Heat Transfer

– Mode of Heat Transfer

Conduction

1. Heat transfer in Conductor due to heat Current.

2. Medium is requred for heat transfer but medium doesn't move

Convection

- Heat transfer due to actual movement of medium

Radiation

- Heat transfer take's place by electromagnetic-wave
- Medium doesn't requered for heat transfer.

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ΔQ

CONDUCTION

$$\frac{\Delta Q}{\Delta t} \propto \frac{A\,(T_f - T_i)}{L}$$

$$\frac{\delta Q}{\delta t} = -\frac{KA}{L}\left(T_f - T_i\right)$$

$\frac{dQ}{dt}$ = Rate of heat flow per second
ie power

$$\boxed{\frac{\Delta Q}{\Delta t} = \frac{KA}{L}\left(T_H - T_L\right)}$$

$$\boxed{\frac{dQ}{dt} = -KA\left(\frac{dT}{dx}\right)}$$

T_H = Higher temp

T_L = Lower temp

K = Thermal Conductivity of Material

L = length of the Conductor

A = Crossectional Area of the conductor

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Concept of Steady state heat flow

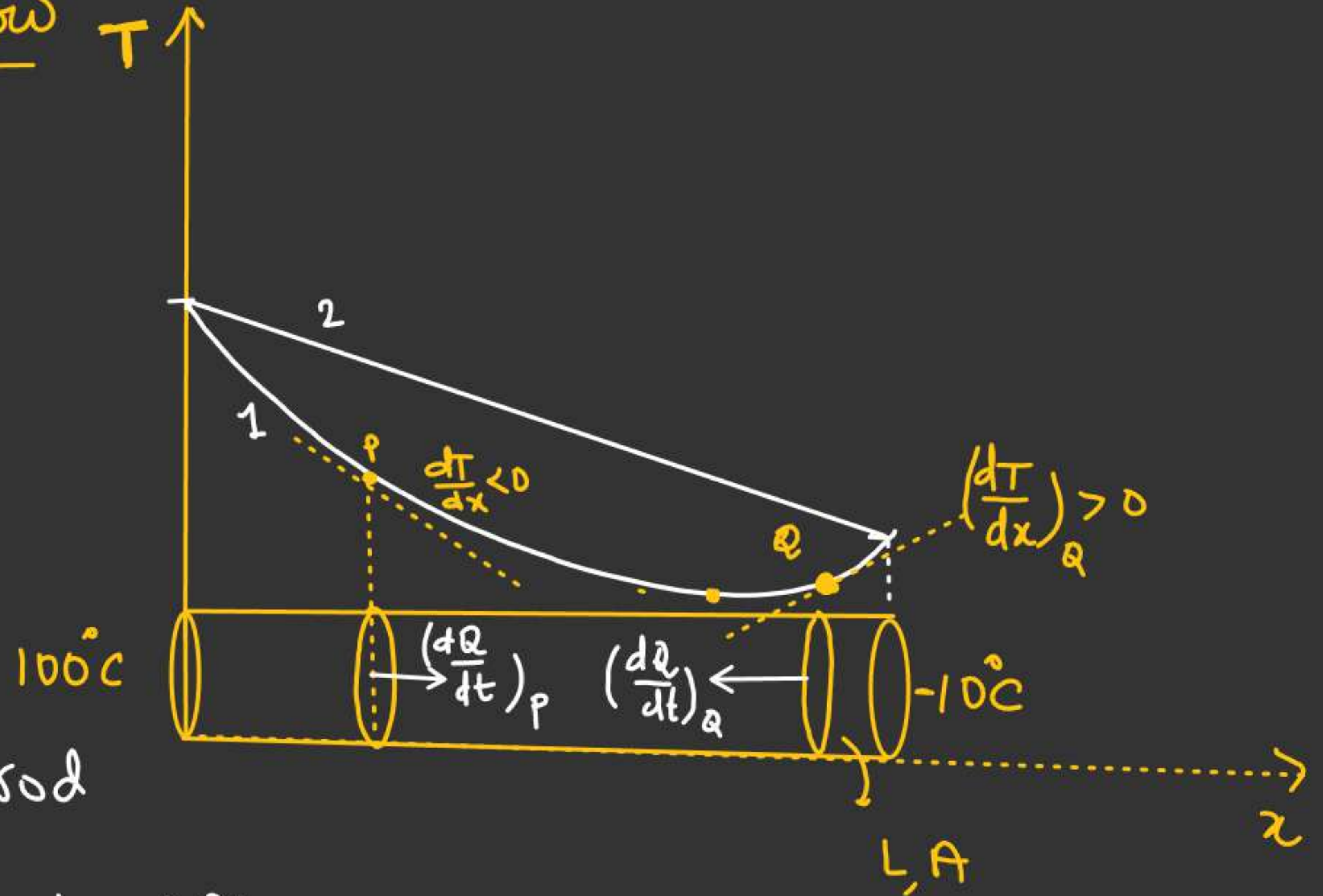
$$\boxed{\frac{dQ}{dt} = -KA\left(\frac{dT}{dx}\right)}$$

