temperature is 20°C. the temperature at which the clock will show correct time, and the coefficient of linear expansion (α) of the metal of the pendulum shaft are respectively :

[JEE-Mains 2016]

(1) 66°C ; $\alpha = 1.85 \times 10^{-4}/^\circ\text{C}$

(2) 30°C ; $\alpha = 1.85 \times 10^{-3}/^\circ\text{C}$

(3) 55°C ; $\alpha = 1.85 \times 10^{-2}/^\circ\text{C}$

(4) 25°C ; $\alpha = 1.85 \times 10^{-5}/^\circ\text{C}$

Ans.

(4)

Sol.

$$T = 2\pi \sqrt{\frac{\ell}{g}}$$

$$\frac{\Delta T}{T} = \frac{1}{2} \frac{\Delta \ell}{\ell}$$

When clock gain 12 sec

$$\frac{12}{T} = \frac{1}{2} \alpha (40 - \theta)$$

When clock lose 4 sec.

$$\frac{4}{T} = \frac{1}{2} \alpha (\theta - 20) \quad \dots(2)$$

From equation (1) & (2)

$$3 = \frac{40 - \theta}{\theta - 20}$$

$$3\theta - 60 = 40 - \theta$$

$$4\theta = 100$$

$$\boxed{\theta = 25^\circ\text{C}}$$

from equation (1)

$$\frac{12}{T} = \frac{1}{2} \alpha (40 - 25)$$

$$\frac{12}{24 \times 3600} = \frac{1}{2} \alpha \times 15$$

$$\alpha = \frac{24}{24 \times 3600 \times 15}$$

$$\alpha = 1.85 \times 10^{-15} / ^\circ\text{C}$$

15. A copper ball of mass 100 gm is at a temperature T. If it is dropped in a copper calorimeter of mass 100 gm, filled with 170 gm of water at room temperature. Subsequently, the temperature of the system is found to be 75°C. T is given by : **[JEE-Mains 2017]**

(Given : room temperature = 30°C, specific heat of copper = 0.1 cal/gm°C)

- (1) 800°C (2) 885°C (3) 1250°C (4) 825°C

Ans. (2)

Sol. Heat given = Heat taken

$$(100)(0.1)(T - 75) = (100)(0.1)(45) + (170)(1)(45)$$

$$10(T - 75) = 450 + 7650 = 8100$$

$$T - 75 = 810$$

$$T = 885 ^\circ\text{C}$$

16. An external pressure P is applied on a cube at 0°C so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by : **[JEE-Mains 2017]**

- (1) $\frac{P}{3\alpha K}$ (2) $\frac{P}{\alpha K}$ (3) $\frac{3\alpha}{PK}$ (4) $3PK\alpha$

Ans. (1)

Sol. Due to thermal expansion

$$\frac{\Delta v}{v} = 3\alpha\Delta T$$

Due to External pressure

$$\frac{\Delta v}{v} = \frac{P}{K}$$

Equating both we get

$$3\alpha\Delta T = \frac{P}{K}$$

$$\Delta T = \frac{P}{3\alpha K}$$

17. An unknown metal of mass 192 g heated to a temperature of 100°C was immersed into a brass calorimeter of mass 128 g containing 240 g of water a temperature of 8.4°C. Calculate the specific heat of the unknown metal if water temperature stabilizes at 21.5°C (Specific heat of brass is 394 J kg⁻¹ K⁻¹) [JEE Main-2019]

(1) 458 J kg⁻¹ K⁻¹ (2) 916 J kg⁻¹ K⁻¹ (3) 654 J kg⁻¹ K⁻¹ (4) 1232 J kg⁻¹ K⁻¹

Ans. (2)

Sol. $\frac{192}{1000} \cdot S \cdot (78.5) = \frac{128}{1000} \times 394 \times 13.1 + \frac{240}{1000} \times 4200 \times 13.1$
 $S = 919.94 \text{ J/kg-k}$
 most accurate as is 916 J kg⁻¹ k⁻¹

18. Ice at -20° C is added to 50 g of water at 40°C. When the temperature of the mixture reaches 0°C, it is found that 20 g of ice is still unmelted. The amount of ice added to the water was close to (Specific heat of water = 4.2 J/g/°C) Specific heat of Ice = 2.1 J/g/°C. Heat of fusion of water at 0°C = 334 J/g) [JEE Main-2019]

(1) 40 g (2) 50 g (3) 100 g (4) 60 g

Ans. (1)

Sol. Let amount of ice be X gm.

Net heat loss = Net heat gain.

$$\Rightarrow 50 \times 4.2 \times 40 = 20 \times 2.1 \times x + (x-20) \times 334$$

$$= 376 x = 15080$$

$$\Rightarrow x = \frac{15080}{376}$$

$$\Rightarrow x = 40.106$$

19. A metal ball of mass 0.1 kg is heated upto 500°C and dropped into a vessel of heat capacity 800 JK⁻¹ and containing 0.5 kg water. The initial temperature of water and vessel is 30°C. What is the approximate percentage increment in the temperature of the water ? [Specific Heat Capacities of water and metal are, respectively, 4200 J kg⁻¹ K⁻¹ and 400 JKg⁻¹ K⁻¹] [JEE Main-2019]

(1) 15% (2) 30% (3) 20% (4) 25%

Ans. (3)

Sol. $0.1 \times 400(500 - T) = 0.5 \times 4200 (T - 30) + 800 (T - 30)$

$$20000 - 40T = 2900T - 30 \times 2900$$

$$T = 36.4^\circ \text{C}$$

$$\frac{\Delta T}{T} \Rightarrow \frac{6.4}{30}$$

$$\boxed{\frac{\% \Delta T}{T} \Rightarrow 20\%}$$

20. When 100 g of a liquid A at 100°C is added to 50 g of a liquid B at temperature 75°C, the temperature of the mixture becomes 90°C. The temperature of the mixture, if 100 g of liquid A at 100°C is added to 50 g of liquid B at 50°C, will be : [JEE Main-2019]
(1) 60°C (2) 70°C (3) 80°C (4) 85°C

Ans. (3)

