Heat Transfer

① Modes → Convection, conduction, Radiation

② Conduction

T_1 ⟵ L ⟶ T_2

$T_1 > T_2$

$$\boxed{\frac{dQ}{dt} = \frac{KA(T_1 - T_2)}{L}}$$

$i = \frac{dQ}{dt}$ - heat current

$T_1 - T_2 = \Delta T$ (temp diff)

K = coeff. of thermal conductivity

③ Comparision of conduction to electric current

V_1 —R— V_2 T_1 —R— T_2

$i = \frac{V_1 - V_2}{R}$ $i = \frac{dQ}{dt}$

$T_1 - T_2 \to$ temp diff

$$\boxed{R = \frac{L}{KA}} \quad \boxed{i = \frac{T_1 - T_2}{R}}$$

④ Junction temperature & interface

T_1 L_1K_1 T L_2K_2 T_2

i = const

$$\frac{T_1 - T}{\frac{L_1}{K_1A}} = \frac{T - T_2}{\frac{L_2}{K_2A}}$$

(i) $i = i_1 + i_2$

$$\frac{T_1 - T}{R_1} = \frac{T - T_2}{R_2} + \frac{T - T_3}{R_3}$$

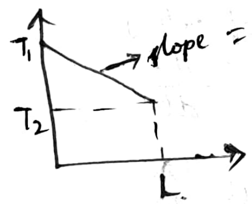
(ii) $i + i_2 + i_3 = 0$

$$\frac{T - T_1}{R_1} + \frac{T - T_2}{R_2} + \frac{T - T_3}{R_3} = 0$$

⑤ Temp. variation of steady state:

T_1 ⟵ L ⟶ T_2 $(T_1 > T_2)$

⟵ x ⟶ $T(x)$



$$\frac{T_1 - T(x)}{\frac{x}{K_1A_1}} = \frac{T_1 - T_2}{\frac{L}{K_1A_1}}$$

$$\boxed{T(x) = T_1 - \left(\frac{T_1 - T_2}{L}\right)x}$$

⑥ Equivalent thermal conductivity:

(here A is always equal)

Series $\to i$ = const

θ_1 $\frac{L_1}{K_1}$ $\frac{L_2}{K_2}$ θ, A $\Rightarrow$ $\frac{L_1 + L_2}{K_S}$, A

$$R_S = R_1 + R_2 \Rightarrow \boxed{\frac{L_1 + L_2}{K_S A} = \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A}}$$

if $L_1 = L_2 = L$

$$\boxed{K_S = \frac{2K_1K_2}{K_1 + K_2}}$$

Parallel

* (L is const)

L, K_1 → A_1; K_2 → A_2; L

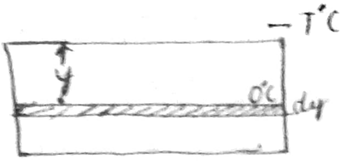
$$1/R_p = 1/R_1 + 1/R_2$$

$$\frac{K_p(A_1 + A_2)}{L} = \frac{K_1A_1}{L} + \frac{K_2A_2}{L}$$

if $A_1 = A_2 = A$

$$\boxed{K_p = \frac{K_1 + K_2}{2}}$$

⑦ Freezing of lake



$$\frac{dQ}{dt} = \frac{KA(T)}{y}$$

$$\rho A L_{ice}\int_0^y y\,dy = KAT\int_0^t dt$$

time taken to freeze lake

$$\boxed{t = \frac{\rho L_{ice} y^2}{2KT}}$$

⑧ Thermal radiation

Prevost theory

except 0 K, it emit all radiations

$\rightsquigarrow T_s \; (T) \rightsquigarrow$ radiated

$T_s > T$

absorbed radiated

$T_s = T$

Kirchoff's law

Good absorber is also good emitter

$e = a = 1$

↓

black body

Stephen's law

$$\frac{dQ}{dt} = \sigma A e T^4$$

$\frac{dt}{}$ → emissive power

$\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$

⑨ Stefen's - Boltzmann law:

rate of heat lost ← $\frac{dQ}{dT} = e\sigma A(T^4 - T_0^4)$

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

→ rate of cooling

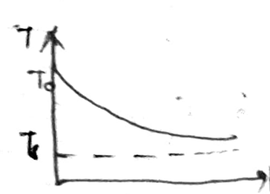
$$\frac{dQ}{dT} = \frac{-ms\,dT}{dt}$$

⑩ Newton's laws of cooling:

$$\frac{dT}{dt} = K\left[\frac{T_1 + T_2}{2} - T_0\right]$$

$T = T_s + (T_0 - T_s)e^{-ct}$

T_0 = temp at 0°C



⑪ Wein's displacement law:

$\lambda \propto \frac{1}{T}$ $\lambda = b/T \Rightarrow \boxed{\lambda T = b}$ $b = 2.89 \times 10^{-3}\ mK)$