For graph - 1

$\frac{dT}{dx}$ is different at every point

So, $\frac{dQ}{dt}$ is different through every crossectional area of the rod

this state is non-steady state heatflow.



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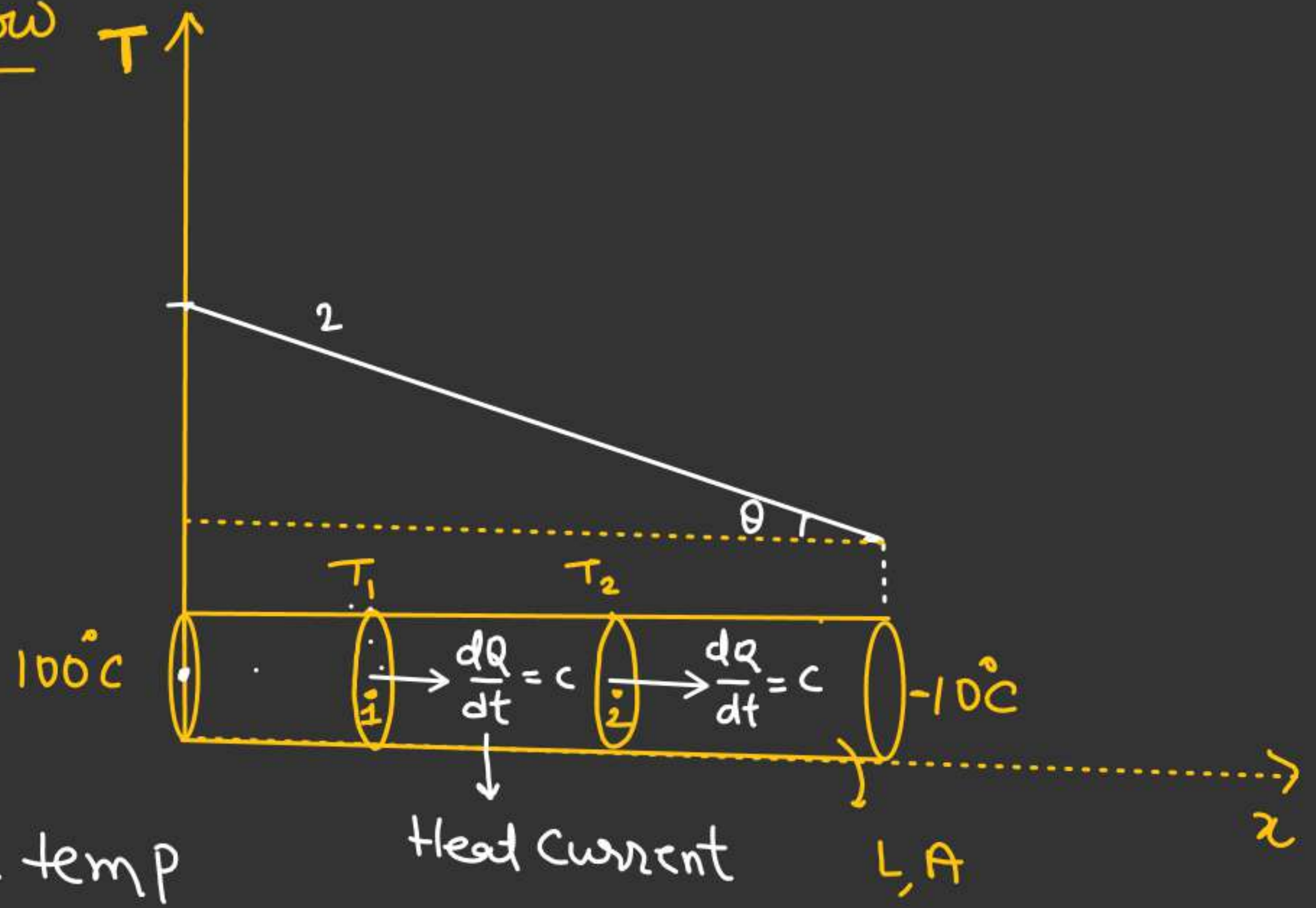
Concept of Steady state heat flow

