Physicsaholics

# DPP – 2 (Heat Transfer)

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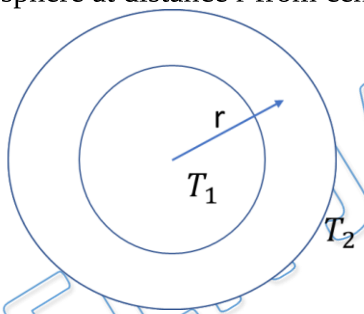
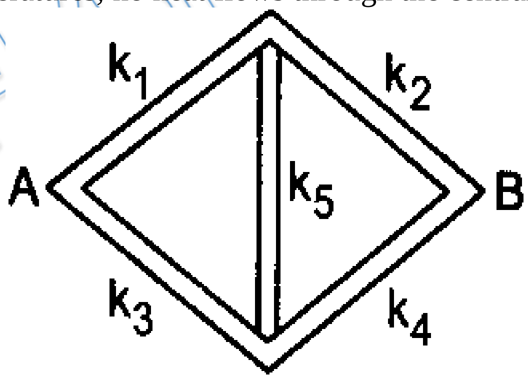
| Written Solutionon Website:- | https://physicsaholics.com/note/notesDetalis/83 |

Q 1. A hollow conducting sphere has inner radius R and outer radius 2R. Temperatures of inner cavity and surroundings are $T_1$ $and$ $T_2$ ($T_2 < T_1$ ) respectively . These temperatures are not changing with time.
Temperature gradient in sphere at distance r from centre is directly proportional to




(a) r
(b) 1/r
(c) $r^2$
(d) None of the above

Q 2. Five rods of the same dimensions are arranged as shown. They have thermal conductivities $k_1$, $k_2$, $k_3$, $k_4$ and $k_5$. When points A and B are maintained at different temperatures, no heat flows through the central rod. It follows that




(a) $k_1 = k_4$ and $k_2 = k_3$ (b) $k_1/k_4 = k_2/k_3$
(c) $k_1k_4 = k_2k_3$ (d) $k_1k_2 = k_3k_4$

Q 3. Ice starts freezing in a lake with water at $0^0$C when the atmospheric temperature is -$10^0$C. If the time taken for 1 cm of ice to be formed is 12 minutes the time taken for the thickness of the ice to change from 1 cm to 2 cm will be
(A) 12 minutes
(B) less than 12 minutes

(C ) more than 12 minutes but less than 24 minutes
(D) more than 24 minutes

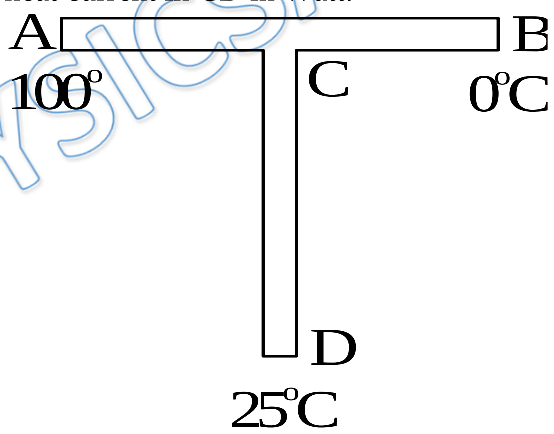
Q 4. A pond of water at 0°C is covered with layer of ice 4 cm thick if air temperature is -10°C (constant), how long it takes ice thickness to increase to 8 cm? $K_{ice}$ = 2 W/m°C, $L_f$ = 80 cal/gm, $\rho_{ice}$ = 900 kg/m$^3$.

Q 5. Water in pond is at 0°C. The temperature of ambient air is constant at -20°C. Thickness x of ice film in centimeter increases with t in second according to relation (density of ice = 0.917 g/cc, conductivity of ice = 0.005 cgs and latent heat of ice = 80 cal/gm)
(a) $x = 2.73 \times 10^{-3}\, t$
(b) $x^2 = 2.73 \times 10^{-3}\, t$
(c) $t^2 = 2.73 \times 10^{-3} x$
(d) $t = 2.73 \times 10^{-3} x$

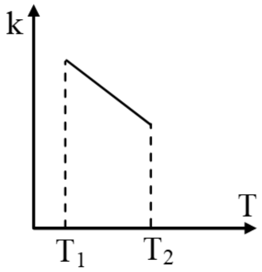
Q 6. A hollow metallic sphere of radius 20 cm surrounds a concentric metallic sphere of radius 5 cm. The space between the two spheres is filled with a nonmetallic material. The inner and outer spheres are maintained at 50°C and 10°C respectively and it is found that 100 J of heat passes from the inner sphere to the outer sphere per second. Find the thermal conductivity of the material between the spheres.

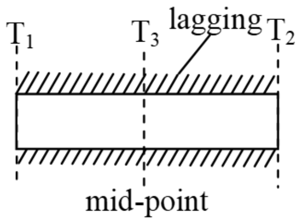
Q 7. For a solid cylinder of length $L_0$, area A conductivity varies with temperature Tas $k = k_0(1 + \alpha T)$. If one end is at $2T_0$ and other at $T_0$, find rate of heat flow?

