Assignment-1

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1] Explain the modes of heat transfer.

Ans There are 3 different modes of heat transfer:-
i) Conduction, ii) Convection, iii) Radiation.

Conduction:- Conduction is the mode of heat transfer in which energy is exchanged b/w the high temperature region to the low temperature region by Kinetic motion or direct impact of molecules.

Convection:- Convection is the mode of heat transfer in which energy exchange takes place b/w high temperature region to the low temperature region due to molecular motion & macroscopic motion of the fluid particles.

Radiation:- Radiation is the mode of heat transfer in which heat transfer takes place b/w two substances even without any medium through electromagnetic waves or quanta. The transfer by radiation is maximum if two substance exchanging heat are seperated by perfect vacuum.

2] State the laws governing 3 basic mode of heat transfer.

Ans i) Fourier law of Conduction:- It states that the rate of heat flow by conduction in a given direction is proportional to the area normal to the direction of heat flow & to the gradient of temperature in that direction.

$$\boxed{Q_x = -KA\frac{dT}{dx}} \; W$$

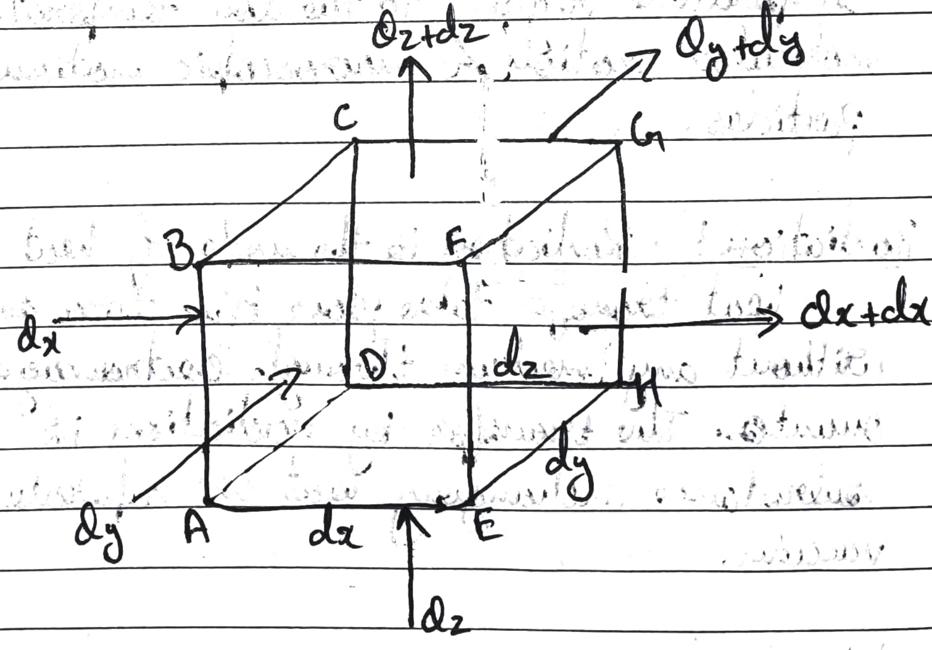
ii) Newtons law of Cooling:- It states that the rate of heat transfer by convection b/w a surface & a fluid is directly proportional to the surface area of heat transfer & the temperature difference between them. $\boxed{Q = hA(T_s - T_\infty)}$ W

iii) Stefan - Boltzmann law:- It states that radiation energy emitted by a black body is proportional to the surface area & fourth power of its absolute temperature.

$$\boxed{Q = \sigma \varepsilon A T^4} \text{ W}$$

3] Derive general three dimensional heat conduction equation in Cartesian coordinates.

Ans



(Net heat conducted into the element along dx, dy, dz per unit time) + (Internal heat generated per unit time) = (Increase in internal energy per unit time) + (work done by element per unit time)

→ (1)

The rate of heat flow into the element in x-direction through the face ABCD is

$$Q_x = -K_x \frac{\partial T}{\partial x} dy\,dz$$

where, K_x = Thermal Conductivity of material in x-direction.