$$\boxed{\frac{dQ}{dt} = -KA\left(\frac{dT}{dx}\right)}$$



For graph (2).

$$\frac{dT}{dx} = \text{Constant}$$

$$\Rightarrow \frac{dQ}{dt} = \text{Constant}$$

$\Rightarrow$ At the time of Steady state, the temp assign by every part of the rod remain constant w.r.t time.

i.e Neither any part of rod absorb any heat nor released any heat

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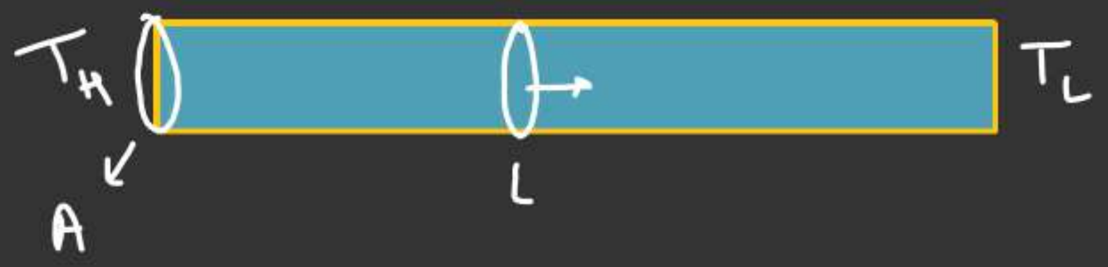


$$\frac{\Delta Q}{\Delta t} = -\frac{KA}{L}\left(T_L - T_H\right)$$

$$\frac{\Delta Q}{\Delta t} = \frac{KA}{L}\left(T_H - T_L\right)$$

$$\Downarrow$$

$$i_{th} = \frac{(T_H - T_L)}{L/KA}$$

thermal current

thermal resistence

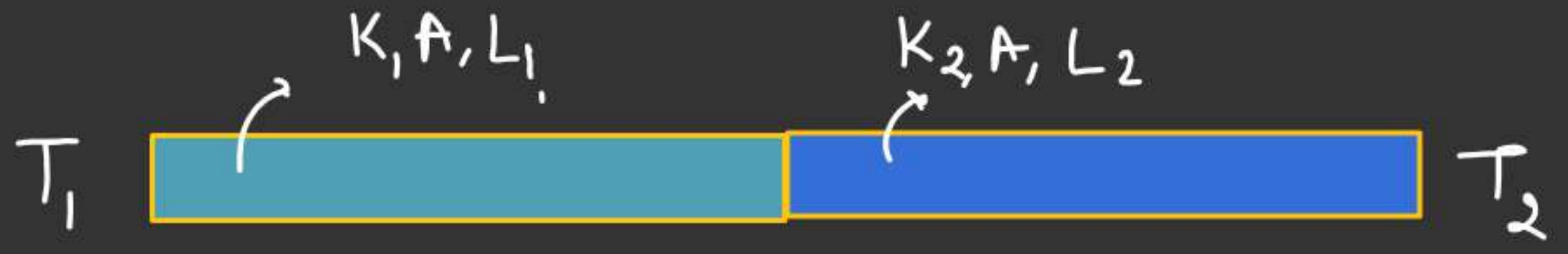
$$i = \left(\frac{V_1 - V_2}{R}\right) \checkmark$$

