HINTS AND SOLUTION'S OF HEAT TRANSFER

EXERCISE-1

PART - I

भाग - I

A-1. A = 100 cm^2

$i_H = \dfrac{90-10}{(1\times10^{-2})} \times (0.8)\ (100 \times 10^{-4})$

ℓ = 1 cm

$\dfrac{dq}{dt} = i_H = 80 \times 0.8 = 64$ J/s

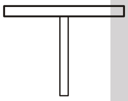
Q = 64 × 1 = 64 J

A-2. $i_H = \dfrac{dQ}{dt}$

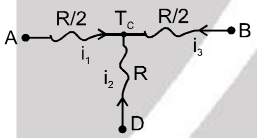
$i_H = \dfrac{\Delta T}{(L/KA)} = \dfrac{(100-0)\times 42\times 0.04}{1} \times 10^{-4} = 168 \times 10^{-4}$

$i_H = \dfrac{Q}{t} = \dfrac{mL}{t}\left(\dfrac{m}{t}\right) = \dfrac{i_H}{L} = \dfrac{168\times10^{-4}}{3.36\times10^{5}} = \dfrac{1}{2} \times 10^{-7}$ kg/s.

A-3.



(Thermal resistance) R = $\dfrac{L}{KA}$ = 5.0 K/W



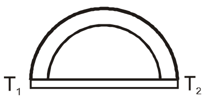
$\Rightarrow \dfrac{T_A - T_C}{R/2} + \dfrac{T_D - T_C}{R} + \dfrac{T_B - T_C}{R/2} = 0$

$2T_A - 2T_C + T_D - T_C + 2T_B - 2T_C = 0$

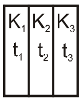
$200 + 25 + 0 = 5T_C \qquad T_C = \dfrac{225}{5} = 45$

$i_{CD} = \dfrac{T_C - T_D}{R} = \dfrac{45-25}{5} = 4$ W

A-4.



$\dfrac{i_1}{i_2} = \dfrac{\Delta T/R_1}{\Delta T/R_2} = \dfrac{R_2}{R_1} = \dfrac{2R}{\pi R} = \dfrac{2}{\pi}$

A-5. 

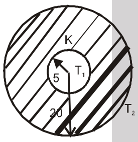
$R_{eq} = R_1 + R_2 + R_3$ (series combination)

$$\frac{t_1+t_2+t_3}{K_{eq}A} = \frac{t_1}{K_1A} + \frac{t_2}{K_2A} + \frac{t_3}{K_3A}$$

$$\frac{t_1+t_2+t_3}{K_{eq}} = \frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3}$$

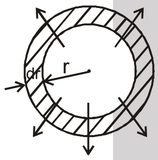
$$K_{eq} = \frac{t_1+t_2+t_3}{\frac{t_1}{K_1}+\frac{t_2}{K_2}+\frac{t_3}{K_3}}$$

B-1.



$T_1 = 50^oC$ Choose a element of width dr

$T_2 = 10^oC$ at a Radial distance r



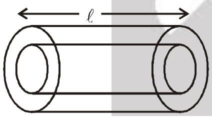
$$dR = \frac{dr}{K4\pi r^2}$$

$$R_{eq} = \frac{1}{4\pi K}\int_5^{20}\frac{dr}{r^2} = \frac{1}{4\pi K}\left[\frac{r^{-2+1}}{-1}\right]_5^{20} = \frac{1}{4\pi K}\left[\frac{1}{5}-\frac{1}{20}\right]$$

$$= \frac{1}{4\pi K}\left(\frac{1}{5}-\frac{1}{20}\right) \times \frac{1}{10^{-2}} = \frac{10^2}{4\pi K}\left(\frac{4-1}{20}\right) = \frac{3}{4\pi K}\ \frac{10^2}{20}$$

$$i = 160\pi = 40\ \frac{(4\pi K)20}{3\times 100} \qquad K = \frac{16\times 30\times 10}{40\times 4\times 2} = 15$$

B-2.

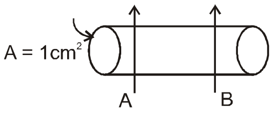


Let an element which is hollow cyl. of Radius r and width dr

$$dR = \frac{dr}{K\ \ 2\pi r.\ell} \qquad R = \frac{1}{2\pi K\ell}\int_{R_1}^{R_2}\frac{dr}{r} = \frac{1}{2\pi K\ell}\left(\ln\ \ r\right)_{R_1}^{R_2} = \ln\left(\frac{R_2}{R_1}\right)$$

$$i_H = \frac{T_2-T_1}{\frac{1}{2\pi K\ell}\ell n(R_2/R_1)} = \frac{2\pi K\ell(T_2-T_1)}{\ell n(R_2/R_1)}$$

C-1.



$\frac{dT}{dx}$ = 5ºC/Cm

$\left(\frac{dT}{dx}\right)_A = 5$ $\quad$ $\left(\frac{dT}{dx}\right) = 2.6$ $\quad$ i = $\frac{\Delta T}{L}$ (KA)

$i_A = \left(\frac{dT}{dx}\right)_A$ KA $\qquad$ $i_B = \left(\frac{dT}{dx}\right)_B$ KA

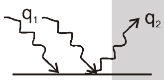
$i = \left(\frac{dQ}{dt}\right)_{\text{Absorb}_{\text{अवशोषण}}} = \left[\left(\frac{dT}{dx}\right)_A - \left(\frac{dT}{dx}\right)_B\right]$ KA = ms $\frac{d\theta}{dt}$

$(5 - 2.6) \times 200 \times (1 \times 10^{-2})$ = ms $\frac{d\theta}{dt}$

2.4×2 = ms $\frac{d\theta}{dt}$ = 4.8

ms = 0.4 J/C $\qquad$ $\frac{d\theta}{dt} = \frac{4.8}{0.4}$ = 12ºC/s

D-1.



Absorptive power = $\frac{q_1 - q_2}{q_1} = \frac{Q_a}{Q_i}$

Emissivity = $\frac{q_1 - q_2}{q_1}$

Absorptive power = Emissivity

D-2. A = 1cm^2

T_s = 27ºC = 300 K

T_b = 327ºC = 600 K

P = σ e A $(600^4 - 300^4)$

$= 6 \times 10^{-8} \times 1 \times 10^{-4} (6^4 - 3^4) \times 10^8 = 0.73$ W

D-3. λ_{blue} = 5000 Aº

$\lambda_m \times T$ = constant = b

λ_{Red} = 7500 Aº

$T_{blue} = \frac{b}{\lambda_{blue}} = \frac{0.3}{5 \times 10^{-5}} = 6 \times 10^3$ K

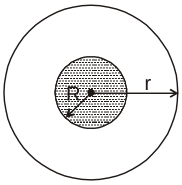
$T_{red} = \frac{b}{\lambda_{Red}} \quad \frac{0.3}{7.5 \times 10^{-5}} = 4 \times 10^3$ K

D-4 P = ms × 3 $\qquad$ ms = $\frac{P}{3}$

mL = P × 30 $\qquad$ mL = P × 30

$\frac{ms}{mL} = \frac{P}{3 \times P \times 30} = \frac{1}{90}$.

