Nov.14/17
THERMAL SCI.

$\lambda = \boxed{0.3 - 3}\ \mu m$ → solar radiation

↓ $\tau_\lambda \simeq 90\%$

Infrared wave : $0.76 - 100\ \mu m$

$\lambda > 3\ \mu m$

Example 12-1 : $D = 20\ cm$ ≈ blackbody

$T = 800\ K$

a) blackbody emissivity

b) total radiation emitted (5 min)

c)

→ a) $E_b = \sigma T^4$ → T must be in absolute scale

↳ kW/m^2 ↳ $5.67 \times 10^{-8}\ W/m^2 \cdot K^4$ (same with $PV = mRT$)

$E_b = 23.2\ kW/m^2$

b) $Q_{rad} = E_b \times A_s \times \Delta t$

$= (23.2\ kW/m^2) \times (\pi (0.02m)^2) \times (5\ \cancel{min})\left(\frac{60\ sec}{1\ \cancel{min}}\right)$

$= 875\ kJ$

c) $$E_{b\lambda} = \frac{C_1}{\lambda^5 \left[\exp\left(C_2/\lambda T\right) - 1\right]}$$

$C_1 = 3.78177 \times 10^8\ W\mu m^4/m^2$

$C_2 = 1.43878 \times 10^4\ \mu m \cdot K$

(μm)

↳ in absolute

$= 3846\ W/m^2 \cdot \mu m$

Chapter 13 : Radiation Heat Transfer

Obj : ① View factor / Shape factor / Configuration factor

↳ angle factor

② Calculate radiation heat transfer between BB's

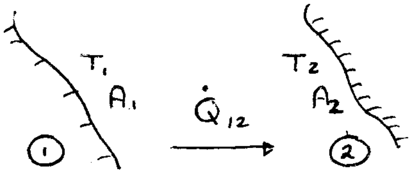
③ " ～～～～ " non-black surfaces.

④ Radiation shield and its use

Nov. 16/17

THERMAL

Radiation heat transfer : Black surfaces



$E_b = \sigma T^4$

F_{12} = Radiation leaving ① and directly striking ②

$\dot{Q}_{12}$ = rad. leaving 1 and striking 2 − rad. leaving 2 and striking 1

$\dot{Q}_{12} = E_{b1} \times A_1 \times F_{12} - E_{b2} \times A_2 \times F_{21}$

Reciprocity relation : $A_1 F_{12} = A_2 F_{21}$

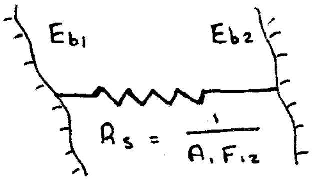
$\Rightarrow A_1 F_{12} E_{b1} - E_{b2} A_1 F_{12}$

$\Rightarrow A_1 F_{12} (E_{b1} - E_{b2}) = A_1 F_{12} (T_1^4 - T_2^4)$

$\dot{Q}_{12} = A_1 F_{12} (E_{b1} - E_{b2})$

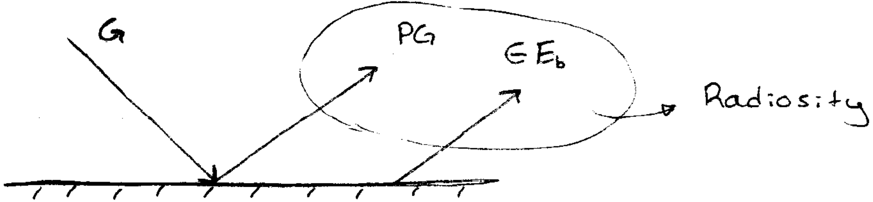
$\dot{Q}_{12} = \dfrac{E_{b1} - E_{b2}}{R_s}$ $\quad\therefore R_s = \dfrac{1}{A_1 F_{12}}$

space / shape resistance



N surfaces:

$\underset{\text{net}}{\dot{Q}_i} = \sum_{j=1}^{N} Q_{ij} = \sum_{j=1}^{N} A_i F_{ij} (T_i^4 - T_j^4)$



non-black surface

(opaque) → $\tau = 0$

$\alpha + \rho + \cancel{\tau}^{0} = 1$

$\therefore \alpha + \rho = 1$ $\quad | \ \epsilon - \alpha$

$\therefore \epsilon + \rho = 1$

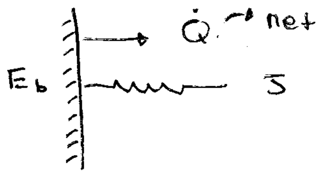
$\therefore \rho = 1 - \epsilon$ or $\rho = 1 - \alpha$

J = Rad. emitted + Rad. reflected

$= \epsilon E_y + \rho G$

$J = \epsilon E_b + (1 - \epsilon) G$

Net radiation to or from a surface



Radiosity = J

$\dot{Q}$ = rad. leaving the surface ...