Q 8. A rod CD of thermal resistance 5.0 K/W is joined at the middle of an identical rod AB as shown in fig. The ends A, B and D are maintained at 100°C, 0°C and 25°C respectively. Find the heat current in CD in Watt.




Q 9. Over a certain temperature range, the thermal conductivity k of a metal is not constant but varies as indicated in figure. A lagged rod of the metal has its ends maintained at temperatures $T_1$ and $T_2 (T_2 > T_1)$ as shown in figure. Which one of the following correctly describes how $T_3$, the temperature at the mid-point of the rod, compares with $T_1$ and $T_2$ ?



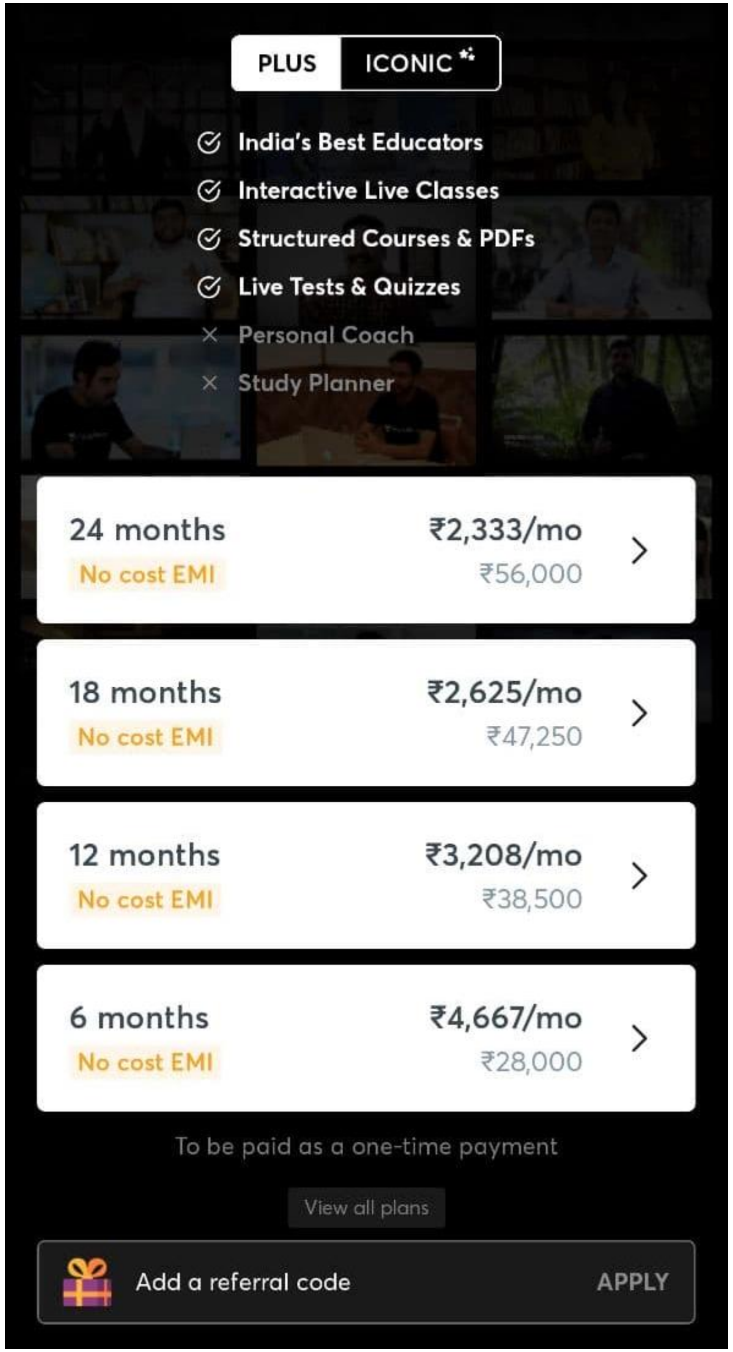




(A) $T_3 = (T_1 + T_2)/2$ (B) $T_3 = (T_1 - T_2)/2$
(C) $T_3 > (T_1 + T_2)/2$ (D) $T_3 < (T_1 + T_2)/2$



# Answer Key

| | | | | |
|---|---|---|---|---|
| **Q.1 d** | **Q.2 c** | **Q.3 d** | **Q.4 10.03 hrs.** | **Q.5 b** |
| **Q.6 3** | **Q.7** $\frac{k_0 A T_0}{L_0}\left(1+\frac{3\alpha T_0}{2}\right)$ | **Q.8 4** | **Q.9 d** | |