D-5. Given:



$$\frac{(\sigma \quad T^4)\ \ (4\pi R^2)}{(4\pi r^2)} = 1400$$

$$\therefore \text{ T} = \left(\frac{1400 \times r^2}{\sigma \quad R^2}\right)^{1/4}$$

$$= \left[\frac{1400 \times (1.5\times10^{11})^2}{(5.67\times10^{-8})\times(7\times10^{8})^2}\right]^{1/4}$$

= 5803 K

D-6 Area of sphere A = $4\pi r^2$

Mass of sphere $m = \left(\frac{4}{3}\pi\rho r^3\right)$

Now, energy radiation per second = (σAT^4)

$$\therefore \qquad mc\left(-\frac{dT}{dt}\right) = \sigma AT^4$$

or $$\int_0^t dt = \left(\frac{-mc}{\sigma A}\right)\int_{200}^{100} T^{-4}\,dT$$

or $$t = \frac{mc}{3\sigma A}\left[\frac{1}{(100)^3} - \frac{1}{(200)^3}\right]$$

$$= \frac{7 \quad mc}{3\times8\sigma \quad A} \times 10^{-6} = \frac{7 \quad mc\times10^{-6}}{24 \quad \sigma \quad A}$$

Substituting the values

$$t = \frac{\left(7\frac{4}{3}\pi\rho r^3\right)\ \ (c)\ \ \times10^{-6}}{3\times8\times5.67\times10^{-8}\times4\pi r^2} = 1.71\ \rho rc$$

E-1. $$\frac{70-60}{5} = K\left[\frac{70+60}{2} - 30\right]$$

$$\Rightarrow \qquad \frac{10}{5} = K\,[65 - 30] \qquad ...(i)$$

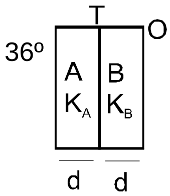
Now $$\frac{60-50}{t} = K\,[65 - 30] \qquad ...(ii)$$

Dividing equation (i) and (ii)

$$\frac{t}{5} = \frac{35}{25} \qquad t = \frac{7}{5}\times5 = 7\,\text{min}$$

PART - II

A-1.



$K_A = 2K_B = 2K$

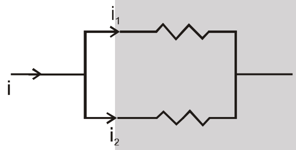
$\left(\frac{36 - T}{d}\right) K_A A = \left(\frac{T - 0}{d}\right) K_B A$

$(36 - T)\, 2K = T K$

$T = \frac{72}{3} = 24$

ΔT = temp diff = 36 – 24 = 12

A-2.



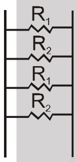
$i_1 = \frac{(100 - 20)}{3 \times 10^{-2}} (209)\, 9 \times 10^{-4}$

$i_2 = \frac{100 - 20}{3 \times 10^{-2}} (385)\, 9 \times 10^{-4}$

$i_T = i_1 + i_2 = 1.42 \times 10^3$ W

$\frac{i_{Cu}}{i_{Al}} = \frac{i_2}{i_1} = \frac{385}{209}$

A-3. It`s a parallel Combination



$R_1 = \frac{d}{K_1 A}$ $\quad R_2 = \frac{d}{K_2 A}$

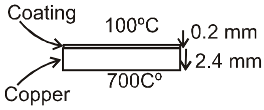
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} +$ ....upto n^{th}

$\frac{1}{R_{eq}} = \frac{n}{2R_1} + \frac{n}{2R_2} = \frac{n}{2}\left(\frac{R_1 + R_2}{R_1 R_2}\right)$

$R_{eq} = \frac{2(R_1 R_2)}{n(R_1 + R_2)} \Rightarrow \quad \frac{d}{K_{eq}(nA)} = \frac{2\left(\frac{d}{K_1 A}\right) \times \frac{d}{K_2 A}}{n \frac{d}{A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)}$

$\Rightarrow \quad K_{eq} = \frac{K_1 + K_2}{2}$

A-4.

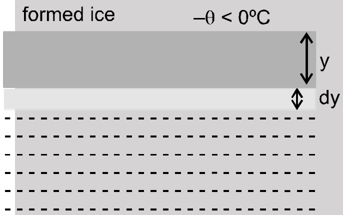


$$i_H = \frac{\Delta T}{R_{eq}} = \frac{700-100}{R_1+R_2} \quad \text{Where } R_{eq} = R_1 + R_2 = \frac{0.24}{0.9\times 400} + \frac{0.02}{0.15\times 400}$$

$$i_H = \frac{dQ}{dt} = \frac{\Delta Q}{\Delta t} = \frac{\Delta m.L}{\Delta t}$$

$$\frac{\Delta m}{\Delta t} = \frac{i_H}{L} \qquad \text{where } L = 540 \text{ cal/gm} ; \Delta t = 3600 \text{ sec.}$$

A-5. $$i_H = \frac{0-(-\theta)}{(y/KA)} = \frac{\theta \quad KA}{y} = \frac{dQ}{dt}$$



$$\frac{dQ}{dt} = L\frac{dm}{dt} = L\frac{\rho.A \quad dy}{dt}$$

$$\frac{KA\theta}{y} = \rho AL\frac{dy}{dt}$$

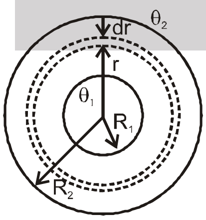
$$\int_2^4 y\,dy = \int_0^{3600}\left(\frac{K\theta}{\rho L}\right)dt$$

$$\left(\frac{y^2}{2}\right)_2^4 = \frac{K\theta}{\rho L}(t)_0^{3600} \Rightarrow \frac{1}{2}\times[16-4] = \frac{4\times 10^{-3}\times\theta\times(3600-0)}{0.9\times 80}$$

$$\Rightarrow \qquad \theta = \frac{1}{2}\times\frac{12\times 0.9\times 80}{4\times 3600\times 10^{-3}} = 30°C$$

$\therefore$ $\theta = -30°C$ **Ans.**

B-1.



$$\theta_1 - \theta_2 = \Delta\theta \qquad \frac{\theta_1-\theta}{\int_{R_1}^{R}\frac{dr}{K4\pi r^2}} = \frac{\theta_1-\theta_2}{\int_{R_1}^{R_2}\frac{dr}{K4\pi r^2}}$$

$$\frac{\Delta\theta/2}{\frac{1}{4\pi K_1}\left[\frac{1}{R_1}-\frac{1}{R}\right]} = \frac{\Delta\theta}{\frac{1}{4\pi K_1}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)} \qquad \Rightarrow \qquad R = \frac{2R_1R_2}{R_1+R_2}$$

C-1. $\left(-\dfrac{dT}{dt}\right) = \dfrac{\sigma eA}{mS}\ [T^4 - T_S^4]$

Rate of temperature fall will be maximum when ($T^4 - T_S^4$) has mass value i.e. T has max. value

$\left(-\dfrac{dT}{df}\right)_{max} = \dfrac{\sigma eA}{mS}\ [500^4 - 300^4]$ Put all values & get answer.