The rate of heat flow out of the element in x direction through the face at $(x = dx)$ EFGH is.

$$Q_{x+dx} = Q_x + \frac{\partial (Q_x)}{\partial x} dx = \left(-K_x \frac{\partial T}{\partial x} dy\,dz\right) - \left(\frac{\partial}{\partial x}\left(K_x \frac{\partial T}{\partial x}\right) dx\,dy\,dz\right)$$

The net rate of heat entering the element in x direction is the difference b/w entering & leaving heat flow rate is given by,

$$Q_x - Q_{x+dx} = \frac{\partial}{\partial x}\left(K_x \frac{\partial T}{\partial x}\right) dx\,dy\,dz$$

$$Q_y - Q_{y+dy} = \frac{\partial}{\partial y}\left(K_y \frac{\partial T}{\partial y}\right) dx\,dy\,dz$$

$$Q_z - Q_{z+dz} = \frac{\partial}{\partial z}\left(K_z \frac{\partial T}{\partial z}\right) dx\,dy\,dz$$

The net heat conducted into the element dx dy dz per minute =

$$\left\{\frac{\partial}{\partial x}\left(K_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial T}{\partial z}\right)\right\} dx\,dy\,dz$$

$\rightarrow$ (2)

Let q_g be the internal heat generation per unit time per unit volume, the rate energy generation in the element =

$$q_g \times dx\,dy\,dz \quad \text{--- (3)}$$

The change in internal energy for the unit time = (mass of element)(specific heat) x change of temp per unit time.

$$= (\rho)(dx\,dy\,dz) \times C_p \frac{\partial T}{\partial t}$$

$$= \rho C_p \frac{\partial T}{\partial t}\, dx\,dy\,dz \quad \text{--- (4)}$$

The work done by the element per unit time is very small because the flow work done by solids due to temperature change is negligible.

$$= 0 \quad \text{--- (5)}$$

Substituting eq (2), (3), (4), (5) in eq (1) we get

$$\left\{\frac{\partial}{\partial x}\left(K_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial T}{\partial z}\right)\right\} dx\,dy\,dz + q_g\, dx\,dy\,dz$$

$$= \rho C_p \frac{\partial T}{\partial t}\, dx\,dy\,dz + 0$$

dividing both sides by $dx\,dy\,dz$

$$\left\{\frac{\partial}{\partial x}\left(K_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial T}{\partial z}\right)\right\} + q_g = \rho C_p \frac{\partial T}{\partial t}$$

For isotropic materials,

$K_x = K_y = K_z = K$ the general 3D heat conduction equation becomes :

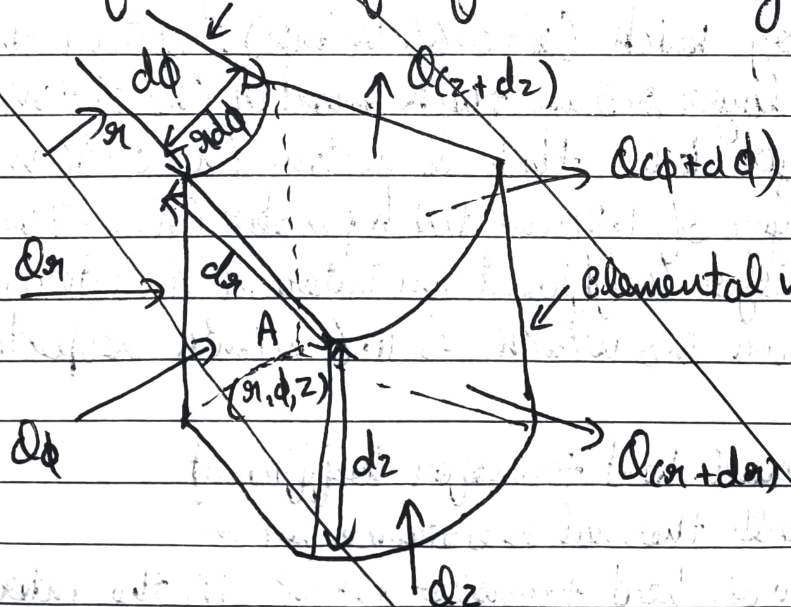
$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q_g}{K} = \frac{\rho C_p}{K}\frac{\partial T}{\partial t}$$

