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Temperature and Heat

Temperature and Thermal Equilibrium

the zeroth law of thermodynamics

if C is initially in thermal equilibrium with both A and B, then A and B are also in thermal equilibrium

Thermal Expansion

linear expansion

$\Delta L = \alpha L_0 \Delta T$ for ΔT less than $100°C$

α : coefficient of linear expansion

$L = L_0 + \Delta L = L_0 + \alpha L_0 \Delta T = L_0(1+\alpha\Delta T)$

volume expansion

$\Delta V = \beta V_0 \Delta T$ for ΔT less than $100°C$

β : coefficient of volume expansion

$dV = \frac{dV}{dL} dL = 3L^2 dL$, $dL = \alpha L_0 dT$

$= 3L_0^2 \alpha L_0 dT$

$= 3\alpha V_0 dT$

$\Rightarrow \beta = 3\alpha$

$V_i + \Delta V = (l+\Delta l)(w+\Delta w)(h+\Delta h)$

$= (l+\alpha l\Delta T)(w+\alpha w\Delta T)(h+\alpha h\Delta T)$

$= lwh(1+\alpha\Delta T)^3$

$= V_i[1+3\alpha\Delta T+3(\alpha\Delta T)^2+(\alpha\Delta T)^3]$

thermal stress

$\left(\frac{\Delta L}{L_0}\right)_{thermal} = \alpha\Delta T$ $\quad Y = \frac{F/A}{\Delta L/L_0}$, $\left(\frac{\Delta L}{L_0}\right)_{tension} = \frac{F}{AY}$

$\left(\frac{\Delta L}{L_0}\right)_{thermal} - \left(\frac{\Delta L}{L_0}\right)_{tension} = \alpha\Delta T + \frac{F}{AY} = 0$ if the length is to be constant

$\frac{F}{A} = -Y\alpha\Delta T$

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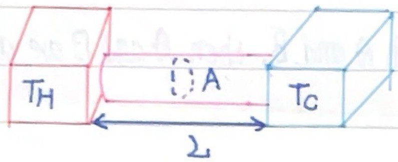
Mechanisms of Heat Transfer

conduction



heat current $H = \frac{dQ}{dt} = kA \underbrace{\frac{T_H - T_C}{L}}_{\text{temperature gradient}}$ k thermal conductivity

$$\Rightarrow H = \frac{dQ}{dt} = -kA\frac{dT}{dx}$$

$$= \frac{A(T_H - T_C)}{R}$$ where thermal resistance $R = \frac{L}{k}$

convection

$H \propto$ surface area

$\propto \frac{1}{\text{viscosity}}$

$\underset{\sim}{\propto} \frac{5}{4}$ power of temperature difference between the surface and the main body of fluid

radiation

$H = Ae\sigma T^4$, e , emissivity between 0 and 1

$\Rightarrow$ Stefan-Boltzmann law

the rate of radiation from a particular surface to the rate of radiation from an equal area of an ideal radiating surface at the same T

σ, Stefan-Boltzmann constant

$$H_{net} = Ae\sigma T^4 - Ae\sigma T_s^4 = Ae\sigma(T^4 - T_e^4)$$