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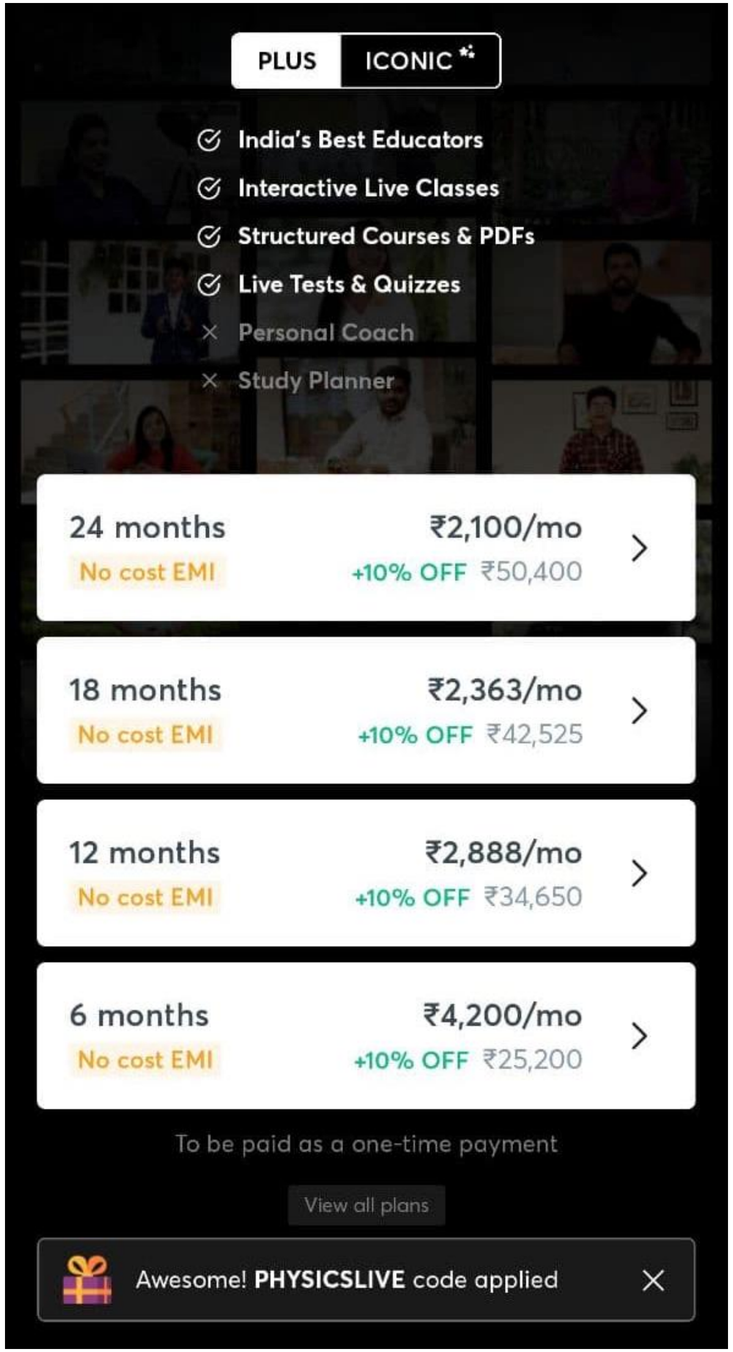
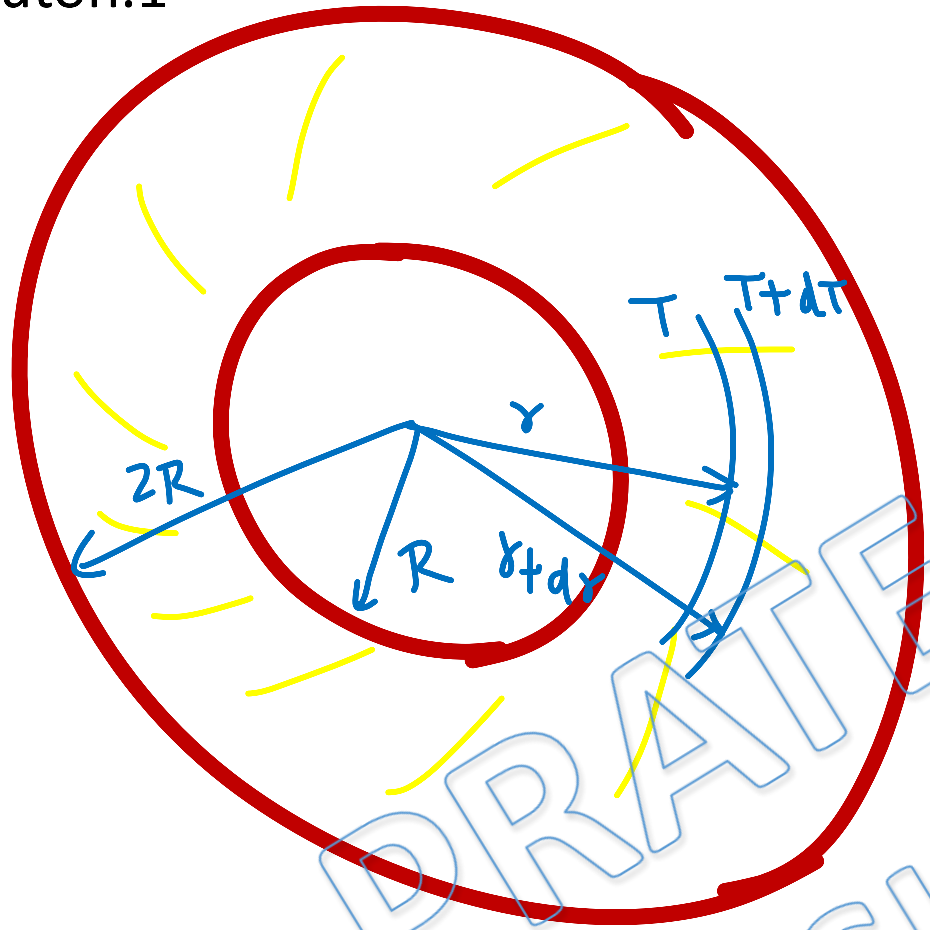