C-2. Rate of radiation per unit area is proportional to (T^4)

$\therefore$ P α AT^4

$\Rightarrow$ P α r^2.

Also $ms\dfrac{dT}{dt} \propto AT^4$ $\therefore$ $\dfrac{dT}{dt} = R \propto \dfrac{1}{r}$

(because $m = (v\rho) \propto r^3$ and $A \propto r^2$)

C-3. Equal area means equal power output. A_3 area pertains to highest wavelength range, thus photons with minimum range of frequency. Thus maximum number of photons are required from this segment to keep the power same.

D-1. For small temperature difference, Stefan's law can written as

$\Delta u = e\sigma A[(T + \Delta T)^4 - T^4]$

or $\Delta u = e\sigma AT^4\left[\left[1+\dfrac{\Delta T}{T}\right]^4 - 1\right]$

or $\Delta u = e\sigma AT^4 \times 4 \times \dfrac{\Delta T}{T}$

or $\Delta u \propto \Delta T$

Hence Newton's law of cooling is a special case of stefan's law.

D-2. $\because$ Rate of cooling, $y = (T - T_0)\,k$ (from Newton's law of cooling)

T_0 : surrounding temperature

k : +ve constant

$\Rightarrow$ graph is straight line with +ve slope

PART - III

1. (a) Initially more heat will enter through section A due to temperature difference and no heat will flow through section B because initially there is no temperature difference.

(b) At steady state rate of heat flow $\left(\dfrac{dQ}{dt}\right)$ is same for all sections

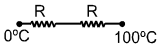
(c) At steady state $\dfrac{dQ}{dt} = kA\left|\dfrac{dT}{dx}\right|$ or $\left|\dfrac{dT}{dx}\right| = \dfrac{1}{kA}\left(\dfrac{dQ}{dt}\right)$

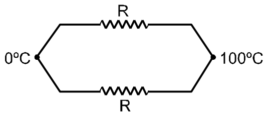
$\left|\dfrac{dT}{dx}\right|$ is inversely proportional to area of cross-section. Hence is maximum at B and minimum at A

(d) At steady state heat accumulation = 0

So $\dfrac{dT}{dt} = 0$ for any section.

EXERCISE-2
PART - I

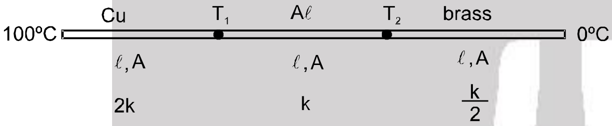
1. 



$\frac{Q_1}{t_1} = i_{H_1} = \frac{100-0}{2R} = \frac{50}{R}$ $\quad$ $i_H = \frac{100}{R/2} = \frac{200}{R} = \frac{Q_2}{t_2}$

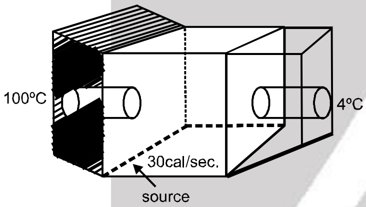
$Q_1 = Q_2 = 10$ cal.

$\frac{50}{R} \times (2) = \frac{200}{R} \times t_2$ $\quad$ $t_2 = \frac{1}{2}$ min.

2. 

$R_{eq} = R_1 + R_2 + R_3$ $\quad$ $R_1 = \frac{\ell}{(2k)A}$, $R_2 = \frac{\ell}{kA}$, R_3 $\frac{\ell}{\left(\frac{k}{2}\right)A}$

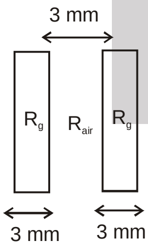
$\frac{100-0}{R_{eq}} = \frac{100-T_1}{R_1} = \frac{100-T_2}{R_1+R_2} = \frac{T_2-0}{R_3}$

3. 

$36 = \left(\frac{T-100}{8}\right)kA + \left(\frac{T-4}{8}\right)kA$

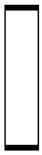
K = 0.5 cal/ºc/cm

A = 12 cm^2.

4. 

(A)

$R_{eq} = 2\,R_g + R_{air} = \frac{2\ \ (3\ \ mm)}{k_g\ \ A} + \frac{(3\ \ mm)}{k_{air}\ \ A}$



(B)

R = $\dfrac{6\ \ mm}{k_g.\ \ A}$

$$\frac{i_A}{i_B} = \frac{\frac{\Delta T}{R_{eq}}}{\frac{\Delta T}{R}} = \frac{R}{R_{eq}} = \frac{\frac{6\ \ mm}{K_g.\ \ A}}{\frac{2\ \ (3\ \ mm)}{K_g\ \ A} + \left(\frac{3\ \ mm}{K_{air}\ \ A}\right)}$$

$$= \frac{\frac{1}{K_g}}{\frac{2\ \ K_{air}\ \ + K_g}{2K_g.\ \ K_{air}}} = \frac{2K_{air}}{K_g\ \ +\ \ 2\ \ K_{air}}$$

5. Thermal resistance R = $\dfrac{\ell}{KA}$

for same temperature difference, thermal current $\alpha\ \dfrac{1}{R}$

$$\Rightarrow \frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{\ell_2}{K_2A_2} \Big/ \frac{\ell_1}{K_1A_1} = \frac{\ell_2}{\ell_1}\ \frac{A_1}{A_2}\frac{K_1}{K_2}$$

$$= \frac{1}{2}x\frac{1^2}{2^2}x\frac{1}{1} = 1/8$$

6. 25 cm from cold end is at 25°C (since temperature gradient is 1°C/cm)

∴ rod shound be touched at this point to ensure no heat transfer.

7. $H = \sigma\ e\ A\ T^4$ $\qquad$ $H\ \alpha\ A\ \ \alpha\ r^2$

$C = \dfrac{\sigma\ \ e\ \ A}{ms}\ (4T_s^3\ \Delta T)$ $\qquad$ $C\ \alpha\ \dfrac{A}{m}\ \alpha\ \dfrac{r^2}{r^3}\ \alpha\ r$

8. $$\frac{\sigma \times 4\pi R^2.T_s^{\ 4}}{4\pi d^2} \times \pi r^2 \quad = \quad \sigma \times 4\pi r^2 \times T_e^{\ 4}$$

$$\frac{\sigma R^2 T_s^{\ 4}}{d^2} = \alpha\, 4T_e^{\ 4}$$

$$Ts = \sqrt{\frac{2d}{R}}\,Te$$

9. Wein's displacement law for a perfectly black body is -

$\lambda m\ \ T$ = constant = Wein's constant b

Here λ_m is the minimum wavelength corresponding to maximum intensity I.

or

From the figure

$(\lambda_m)_1\ <\ (\lambda_m)_3\ <\ (\lambda_m)_2$

Therefore $\qquad T_1\ >\ T_3\ >\ T_2$

→ objective questions based on Wein's displacement law are usually asked in IIT-JEE. Question number 34 of section I of JEE-1998 is also based on Wein's displacement law.