Sol. $100 \times S_A(100 - 90) \Rightarrow 50 \times S_B(90 - 75)$

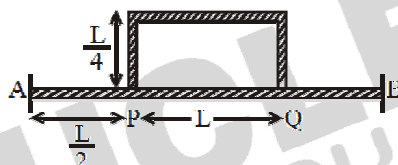
$$2S_A = 1.5 S_B$$

From 2nd condition

$$100 \times S_A \times (100 - R) \Rightarrow 50 \times S_B \times (T - 50)$$

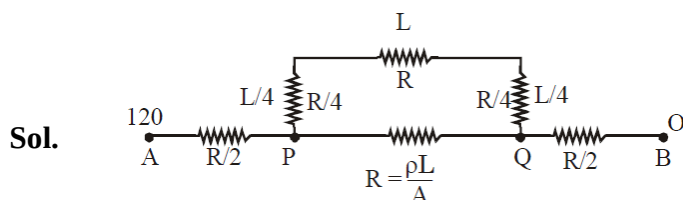
$$T = 80^\circ\text{C}$$

21. Temperature difference of 120°C is maintained between two ends of a uniform rod AB of length 2L. Another bent rod PQ, of same cross section as AB and length $\frac{3L}{2}$, is connected across AB (See Figure). In steady state, temperature difference between P and Q will be close to : [JEE Main-2019]



- (1) 60°C (2) 75°C (3) 35°C (4) 45°C

Ans. (4)



Sol.

$$\frac{\Delta T}{R_{eq}} = I = \frac{(120)5}{8R} = \frac{120 \times 5}{8R}$$

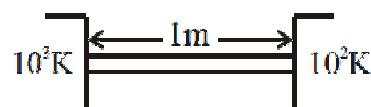
$$\Delta T_{PQ} = \frac{120 \times 5}{8R} \times \frac{3}{5} R = \frac{360}{8} = 45^\circ\text{C}$$

22. A heat source at $T = 10^3 \text{ K}$ is connected to another heat reservoir at $T = 10^2 \text{ K}$ by a copper slab which is 1 m thick. Given that the thermal conductivity of copper is $0.1 \text{ WK}^{-1} \text{ m}^{-1}$, the energy flux through it in the steady state is : [JEE Main-2019]
(1) 200 Wm^{-2} (2) 90 Wm^{-2} (3) 65 Wm^{-2} (4) 120 Wm^{-2}

Ans. (2)

Sol. $\left(\frac{dQ}{dt}\right) = \frac{kA\Delta T}{\ell}$

energy flux is rate of flow of heat per unit area



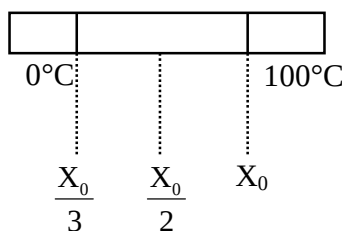
$$\therefore \Rightarrow \frac{1}{A} \left(\frac{dQ}{dt} \right) = \frac{(0.1)(900)}{1} = 90 \text{ W/m}^2$$

23. A thermometer graduated according to a linear scale reads a value x_0 when in contact with boiling water, and $x_0/3$ when in contact with ice. What is the temperature of an object in 0°C , if this thermometer in the contact with the object reads $x_0/2$? [JEE Main-2019]

(1) 35 (2) 25 (3) 60 (4) 40

Ans. (2)

Sol.



Temp. is measures with linear scale

Thus $\left(\frac{2X_0}{3} \right) = 100^\circ\text{C}$ therefore $\frac{X_0}{6} \Rightarrow 25^\circ\text{C}$

24. A cylinder of radius R is surrounded by a cylindrical shell of inner radius R and outer radius $2R$. The thermal conductivity of the material of the inner cylinder is K_1 and that of the outer cylinder is K_2 . Assuming no loss of heat, the effective thermal conductivity of the system for heat flowing along the length of the cylinder is: [JEE Main-2019]

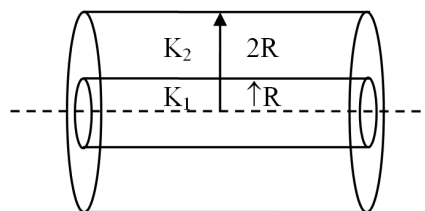
(1) $\frac{K_1 + K_2}{2}$ (2) $\frac{2K_1 + 3K_2}{5}$ (3) $K_1 + K_2$ (4) $\frac{K_1 + 3K_2}{4}$

Ans. (4)

Sol. $R_1 = \frac{L}{K_1(\pi R^2)}$; $R_2 = \frac{L}{K_2(3\pi R^2)}$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{[K_1 + K_2(3)]\pi R^2}{L} = \frac{k_{eq}(4\pi R^2)}{L}$$

$$k_{eq} = \frac{(K_1 + 3K_2)}{4}$$



25. A rod, of length L at room temperature and uniform area of cross section A , is made of a metal having coefficient of linear expansion $\alpha/^\circ\text{C}$. It is observed that an external compressive force F , is applied on each of its ends, prevents any change in the length of the rod, when its temperature rises by ΔT K. Young's modulus, Y , for this metal is : [JEE Main-2019]

(1) $\frac{F}{2A\alpha\Delta T}$ (2) $\frac{F}{A\alpha(\Delta T - 273)}$ (3) $\frac{F}{A\alpha\Delta T}$ (4) $\frac{2F}{A\alpha\Delta T}$

Ans. (3)

Sol. Young's modulus $y = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{(\Delta l/l)} = \frac{F}{A(\alpha \Delta T)}$

- 26.** Two rods A and B of identical dimensions are at temperature 30°C . If A is heated upto 180°C and B upto $T^\circ\text{C}$, then the new lengths are the same. If the ratio of the coefficients of linear expansion of A and B is $4 : 3$, then the value of T is :- **[JEE Main-2019]**

- (1) 200°C (2) 230°C (3) 270°C (4) 250°C

Ans. (2)

Sol. $l + \Delta l_A = l + \Delta l_B$

$$\Delta l_A = \Delta l_B$$

$$l \alpha_1 \Delta T_1 = l \alpha_2 \Delta T_2$$

$$\frac{\alpha_1}{\alpha_2} = \frac{\Delta T_2}{\Delta T_1}$$

$$\frac{4}{3} = \frac{T - 30}{180 - 30}$$

Thus $T = 230^\circ\text{C}$

- 27.** A non-isotropic solid metal cube has coefficients of linear expansion as : $5 \times 10^{-5}/^\circ\text{C}$ along the x-axis and $5 \times 10^{-6}/^\circ\text{C}$ along the y and the z-axis. If the coefficient of volume expansion of the solid is $C \times 10^{-6}/^\circ\text{C}$ then the value of C is **[JEE Main-2020]**

Ans. (60)

Sol. $\gamma = \alpha_x + \alpha_y + \alpha_z$

$$= 5 \times 10^{-5} + 5 \times 10^{-6} + 5 \times 10^{-6}$$

$$= (50 + 5 + 5) \times 10^{-6}$$

$$\gamma = 60 \times 10^{-6}$$

$$C = 60$$

- 28.** M grams of steam at 100°C is mixed with 200 g of ice at its melting point in a thermally insulated container. If it produces liquid water at 40°C [heat of vaporization of water is 540 cal/g and heat of fusion of ice is 80 cal/g], the value of M is _____.