# Written Solution

**DPP- 2 Heat Transfer: Kirchhoff's law, Wheatstone bridge, Radial and cylindrical flow of heat**

**By Physicsaholics Team**

Soluton.1




hollow sphere

Let Radial heat Current in sphere = $i$

Equation of heat Current for differential spherical shell

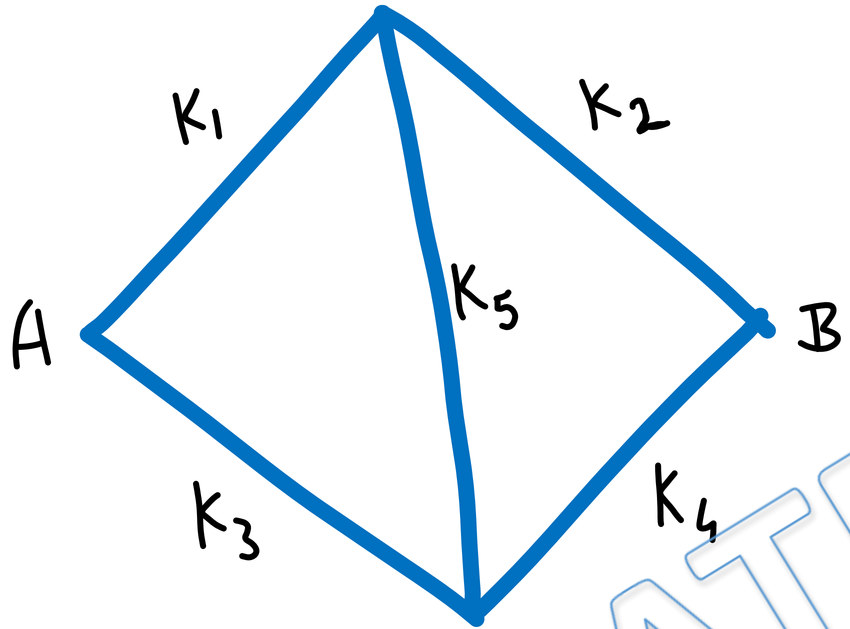
$$\frac{dQ}{dt} = i = \frac{K(4\pi r^2)\,dT}{dr}$$

$\Rightarrow$ Temperature gradient $\frac{dT}{dr} = \frac{i}{4\pi K r^2}$

$$\Rightarrow \quad \frac{dT}{dr} \propto \frac{1}{r^2}$$

Ans.d

Soluton.2




no heat flow in central Rod

$\Rightarrow$ ballonced wheat stone bridge.

$$\Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4}$$ where R means thermal resistance

$$\Rightarrow \frac{K_2}{K_1} = \frac{K_4}{K_3}$$

$$\Rightarrow K_1 K_4 = K_2 K_3$$

Ans(c)

# Soluton.3

If $t$ is time required to freeze $x$ thickness of ice.

$$t \propto x^2 \Rightarrow t = Cx^2, \; C \text{ is Constant}$$

$$\Rightarrow \quad 12\,\text{min} = C \times (1\,\text{cm})^2 \Rightarrow C = 12\,\text{min}/\text{cm}^2.$$

$$\Rightarrow \quad t = 12x^2$$

time taken to freeze 2 cm thickness of ice.

