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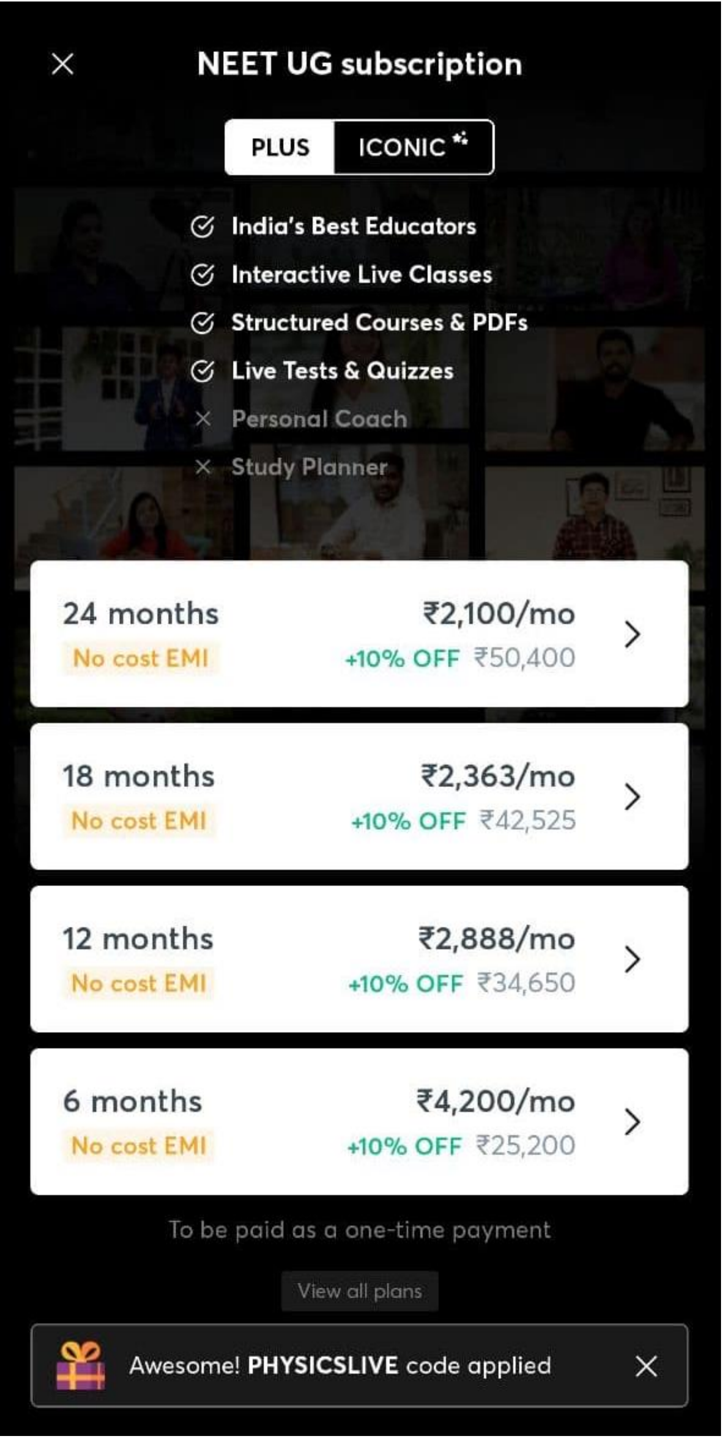