10. Rate of cooling $\left(-\frac{dT}{dt}\right) \propto$ emissivity (e)

From the graph,

$$\left(-\frac{dT}{dt}\right)_x > \left(-\frac{dT}{dt}\right)_y \qquad \therefore \qquad e_x > e_y$$

Further emissivity (e) $\propto$ absorptive power (1) (good absorbers are good emitters also)

$\therefore \quad a_x > a_y$

Hence the correct answer is (3).

Note : Emissivity is a pure ratio (dimensionless) while the emissive power has a unit J/s or watt.

11. $Q \propto AT^4$ and $\lambda_m = T$ = constant. Hence,

$$Q \propto \frac{A}{(\lambda_m)^4} \qquad \text{or} \qquad Q \propto \frac{r^2}{(\lambda_m)^4}$$

$$Q_A : Q_B : Q_C = \frac{(2)^2}{(3)^4} : \frac{(4)^2}{(4)^4} : \frac{(6)^2}{(5)^4}$$

$$= \frac{4}{81} : \frac{1}{16} : \frac{36}{625}$$

= 0.05 : 0.0625 : 0.0576

i.e. $\quad Q_B$ is maximum.

Hence, the correct option is (2).

12. According to Wien's displacement law

$\lambda_m T$ = constant

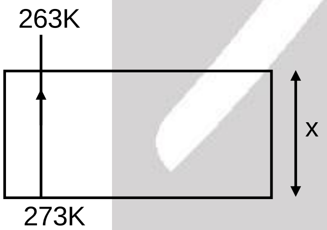
$$\therefore \qquad T \propto \frac{1}{\lambda_{max}}$$

from graph $\lambda_{max(1)} > \lambda_{max(2)} > \lambda_{max(3)}$

$\therefore \quad T_1 < T_2 < T_3$

the material having law temperature has the graph having lower peak.

10.



$$\frac{KA(10)}{x} = L\frac{d}{dt}(\rho A x)$$

$$\frac{2.2 \times (10)}{x} = 3.4 \times 10^5 \times 0.9 \times 10^3 \frac{dx}{dt}$$

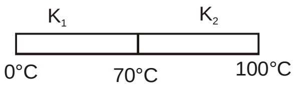
$$\frac{22}{3.4 \times 0.9 \times 10^8} \int_0^t dt = \int_0^{0.5} x\,dx$$

$$\frac{22}{306 \times 10^6} t = \frac{1}{2}(0.5)^2$$

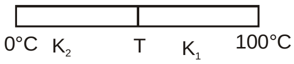
$$t = \frac{(0.5)^2 \times 306 \times 10^6}{44} \text{sec} = \frac{306}{44 \times 4} \times 10^6 \text{ sec} = \frac{306000 \times 10^3}{44 \times 4 \times 24 \times 3600} \approx 20 \text{ days}$$

PART - II

1.



Heat current is same $i_H = \dfrac{70-0}{R_1} = \dfrac{100-70}{R_2} \Rightarrow \dfrac{R_2}{R_1} = 3/7 \Rightarrow \dfrac{K_1}{K_2} = 3/7$



Heat current is same $i_H = \dfrac{T-0}{R_2} = \dfrac{100-T}{R_1}$

$\Rightarrow \dfrac{100-T}{T} = \dfrac{R_1}{R_2} = \dfrac{K_2}{K_1} = 7/3$

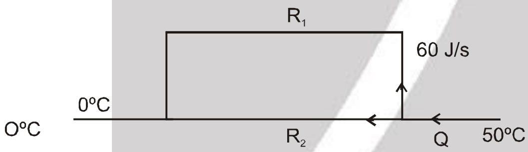
$\Rightarrow 300 - 3T = 7T \Rightarrow T = 30°C$ **Ans.**

2. Let T = 100º C
& T_0 = 50ºC

Heat = $(T - T_0)\dfrac{A}{\ell}(K_S + K_B) \times 10 \times 60$

$= (100 - 50) \times \left(\dfrac{0.2\times10^{-4}}{31\times10^{-2}}\right) \times (46 + 109) \times 10 \times 60 = 300$ J

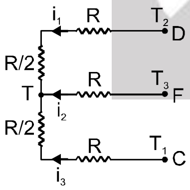
3.



R_1 = thermal resistance of bent part = $\dfrac{60}{K\ \ A}$, $R_2 = \dfrac{50}{KA}$

$\left(\dfrac{R_2}{R_1+R_2}\right)Q = 60$ J/s $\quad\Rightarrow\quad$ Q = 132 j/s

4.

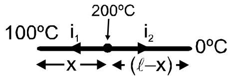


by KCL at junction we can find T.

$i_1 + i_2 + i_3 = 0$

$\dfrac{T_2-T}{R+\dfrac{R}{2}} + \dfrac{T_3-T}{R} + \dfrac{T_1-T}{R+\dfrac{R}{2}} = 0$.

5.



$i_1 = \dfrac{dQ_1}{dt} = \dfrac{(200-100)kA}{x} = L_V \dfrac{dm_{steam}}{dt}$

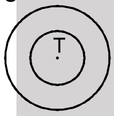
$i_2 = \dfrac{dQ_2}{dt} = \dfrac{(200-0)\ \ kA}{(\ell - x)} = L_f \dfrac{dm_{fusion}}{dt}$

According to problem,

$$\frac{dm_{steam}}{dt} = \frac{dm_{fusion}}{dt}$$

$$\frac{100kA}{x\,L_v} = \frac{200kA}{(\ell - x)L_f}. \quad \Rightarrow \qquad x = \frac{2\ell}{29} = 0.1 \text{ m} = 10 \text{ cm}$$

6. For any general moment 1000ºC.



$i_H = \dfrac{1000-T}{R_{eq}} = \dfrac{dQ}{dt}$

where $R_{eq} = \displaystyle\int \frac{dx}{k(4\pi x^2)} = \frac{1}{4\pi k}\left(\frac{x^{-2+1}}{-2+1}\right)_{R_1}^{R_2}$

$$R_{eq} = \frac{1}{4\pi k}\left\{\frac{1}{R_1} - \frac{1}{R_2}\right\} = \frac{1}{50}$$

Now, mass of water inside cavity

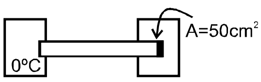
$$M = \rho \times \frac{4}{3}\pi R_1^3$$

$$\frac{dQ}{dt} = MS\,\frac{d\theta}{dt} = \frac{1000-T}{R_{eq}} \qquad (d\theta = dT)$$

$$\int_{0^\circ}^{100^\circ} \frac{dT}{(1000-T)} = \frac{1}{(R_{eq}MS)}\int_0^t dt$$

$$t = R_{eq}\,MS \times \left\{\ell n\left(\frac{1000}{900}\right)\right\}$$

7.