$$t' = 12 \times 4 = 48\,\text{min}.$$

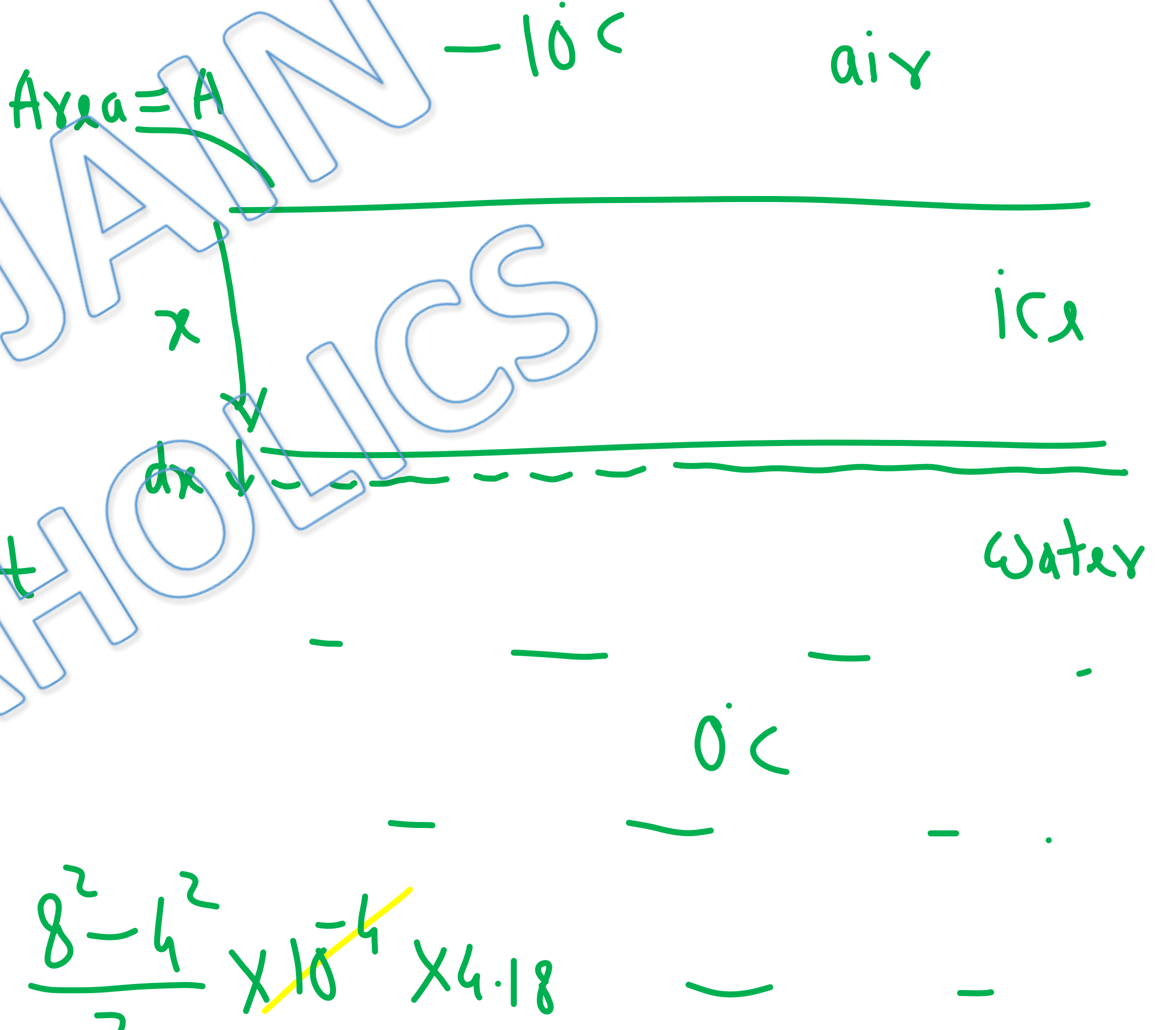
time taken to increase thickness from 1 cm to 2 cm

$$= (48 - 12) = 36\,\text{min} > 24\,\text{min}$$

Ans (d)

Soluton.4

Rate of heat flow through ice




Slab $\frac{d\theta}{dt} = \frac{KA\times 10}{x}$

$\Rightarrow \quad L\frac{dm}{dt} = \frac{2A\times 10}{x\times 4.18}$

$\Rightarrow 4.18\times 80\times 10^3\times 900\, A\, x\, dx = 2A\times 10\, dt$

$\Rightarrow 4.18\times 3600\times 10^3\times\int_{4\times10^{-2}}^{8\times10^{-2}} x\, dx = \frac{\int dt}{4}$

$\Rightarrow \quad t = 3600\times 10^3\times\frac{8^2-4^2}{2}\times 10^{-4}\times 4.18$