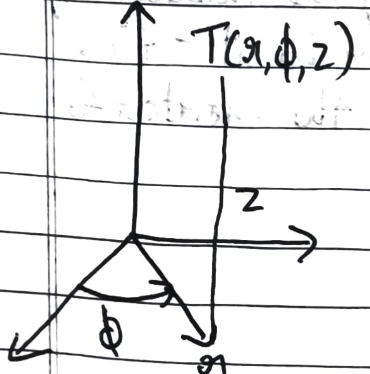
$$\boxed{\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q_g}{K} = \frac{1}{\alpha}\frac{dT}{dt}}$$ //

where $\alpha = \frac{K}{\rho C_p}$ & is called thermal diffusivity.

4] Derive an expression for the temperature distribution & rate of heat transfer for a hollow cylinder.

Ans





$x = r\cos\phi$

$y = r\sin\phi$ & $\phi = \tan^{-1}\left(\frac{y}{x}\right)$

$z = z$

The 3D general heat conduction in Cylindrical coordinates is given by.

$$\frac{1}{r}\frac{\partial}{\partial r}\left(\frac{\partial T}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2}+\frac{\partial^2 T}{\partial z^2}+\frac{q_g}{K}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

For one dimensional radial heat conduction the above equation reduces to

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)=0 \quad \text{Or,}$$

$$\frac{d}{dr}\left(r\frac{dT}{dr}\right)=0$$

5] A wall is constructed of several layers. The first layer consists of brick ($K=0.66\ W/mK$), 25cm thick, the second layer 2.5 cm thick mortar ($K=0.7\ W/mK$), The third layer 10cm thick limestone ($K=0.66\ W/mK$) & outer layer of 1.25cm thick plaster ($K=0.7\ W/mK$). The heat transfer coefficient on interior & exterior wall layers are $5.8\ W/m^2K$ & $11.6\ W/m^2K$ respectively. Find,

a) overall heat transfer coefficient
b) overall thermal resistance per m^2
c) Rate of heat transfer per m^2, if the interior of the room is at $26°c$ while outer air is at $-7°c$.
d) Temperature at the junction b/w the mortar & limestone.

Ans Given,

$L_1 = 25cm = 0.25m$, $K_1 = 0.66 \, W/m.K$

$L_2 = 2.5cm = 0.025m$, $K_2 = 0.7 \, W/m.K$

$L_3 = 10cm = 0.1m$, $K_3 = 0.66 \, W/m.K$

$L_4 = 1.25cm = 0.0125m$, $K_4 = 0.7 \, W/m.K$

$h_1 = 5.8 \, W/m^2K$, $h_2 = 11.6 \, W/m^2K$

$T_{\infty 1} = 26°c$, $T_{\infty 2} = -7°c$

$$R_1 = \frac{1}{h_1 A} = \frac{1}{5.8 \times 1} = 0.1724 \, K/W$$

$$R_2 = \frac{L_1}{K_1 A} = \frac{0.25}{0.66 \times 1} = 0.378 \, K/W$$

$$R_3 = \frac{L_2}{K_2 A} = \frac{0.025}{0.7 \times 1} = 0.0357 \, K/W$$

$$R_4 = \frac{L_3}{K_3 A} = \frac{0.1}{0.66 \times 1} = 0.1515 \, K/W$$

$$R_5 = \frac{L_4}{K_4 A} = \frac{0.0125}{0.7 \times 1} = 0.0178 \, K/W$$

$$R_6 = \frac{1}{h_2 A} = \frac{1}{11.6 \times 1} = 0.0862 \, K/W$$

i) overall heat transfer coefficient.