Blackened portion will absorbs heat energy by radiation and delivered to 0ºC chamber by conduction process.

$\dfrac{(17)}{1}kA = \dfrac{17-0}{R} = \sigma eA\,\{(300)^4 - (290)^4\} \Rightarrow\ k = 3.6$ W/m–ºC

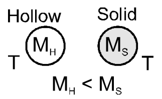
e = 1 for blackwened object.

8. $E = \sigma eA\left[(1000)^4 - (300)^4\right]$

where $A = 4\pi r^2$ & $r = 0.01$ m.

PART - III

1. Bad absober is a bad emitter and good reflector. Bad reflector is a good emitter.

2.


$P_{emitte} = \sigma eAT^4$ since $T_1 = T_2$

$P_{absorb} = \sigma eAT_S^4$ So $P_1 = P_2$ at $t = 0$

cooling rate $\left(-\frac{dT}{dt}\right) = \frac{\sigma eA}{mS}\,[T^4 - T_S^4]$

since $M_H < M_S$, so cooling rate will be different since cooling rate is not same so both will not have same temp at any instant t (except t = 0)

3.
$P_1 = P_2$

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

$\frac{T_A}{T_B} = \left(\frac{0.81}{0.01}\right)^{1/4} = 3$

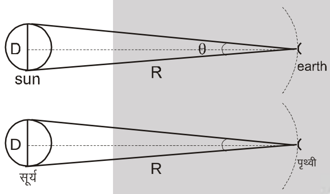
$T_B = \frac{T_A}{3} = \frac{5802}{3} = 1934$ K

$T_A \lambda_A = T_B \lambda_B$

$T_A \lambda = T_B (\lambda + 1)$

$\lambda = \frac{1}{2}$ μm

$\lambda_B = \lambda + 1 = 1.5$ μm

4.


Let the diameter of the sun be D and its distance from the earth be R.

$$\frac{D}{R} = \theta$$

The radiation emitted by the surface of the sun per unit time is

$$4\pi\left(\frac{D}{2}\right)^2 \sigma T^4 = \pi D^2 \sigma T^4.$$

At distance R, this radiation falls on an area $4\pi R^2$ in unit time. The radiation received at the earth's surface per unit time per unit area is, therefore.

$$s = \frac{\pi D^2 \sigma T^4}{4\pi R^2} = \frac{\sigma T^4}{4}\left(\frac{D}{R}\right)^2.$$

Thus, $s \propto T^4$ and $s \propto \theta^2$

5. $T\lambda$ = Constant $\nu_m = \frac{C}{\lambda_{max}}$, $\frac{T}{\nu_{max}}$ = Constant

$\frac{T_1}{\nu_1} = \frac{T_2}{\nu_2}$ $\nu_2 = \frac{T_2}{T_1} . \nu_1 = \frac{2\ T}{T} . \nu_1 = 2\nu_1$

$E = \sigma e A T^4$

$E \propto T^4$

$\frac{E_2}{E_1} = (2)^4 = 16$

6. $$\frac{T_1 - T_j}{\dfrac{L}{k_A A}} = \frac{T_2 - T_j}{\dfrac{L}{k_B A}}$$

$\Rightarrow \quad (T_1 - T_j)k_A = (T_2 - T_j)k_B$

So T_j depends on k_A, k_B & T_1, T_2

$$\frac{L}{k_A A} + \frac{L}{k_B A} = \frac{2L}{k_{eq} A} \quad \Rightarrow \quad k_{eq} = \frac{2k_A k_B}{k_A + k_B}$$

B, C, D are correct.

PART - IV

1. In steady state $\left.\frac{\Delta Q}{\Delta t}\right|_{\text{layer 1}} = \left.\frac{\Delta Q}{\Delta t}\right|_{\text{layer 4}}$

$\Rightarrow \frac{0.06 \times A \times (30-25)}{1.5 \times 10^{-2}} = \frac{0.10 \times A \times \Delta T}{3.5 \times 10^{-2}} \Rightarrow \Delta T = 7°C$

$T_3 = (-10 + 7)°C = -3°C$

2. $\left.\frac{\Delta Q}{\Delta t}\right|_{\text{layer 1}} = \left.\frac{\Delta Q}{\Delta t}\right|_{\text{layer 3}} \Rightarrow \frac{0.06 \times A \times 5}{1.5 \times 10^{-2}} = \frac{0.04 \times A \times \Delta T}{2.8 \times 10^{-2}} \Rightarrow \Delta T = 14°C$

$T_3 = (-3 + 14)°C = 11°C$

3. $\left.\frac{\Delta Q}{\Delta t}\right|_{\text{layer 1}} = \left.\frac{\Delta Q}{\Delta t}\right|_{\text{layer 2}} \qquad \left.\frac{\Delta Q}{\Delta t}\right|_{\text{परत 1}} = \left.\frac{\Delta Q}{\Delta t}\right|_{\text{परत 2}}$

$\Rightarrow \frac{0.06 \times A \times 5}{1.5 \times 10^{-2}} = \frac{K_2 \times A \times 14}{1.4 \times 10^{-2}}$

$\Rightarrow K_2 = 0.02$ W/mK

4. We have $\theta - \theta_s = (\theta_0 - \theta_s)\, e^{-kt}$

where θ_0 = Initial temperature of body = 40°C

θ = temperature of body after time t.

Since body cools from 40 to 38 in 10min, we have

$38 - 30 = (40 - 30)\, e^{-k\,10}$ .... (1)

Let after 10 min, The body temp. be θ

$\theta - 30 = (38 - 30)\, e^{-k\,10}$ .... (2)

$\frac{(1)}{(2)}$ gives $\frac{8}{\theta - 30} = \frac{10}{8}$, $\theta - 30 = 6.4 \quad \Rightarrow \theta = 36.4$ °C

5. Temperature decreases exponentially.

6. During heating process from 38 to 40 in 10 min. The body will lose heat in the surrounding which will be exactly equal to the heat lost when it is cooled from 40 to 38 in 10 min, which is equal to ms $\Delta\theta = 2 \times 2 = 4$ J.

During heating process heat required by the body = m s $\Delta\theta$ = 4 J.

$\therefore$ Total heat required = 8 J.

