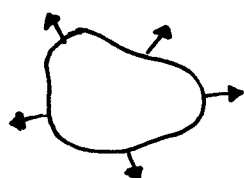


OCT. 26/17
THERMAL

Chapter 1: Heat Transfer

Introduction and basic concepts

Radiation: electromagnetic waves → 1) thermal radiation



($T > 0K$, then
radiation exists)

2) non-thermal (x-ray,
radiowaves, microwaves)

1) + 2) Conduction and convection → material medium

3) Rad → do not require medium

↳ max in vacuum

Stefan - Boltzmann:

Black body ← $\dot{Q}_{emit, max} = \sigma (A_s)(T_s)^4$ absolute
 ↳ Stefan-Boltzmann constant

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

For real surfaces:

$$\dot{Q}_{emit} = \epsilon \sigma A_s T_s^4$$

↳ emissivity

For black body $\epsilon = 1$

For others: $0 \leq \epsilon \leq 1$

T1-6

Aluminum foil

ϵ
0.07

Black Paint

0.98

White paper

0.92 → 0.97

Human skin

0.95

$\dot{Q}_{emit} = \epsilon \sigma A_s T_s^4$

Kirchoff's Law:

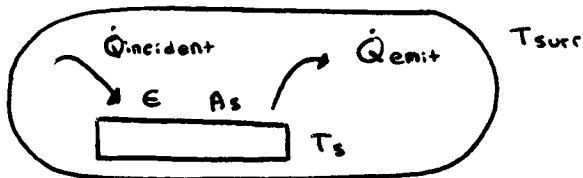
↳ ϵ, α
emissivity absorptivity

$\dot{Q}_{absorbed} = \alpha \dot{Q}_{incident}$

A hand-drawn diagram of a rectangle representing a surface. An arrow labeled $\dot{Q}_{incident}$ points towards the right side of the rectangle. An arrow labeled $\dot{Q}_{absorbed}$ points away from the left side of the rectangle. The interior of the rectangle is filled with diagonal hatching lines.

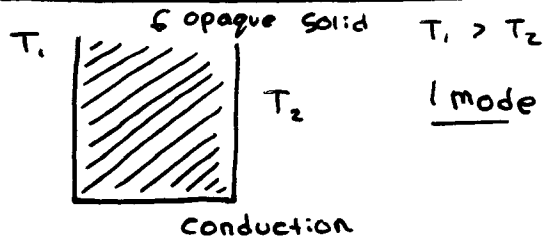
- At same temperature + wavelength

$\epsilon = \alpha$

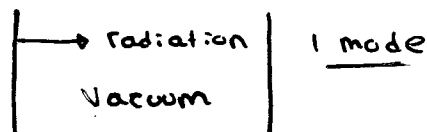


$$\dot{Q}_{\text{rad}} = \epsilon \sigma A_s (T_s^4 - T_{\text{surr}}^4)$$

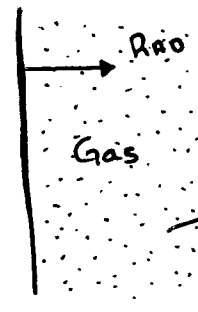
Simultaneous heat transfer mechanisms



1 mode



1 mode



2 modes

Stationary → conduction
moving → convection

Example 1.9 (2nd textbook)

$$\left\{ \begin{array}{l} \epsilon_{\text{skin}} = 0.95 \\ \sigma = 5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4} \end{array} \right. \quad \left\{ \begin{array}{l} \dot{Q}_{\text{rad, summer}} = 40.9 \text{ W} \\ \dot{Q}_{\text{rad, winter}} = 152 \text{ W} \end{array} \right.$$

Example 1.10 (2nd textbook)

$$\left\{ \begin{array}{l} \epsilon_{\text{skin}} = 0.95 \\ \sigma = 5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4} \end{array} \right. \quad \begin{array}{l} T_{\text{si}} = 29^\circ\text{C} + 273 \text{ K} = 302 \text{ K} \\ A_s = 1.6 \text{ m}^2 \quad T_{\text{surr}} = 20^\circ\text{C} + 273 \text{ K} \end{array}$$

$$\dot{Q}_{\text{radiation}} = (0.95)(5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4})((302)^4 - (273)^4)(1.6)$$

$$\dot{Q}_{\text{radiation}} = 81.7 \text{ W}$$

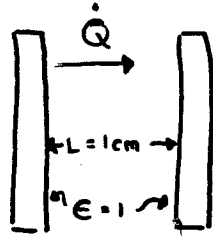
$$\dot{Q}_{\text{convection}} = h A_s (T_s - T_\infty)$$

Conv. coeff. Surface area Fluid temp

$$\begin{aligned} \dot{Q}_{\text{convection}} &= (6)(16)(29 - 20) \\ &= 86.4 \text{ W} \end{aligned}$$

$$\dot{Q}_{\text{total}} = 81.7 \text{ W} + 86.4 \text{ W} = 168.1 \text{ W}$$

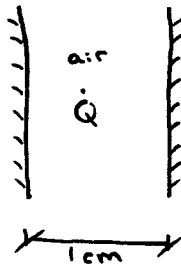
Example 1-11 (second textbook)



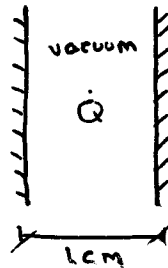
$$A_s = 1 \text{ m}^2$$

$$T_1 = 300 \text{ K} \quad T_2 = 200 \text{ K}$$

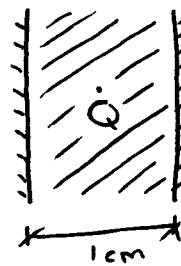
a) atmos. air



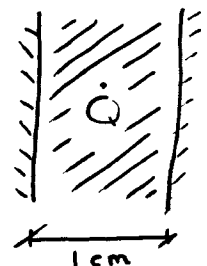
b) vacuum



c) urethane



d) superinsulation



From TA-15 : Air Property Table

① $k_{\text{air}} = 0.0219 \text{ W/m}\cdot\text{K}$

② $\sim \text{vacuum}$

③ $k_{\text{urethane}} \Rightarrow k = 0.026 \text{ W/m}\cdot\text{K} \text{ (A-6)}$

④ $k_{\text{superinsulation}} \Rightarrow k = 0.00002 \text{ W/m}\cdot\text{K}$

$$\left. \begin{aligned} \text{a) } \dot{Q}_{\text{conduction}} &= kA \left(\frac{T_1 - T_2}{L} \right) = 219 \text{ W} \\ \dot{Q}_{\text{radiation}} &= \epsilon \sigma A (T_1^4 - T_2^4) = 369 \text{ W} \end{aligned} \right\} \dot{Q} = 588 \text{ W}$$

b) $\dot{Q}_{\text{radiation}} = \epsilon \sigma A (T_1^4 - T_2^4) = 369 \text{ W}$

c) $\dot{Q}_{\text{conduction}} = kA \left(\frac{T_1 - T_2}{L} \right) = 260 \text{ W}$

d) $\dot{Q}_{\text{conduction}} = kA \left(\frac{T_1 - T_2}{L} \right) = 0.2 \text{ W}$