Equivalent thermal Conductivity

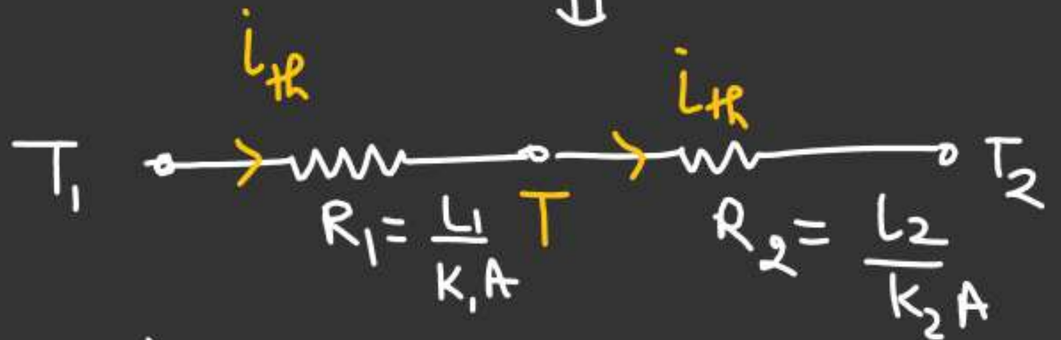
$T_1 > T_2$

⇒ Junction temp

⇒ Equivalent thermal conductivity



⇓



$$i_{th} = \frac{T_1 - T}{\frac{L_1}{K_1 A}} = \frac{T - T_2}{\frac{L_2}{K_2 A}}$$

$$\frac{K_1}{L_1}(T_1 - T) = \frac{K_2}{L_2}(T - T_2)$$

$$\frac{K_1 T_1}{l_1} + \frac{K_2 T_2}{l_2} = \left(\frac{K_1}{L_1} + \frac{K_2}{L_2}\right) T$$

$$\boxed{\frac{K_1 T_1 l_2 + K_2 T_2 L_1}{K_1 l_2 + K_2 L_1} = T}$$

$$\left.\begin{aligned} K_1 &= K_2 = K \\ L_1 &= l_2 = L \end{aligned}\right\} \Rightarrow \boxed{T = \frac{T_1 + T_2}{2}}$$