[JEE Main-2020]

Ans. (40)

Sol. $M \times 540 + M + 60 = 200 \times 80 + 200 \times 1 \times (40 - 0)$

$$\Rightarrow M = 40$$

29. Three containers C_1 , C_2 and C_3 have water at different temperatures. The table below shows the final temperature T when different amounts of water (given in liters) are taken from each container and mixed (assume no loss of heat during the process) [JEE Main-2020]

C_1	C_2	C_3	T
1l	2l	–	60°C
–	1l	2l	30°C
2l	–	1l	60°C
1l	1l	1l	θ

The value of θ (in °C to the nearest integer) is _____.

Ans. (50)

Sol. According to table and applying law of calorimetry

$$T_1 + 2T_2 = 180 \quad \text{.....(1)}$$

$$T_2 + 2T_3 = 90 \quad \text{.....(2)}$$

$$2T_1 + T_3 = 180 \quad \text{.....(3)}$$

Adding (1) + (2) + (3)

$$3(T_1 + T_2 + T_3) = 450$$

$$T_1 + T_2 + T_3 = 150^\circ$$

Hence,

$$150 = 3\theta$$

$$\theta = 50^\circ\text{C}$$

30. A body of mass $m = 10$ kg is attached to one end of a wire of length 0.3 m. The maximum angular speed (in rad s^{-1}) with which it can be rotated about its other end in space station is (Breaking stress of wire = $4.8 \times 10^7 \text{ Nm}^{-2}$ and area of cross-section of the wire = 10^{-2} cm^2) is : [JEE Main-2020]

Ans. (4.00)

Sol. $T = m\omega^2 l$

$$\text{Breaking stress} = \frac{T}{A} = \frac{m\omega^2 l}{A}$$

$$\Rightarrow \omega^2 = \frac{4.8 \times 10^7 \times (10^{-2} \times 10^{-4})}{10 \times 0.3} = 16$$

$$\Rightarrow \omega = 4$$

31. Two steel wires having same length are suspended from a ceiling under the same load. If the ratio of their energy stored per unit volume is 1 : 4, the ratio of their diameters is: [JEE Main-2020]

(1) 1 : 2

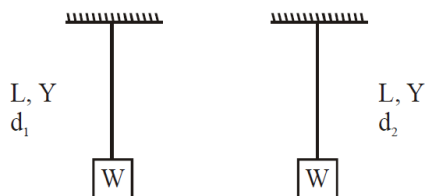
(2) $\sqrt{2} : 1$

(3) 2 : 1

(4) $1 : \sqrt{2}$

Ans. (2)

Sol.



$$\frac{\text{Energy stored}}{\text{Volume}} = \frac{1}{2} \frac{(\text{Stress})^2}{Y}$$

$$\frac{u_1}{u_2} = \frac{1}{4} \Rightarrow 4u_1 = u_2$$

$$4 \frac{1}{2Y} \left[\frac{W \cdot 4}{\pi d_1^2} \right]^2 = \frac{1}{2Y} \left[\frac{W \cdot 4}{\pi d_2^2} \right]^2$$

$$4 = \left(\frac{d_1}{d_2} \right)^4$$

$$\Rightarrow \frac{d_1}{d_2} = \sqrt{2} : 1$$

EXERCISE # (JA)

1. Two rods one of aluminium of length l_1 having coefficient of linear expansion α_a , and other steel of length l_2 having coefficient of linear expansion α_s are joined end to end. The expansion in both the rods is same on variation of temperature. Then the value of $\frac{l_1}{l_1 + l_2}$ is

[JEE' (Scr) 2003]

- (A) $\frac{\alpha_s}{\alpha_a + \alpha_s}$ (B) $\frac{\alpha_s}{\alpha_a - \alpha_s}$ (C) $\frac{\alpha_a + \alpha_s}{\alpha_s}$ (D) None of these

Ans. A

Sol. The length of each rod increases by the same amount

$$\Delta l_a = \Delta l_s$$

$$l_1 \alpha_a \Delta T = l_2 \alpha_s \Delta T$$

$$\frac{l_2}{l_1} = \frac{\alpha_a}{\alpha_s}$$

$$\Rightarrow \frac{l_2}{l_1} + 1 = \frac{\alpha_a}{\alpha_s} + 1$$

$$\Rightarrow \frac{l_1}{l_1 + l_2} = \frac{\alpha_s}{\alpha_a + \alpha_s}$$

2. 2 kg ice at -20°C is mixed with 5 kg water at 20°C . Then final amount of water in the mixture would be; Given specific heat of ice = $0.5 \text{ cal/g}^\circ\text{C}$, specific heat of water = $1 \text{ cal/g}^\circ\text{C}$, Latent heat of fusion of ice = 80 cal/g .

[JEE' (Scr) 2003]

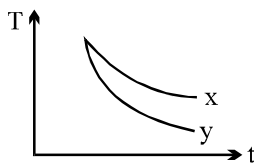
- (A) 6 kg (B) 5 kg (C) 4 kg (D) 2 kg

Ans. A

Sol. Heat lost = Heat gain

3. If emissivity of bodies X and Y are e_x and e_y and absorptive power are A_x and A_y then

[JEE' (Scr) 2003]



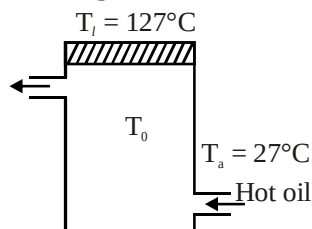
- (A) $e_y > e_x$; $A_y > A_x$ (B) $e_y < e_x$; $A_y < A_x$ (C) $e_y > e_x$; $A_y < A_x$ (D) $e_y = e_x$; $A_y = A_x$

Ans. A

- Sol.** $-\frac{dT}{dt} \propto e$ (i)
 $e = a$ (ii)

4. Hot oil is circulated through an insulated container with a wooden lid at the top whose conductivity $K = 0.149 \text{ J/(m}^\circ\text{C-sec)}$, thickness $t = 5 \text{ mm}$, emissivity $= 0.6$. Temperature of the top of the lid in steady state is at $T_l = 127^\circ$. If the ambient temperature $T_a = 27^\circ\text{C}$. Calculate
(a) rate of heat loss per unit area due to radiation from the lid.