7 to 9. (a) At steady state

heat gained per unit time = heat lost per unit time

40W = heat lost

(b) from Newton's law of cooling,

$\frac{dQ}{dt} \propto (T - T_0) \Rightarrow \frac{dQ}{dt} = k(T - T_0)$

$\Rightarrow$ at 60º C $\quad k(60 - 25) = 40 \Rightarrow k = \frac{40}{35}$

Now, at 39º C, rate of heat loss = k (39 – 25) = 16 W

(c) 40 = k (60 – 25) = k (T – 25)

and $\frac{dT}{dt} = \frac{(39-25)}{2\times 60} = \frac{T-25}{t}$

$\Rightarrow T - 25 = \frac{7t}{60}$

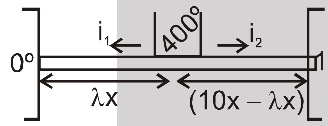
Further $\frac{dQ}{dt} = (T - 25)\,k = \frac{T-25}{35} \times 40$

$Q = \int\left(\frac{dQ}{dt}\right)dt \qquad Q = \int_0^{2\times 60} \frac{2}{15}\times t\,dt$

$Q = \frac{2}{15\times 2}\left[t^2\right]_0^{2\times 60} \Rightarrow Q = 960$ J

EXERCISE-3
PART - I

1.



$i_1 = \frac{400-0}{(\lambda x/kA)}$, $i_2 = \frac{400-100}{(10-\lambda)x/kA}$

$\frac{i_1}{i_2} = \frac{\left(\frac{dm}{dt}\right)L_f}{\left(\frac{dm}{dt}\right)L_v} = \frac{L_f}{L_v}$

$\frac{400/\lambda x}{300/(10-\lambda)x} = \frac{80}{540} \Rightarrow \lambda = 9$

2. $(\lambda_m)_B = 3(\lambda_m)_A$

$\Rightarrow T_A = 3T_B$

$E_1 = 4\pi(6)^2 \sigma T_A^4 = 4\pi(6)^2(3T_B)^4$

$E_2 = 4\pi(18)^2 \sigma T_B^4$

$\frac{E_1}{E_2} = 9.$

3. **A :** At steady state, heat flow through A and E are same.

C : $\Delta T = i \times R$

'i' is same for A and E but R is smallest for E.

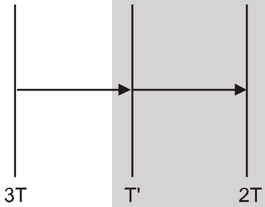
D : $i_B = \dfrac{\Delta T}{R_B}$, $i_C = \dfrac{\Delta T}{R_C}$, $i_D = \dfrac{\Delta T}{R_D}$

if $i_c = i_B + i_D$

Hence $\dfrac{1}{R_C} = \dfrac{1}{R_B} + \dfrac{1}{R_D}$

$$\Rightarrow \frac{8KA}{\ell} = \frac{3KA}{\ell} + \frac{5kA}{\ell}$$

4.



In steady state energy absorbed by middle plate is equal to energy released by middle plate.

$\sigma A(3T)^4 - \sigma A(T')^4 = \sigma A(T')^4 - \sigma A(2T)^4$

$(3T)^4 - (T')^4 = (T')^4 - (2T)^4$

$(2T')^4 = (16 + 81)\, T^4$

$T' = \left(\dfrac{97}{2}\right)^{1/4} T$

5. In configuration 1 equivalent thermal resistance is $\dfrac{3R}{2}$

In configuration 2 equivalent thermal resistance is $\dfrac{R}{3}$

Thermal Resistance $\propto$ time taken by heat flow from high temperature to low temperature

6. In steady state

$I\pi R^2 = \sigma(T^4 - T_0^4)4\pi R^2$

$\Rightarrow \quad I = \sigma\,(T^4 - T_0^4)\,4$

$\Rightarrow \quad T^4 - T_0^4 = 40 \times 10^8$

$\Rightarrow \quad T^4 - 81 \times 10^8 = 40 \times 10^8$

$\Rightarrow \quad T^4 = 121 \times 10^8$

$\Rightarrow \quad T \approx 330$ K

7. According to Wien's displacement law

$\lambda_{m_A} T_A = \lambda_{m_B} T_B$

Ratio of energy radiated per unit time

$$\frac{E_A}{E_B} = \frac{\sigma T_A^4 A_A}{\sigma T_B^4 A_B} \qquad \frac{10^4 E}{E} = \frac{(\sigma)(4\pi)(400r)^2 T_A^4}{(\sigma)(4\pi)(r)^2 T_B^4} \text{C}$$

$$\left\{\frac{\lambda_B}{\lambda_A}\right\}^4 .(400)^2 = 10^4 \Rightarrow \left\{\frac{\lambda_A}{\lambda_B}\right\}^4 = 2^4 \Rightarrow \frac{\lambda_A}{\lambda_B} = 2$$

8. Towards the end of the life filament will become thinner. Resistance will increase and so consumed power will be less, so it will emit less light. Temperature distribution will be non uniform. At the position where temperature is maximum, filament will break. Black body radiation curve will become flat so the filament consumes less electrical power towards the end of the life of the bulb.

9. $\log_2 \frac{P_1}{P_0} = 1$

therefore, $\frac{P_1}{P_0} = 2$

according to steffan's law

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{2767+273}{487+273}\right)^4 = 4^4$$

$$\frac{P_2}{P_1} = \frac{P_2}{2\,P_0} = 4^4$$

$$\frac{P_2}{P_0} = 2 \times 4^4$$

$$\log_2 \frac{P_2}{P_0} = \log_2 \left[2 \times 4^4\right]$$

$$= \log_2 2 + \log_2 4^4$$
$$= 1 + \log_2 2^8$$
$$= 1 + 8 = 9$$

10. (A) Since the temperature of the body remains same, therefore heat radiated by the body is same as before. ($W_1 = \sigma a T^4 = \sigma a(310)^4$)

(B) $W \propto$ Area

If exposed area decreases, energy radiated also decreases.

(C) $\lambda_m T = b \quad \Rightarrow \quad T\uparrow, \quad \lambda_m \downarrow$

(D) ($W_1 = \sigma a T^4 = \sigma a(310)^4$)

Since it is given that $\sigma T_0^4 = 460\ \text{Wm}^{-2}$

Hence, $\sigma a(310)^4 > 460\ \text{Wm}^{-2}$

So (D) option is wrong

11. since rate of heat flow is same, we can say

$$\frac{300-200}{R_1} = \frac{200-100}{R_2}$$

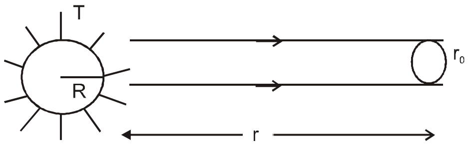
$R_1 = R_2$

$$\Rightarrow \frac{L_1}{K_1A_1} = \frac{L_2}{K_2A_2}$$

$$\Rightarrow \frac{K_1}{K_2} = \frac{A_2}{A_1} = 4$$

PART - II

1.