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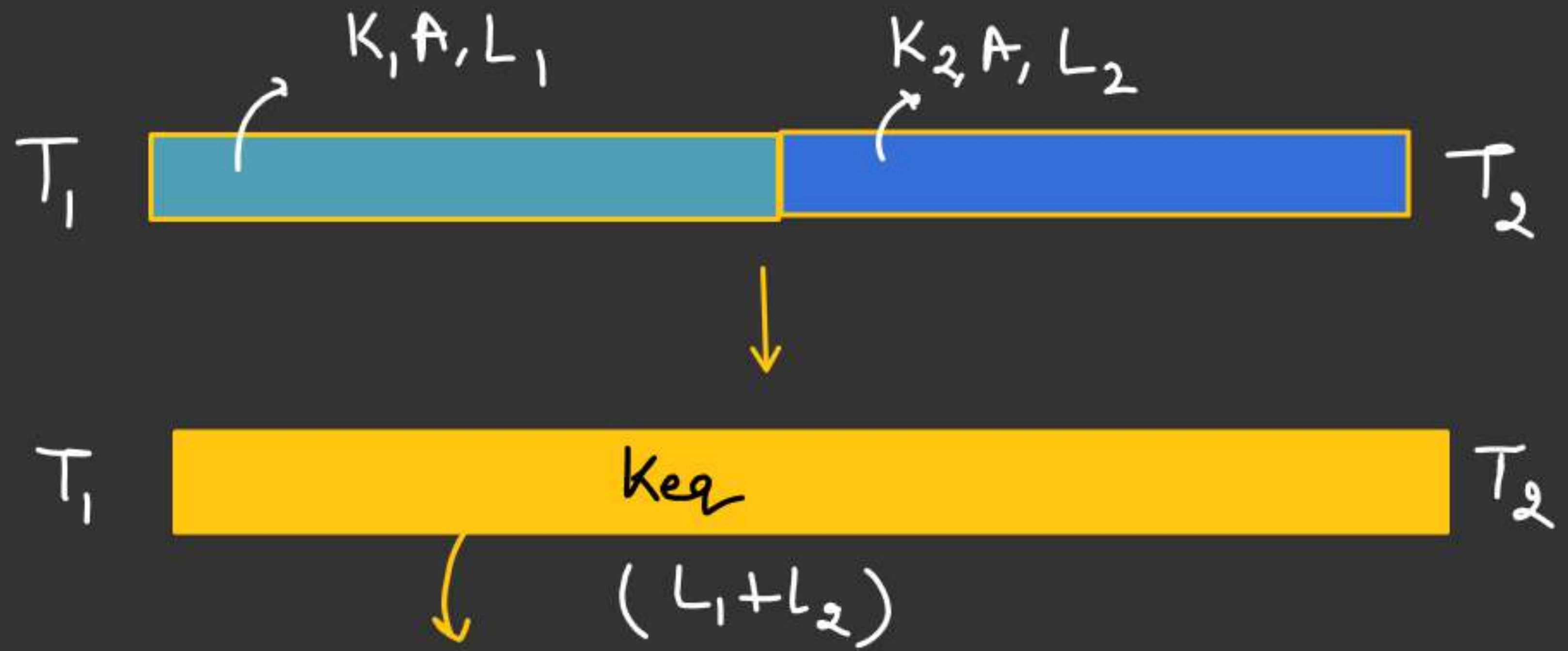
Equivalent thermal Conductivity

$T_1 > T_2$



$$R_{eq} = \frac{(L_1 + L_2)}{K_{eq} A}$$

⇒ Equivalent thermal conductivity

$$R_{eq} = R_1 + R_2$$

$$\frac{L_1 + L_2}{K_{eq} A} = \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A}$$