$$U = \frac{1}{A \Sigma R_{th}} = \frac{1}{A(R_1 + R_2 + R_3 + R_4 + R_5 + R_6)}$$

$$= \frac{1}{1 \times (0.1724 + 0.378 + 0.0357 + 0.1515 + 0.0178 + 0.0862)}$$

$$U = \frac{1}{0.8424} \quad \text{or},$$

$$U = 1.187 \ W/m^2K.$$

ii) The overall thermal resistances

$$\Sigma R_{th} = \frac{1}{UA} = \frac{1}{1.187 \times 1}$$

$$= 0.8424 \ K/W$$

iii) The heat flow rate through the composite per m^2

$$Q = \frac{T_{\infty_1} - T_{\infty_2}}{\Sigma R_{th}} = \frac{26-(-7)}{0.8424}$$

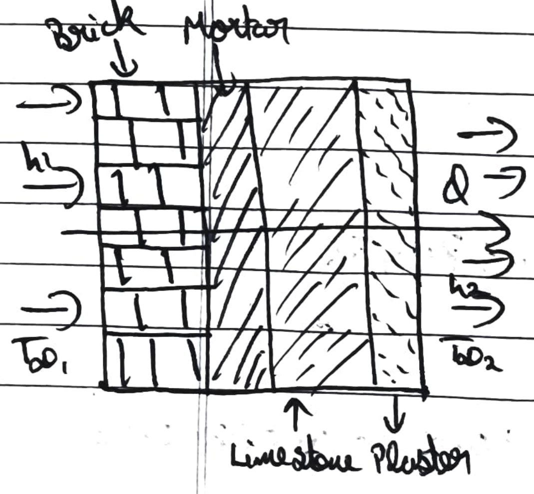
$$= 39.17 \ W/m^2$$

iv) The temperature at the interface of mortar & limestone can be calculated as:

$$Q = \frac{T_{\infty_1} - T_3}{R_1 + R_2 + R_3}$$

$$\text{or}, \ T_3 = T_{\infty_1} - 39.17 \times (0.1724 + 0.378 + 0.0357)$$

$$= 3^\circ C$$



$$T_{\infty_1} \ T_1 \ T_2 \ T_3 \ T_4 \ T_5 \ T_{\infty_2}$$

$$R_1 \ R_2 \ R_3 \ R_4 \ R_5 \ R_6$$

6] Explain Briefly the mechanism of conduction convection radiation heat transfer.

Ans

Conduction :- conduction is heat transfer through stationary matter by physical contact.
Heat transferred from the burner of a stove through the bottom of a pan to food in the pan is transferred by conduction.

convection :- convection is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced - air furnace & in weather systems.

Heat transfer by radiation occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of earth by the sun.

7] write three Dimensional heat conduction equations in Cartesian co-ordinate systems. Explain the terms involved.

Ans

Same As [03] //

8] A 290 mm steam main, 210 m long is covered with 50 mm of high temperature insulation ($K = 0.092\ W/m^\circ C$) & 40 mm low temperature insulation ($K = 0.062\ W/m^\circ C$) the inner and outer surface temperature as measured are $390^\circ c$ & $40^\circ c$ respectively. Determine.

a) The total heat loss per hour.

b) The total heat loss per m^2 of outer surface.

c) Temperature b/w two layers of insulation. Neglecting Condition through pipe material.

Ans outside dia of pipe, $d_1 = 240\,mm = 24\,cm$
outside dia of first layer $d_2 = 24 + 2 \times 5$
$= 34\,cm$

outside dia of second layer $d_3 = 34 + 2 \times 4 = 42\,cm$
$K_1 = 0.092\,W/mK$, $K_2 = 0.062\,W/mK$

i) Total heat loss per hour.