Total radiant power incident of earth = $\left(\frac{\sigma(4\pi R^2)T^4}{4\pi r^2}\right)\pi r_0^2$

(Taking sun as a block body)

2. Let temperature of the interface = T

$$\frac{T_1 - T}{\left(\frac{L_1}{AK_1}\right)} = \frac{T - T_2}{\left(\frac{L_2}{K_2 A}\right)}$$

$$\Rightarrow \quad T\left(\frac{L_1}{K_1} + \frac{L_2}{K_2}\right) = \frac{T_1 L_2}{K_2} + \frac{T_2 L_1}{K_1}$$

$$\Rightarrow \quad T = \frac{T_1 K_1 L_2 + T_2 L_1 K_2}{L_1 K_2 + L_2 K_1}$$

3. $\frac{dQ}{dt} = -kA\frac{d\theta}{dx}$

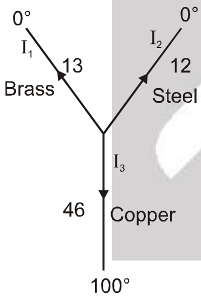
at steady state $\frac{dQ}{dt}$ = constant.

$d\theta \ \alpha - dx$

$\int_{\theta_0}^{\theta} d\theta = -k\int_0^x dx \quad \theta = \theta_0 - kx$

4. According to Newtons cooling law option **(3)** is correct Answer.

5.



$I_1 + I_2 + I_3 = 0$

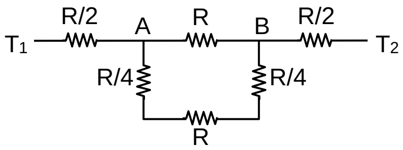
$$\frac{K_1(T-0)}{\ell_1} + \frac{K_2(T-0)}{\ell_2} + \frac{K_3(T-100)}{\ell_3} = 0$$

$$\frac{0.12}{12}T + \frac{0.26}{13}T + \frac{0.92}{46}(T-100) = 0$$

T = 40°C

$\frac{dQ}{dt}$ through copper $\frac{0.92 \times 4}{46}$ = (100 – 40) = 4.8 cal/sec.

6.



$$T_A - T_B = \frac{T_1 - T_2}{\frac{8R}{5}} \times \frac{3R}{5} = \frac{3}{8} \times 120 = 45^{o}C$$

7. $$-\frac{dT}{dt} = \frac{4\sigma e A T_0^{3}(T - T_0)}{ms}$$

$\rho_A < \rho_B$

$m_A < m_B$

at $\quad t = 0 \qquad -\frac{dT}{dt} = \frac{1}{ms}$

High level Problems (HLP)

SUBJECTIVE QUESTIONS

1. $$\frac{R_A}{R_C} = \frac{k_C}{k_A} = \frac{1}{2}$$

& $$\frac{R_B}{R_D} = \frac{k_D}{k_B} = \frac{1}{2}$$

$\because \ \frac{R_A}{R_C} = \frac{R_B}{R_D} \Rightarrow$ Balanced W. S. B.

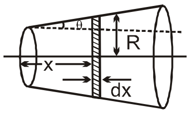
$$\Rightarrow \quad \frac{(\theta_2 - \theta)}{R_B} = \frac{\theta_2 - \theta_1}{R_A + R_B} \quad \Rightarrow \quad \theta = \frac{3\theta_1 + \theta_2}{4}$$

$\Rightarrow$ Rate of heat flow from the source

$$= \frac{(\theta_2 - \theta_1)}{\left(\frac{(R_A + R_B)(R_C + R_D)}{R_A + R_B + R_C + R_D}\right)}$$

$$= \frac{(\theta_2 - \theta_1)}{\left(\frac{\left(\frac{1}{k_A} + \frac{1}{k_B}\right)\left(\frac{1}{k_C} + \frac{1}{k_D}\right)\frac{\ell}{A}}{\frac{1}{k_A} + \frac{1}{k_B} + \frac{1}{k_C} + \frac{1}{k_D}}\right)} = \frac{3k_0 A(\theta_2 - \theta_1)}{8\ell}$$

2.



$$i_H = \frac{T_H - T_C}{R_{eq}}$$

$$dR = \frac{dx}{K\pi R^2} \qquad \tan\theta = \frac{R - R_1}{x} = \frac{R_2 - R_1}{L}$$

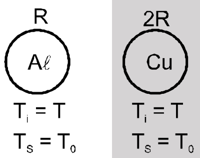
$$\Rightarrow \quad R = R_1 + x\left(\frac{R_2 - R_1}{L}\right)$$

$$R_{eq} = \int dR = \int \frac{dx}{k\pi\left[R_1 + \frac{x(R_2 - R_1)}{L}\right]^2}$$

$$\Rightarrow \quad R_{eq} = \frac{L}{k\pi R_1 R_2}$$

$$i_H = \frac{T_H - T_C}{R_{eq}} . = \frac{K\pi R_1 \quad R_2(T_H - T_C)}{L}$$

3.



$e_{Al} = e_{cu}$

C – cooling rate H – heat loss

$$\frac{H_{A\ell}}{H_{Cu}} = \frac{\sigma e A_{Al}(T_{Al}{}^4 - T_0{}^4)}{\sigma e A_{Cu}(T_{Cu}{}^4 - T_0{}^4)}$$

at t = 0 $\quad T_{A\ell} = T_{cu} = T.$

$$= \quad \frac{A_{Al}}{A_{Cu}} = \frac{R^2}{(2R)^2} = \frac{1}{4}.$$

(b) C – cooling rate

$$\frac{C_{A\ell}}{C_{Cu}} = \left(\frac{A_{A\ell}}{m_{A\ell}.S_{A\ell}}\right)\left(\frac{m_{cu}S_{cu}}{A_{cu}}\right)$$

$$= \left(\frac{A_{A\ell}}{A_{cu}}\right)\left(\frac{m_{cu}}{m_{A\ell}}\right)\left(\frac{S_{cu}}{S_{A\ell}}\right) = \left(\frac{R}{2R}\right)^2 \times \left\{\left(\frac{2R}{R}\right)^3 \times 3.4\right\} \times \frac{390}{900} = 2.9$$

4. (a) $Q_{max} = ms\,(T_1 - T_0)$

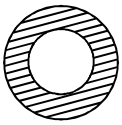
The body will keep losing heat until it comes in thermal equilibrium with the surrounding.

(b) $0.5\ ms\,(T_1 - T_0) = ms\,(T_1 - T)$

$$\Rightarrow \quad T = 0.5\,(T_1 + T_0)$$

and $\quad \dfrac{dT}{dt} = -k(T - T_0)$

$$\int_{T_1}^{0.5(T_1+T_0)} \frac{dT}{-(T - T_0)} = \int_0^t k \quad dt \qquad \text{or} \qquad t = \frac{\ell n 2}{k}$$

5. 