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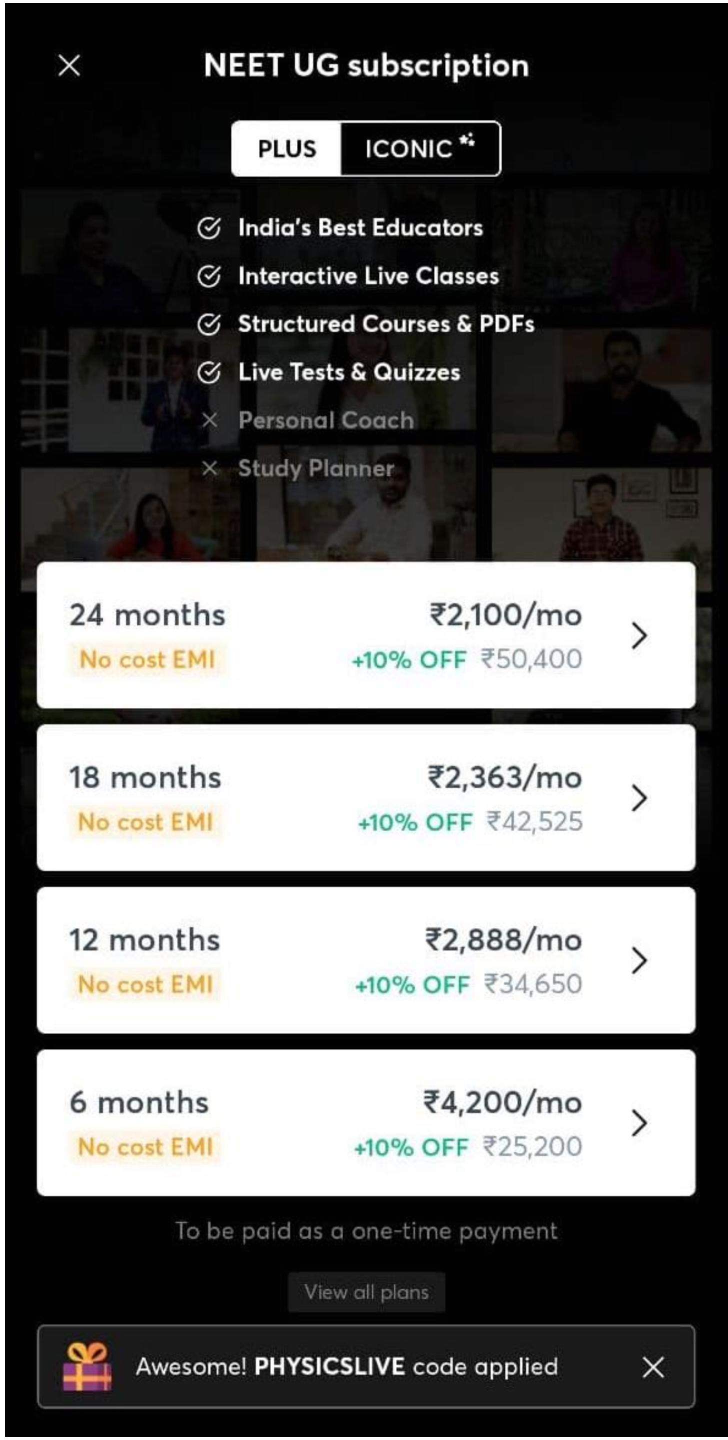

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Physics DPP

DPP-1 Heat Transfer: Conduction: Rate of flow of heat, Combination of rods (Series & Parallel)

By Physicsaholics Team

Q) Which of the following cylindrical rods, (given radius r and length l) each made of the same material and whose ends are maintained at the same temperature will conduct most heat?

(a) $r = 2r_o; l = 2l_o$

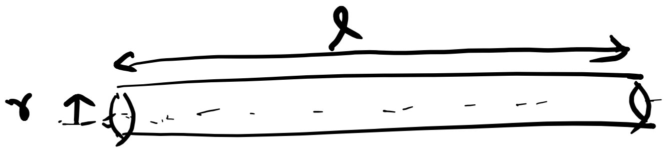
(b) $r = 2r_o; l = l_o$

(c) $r = r_o; l = 2l_o$

(d) $r = r_o; l = l_o$

Ans. b

Solution:



$I_H = \frac{KA\Delta\theta}{L}$; when $\Delta\theta$ = constant

$\Rightarrow I_H \propto \frac{A}{L}$

(i) $r = 2r_0$; $l = 2l_0$

$I_{H_1} \propto \frac{\pi(2r_0)^2}{2l_0} = \frac{2\pi r_0^2}{l_0}$

(ii) $r = 2r_0$, $l = l_0$

$I_{H_2} \propto \frac{\pi(2r_0)^2}{l_0} = \frac{4\pi r_0^2}{l_0}$

(iii) $r = r_0$; $l = 2l_0$

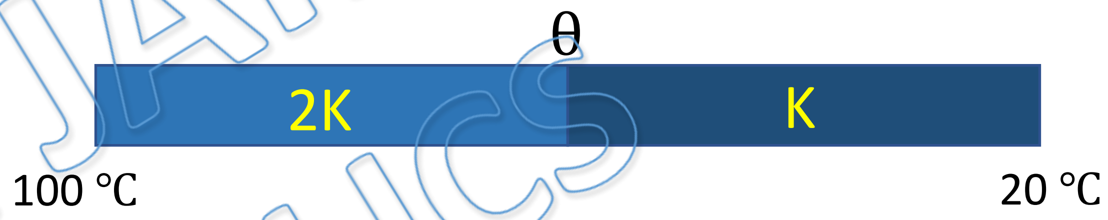
$I_{H_3} \propto \frac{\pi r_0^2}{2l_0}$