$$Q_{tot} = \frac{2\pi l (T_1 - T_3)}{\frac{\ln(d_2/d_1)}{K_1} + \frac{\ln(d_3/d_2)}{K_2}}$$

$$= \frac{2\pi \times 210\,(390 - 40)}{\frac{\ln(34/24)}{0.092} + \frac{\ln(42/34)}{0.062}}$$

$$= \frac{2\pi \times 210\,(390-40)}{3.78 + 3.40}$$

$$= 64319.51\,W$$

$$= \frac{64319.5 \times 3600}{1000} = 231550.2\,KJ/h$$

ii) Total heat lost per m^2 of outer surface

$$= \frac{Q_{tot}}{\pi d_3 l} = \frac{231550.2}{\pi \times (0.42 \times 210)}$$

$$= 835.65\,KJ/h$$

iii) Temperature between 2 layers.

$$\frac{Q}{l} = \frac{2\pi K (t_1 - t_2)}{\ln(d_2/d_1)}$$

$$\frac{64319.51}{210} = \frac{2 \times \pi \times 0.092 (390 - t_2)}{\ln(34/24)}$$

$$306.28 = \frac{225.44 - 0.578 t_2}{\ln(34/24)}$$

$$106.67 = 225.44 - 0.578 t_2$$

$$0.578 t_2 = 225.44 - 106.67$$

$$\boxed{t_2 = 205.48}$$

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2] An exterior wall of house may be approximated by a 0.1m layer of common brick ($K = 0.7$ W/m°C) followed by point 0.04m layer of gypsum plaster ($K = 0.48$ W/m°C). What thickness of loosely packed rock wool insulation ($K = 0.065$ W/m°C) should be added to reduce the heat loss through the wall by 80%.

Ans

Thickness of common brick $L_A = 0.1$m

Thickness of gypsum plaster $L_B = 0.04$ m

Thickness of rock wool, $L_c = x$ (in m) = ?

$K_A = 0.7$ W/m°C, $K_B = 0.48$ W/m°C, $K_c = 0.065$ W/m°C

$$Q_1 = \frac{A(\Delta t)}{\frac{L_A}{K_A} + \frac{L_B}{K_B}} = \frac{A(\Delta t)}{\frac{0.1}{0.7} + \frac{0.04}{0.48}} \quad \text{— (1)}$$

$$Q_2 = \frac{A(\Delta t)}{\frac{L_A}{K_A} + \frac{L_B}{K_B} + \frac{L_C}{K_C}} = \frac{A(\Delta t)}{\frac{0.1}{0.7} + \frac{0.04}{0.48} + \frac{x}{0.065}} \quad \text{—— (2)}$$

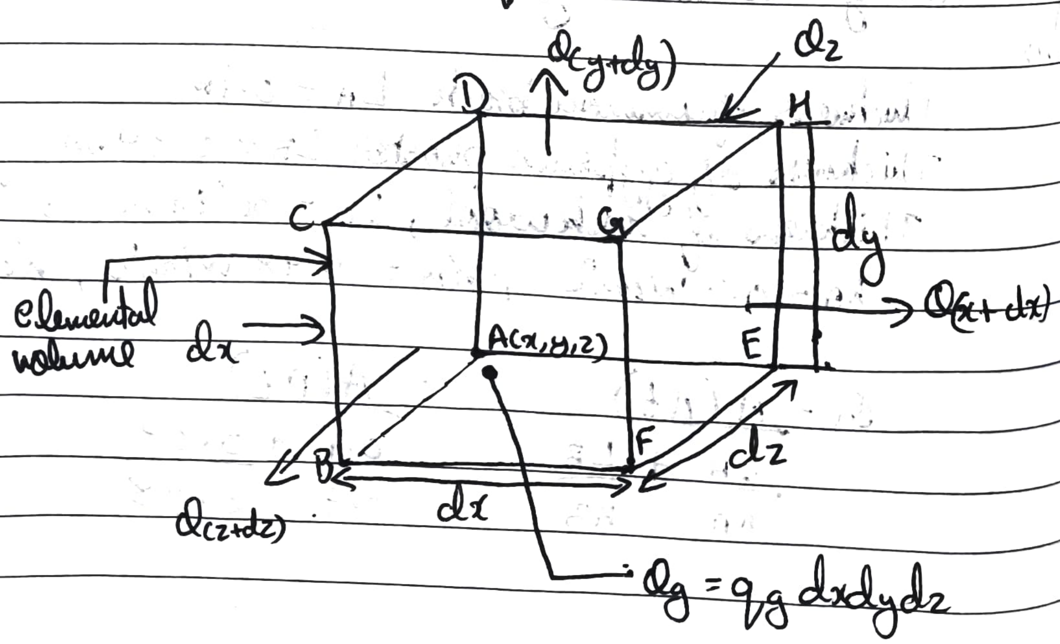
$$Q_2 = (1-0.8)\,Q_1$$
$$= 0.2\,Q_1 \quad \text{—— Given.}$$