... − rad. incident on the surface

$$\boxed{\dot{Q} = A(J - G)}$$

From: $G = \frac{J - \epsilon E_b}{1 - \epsilon}$

$$\dot{Q} = A\left(J - \left(\frac{J - \epsilon E_b}{1-\epsilon}\right)\right)$$

$$= \frac{A\epsilon}{1-\epsilon}\left(E_b - J\right)$$

$$\dot{Q} = \frac{E_b - J}{1 - \epsilon / A\epsilon} \Rightarrow \frac{E_b - J}{R_{surface}}$$

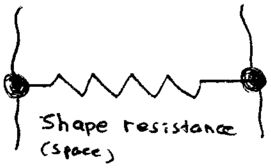
↳ $R_{surface} = \frac{1-\epsilon}{A\epsilon}$

$\frac{1}{A_1 F_{12}}$

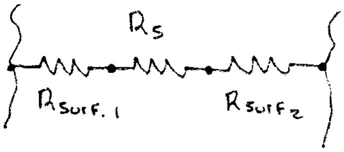
(space or)
① Shape resistance

② Surface resistance

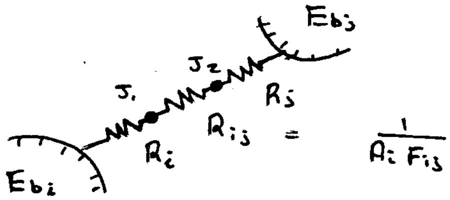
BLACK



NON-BLACK



Radiation heat transfer : non-black surfaces



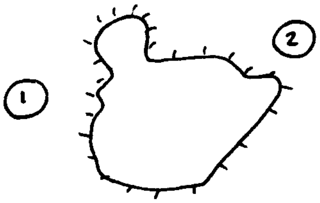
$\dot{Q}_{ij}$ = Radiation leaving i and striking j − Radiation ...

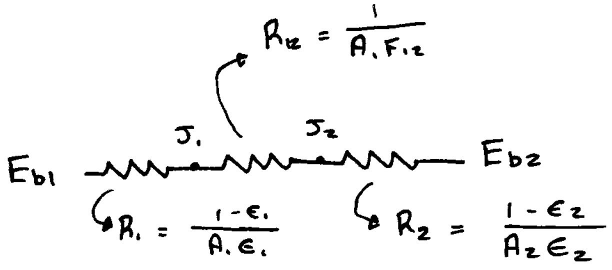
... leaving j and striking i

$$\Rightarrow A_i J_i F_{ij} - A_j J_j F_{ji}$$

$$= A_i F_{ij}(J_i - J_j) = \frac{J_i - J_j}{(1/A_i F_{ij})} \longrightarrow R_{ij} = \frac{1}{A_i F_{ij}}$$

$$\dot{Q}_i = \sum_{j=1}^{N} \dot{Q}_{ij} = \sum_{j=1}^{N} A_i F_{ij}(J_i - J_j)$$





Non-black

$$\dot{Q}_{12} = \frac{E_{b1} - E_{b2}}{R_1 + R_{12} + R_2}$$

$$\hookrightarrow \quad \dot{Q}_{12} = \frac{\sigma(T_1^4 - T_2^4)}{\left[\left(\frac{1-\epsilon_1}{A_1\epsilon_1}\right) + \left(\frac{1}{A_1F_{12}}\right) + \left(\frac{1-\epsilon_2}{A_2\epsilon_2}\right)\right]}$$

Example: 3-7

$T_1 = 800$ K $\epsilon_1 = 0.2$ (Two very large parallel plates)

$T_2 = 500$ K $\epsilon_2 = 0.7$

$A_1 = A_2 = A$

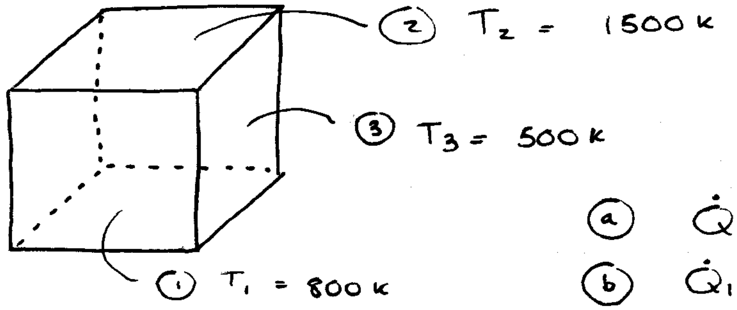
$F_{12} = F_{21} = 1$

$$\dot{Q}_{12} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

$$\hookrightarrow \frac{\dot{Q}_{12}}{A} = \dot{q}_{12} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} = 3625 \text{ W/m}^2$$

Example: 3-6

black



ⓐ $\dot{Q}_{13} = A_1 F_{13} \sigma (T_1^4 - T_3^4)$

ⓑ $\dot{Q}_{12} = A_1 F_{12} \sigma (T_1^4 - T_2^4)$

ⓒ $\dot{Q}_1 = \sum_{j=1}^{3} Q_{ij}$

ⓐ = 25

ⓑ Fig 13-5 : $F_{12} = 0.2$; $F_{11} = 0$

From ℓ = $\cancel{F_{11}}^{0} + F_{12} + F_{13} = 1$

$\therefore F_{13} = 1 - 0.2 = 0.8$