$= \frac{360\times 48}{2\times 60\times 60}\times 4.18\ hr = 10.03\ hr$

Ans. 10.03 hrs

Rate of Heat flow through ice slab

Soluton.5 $\frac{dQ}{dt} = \frac{KA \times 20}{x}$

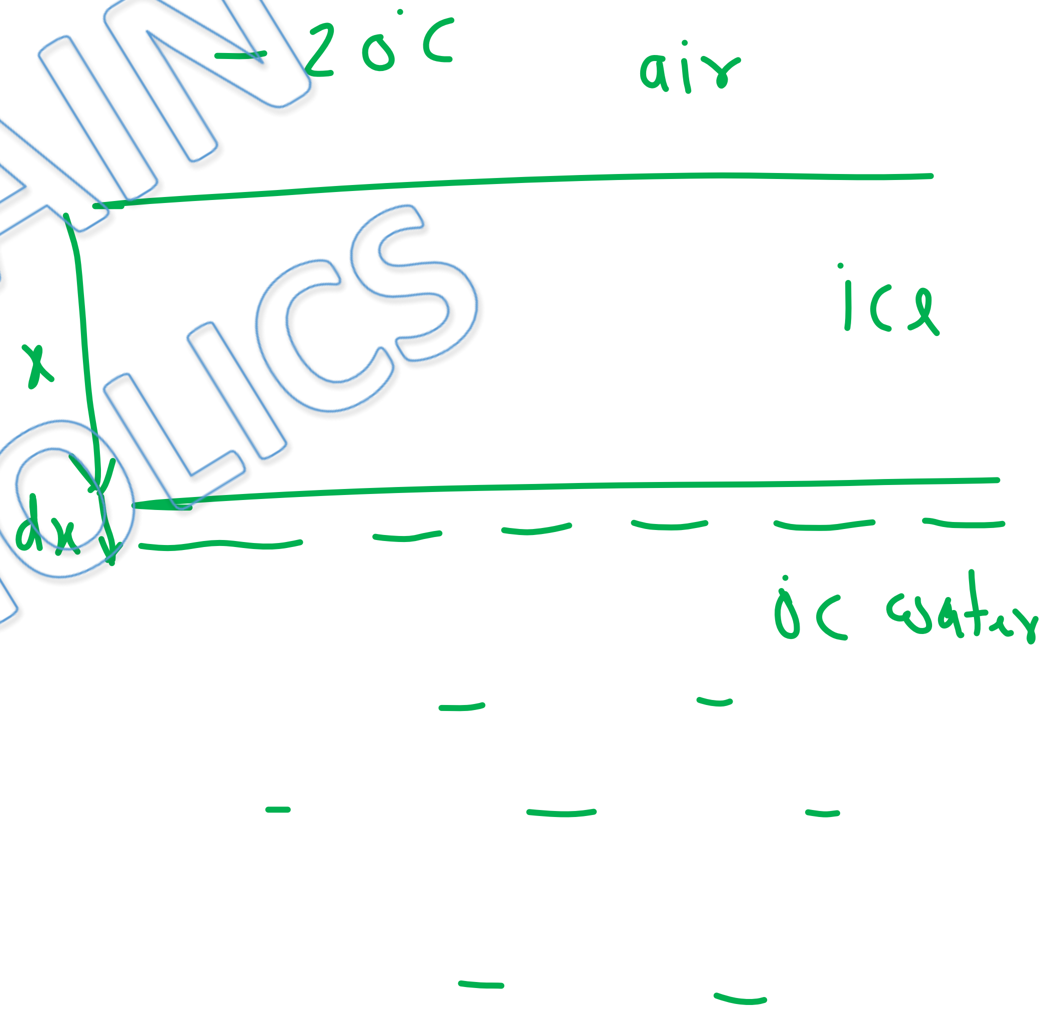
$\Rightarrow \quad L\frac{dm}{dt} = \frac{20KA}{x}$

$\Rightarrow \quad \frac{L\rho A\,dx}{dt} = \frac{20KA}{x}$

$\Rightarrow \quad \int_0^x x\,dx = \frac{20K}{L\rho}\int_0^t dt$

$\Rightarrow \quad \frac{x^2}{2} = \frac{20 \times .005}{.917 \times 80}\,t$

$\Rightarrow \quad x^2 = 2.73 \times 10^{-3}\,t$




Ans(b)

Soluton.6

Thermal resistance of differential shell

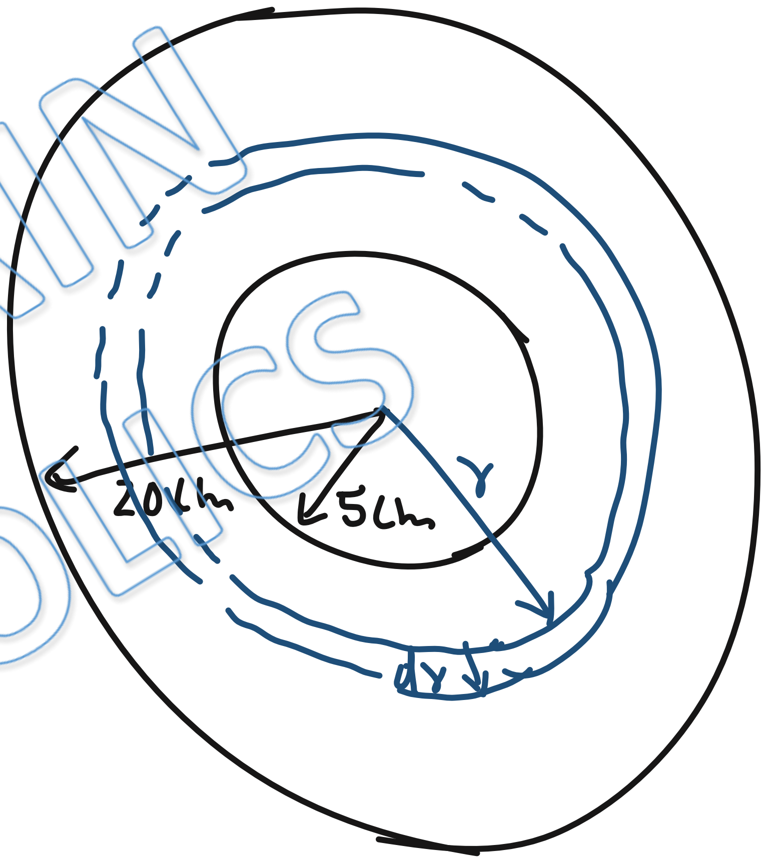
$$dR = \frac{dr}{K\,4\pi r^2}$$

All such shells are in series.

