03.03.2025

Applied Heat Transfer

Assignment 1

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① 1.1 Primary mode of Heat Transfer here is convection.

(i) Conduction - Initially some heat is transferred to the pot from the stove in the form of conduction as they are in contact with each other.

(ii) Radiation - Some amount of heat is also transferred by radiation to the pot and water but is very less in comparison to ~~cond~~ convection.

(iii) Convection - When the water starts to heat, hot water from the bottom of the pot starts to rise and denser water from the top moves downwards which creates convection currents. As the water starts to boil molecules of air or bubbles also form at the surface and move upwards. Thus, convection is the primary ~~source~~ mode of heat transfer.

1.2 Conduction is the primary mode of heat transfer.

(i) Here the rod is in direct contact of the flame at one end which vibrates metal rod atoms and gain energy. These vibrations are passed along the length of the rod through collisions between adjacent atoms and free electrons in the metal.

(ii) Convection is not happening here as there is no fluid movement.

(iii) Radiation might contribute to heating the rod initially but primary mode of heat transfer through rod is ~~convection~~ conduction.

② Heat loss from a 200L cylindrical hot water tank in a house is a transient heat transfer problem. It is 3-D heat transfer problem. This is because as the time passes ~~the~~ there will be more heat transfer ~~as~~ if the temperature difference of the tank and atmosphere increases, making it unsteady heat transfer problem. Also in real conditions heat transfer will take place in all directions so it is a 3-Dimensional heat transfer problem.

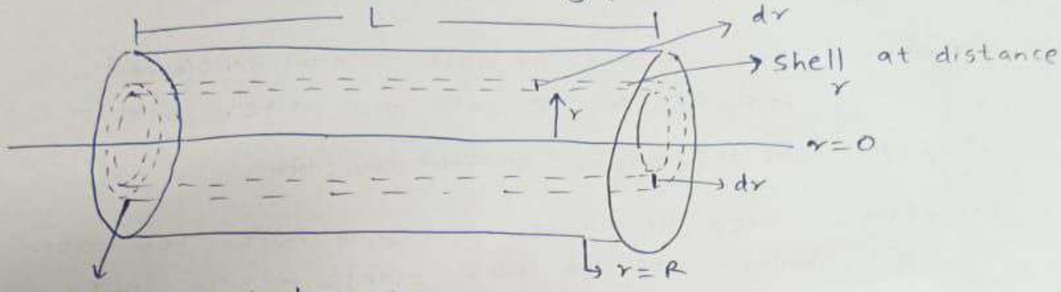
③ Steady One-dimensional heat conduction equation for a long cylinder with constant conductivity.

rate of heat generation = $g\ (\frac{W}{m^3})$

Assumptions:

1. Steady state $\rightarrow \frac{\partial T}{\partial t} = 0$
2. Heat flows radially (1-D heat transfer)
3. Constant k
4. Volumetric heat generation - $g\ (W/m^3)$

(a) Heat
(b) One
(c) NO
(d) the



Energy Balance:

Rate of heat conducted into the shell + Rate of heat generated within the shell = Rate of heat conducted out

$$\Rightarrow q_{in} + g - q_{out} = 0 \quad \text{[For the shell]}$$

↳ steady

$$\Rightarrow -k A_{c_{in}} \frac{dT}{dr}\bigg|_{r=r} + k A_{c_{out}} \frac{dT}{dr}\bigg|_{r=r+dr} + g(2\pi r L\, dr) = 0$$

$$\Rightarrow -k \times (2\pi r L) \times \frac{dT}{dr}\bigg|_{r=r} + k\left(2\pi (r+dr) L\right) \frac{dT}{dr}\bigg|_{r=r+dr} + g \times 2\pi r L\, dr = 0$$

$\div$ by ~~$2\pi r L$~~ $2\pi L\, dr$

$$\Rightarrow \frac{k(r+dr)\frac{dT}{dr}\Big|_{r+dr} - k r \frac{dT}{dr}\Big|_{r}}{dr} + g r = 0$$

$$\Rightarrow k \frac{\partial}{\partial r}\left(r \frac{\partial T}{\partial r}\right) + g r = 0$$

$$\Rightarrow \boxed{\frac{1}{r} \frac{\partial}{\partial r}\left(r \frac{\partial T}{\partial r}\right) = -\frac{g}{k}}$$

① constant thermal conductivity k
② Vol. heat gen. 'g'
③ 1-D steady Heat conduction equation for cylinder

✱ [$x = 1$

(4)

$$\boxed{\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}}$$

(a) Heat transfer is transient as there is a term of $\frac{\partial T}{\partial t}$.

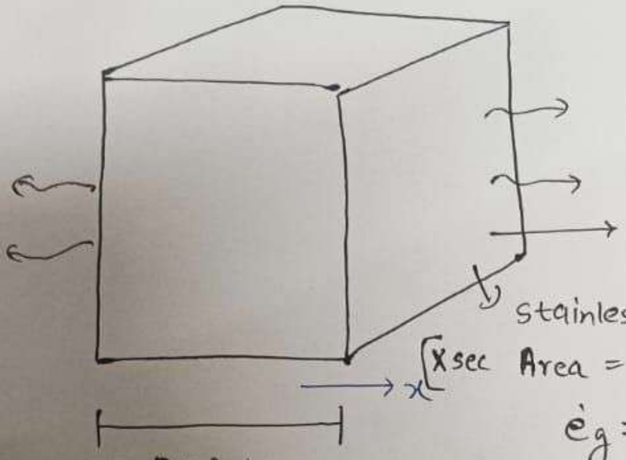
(b) One dimensional heat transfer (in x- direction)

(c) No, there is no heat generation term

(d) thermal conductivity is constant $\left(\alpha = \frac{K}{\rho c_p}\right)$

(5)

[Steady Operation]



$q = ?$ (Heat Flux)

stainless steel (thermal conductivity (K))

[Xsec Area = A]

$\dot{e}_g = 5 \times 10^6 \frac{W}{m^3}$

* $\left[x = -\frac{L}{2} \longleftarrow \overset{x=0}{\bullet} \longrightarrow x = L/2\right]$

For a plane wall, in steady operation

$$\frac{d^2T}{dx^2} = \frac{-\dot{e}_g}{K}$$

$$\boxed{\frac{dT}{dx} = -\frac{\dot{e}_g}{K}x + C_1}$$

$$\left\{ \begin{array}{l} BC_1 : \left.\frac{dT}{dx}\right|_{x=0} = 0 \\ \qquad\qquad \downarrow \\ \qquad\qquad \text{at centre} \\ \therefore C_1 = 0 \end{array} \right.$$

$\therefore$ q (heat flux) at surface

$$\Rightarrow \frac{-KA \left.\frac{dT}{dx}\right|_{x=\frac{L}{2}}}{A} = \dot{e}_g \frac{L}{2}$$

$$= 5 \times 10^6 \frac{W}{m^3} \times \frac{0.03}{2} m$$

$$= 0.075 \times 10^6 \frac{W}{m^2}$$

$$\therefore \boxed{q = 7.5 \times 10^4 \frac{W}{m^2}}$$