(b) temperature of the oil. (Given $\sigma = \frac{17}{3} \times 10^{-8}$)

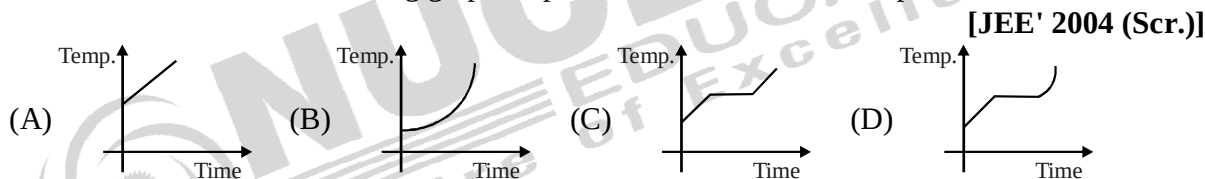


Ans. (a) 595 watt/m^2 ; (b) $T_o \approx 420 \text{ K}$

Sol. (a) $E = e\sigma(T^4 - T_0^4) = 0.6 \times \frac{17}{3} \times 10^{-8} [(400)^4 - (300)^4] = 595 \text{ w/m}^2$

(b) $\frac{kA(T_{\text{oil}} - T)}{\ell} = 595 \times A$

5. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm . The rate of heating is constant. Which of the following graphs represents the variation of temperature with time?



Ans. C

6. A cube of coefficient of linear expansion α_s is floating in a bath containing a liquid of coefficient of volume expansion γ_l . When the temperature is raised by ΔT , the depth upto which the cube is submerged in the liquid remains the same. Find the relation between α_s and γ_l , showing all the steps.

[IIT JEE -2004]

Ans. $\gamma_l = 2\alpha_s$

Sol. When the temperature is increased, volume of the cube will increase while density of liquid will decrease. The depth upto which the cube is submerged in the liquid remains the same, hence the upthrust will not change.

$$F = F'$$

$$\therefore V_i \rho_L g = V'_i \rho'_L g \quad (V_i = \text{volume immersed})$$

$$\therefore (Ah_i) (\rho_L) (g) = (1 + 2\alpha_s \Delta T) (Ah_i) \left(\frac{\rho_L}{1 + \gamma_L \Delta T} \right) g$$

Solving this equation, we get $\gamma_L = 2\alpha_s$.

7. Three discs A, B, and C having radii 2 m, 4 m and 6 m respectively are coated with carbon black on their outer surfaces. The wavelengths corresponding to maximum intensity are 300 nm, 400 nm and 500 nm respectively. The power radiated by them are Q_A , Q_B and Q_C respectively. **[JEE' 2004 (Scr.)]**

(A) Q_A is maximum (B) Q_B is maximum (C) Q_C is maximum (D) $Q_A = Q_B = Q_C$

Ans. B

Sol. $Q \propto AT^4$... (i)

$l_m T = \text{constant}$... (ii)

$$\Rightarrow Q \propto \frac{A}{(\alpha_m)^4} \propto \frac{r^2}{\alpha_m^4}$$

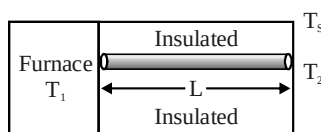
8. Two identical conducting rods are first connected independently to two vessels, one containing water at 100°C and the other containing ice at 0°C . In the second case, the rods are joined end to end and connected to the same vessels. Let q_1 and q_2 g/s be the rate of melting of ice in the two cases respectively. The ratio q_2/q_1 is **[JEE' 2004 (Scr.)]**

(A) 1/2 (B) 2/1 (C) 4/1 (D) 1/4

Ans. D

Sol. $\left(\frac{dm}{dt}\right)_L = \frac{\Delta T}{R_{eq}}$

9. One end of a rod of length L and cross-sectional area A is kept in a furnace of temperature T_1 . The other end of the rod is kept at a temperature T_2 . The thermal conductivity of the material of the rod is K and emissivity of the rod is e . It is given that $T_2 = T_s + \Delta T$, where $\Delta T \ll T_s$, T_s being the temperature of the surroundings. If $\Delta T \propto (T_1 - T_s)$, find the proportionality constant that heat is lost only by radiation at the end where the temp. of the rod is T_2 . **[IIT-JEE 2004]**



Ans. $\frac{K}{4e\sigma LT_s^3 + K}$

Sol. Heat conduction through rod is

$$Q = \frac{kA(T_1 - T_2)\Delta t}{\ell} \quad \dots (i)$$

Energy emitted by surface of rod in same time Δt is

$$E = e\sigma A(T_2^4 - T_s^4)\Delta t \quad \dots (ii)$$

$E = Q$ at thermal equilibrium

10. 2 litre water at 27°C is heated by a 1 kW heater in an open container. On an average heat is lost to surroundings at the rate 160 J/s. The time required for the temperature to reach 77°C is

[JEE' 2005 (Scr)]

- (A) 8 min 20 sec (B) 10 min (C) 7 min (D) 14 min

Ans. A

Sol. Net heat given/sec = $1000 - 160$
= 840 J/s

if it takes time t then

$$840 t = 2000 \times 4.2 \times (77 - 27)$$

$$t = 500 \text{ sec} = 8 \text{ min } 20 \text{ sec.}$$

11. 1 calorie is the heat required to increased the temperature of 1 gm of water by 1°C from

[JEE' 2005 (Scr)]

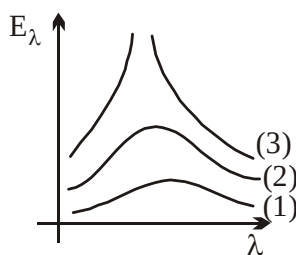
- (A) 13.5°C to 14.5°C at 76 mm of Hg
(B) 14.5°C to 15.5°C at 760 mm of Hg
(C) 0°C to 1°C at 760 mm of Hg
(D) 3°C to 4°C to 760 mm of Hg