net resistance $R = \frac{1}{4\pi K}\int_{5\times10^{-2}}^{20\times10^{-2}} \frac{dr}{r^2}$

$$\Rightarrow R = \frac{1}{4\pi K}\left[\frac{1}{5\times10^{-2}} - \frac{1}{20\times10^{-2}}\right]$$

$$= \frac{3}{4\pi K \times 20\times10^{-2}}$$

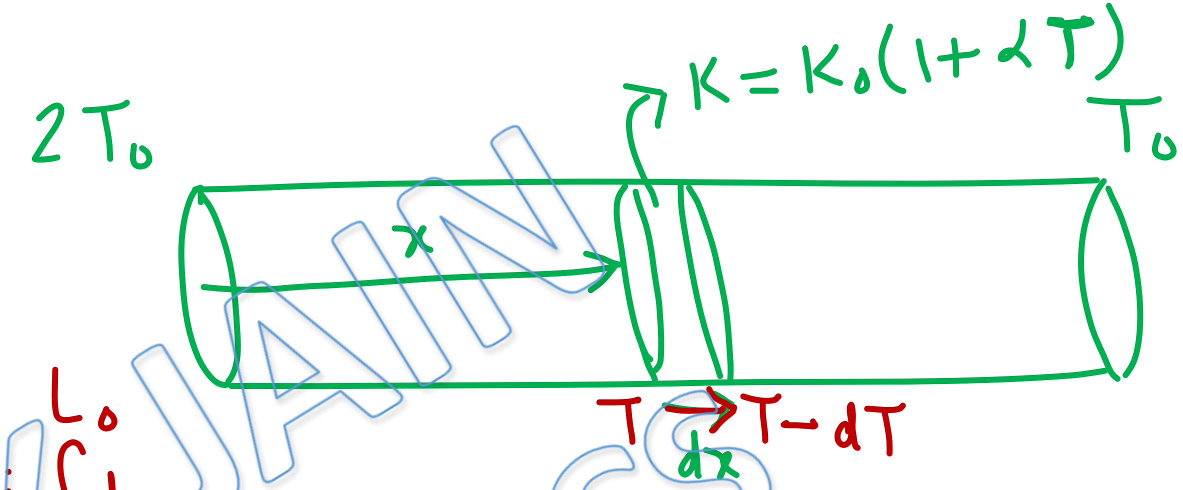



now $\frac{\Delta Q}{\Delta t} = \frac{\Delta T}{R} \Rightarrow \frac{100}{1} = \frac{40\times4\pi K\times20\times10^{-2}}{3}$

$$\Rightarrow K = \frac{300}{8\times4\pi} \simeq 3$$

Ans(3)

## Soluton.7




for differential disc

$$\frac{dq}{dt} = -\frac{AK_0(1+\alpha T)\,dT}{dx} = i$$

$$\Rightarrow \quad -AK_0 \int_{2T_0}^{T_0} (1+\alpha T)\,dT = i\int_0^{L_0} dx$$

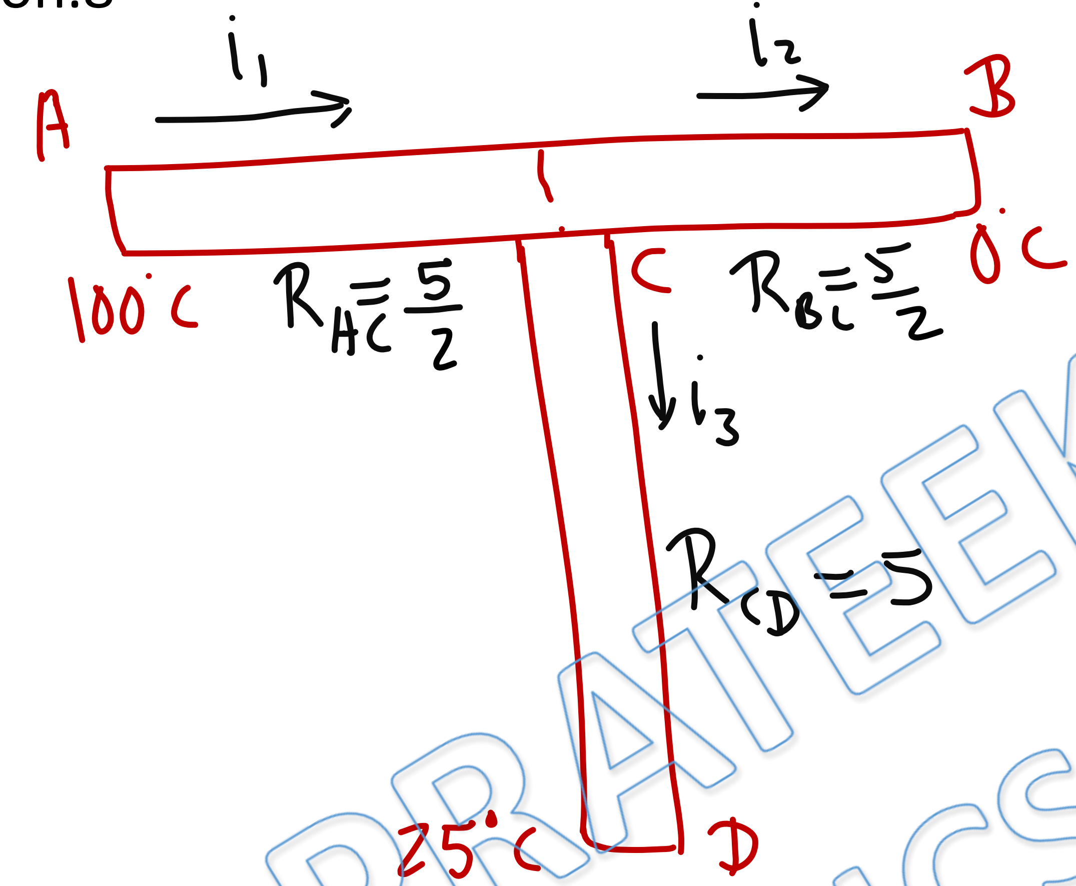
$$\Rightarrow \quad -AK_0\left[T + \frac{\alpha T^2}{2}\right]_{2T_0}^{T_0} = iL_0$$