$$K_{eq} = \left(\frac{L_1 + L_2}{\frac{L_1}{K_1} + \frac{L_2}{K_2}}\right)$$

if $L_1 = L_2$

$$K_{eq} = \left(\frac{2 K_1 K_2}{K_2 + K_1}\right) \checkmark$$

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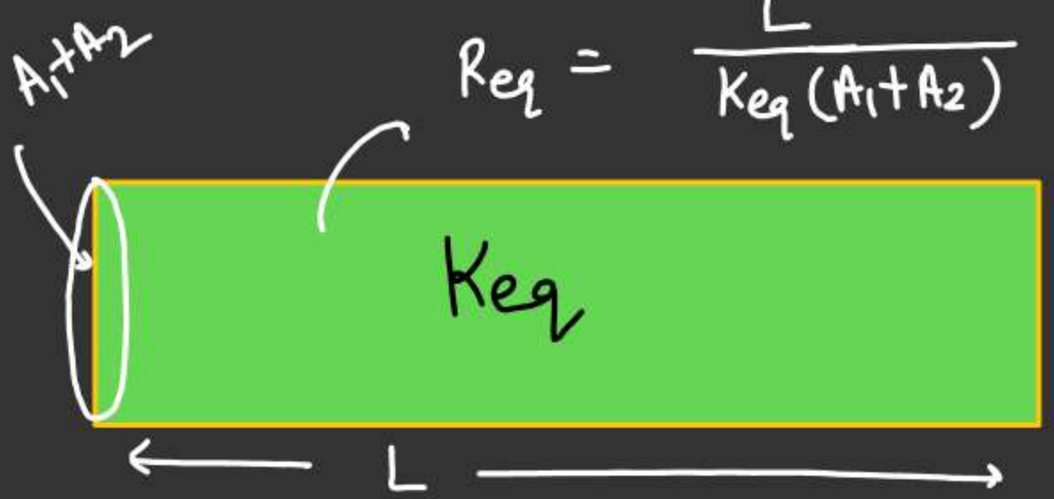
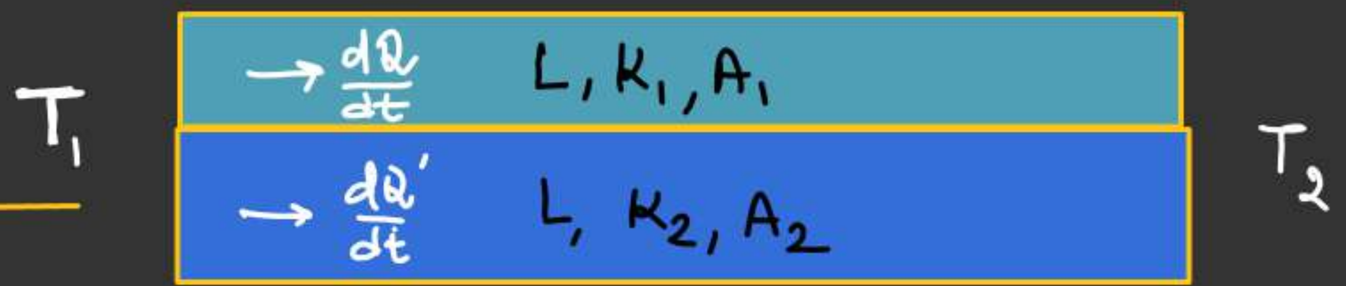
K_{eq} in parallel Combination

$T_1 > T_2$

$$R_{eq} = \frac{L}{K_{eq}(A_1+A_2)}$$





$\Downarrow$

$$R_1 = \frac{L}{K_1 A_1}$$

$$R_2 = \frac{L}{K_2 A_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{K_{eq}(A_1+A_2)}{\cancel{L}} = \frac{K_1 A_1}{\cancel{L}} + \frac{K_2 A_2}{\cancel{L}}$$