Ans. B

Sol. Defination of 1 calorie

12. Three graphs marked as 1, 2, 3 representing the variation of maximum emissive power and wavelength of radiation of the sun, a welding arc and a tungsten filament. Which of the following combination is correct

[JEE' 2005 (Scr)]



- (A) 1-bulb, 2 $\rightarrow$ welding arc, 3 $\rightarrow$ sun (B) 2-bulb, 3 $\rightarrow$ welding arc, 1 $\rightarrow$ sun
(C) 3-bulb, 1 $\rightarrow$ welding arc, 2 $\rightarrow$ sun (D) 2-bulb, 1 $\rightarrow$ welding arc, 3 $\rightarrow$ sun

Ans. A

Sol. $\lambda_m T = \text{constant}$

$$\text{Here } \lambda_{m_1} > \lambda_{m_2} > \lambda_{m_3}$$

$$\Rightarrow T_1 < T_2 < T_3$$

$$T_3 \Rightarrow \text{Sun}$$

$$T_2 \Rightarrow \text{welding arc}$$

$$T_1 \Rightarrow \text{bulb}$$

13. In which of the following phenomenon heat convection does not take place [JEE' 2005 (Scr)]
 (A) land and sea breeze
 (B) boiling of water
 (C) heating of glass surface due to filament of the bulb
 (D) air around the furnace

Ans. C

Sol. Heat transfer of glass bulb from filament is through radiation. A medium is required for convection process. As a bulb is almost evacuated, heat from the filament is transmitted through radiation.

14. A spherical body of area A, and emissivity $e = 0.6$ is kept inside a black body. What is the rate at which energy is radiated per second at temperature T [JEE' 2005 (Scr)]
 (A) $0.6 \sigma AT^4$ (B) $0.4 \sigma AT^4$ (C) $0.8 \sigma AT^4$ (D) $1.0 \sigma AT^4$

Ans. A

Sol. $P = e\sigma AT^4$

15. In an insulated vessel, 0.05 kg steam at 373 K and 0.45 kg of ice at 253 K are mixed. Then, find the final temperature of the mixture.
 Given, $L_{\text{fusion}} = 80 \text{ cal/g} = 336 \text{ J/g}$, $L_{\text{vaporization}} = 540 \text{ cal/g} = 2268 \text{ J/g}$,
 $S_{\text{ice}} = 2100 \text{ J/kg K} = 0.5 \text{ cal/gK}$ and $S_{\text{water}} = 4200 \text{ J/kg K} = 1 \text{ cal/gK}$ [IIT JEE- 2006]

Ans. 273 K

Sol. $\Sigma \Delta Q = 0$

Heat lost by steam to convert into 0°C water

$$H_L = 0.05 \times 540 + 0.05 \times 100 \times 1$$

$$= 27 + 5 = 32 \text{ kcal}$$

Heat required by ice to change into 0°C water

$$H_g = 0.45 \times \frac{1}{2} \times 20 + 0.45 \times 80 = 4.5 + 36.00 = 40.5 \text{ kcal}$$

Thus, final temperature of mixture is $0^\circ\text{C} = 273 \text{ K}$

16. In a dark room with ambient temperature T_0 , a black body is kept at a temperature T. Keeping the temperature of the black body constant (at T), Sun rays are allowed to fall on the black body through a hole in the roof of the dark room. Assuming that there is no change in the ambient temperature of the room, which of the following statement(s) is/are correct?

[IIT JEE- 2006]

(A) The quantity of radiation absorbed by the black body in unit time will increase.

(B) Since emissivity = absorptivity, hence the quantity of radiation emitted by black body in unit time will increase.

(C) Black body radiates more energy in unit time in the visible spectrum.

(D) The reflected energy in unit time by the black body remains same.

Ans. AD

17. Column I gives some devices and column II gives some processes on which the functioning of these devices depend. Match the devices in column I with the processes in column II and indicate your answer by darkening appropriate bubbles in the 4×4 matrix given in the ORS.

[IIT JEE-2007]

Column-I

- (A) Bimetallic strip
(B) Steam engine
(C) Incandescent lamp
(D) Electric fuse

Column-II

- (P) Radiation from a hot body
(Q) Energy conversion
(R) Melting
(S) Thermal expansion of solids.

Ans. (A) QS, (B) Q (C) PQ (D) QR or (A) S, (B) Q, (C) P, (D) R

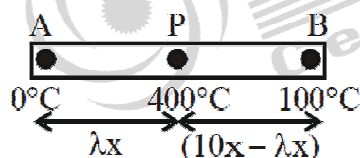
18. A metal rod AB of length $10x$ has its one end A in ice at 0°C and the other end B in water at 100°C . If a point P on the rod is maintained at 400°C , then it is found that equal amounts of water and ice evaporate and melt per unit time. The latent heat of evaporation of water is 540 cal/g and latent heat of melting of ice is 80 cal/g . If the point P is at a distance of λx from the ice end A, find the value of λ .

[Neglect any heat loss to the surrounding.]

[IIT JEE-2009]

Ans. 9

Sol.



For ice melting at 0°C

$$L_1 \frac{dm_1}{dt} = \frac{kA400}{\lambda x} \quad \dots(i)$$

For water evaporation at 100°C

$$L_2 \frac{dm_2}{dt} = \frac{kA(400 - 100)}{(10 - \lambda)x}$$

$$\frac{dm_1}{dt} = \frac{dm_2}{dt}$$

19. Two spherical bodies A (radius 6 cm) and B (radius 18 cm) are at temperature T_1 and T_2 respectively. The maximum intensity in the emission spectrum of A is at 500 nm and in that of B is at 1500 nm. Considering them to be black bodies, what will be the ratio of the rate of total energy radiated by A to that of B?