(iv) $r = r_0$, $l = l_0$

$I_{H_4} = \frac{\pi r_0^2}{l_0}$

$\Rightarrow I_{H_2} > I_{H_1} > I_{H_4} > I_{H_3}$

Q) In the following situations, the length and area of cross-section of each rod is same. Find temperature θ at junction of rods



(a) $\frac{220}{3}$ °C

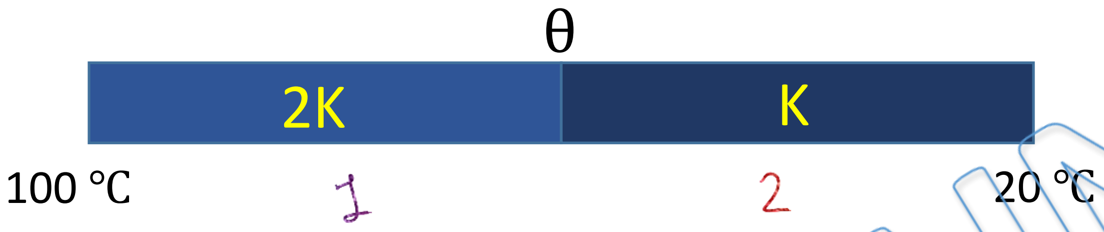
(b) $\frac{220}{5}$ °C

(c) $\frac{160}{5}$ °C

(d) $\frac{160}{3}$ °C

Ans. a

Solution:



$$I_1 = I_2$$

$$\frac{(2K)(A)(100-\theta)}{L} = \frac{(K)(A)(\theta-20)}{L}$$

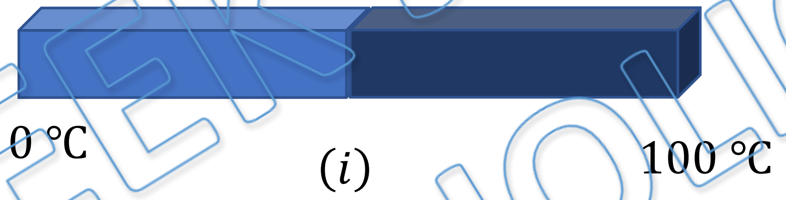
$$2(100-\theta) = (\theta-20)$$

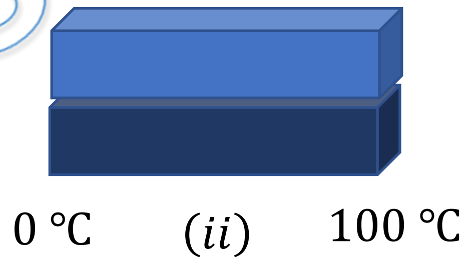
$$200 - 2\theta = \theta - 20$$

$$220^\circ C = 3\theta$$

$$\boxed{\theta = \frac{220}{3}\ ^\circ C}$$ Ans.

Q) Two identical square rods of metal are welded end to end as shown in figure (i), 20 calories of heat flows through it in 4 minutes. If the rods are welded as shown in figure (ii), the same amount of heat will flow through the rods in





(a) 1 minute

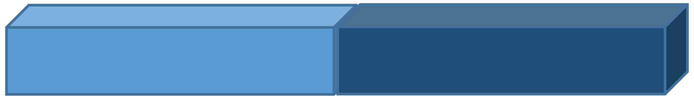
(b) 2 minutes

(c) 4 minutes

(d) 16 minutes

Ans. a

Solution:



0 °C (i) 100 °C

0 °C (ii) 100 °C

Case-1

$$I = \frac{\Delta\theta}{R}$$

$$R_{eq} = 2R$$

$$I_1 = \frac{\Delta\theta}{2R}$$

$$\frac{20}{4} = \frac{(100)}{2R} \quad \text{—(1)}$$

Case-2

$$R_{eq} = R/2$$

$$I_2 = \frac{\Delta\theta}{R_{eq}} = \frac{100}{(R/2)}$$

$$\frac{20}{t} = \frac{100}{(R/2)} \quad \text{—(2)}$$

$$\Rightarrow \frac{(1)}{(2)} \Rightarrow \frac{20/4}{20/t} = \frac{100/2R}{100/(R/2)}$$

$$\Rightarrow \frac{t}{4} = \frac{1}{4} \Rightarrow \boxed{t = 1 \text{ minute}} \text{ Ans.}$$