$$\Rightarrow \quad i = \frac{AK_0}{L_0}\left[(2T_0 - T_0) + \frac{\alpha}{2}(4T_0^2 - T_0^2)\right]$$

$$= \frac{AK_0T_0}{L_0}\left[1 + \frac{3\alpha}{2}T_0\right]$$

Ans . $\frac{K_o A T_o}{L_o}\left(1 + \frac{3\alpha T_o}{2}\right)$

Soluton.8




$$i_1 = i_3 + i_2$$

$$\Rightarrow \frac{100 - T_c}{5/2} = \frac{T_c - 0}{5/2} + \frac{T_c - 25}{5}$$

$$\Rightarrow 200 - 2T_c = 2T_c + T_c - 25$$

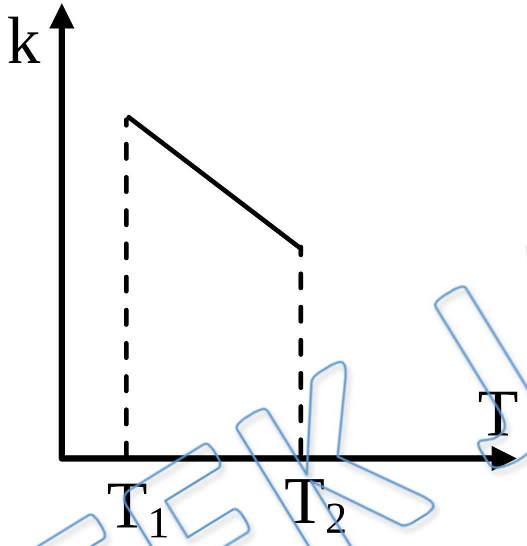
$$\Rightarrow 5T_c = 225$$

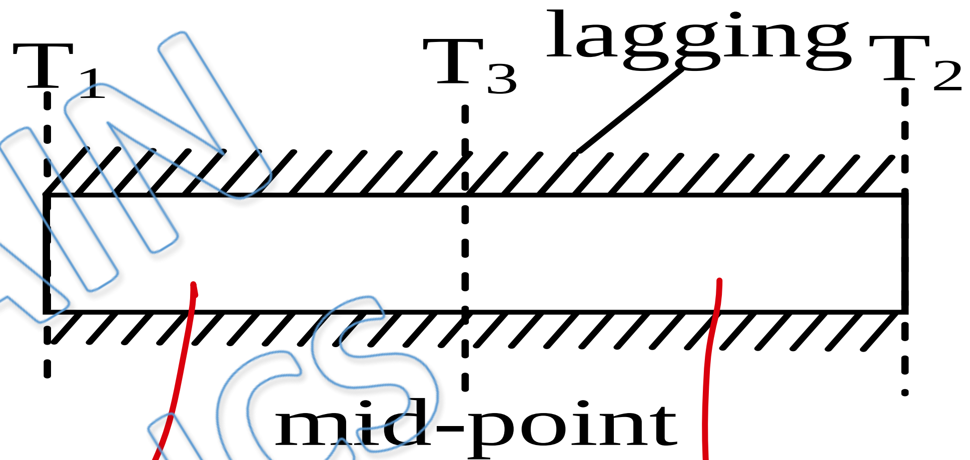
$$\Rightarrow T_c = 45$$

$$i_3 = \frac{45 - 25}{5} = 4$$

Ans.4

Soluton.9




temperature difference of $T_3$ from $T_1$ is low $\Rightarrow T_3 < \frac{T_1+T_2}{2}$

Ans (d)

low Temperature
$\Rightarrow$ high K
$\Rightarrow$ low R
$\Rightarrow$ low $\Delta T$

high temperature
$\Rightarrow$ low K
$\Rightarrow$ high R
$\Rightarrow$ high $\Delta T$

Ans.d

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# Chalo Niklo