[IIT JEE- 2010]

Ans. 9

Sol. $\lambda_m T = b \Rightarrow \lambda_m \propto \frac{1}{T}$

$$\frac{T_A}{T_B} = \frac{\lambda_B}{\lambda_A} = \frac{1500}{500} = 3$$

Energy radiated = $E = \sigma AT^4$

$A = 4\pi R^2$

$$\frac{E_A}{E_B} = \left(\frac{T_A}{T_B}\right)^4 \left(\frac{R_A}{R_B}\right)^2 = 3^4 \left(\frac{6}{18}\right)^2 = 9$$

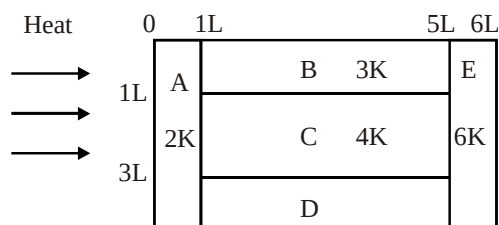
20. A piece of ice (heat capacity = $2100 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$ and latent heat = $3.36 \times 10^5 \text{ J kg}^{-1}$) of mass m grams is at -5°C at atmospheric pressure. It is given 420 J of heat so that the ice starts melting. Finally when the ice–water mixture is in equilibrium, it is found that 1 gm of ice has melted. Assuming there is no other heat exchange in the process, the value of m is [IIT JEE- 2010]

Ans. 8

Sol. $420 = (m \times 10^{-3}) (2100)(5) + (1 \times 10^{-3}) \times (3.36 \times 10^5)$
 $m = 8 \text{ gm}$

21. A composite block is made of slabs A, B, C, D and E of different thermal conductivities (given in terms of a constant K) and sizes (given in terms of length, L) as shown in the figure. All slabs are of same width. Heat ' Q ' flows only from left to right through the blocks. Then in steady state [IIT JEE- 2011]

- (A) heat flow through A and E slabs are same
(B) heat flow through slab E is maximum
(C) temperature difference across slab E is smallest
(D) heat flow through C = heat flow through B + heat flow through D.



Ans. ACD or ABCD

Sol. $Q_A = Q_B + Q_C + Q_D = Q_E$

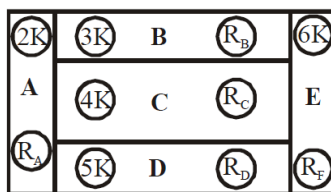
$$R = \frac{\ell}{kA}$$

Let width of slabs be W

$$R_A = \frac{L}{2k(4L)W} = \frac{1}{8kW}$$

$$R_B = \frac{4L}{3kLW} = \frac{4}{3kW}$$

$$R_C = \frac{4L}{4k(2LW)} = \frac{1}{2kW}$$



$$R_D = \frac{4L}{5k(LW)} = \frac{4}{5kW}$$

$$R_E = \frac{L}{6k(4LW)} = \frac{1}{24kW}$$

$$\text{as } Q = \frac{\Delta T}{R} \text{ \& } \Delta T_B = \Delta T_C = \Delta T_D$$

$$Q_B : Q_C : Q_D = \frac{1}{R_B} : \frac{1}{R_C} : \frac{1}{R_D}$$

22. Steel wire of length 'L' at 40°C is suspended from the ceiling and then a mass 'm' is hung from its free end. The wire is cooled down from 40° to 30° C to regain its original length 'L'. The coefficient of linear thermal expansion of the steel is $10^{-5}/^\circ\text{C}$, Young's modulus of steel is 10^{11} N/m^2 and radius of the wire is 1 mm. Assume that $L \gg$ diameter of the wire. Then the value of 'm' in kg is nearly [IIT JEE- 2011]

Ans. 3

Sol. $\Delta L_1 = \frac{FL}{AY} = \frac{mgL}{\pi r^2 Y}$ = Increase in length

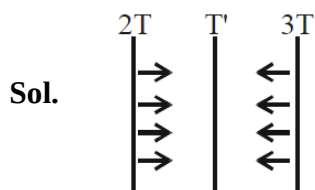
$$\Delta L_2 = L\alpha\Delta T = \text{Decrease in length}$$

$$\Delta L_1 = \Delta L_2$$

23. Three very large plates of same area are kept parallel and close to each other. They are considered as ideal black surfaces and have very high thermal conductivity. The first and third plates are maintained at temperatures 2T and 3T respectively. The temperature of the middle (i.e. second) plate under steady state condition is [IIT JEE -2012]

(A) $\left(\frac{65}{2}\right)^{\frac{1}{4}} T$ (B) $\left(\frac{97}{4}\right)^{\frac{1}{4}} T$ (C) $\left(\frac{97}{2}\right)^{\frac{1}{4}} T$ (D) $(97)^{\frac{1}{4}} T$

Ans. C



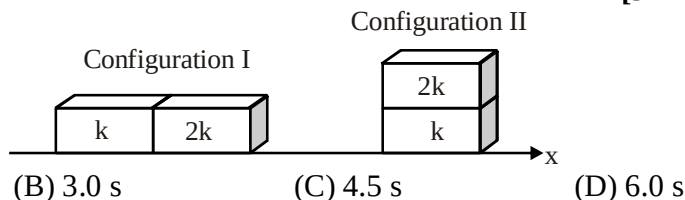
Let temperature of middle plate = T'

$$k(2T)^4 + k(3T)^4 = 2k(T')^4$$

$$T = \left(\frac{97}{2}\right)^{1/4} T$$

24. Two rectangular blocks, having identical dimensions, can be arranged either in configuration I or in configuration II as shown in the figure, On of the blocks has thermal conductivity k and the other 2k. The temperature difference between the ends along the x-axis is the same in both

the configurations. It takes 9s to transport a certain amount of heat from the hot end to the cold end in the configuration I. The time to transport the same amount of heat in the configuration II is : **[JEE Advanced -2013]**



(A) 2.0 s

(B) 3.0 s

(C) 4.5 s

(D) 6.0 s

Ans. A

Sol. $\frac{dQ}{dt} = \frac{\Delta T}{R_{eq}}$

$$dQ = \frac{\Delta T}{R_{eq1}} (dt_1) = \frac{\Delta T}{R_{eq2}} = \frac{\Delta T}{R_{eq2}} (dt_2)$$

25. One end of a horizontal thick copper wire of length $2L$ and radius $2R$ is welded to an end of another horizontal thin copper wire of length L and radius R . When the arrangement is stretched by applying forces at two ends, the ratio of the elongation in the thin wire to that in the thick wire is : **[JEE Advanced-2013]**

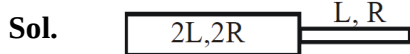
(A) 0.25

(B) 0.50

(C) 2.00

(D) 4.00

Ans. C



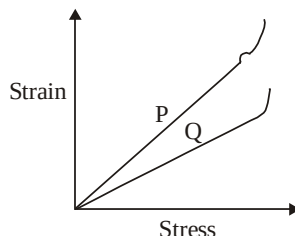
Force same = F

$$Y = \frac{F/A}{\Delta L/A}$$

$$F = YA_1 \frac{\Delta L_1}{L_1} = YA_1 \frac{\Delta L_2}{L_2}$$

$$\frac{\Delta L_2}{\Delta L_1} = \frac{L_2}{L_1} \times \frac{A_1}{A_2}$$

26. In plotting stress versus strain curves for two materials P and Q, a student by mistake puts strain on the y-axis and stress on the x-axis as shown in the figure. Then the correct statement(s) is(are)