Q) The coefficient of thermal conductivity depends upon

(a) Temperature difference of two surfaces

(b) Area of the plate

(c) Thickness of the plate

(d) Material of the plate

Ans. d

Solution:

Coefficient of Thermal Conductivity is the internal property of the metal and is independent of dimensions and other external factors. It only depend on nature of material.

Q) If the coefficient of conductivity of aluminium is 0.5 cal/cm-sec-°C, then in order to conduct 10 cal/sec-cm^2 in steady state, the temperature gradient in aluminium must be:

(a) 0.5 °C/cm

(b) 10 °C/cm

(c) 20 °C/cm

(d) 10.5 °C/cm

Ans. c

Solution:

$K = 0.5$ cal/cm-sec-°C

$$I = \frac{KA(\Delta\theta)}{L}$$

Temperature gradient $= \frac{\Delta\theta}{L}$

$$\frac{\Delta\theta}{L} = \frac{I}{KA}$$

given: $\frac{I}{A} = 10$ cal/sec-cm^2

$$\frac{\Delta\theta}{L} = \frac{I/A}{K} = \frac{10}{0.5}$$

$$\frac{\Delta\theta}{L} = \frac{100}{5} \Rightarrow \boxed{\frac{\Delta\theta}{L} = 20 \ ^\circ C/cm}$$ Ans.

Q) One end of a brass rod 2m long and having 1cm radius is maintained at 250 °C. When a steady state is reached, the rate of heat flow across any cross-section is 0.5 cal/s. What is the temperature of the other end (K = 0.26 cal/sec-cm-°C)

(a) 100 °C (b) 266.5 °C

(c) 127.5 °C (d) 127.5 K

Ans. c

Solution:

$r = 1\,cm.$

$L = 2\,m = 200\,cm$

$I = 0.5\ cal/s$

$$I = \frac{KA(250 - T)}{L}$$

$$0.5 = \frac{(0.26)(\pi \times (1)^2)(250 - T)}{200}$$

$$100 = (0.26)(\pi)(250 - T)$$

$$122.5 = 250 - T$$

$$\Rightarrow \boxed{T = 127.5\ ^\circ C} \text{ Ans.}$$

Q) The length of a rod of aluminium is 1.0 m and its area of cross-section is 5.0 cm^2. Its one end is kept at 250 °C and the at 50 °C. How much heat will flow in the rod in 5.0 minutes . (Thermal conductivity 'K' for Al = $2.0 \times 10^{-1}\ KJs^{-1}m^{-1}°C^{-1}$)

(a) 2000 J
(b) 4000 J
(c) 6000 J
(d) 8000 J

Ans. c

Solution:

$L = 1\,m = 100\,cm$

$A = 5\,cm^2$

$250^\circ C$ $\qquad$ $50^\circ C$

$t = 5\,min$

$Q = ?$

$$I = \frac{Q}{t} = \frac{KA(\Delta\theta)}{L}$$

$$\frac{Q}{(5\times 60)} = \frac{(2\times 10^{-1}\times 10^{3})(5\times 10^{-4})(200)}{1}$$

$$Q = 5\times 60\times 2\times 5\times 200\times 10^{-2}$$

$$Q = 5\times 60\times 2\times 5\times 2$$

$$\boxed{Q = 6000\,J}$$

Ans.

Q) Find the thermal resistance of an aluminium rod of length 0.20 m and area of cross section $1 \times 10^{-4} m^2$. The heat current is along the length of the rod. [Thermal conductivity of aluminium = 200 W/m-K]

(a) $10\ \mathrm{W\ k^{-1}}$
(b) $20\ \mathrm{W\ k^{-1}}$
(c) $30\ \mathrm{W\ k^{-1}}$
(d) $40\ \mathrm{W\ k^{-1}}$

Ans. a

Solution:

$$I = \frac{KA\,\Delta\theta}{L} = \frac{\Delta\theta}{\left(L/KA\right)}$$

$$I = \frac{\Delta\theta}{R}$$

$$\Rightarrow R = \frac{L}{KA} = \frac{0.2}{200 \times 1 \times 10^{-4}}$$

$$R = \frac{2 \times 10^{-3}}{2 \times 10^{2}}$$

$$\boxed{R = 10 \; W K^{-1}}$$ Ans.

