FE Review Course

Heat Transfer

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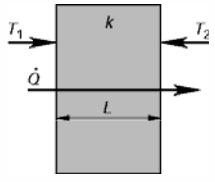
Heat Transfer 11-1a

Conduction

Fourier's Law of Conduction Rate of Heat Transfer:

$$\dot{Q} = -kA\frac{dT}{dx} \qquad 31.1$$

- Through a wall:



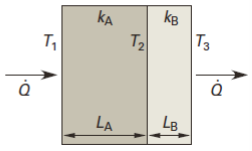
$$\dot{Q} = -\frac{kA(T_2 - T_1)}{L} \qquad 31.2$$

$$Q = \dot{Q}t$$

Thermal Resistance: $R = \frac{L}{kA}$

- Through a composite wall:

Figure 31.1 Composite Slab (Plane) Wall



$$R_{total} = R_1 + R_2 = \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A}$$

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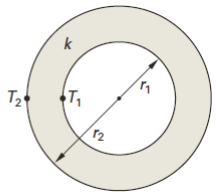
Heat Transfer 11-1b

Conduction

Through a cylindrical wall of length L:

Figure 31.2 Cylindrical Wall



$$\dot{Q} = \frac{A_m k(T_1 - T_2)}{L_{\text{radial}}} = \frac{2\pi k L_{\text{longitudinal}}(T_1 - T_2)}{\ln \frac{r_2}{r_1}} \qquad 31.8$$

$$R = \frac{\ln \frac{r_2}{r_1}}{2\pi k L}$$

Heat Transfer 11-2

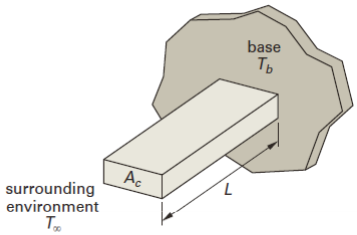
Convection

Convection Heat Transfer

$$r_{\text{critical}} = \frac{k_{\text{insulation}}}{h_\infty} \qquad 31.9$$

For a straight fin:

Figure 31.4 Finite Straight Fin



P = exposed perimeter
k = thermal conductivity
A_c = cross-sectional area
T_b = temperature of fin base
T_∞ = fluid temperature

$$\dot{Q} = \sqrt{hPkA_c}(T_b - T_\infty)\tanh(mL) \qquad 31.18$$

[rectangular fin]

$$m = \sqrt{\frac{hP}{kA_c}} \qquad 31.19$$

$$L_c = L + \frac{A_c}{P} \qquad 31.21$$

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Radiation

$$\dot{Q}_{\text{black}} = \epsilon \sigma A T^4 \qquad 31.16$$

ε = emissivity

$\sigma = 5.67 \times 10^{-8}$ W/m$^2 \cdot$K^4 (Stefan-Boltzmann constant)

Black Body vs. Gray Body

Black Body:

emissivity(ε) = absorptivity (α) = 1

Gray Body:

$\varepsilon = \alpha$, and both are between 0 and 1

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Heat Transfer 11-4

Radiant Heat Transfer

$$\dot{Q}_{12} = \sigma A_1 F_{1-2} (T_1^4 - T_2^4) \qquad 31.17$$

For any body, radiation must be absorbed, reflected, or transmitted through:

$$\alpha + \rho + \tau = 1 \qquad 31.11$$

$$\alpha + \rho = 1 \quad [\text{opaque body; } \tau = 0] \qquad 31.13$$

$$\alpha + \rho = \epsilon + \rho = 1 \quad [\text{gray body; } \tau = 0;\ \alpha = \epsilon] \qquad 31.14$$

$$\alpha = \epsilon = 1 \left[\begin{matrix}\text{black body; } \tau = 0; \\ \rho = 0;\ \alpha = \epsilon\end{matrix}\right] \qquad 31.15$$

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