$$K_{eq} = \left(\frac{K_1 A_1 + K_2 A_2}{A_1 + A_2}\right)$$

[if $A_1 = A_2 = A$

$$\left(K_{eq} = \frac{K_1 + K_2}{2}\right)$$

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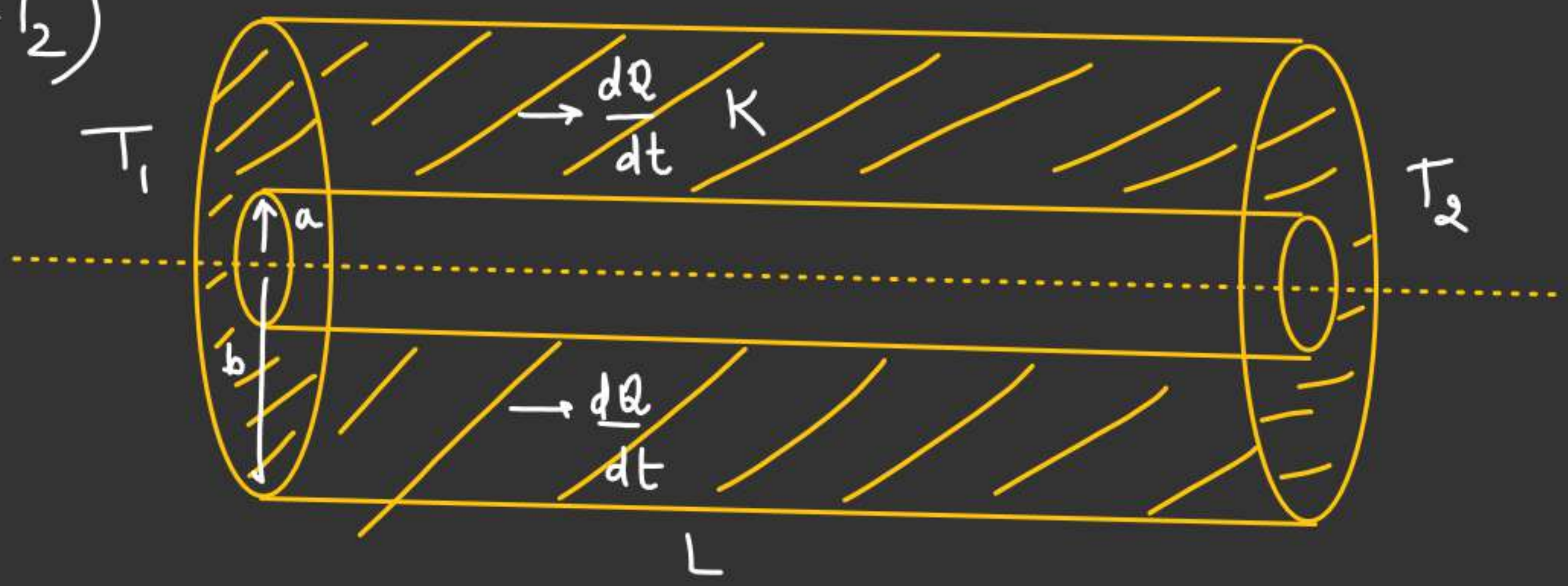
Heat flow in Case of variable Crossectional area

$T_1 > T_2$

$$\frac{dQ}{dt} = i_{th} = \frac{K\ \pi(b^2-a^2)}{L}(T_1-T_2)$$



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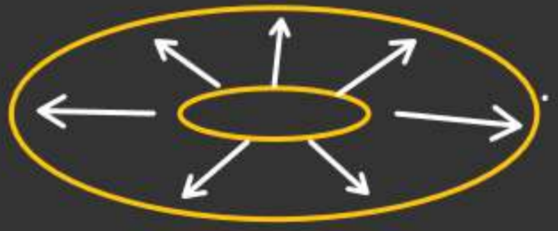
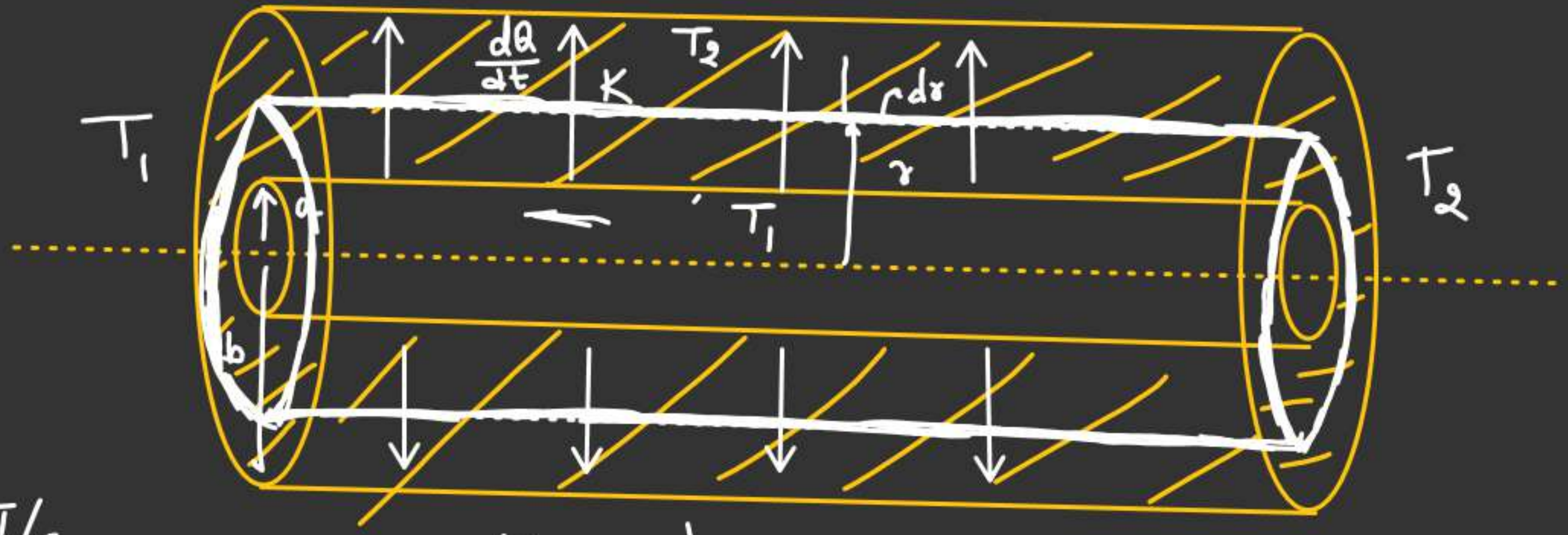
Heat flow in case of variable Crossectional area