- (A) P has more tensile strength than Q
(B) P is more ductile than Q
(C) P is more brittle than Q

[JEE Advanced-2015]

(D) The Young's modulus of P is more than that of Q

Ans. AB

Sol. Slope of this graph represents the reciprocal of Young's modulus.

since Slope of P > Slope of Q

Hence Y of P < Y of Q

27. Two spherical stars A and B emit blackbody radiation. The radius of A is 400 times that of B and A emits 10^4 times the power emitted from B. The ratio (λ_A / λ_B) of their wavelengths λ_A and λ_B at which the peaks occur in their respective radiation curves is [JEE Advanced-2015]

Ans. 2

Sol. $P = e\sigma AT^4$

$\lambda T = \text{constant}$

$$\frac{P_A}{P_B} = \frac{e\sigma A_A T_A^4}{e\sigma A_B T_B^4} = \frac{A_A}{A_B} \frac{T_A^4}{T_B^4} = \frac{r_A^2}{r_B^2} \cdot \frac{\lambda_B^4}{\lambda_A^4}$$

$$10^4 = 400^2 \cdot \left(\frac{\lambda_B}{\lambda_A} \right)^4$$

$$\frac{10^4}{16 \times 10^4} = \left(\frac{\lambda_B}{\lambda_A} \right)^4$$

$$\frac{\lambda_A}{\lambda_B} = \left(\frac{16}{1} \right)^{\frac{1}{4}} = 2$$

28. The ends Q and R of two thin wires, PQ and RS, are soldered (joined) together. Initially each of the wires has a length of 1 m at 10°C . Now the end P is maintained at 10°C , while the end S is heated and maintained at 400°C . The system is thermally insulated from its surroundings. If the thermal conductivity of wire PQ is twice that of the wire RS and the coefficient of linear thermal expansion of PQ is $1.2 \times 10^{-5} \text{ K}^{-1}$, the change in length of the wire PQ is

[JEE Advanced-2016]

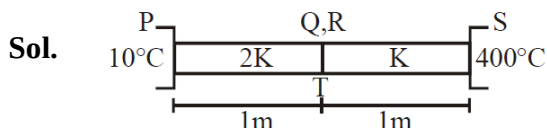
(A) 0.78 mm

(B) 0.90 mm

(C) 1.56 mm

(D) 2.34 mm

Ans. A



Heat flow from P to Q

$$\frac{dQ}{dt} = \frac{2KA(T-10)}{1}$$

Heat flow from Q to S

$$\frac{dQ}{dt} = \frac{KA(400 - T)}{1}$$

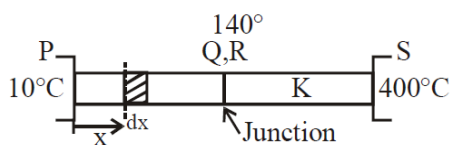
At steady state heat flow is same in whole combination

$$\frac{2KA(T-10)}{1} = KA(400 - T)$$

$$2T - 20 = 400 - T$$

$$3T = 420$$

$$T = 140^\circ$$



Temp of junction is 140°C

Temp at a distance x from end P

$$\text{is } T_x = (130x + 10^\circ)$$

Change in length dx is dy

$$dy = \alpha dx (T_x - 10)$$

$$\int_0^{\Delta y} dy = \int_0^1 \alpha dx (130x + 10 - 10)$$

$$\Delta y = \left[\frac{\alpha x^2}{2} \times 130 \right]_0^1$$

$$\Delta y = 1.2 \times 10^{-5} \times 65$$

$$\Delta y = 78.0 \times 10^{-5} \text{ m} = 0.78 \text{ mm}$$

29. A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated (P) by the metal. The sensor has a scale that displays $\log_2 (P/P_0)$, where P_0 is a constant. When the metal surface is at a temperature of 487°C, the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to 2767 °C?

[JEE Advanced 2016]

Ans. 9

Sol. $P = eA\sigma T^4$ where T is in kelvin

$$\log_2 \frac{eA\sigma(487 + 273)^4}{P_0} = 1 \quad \dots(i)$$

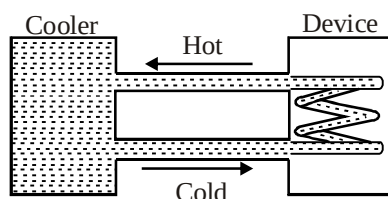
$$\log_2 \frac{eA\sigma(2767 + 273)^4}{P_0} = x \quad \dots(ii)$$

$$(ii) - (i)$$

$$\log_2 \left(\frac{3040}{760} \right)^4 = x - 1$$

$$\therefore x = 9$$

30. A water cooler of storage capacity 120 liters can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device the generates constantly 3 kW of heat (thermal load). The temperature of water fed into the device cannot exceed 30°C and the entire stored 120 litres of water is initially cooled to 10°C . The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is [JEE Advanced-2016]



(Specific heat of water is $4.2 \text{ kJ kg}^{-1} \text{ K}^{-1}$ and the density of water is 1000 kg m^{-3})

- (A) 1600 (B) 2067 (C) 2533 (D) 3933

Ans. B

Sol. $3000 - P = (120 \times 1)(4.2 \times 10^3) \frac{dT}{dt}$

$$\frac{dT}{dt} = \frac{20}{60 \times 60 \times 3}$$

$$P = 2067 \text{ W}$$

31. A human body has a surface area of approximately 1 m^2 . The normal body temperature is 10°C above the surrounding room temperature T_0 . Take the room temperature to be $T_0 = 300 \text{ K}$. For $T_0 = 300 \text{ K}$, the value of $\sigma T_0^4 = 460 \text{ W m}^{-2}$ (where σ is the Stefan-Boltzmann constant). Which of the following options is/are correct? [JEE Advanced-2017]