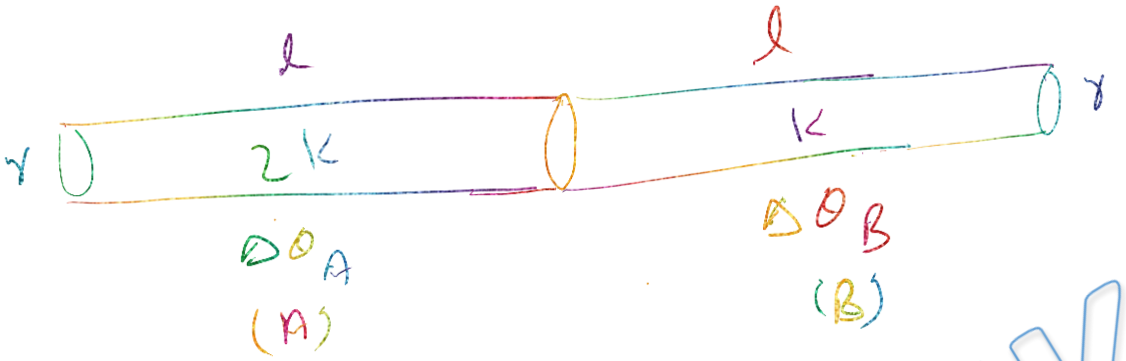
Q) Two rods A and B of same length and radius are joined together in series. the thermal conductivity of A and B are 2K and K. Under steady state conditions, if the temperature difference between the open ends of A and B is 36°C, the temperature difference across 'A' is:

(a) 12 °C (b) 18 °C

(c) 24 °C (d) 9 °C

Ans. a

Solution:



$$I_A = I_B$$

$$\frac{(2K)A(\Delta\theta_A)}{L} = \frac{(K)A(\Delta\theta_B)}{L}$$

$$\boxed{2\Delta\theta_A = \Delta\theta_B}$$

& $\Delta\theta_A + \Delta\theta_B = 36^\circ C$

$\Delta\theta_A + 2\Delta\theta_A = 36^\circ C$

$3\Delta\theta_A = 36^\circ C$

$\boxed{\Delta\theta_A = 12^\circ C}$ Ans.

Q) If the temperature difference between the two side of a wall is doubled, its thermal conductivity

(a) Is doubled

(b) Is halved

(c) Become four times

(d) None of these

Ans. d

Solution:

Thermal conductivity is property of material it does not depend on temperature difference between two sides of wall. So, thermal conductivity will remains same. (*It slightly varies with temperature but according to our syllabus we always consider constant with temperature change.)

Q) A cotton sheet is ironed with hot electricity iron. How is energy transferred through the metal base of the iron to the sheet?

(a) By conduction

(b) By convection only

(c) By radiation only

(d) By convection & Radiation only

Ans. a

Solution:

Conduction occurs when two objects at different temperatures are in contact with each other. Heat flows from the warmer to the cooler object until they are both at the same temperature. The iron and cotton sheet is in contact with each other so, there is conduction between them.

Q) In a steady state the temperature of the ends A and B of a 20 cm long rod AB is 100°C and 0°C. The temperature at the point C distant 9 cm from A is :

(a) 45 °C
(b) 55 °C
(c) 60 °C
(d) 65 °C

Ans. b

Solution:

$$I_{AC} = I_{CB}$$

$$\frac{\cancel{KA}(100-T)}{9\,\cancel{cm}} = \frac{\cancel{KA}(T-0)}{11\,\cancel{cm}}$$

$$11(100-T) = 9(T-0)$$

$$1100 - 11T = 9T$$

$$20T = 1100$$

$$T = \frac{110}{2}$$

$$\boxed{T = 55°C}$$ Ans.

or

Temperature gradient of rod $= G = \dfrac{100-0}{20}$

$$G = 5\ °C/cm.$$

So, Temp difference in length AC

$$T_A - T_C = 5\ °C/cm \times 9\,cm$$

$$100 - T_C = 45\ °C$$

$$\boxed{T_C = 55\ °C}$$ Ans.

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