$$\frac{A(\Delta t)}{\frac{0.1}{0.7} + \frac{0.04}{0.48} + \frac{x}{0.065}} = \frac{0.2 \times A(\Delta t)}{\frac{0.1}{0.7} + \frac{0.04}{0.48}}$$

$$\frac{0.1}{0.7} + \frac{0.04}{0.48} = 0.2\left[\frac{0.1}{0.7} + \frac{0.04}{0.48} + \frac{x}{0.065}\right]$$

$$0.1428 + 0.0833 = 0.2[0.1428 + 0.0833 + 15.385x]$$
$$0.2261 = 0.2[0.2261 + 15.385x]$$
$$x = 0.0588 \text{ m}$$
$$\text{or } x = 58.8 \text{ mm}$$

12] Starting from the fundamental, deduce general form of one dimensional heat conduction equation in cartesian coordinate & arrive at Fourier equation.



t = temperature at the left face ABCD

$\frac{dt}{dx}$ = temperature changes & rate of change along x-dir^n

$\left(\frac{\partial t}{\partial x}\right) dx$ = change of temp through distance dx.

$t + \left(\frac{\partial t}{\partial x}\right) dx$ = Temperature on the right face EFGH

let, k_x, k_y, k_z = Thermal Conductivities.

q_g = Heat generated per unit volume per unit time.

ρ = Mass density of material

c = Specific heat of material

Q = Rate of heat flow in a dir^n.

$Q' = (Q\,d\tau)$ = Total heat flow in that dir^n (in time $d\tau$)

Heat influx $Q'_x = -k_x (dy \cdot dz) \frac{\partial t}{\partial x} \cdot d\tau$ ——— (i)

Heat efflux $Q'_{(x+dx)} = Q'_x + \frac{\partial}{\partial x}(Q'_x)\,dx$ ——— (2)

subtracting (2) from (1)

$$dQ'_x = Q'_x - \left[Q'_x + \frac{\partial}{\partial x}(Q'_x)\,dx\right]$$

$$= -\frac{\partial}{\partial x}(Q'_x)\,dx$$

$$= -\frac{\partial}{\partial x}\left[-k_x (dy \cdot dz)\frac{\partial t}{\partial x} \cdot d\tau\right] dx$$

$$= \frac{\partial}{\partial x}\left[k_x \frac{\partial t}{\partial x}\right] dx \cdot dy \cdot dz \cdot d\tau$$ ——— (3)

Similarly the heat accumulated due to heat flow by conduction along Y & Z direction in time $d\tau$ will be.

$$dQ_y' = \frac{\partial}{\partial y}\left[k_y \frac{\partial t}{\partial y}\right] dx \cdot dy \cdot dz \cdot d\tau \quad — (4)$$

$$dQ_z' = \frac{\partial}{\partial z}\left[k_z \frac{\partial t}{\partial z}\right] dx \cdot dy \cdot dz \cdot d\tau \quad — (5)$$

Net heat accumulated in the element due to conductional heat ~~flow~~ from all the co-ordinate directions considered.