- (A) the amount of energy radiated by the body in 1 second is close to 60 Joules
(B) if the surrounding temperature reduces by a small amount $\Delta T_0 \ll T_0$, then to maintain the same body temperature the same (living) human being needs to radiate $\Delta W = 4\sigma T_0^3 \Delta T_0$ more energy per unit time
(C) Reducing the exposed surface area of the body (i.e. by curling up) allows human to maintain the same body temperature while reducing the energy lost by radiation
(D) If the body temperature rises significantly then the peak in the spectrum of electromagnetic radiation emitted by the body would shift to longer wavelengths

Ans. C

Sol. Assumption : $e = 1$ (Black body radiation)

$$P = \sigma A (T^4)$$

- (A) $P_{\text{rad}} = \sigma AT^4 = \sigma \cdot 1 \cdot (T_0 + 10)^4$
 $= \sigma T_0^4 \left(1 + \frac{10}{T_0}\right)^4$ ($T_0 = 300$ gives)
 $= \sigma (300)^4 \cdot \left(1 + \frac{40}{300}\right) \approx 460 \times \frac{17}{15} \approx 520 \text{ J}$
 $\Rightarrow$ Energy lost in 1 second = 520 Joule
 (B) $P = \sigma A (T^4)$
 Since $T = \text{constant}$
 $P_{\text{radiated}} = \text{constant}$
 (C) Surface area decrease $\Rightarrow$ Energy radiation decreases

32. Two conducting cylinders of equal length but different radii are connected in series between two heat baths kept at temperatures $T_1 = 300 \text{ K}$ and $T_2 = 100 \text{ K}$, as shown in the figure. The radius of the bigger cylinder is twice that of the smaller one and the thermal conductivities of the materials of the smaller and the larger cylinders are K_1 and K_2 respectively. If the temperature at the junction of the two cylinders in the steady state is 200 K , then $K_1/K_2 = \underline{\hspace{2cm}}$. [JEE Advanced-2018]

Ans. 4.00

33. A current carrying wire heats a metal rod. The wire provides a constant power (P) to the rod. The metal rod is enclosed in an insulated container. It is observed that the temperature (T) in the metal rod changes with time (t) as

$$T(t) = T_0 (1 + \beta t^{1/4})$$

where β is a constant with appropriate dimension while T_0 is a constant with dimension of temperature. The heat capacity of the metal is. [JEE Advanced-2019]

$$(1) \frac{4P(T(t) - T_0)^4}{\beta^4 T_0^5} \quad (2) \frac{4P(T(t) - T_0)^2}{\beta^4 T_0^3} \quad (3) \frac{4P(T(t) - T_0)}{\beta^4 T_0^2} \quad (4) \frac{4P(T(t) - T_0)^3}{\beta^4 T_0^4}$$

Ans. (4)

Sol. $P dt = ms d(T(t))$

$$\Rightarrow P dt = mS \frac{T_0 \beta}{4} t^{-3/4} dt$$

$$\Rightarrow S = \frac{4Pt^{3/4}}{m\beta T_0}$$

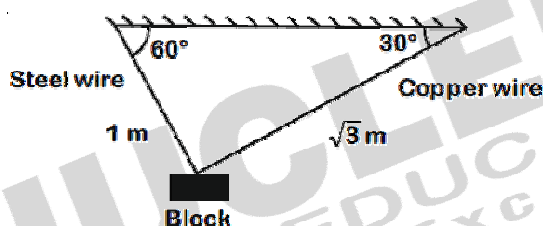
Given $T(t) = T_0(1 + \beta t^{1/4})$

$$\Rightarrow t^{1/4} = \frac{T(t) - T_0}{T_0 \beta}$$

So, $S = \frac{4P}{m\beta T_0} \left(\frac{T(t) - T_0}{T_0 \beta} \right)^3$

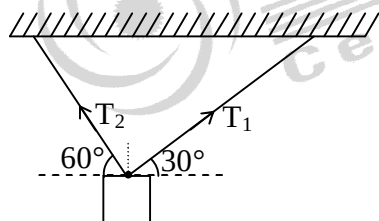
$$\Rightarrow S = \frac{4P(T(t) - T_0)^3}{mT_0^4 \beta^4}$$

34. A block of weight 100 N is suspended by copper and steel wires of same cross sectional area 0.5 cm^2 and length $\sqrt{3} \text{ m}$ and 1 m , respectively. Their other ends are fixed on a ceiling as shown in figure. The angles subtended by copper and steel wires with ceiling are 30° and 60° respectively. If elongation in copper wire is (Δl_c) and elongation in steel wire is (Δl_s) , then the ratio $\frac{\Delta l_c}{\Delta l_s}$ is _____. [JEE Advanced-2019]



Young's modulus for copper and steel are $1 \times 10^{11} \text{ N/m}^2$ and $2 \times 10^{11} \text{ N/m}^2$ respectively.]

Ans.
Sol.



$$T_1 \cos 30^\circ = T_2 \cos 60^\circ \quad \dots(1)$$

$$T_1 \sin 30^\circ + T_2 \sin 60^\circ = 100 \text{ N} \quad \dots(2)$$

Calculating :-

$$T_1 = 50 \text{ N}$$

$$T_2 = 50 \sqrt{3} \text{ N}$$

$$\Delta l_c \Rightarrow \left(\frac{T_1}{A} \right) \frac{l}{y} \Rightarrow \frac{50}{A} \frac{\sqrt{3}}{1 \times 10^{11}}$$

$$\Delta l_s \Rightarrow \left(\frac{T_2}{A} \right) \frac{l}{y} \Rightarrow \frac{50 \times \sqrt{3}}{A \times 2 \times 10^{11}}$$

$$\frac{\Delta l_c}{\Delta l_s} = \frac{2}{1}$$

Answer = 2.00

35. A liquid at 30°C is poured very slowly into a Calorimeter that is at temperature of 110°C . The boiling temperature of the liquid is 80°C . It is found that the first 5 gm of the liquid completely evaporates. After pouring another 80 gm of the liquid the equilibrium temperature is found to be 50°C . The ratio of the Latent heat of the liquid to its specific heat will be _____ $^{\circ}\text{C}$.
[Neglect the heat exchange with surrounding] [JEE Advanced-2019]

Ans. 270.00

Sol. $5 \times s \times (50) + 5L = 30 \text{ (C)}$ (1)

$80 \times s \times (20) = 30 \text{ (C)}$ (2)

From (1) and (2)

$$250s + 5L = 1600s$$

$$\Rightarrow 5L = 1350s$$

$$\Rightarrow L = \frac{1350}{5}s$$

$$\Rightarrow \frac{L}{s} = 270.00$$