R_i = 3cm
R_o = 6 cm

$\frac{dq}{dt}$ = σ e A ($T^4 - 0^4$) = ms. $\frac{dT}{dt}$ $\qquad \int_O^{t_o} dt = \frac{ms}{\sigma e A}\int_{1000}^{500}\frac{dT}{T^4}$

where m = ρ × $\frac{4}{3}\pi(R_o^3 - R_i^3)$ $\qquad$ A = 4 π R_o^2

6. (a) t = $\frac{35-25}{2}$ = 5 sec.

P × t = 90 ×10 or P × 5 = 90 × 10
P = 180 W

(b) P' = $\frac{CdT}{dt}$ = 90 × 0.2 = 18 W

(c) $\frac{P_{30}}{P_{35}} = \frac{30-25}{35-25}$ or P_{30} = 9W (∵ P_{35} = 18 W)

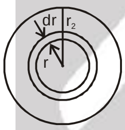
(d) P × t = CΔT + Q_{lost}

180 × t = 90 × 10 + 9 × t or $\quad$ t = $\frac{90\times10}{(180-9)}$ = $\frac{100}{19}$ sec.

7. $\frac{dQ}{dt} = KA\left(\frac{T_2 - T_1}{\ell}\right)$

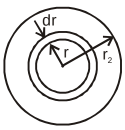
Here A = π ($R_2^2 - R_1^2$)

8. $\int dR = \int_{r_1}^{r_2}\frac{dr}{2\pi\ \ r\ \ \ell\ \ k}$



Solving R = $\frac{\ell n\ \ r_2/r_1}{2\pi\ \ \ell\ \ k}$ $\qquad$ G = $\frac{1}{R}$.

9. $\int dR = \int_{r_1}^{r_2}\frac{dr}{4\pi\ \ r^2\ \ k}$



R = $\frac{(r_2 - r_1)}{4\pi\ \ r_1\ \ r_2\ \ k}$

G = $\frac{1}{R}$ = $\frac{4\pi\ \ r_1\ \ r_2\ \ k}{(r_2 - r_1)}$

10. For the cylinder $R = \frac{\ell n \ r_2/r_1}{2\pi \ \ell \ k}$

$mL = \left(\frac{\theta_2 - \theta_1}{R}\right)$. time

$\Rightarrow$ Where L = latent heat of fusion

$\Rightarrow$ Time = $\frac{mL \times R}{(\theta_2 - \theta_1)} = \frac{mL \ \ \ell n \ \ r_2/r_1}{2\pi \ \ \ell \ \ k.50}$

11. The whole metal plate will always be at uniform temperature (T) since it has infiinite conductivity.

then, $-mc \frac{dT}{dt} = \frac{ks(T_0 - T)}{\ell}$

$\Rightarrow \quad -mc \int_{T_1}^{T_2} \frac{dt}{T_0 - T} = \frac{ks}{\ell} \int_0^t dt$

$\ell n \left(\frac{T_0 - T_2}{T_0 - T_1}\right) = \frac{ks \ \ t}{mc\ell}$

$\Rightarrow \quad t = \frac{mc\ell}{ks} \ \ell n \left| \frac{T_0 - T_2}{T_0 - T_1} \right|$

12. A = 1.6 m^1 e = 1

= p σeA T^4 = (6 × 10^{-8}) (1) 1.6 m^2 (310)^4 = 887 J

13. (a) e σ AT^4 = 0.55 × 6 × 10^{-8} × 1.5 × (323)^4 = 539 W

(b) e σ AT$^4_{\text{Surr.}}$ = 0.55 × 6 × 10^{-8} × 15 × (295)^4 = 375 W

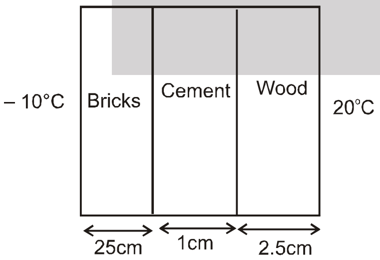
(c) 539 – 375 = 164 W

14. e σ A(T^4 – T$^4_{\text{surroundings}}$) e σ A(T^4 – T$^4_{\text{परिवेश}}$) = 0.97 × 5.67 × 10^{-8} .2 (301^4 – 293^4) = 92.2 W

15. A = 137 m^2

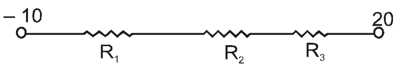
$i_H = \frac{dQ}{dt} = \frac{20 - (-10)}{R_1 + R_2 + R_3}$ = 9 kW

where



$R_1 = \frac{0.25}{1 \times (137)}$ $\quad R_3 = \frac{0.025}{0.125 \times 137}$

$R_2 = \frac{0.01}{1.5 \times 137}$



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

$$\left(\frac{dQ}{dt}\right)\int dx = -\int \frac{A\alpha dT}{T}$$

$$\left(\frac{dQ}{dt}\right) x = A\,\alpha\,\ell n\frac{T_1}{T(x)}$$

$$\left(\frac{dQ}{dt}\right)\ell = A\,\alpha\,\ell n\frac{T_1}{T_2} \quad \Rightarrow \quad \frac{1}{A}\left(\frac{dQ}{dt}\right) = \left(\frac{\alpha}{\ell}\right)\ell n\left(\frac{T_2}{T_1}\right) = q$$

or $$\frac{\ell}{x} = \frac{\ell n\frac{T_1}{T_2}}{\ell n\frac{T_1}{T(x)}}$$

or $$\left(\frac{T_1}{T(x)}\right)^{\ell} = \left(\frac{T_1}{T_2}\right)^{x}$$

or $$T(x) = T_1\left(\frac{T_2}{T_1}\right)^{x/\ell}$$

$$q = \frac{1}{A}\frac{dQ}{dt}$$

Ans. $T(x) = T_1\left(\frac{T_2}{T_1}\right)^{x/\ell}$; $q = (\alpha/\ell)\,\ell n\left(\frac{T_1}{T_2}\right)$

17. $\frac{dQ}{dt} = \frac{Ks}{\ell}(T_1 - T_2)$

where T_1 and T_2 are temperatures of two chunks as function of time 't'.

$$-C_1\frac{dT_1}{dt} = \frac{Ks}{\ell}(T_1 - T_2)$$

$$C_1\frac{dT_2}{dt} = \frac{Ks}{\ell}(T_1 - T_2)$$

or $$-\frac{dT_1}{dt} = \frac{Ks}{\ell C_1}(T_1 - T_2)$$

or $$\frac{dT_2}{dt} = \frac{Ks}{\ell C_2}(T_1 - T_2)$$

or $$\frac{-d(T_1 - T_2)}{dt} = \frac{Ks}{\ell}\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

or $$-\int_{\Delta T_0}^{\Delta T}\frac{d(T_1 - T_2)}{(T_1 - T_2)} = \frac{Ks}{\ell}\left[\frac{1}{C_1} + \frac{1}{C_2}\right]\int_0^t dt$$

Ans. $\Delta T = \Delta T_0\, e^{-\alpha t}$

जहाँ where $\alpha = (1/C_1 + 1/C_2)\, SK/\ell$