$$= \frac{\partial}{\partial x}\left[k_x \frac{\partial t}{\partial x}\right] dx \cdot dy \cdot dz \cdot d\tau + \frac{\partial}{\partial y}\left[k_y \frac{\partial t}{\partial y}\right] dx \cdot dy \cdot dz \cdot \partial\tau +$$

$$\frac{\partial}{\partial z}\left[k_z \frac{\partial t}{\partial z}\right] dx \cdot dy \cdot dz \cdot d\tau$$

$$= \left[\frac{\partial}{\partial x}\left(k_x \frac{\partial t}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial t}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_z \frac{\partial t}{\partial z}\right)\right] dx\, dy\, dz\, d\tau \quad — (6)$$

The total heat generated in the element is given by :

$$Q_g' = q_g\,(dx \cdot dy \cdot dz)\, d\tau \quad — (7)$$

Energy stored in the element :

$$\rho\,(dx \cdot dy \cdot dz)\, c \cdot \frac{\partial t}{\partial \tau} \cdot d\tau \quad — (8)$$

∴ [Heat stored in the body = Mass of the body × specific heat of the body material × rise in the temp of body]

$$\left[\frac{\partial}{\partial x}\left(k_x \frac{\partial t}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial t}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_z \frac{\partial t}{\partial z}\right)\right] dx\,dy\,dz\,d\tau +$$

$$q_g\,(dx.dy.dz)\,d\tau = \rho\,(dx.dy.dz)\,c\,\frac{\partial t}{\partial \tau}\cdot d\tau$$

dividing both sides by $dx\,dy\,dz\,d\tau$

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial t}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial t}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_z \frac{\partial t}{\partial z}\right) + q_g = \rho c \frac{\partial t}{\partial \tau}$$

General heat conduction equation for constant thermal conductivity:

$$\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} + \frac{\partial^2 t}{\partial z^2} + \frac{q_g}{k} = \frac{\rho . c}{k}\cdot\frac{\partial t}{\partial \tau} = \frac{1}{\alpha}\cdot\frac{\partial t}{\partial \tau} \quad (9)$$

where $\alpha = \frac{k}{\rho . c} = \frac{\text{Thermal Conductivity}}{\text{Thermal Capacity}}$

For the case when no internal source of heat generation is present eq (9) reduces to $\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} + \frac{\partial^2 t}{\partial z^2} = \frac{1}{\alpha}\cdot\frac{\partial t}{\partial \tau}$

$$\nabla^2 t = \frac{1}{\alpha}\cdot\frac{\partial t}{\partial \tau} \quad \text{— (Fourier's Equation)}$$

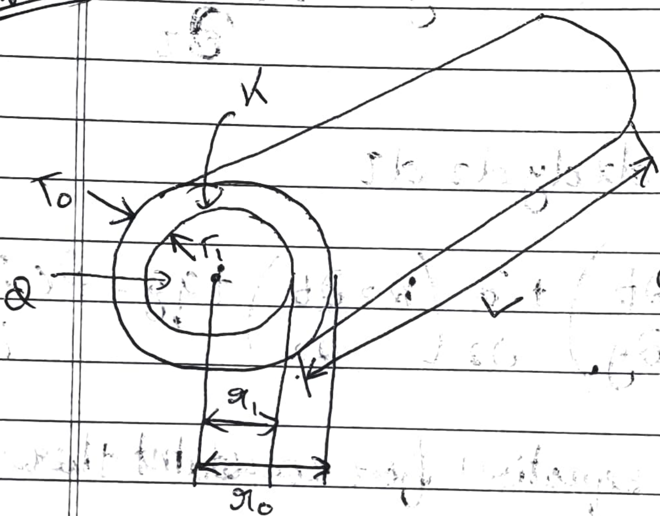
3] Define the three basic modes of heat transfer & the governing laws with supporting relationship.

Ans

Same as Q1 & Q2

4] Derive an expression for the temperature distribution & rate of heat transfer for a hollow cylinder.