$T_1 > T_2$



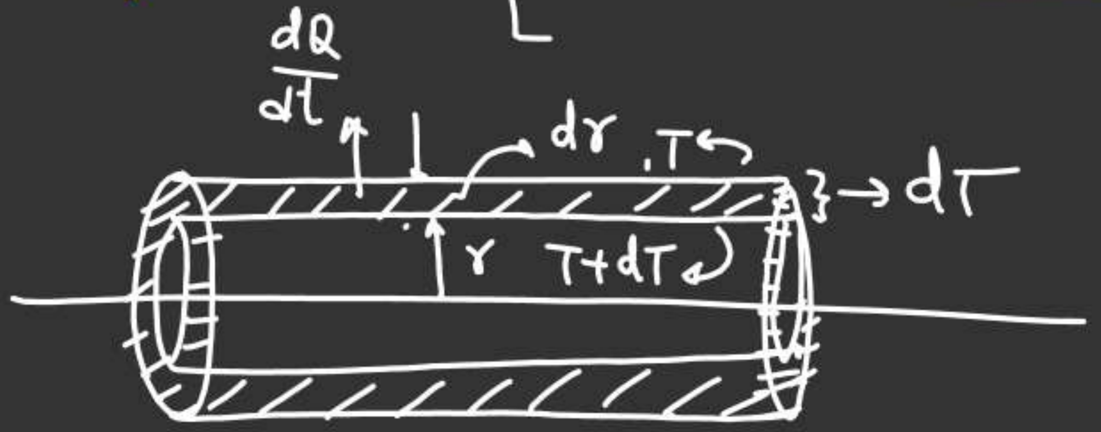


$$\frac{dQ}{dt} = -K(2\pi r L)\frac{dT}{dr}$$

At the time of steady state $= P\ J/s$

$$P = -2\pi K L\left(r\frac{dT}{dr}\right)$$

$$P\int_a^b \frac{dr}{r} = -2\pi K L\int_{T_1}^{T_2} dT$$



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Heat flow in case of variable crossectional area

$T_1 > T_2$

$$P = -2\pi K L \left(r \frac{dT}{dr}\right)$$

$$P \int_a^b \frac{dr}{r} = -2\pi K L \int_{T_1}^{T_2} dT$$

$$\boxed{R_{th} = \frac{1}{2\pi K L} \ln\left(\frac{b}{a}\right)}$$

$$P \ln\left(\frac{b}{a}\right) = -2\pi K L (T_2 - T_1)$$

$$P \ln\left(b/a\right) = (T_1 - T_2) \cdot 2\pi K L$$

$$P = \left(\frac{T_1 - T_2}{\frac{1}{2\pi K L} \ln(b/a)}\right)$$

$$i_{th} = \frac{T_1 - T_2}{R_{th}}$$