Ans



$Q \rightarrow T_1 \text{ ᴧᴧᴧᴧ } T_o \rightarrow Q$

$R_{cyl} = \ln\left(\frac{r_o}{r_1}\right) / (2\pi K L)$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2} + \frac{\partial^2 T}{\partial x^2} + \frac{q_g}{K} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) = 0 \quad \text{or}$$

$$\frac{d}{dr}\left(r\frac{dT}{dr}\right) = 0$$

integrating the above eq^n wrt "r" we get.

$$r\frac{dT}{dr} = C_1$$

$$dT = \frac{C_1}{r}\,dr$$

again integrating w.r.t "r" we get.

$$T(r) = C_1 \ln(r) + C_2 \qquad \text{— (a)}$$

where C_1 & C_2 are constants of integration to be determined by B.C

i) at $r = r_i$, $T = T_i$

$$T_i = C_1 \ln(r_i) + C_2 \qquad \text{— (1)}$$

ii) at $r = r_o$; $T = T_o$

$$T_o = C_1 \ln(r_o) + C_2 \qquad \text{— (2)}$$

eq (1) - (2) gives.

$$(T_i - T_o) = C_1 \ln(r_1) - C_1 \ln(r_o) = C_1 \ln\left(\frac{r_1}{r_o}\right)$$

$$C_1 = \frac{T_1 - T_o}{\ln\left(\frac{r_1}{r_o}\right)} \qquad \text{— (3)}$$

Substituting value of C_1 in eq (1)

$$T_1 = \frac{(T_1 - T_o)}{\ln\left(\frac{r_1}{r_o}\right)} \ln(r_1) + C_2$$

$$C_2 = T_1 - \frac{(T_1 - T_o)}{\ln\left(\frac{r_1}{r_o}\right)} \ln(r_1) \qquad \text{— (4)}$$

substituting the values of C_1 & C_2 in eq (a)

$$\cancel{T_1 = \frac{(T_1 - T_o)}{\ln\left(\frac{r_1}{r_o}\right)}} \quad T(r) = \frac{(T_1 - T_o)}{\ln\left(\frac{r_1}{r_o}\right)} \ln(r) - T_1 - \frac{(T_1 - T_o)}{\ln\left(\frac{r_1}{r_o}\right)} \ln(r_1)$$

$$(T(r) - T_1) = \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)} \ln(r) - \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)} \ln r_1$$

$$(T(r) - T_1) = \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)} \left(\ln(r) - \ln(r_1)\right)$$

$$(T(r) - T_1) = \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)} \ln\left(\frac{r}{r_1}\right)$$

$$\frac{T(r) - T_1}{T_1 - T_0} = \frac{\ln r/r_1}{r_1/r_0} \quad - (5)$$

eq (5) is called temperature distribution eqⁿ

To find heat transfer rate Q.

Applying fourier law, $Q = -KA\frac{dT}{dr}$

$$Q = -KA_{r=r_1}\frac{dT}{dr} \text{ at } r = r_1$$

$$\text{But } \frac{dT}{dr} = C_1 \times \frac{1}{r} = \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)}$$

$$\frac{dT}{dr} \text{ at } r = r_1 = \frac{1}{r_1} \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)}$$

$$\therefore \quad Q = -K(2\pi r_1 L) \times \frac{1}{r_1} \frac{(T_1 - T_0)}{\ln\left(\frac{r_1}{r_0}\right)}$$

$$= \frac{(T_1 - T_0) \times 2\pi K l}{\ln\left(\frac{r_0}{r_1}\right)}$$

$$\boxed{Q = \frac{2\pi K l (T_1 - T_0)}{\ln\left(\frac{r_0}{r_1}\right)}}$$

$$Q = \frac{(T_1 - T_0)}{\ln\left(\frac{r_0}{r_1}\right)}$$

$$Q = \frac{(T_1 - T_0)}{\frac{\ln\left(\frac{r_0}{r_1}\right)}{2\pi K L}} = \frac{\Delta T}{R_{cylinder}}.$$

Comparing the above eqⁿ

$$\boxed{R_{cylinder} = \frac{\ln\left(\frac{r_0}{r_1}\right)}{2\pi K L}}$$