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FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

BME504:Heat and Mass Transfer

Lecture 7

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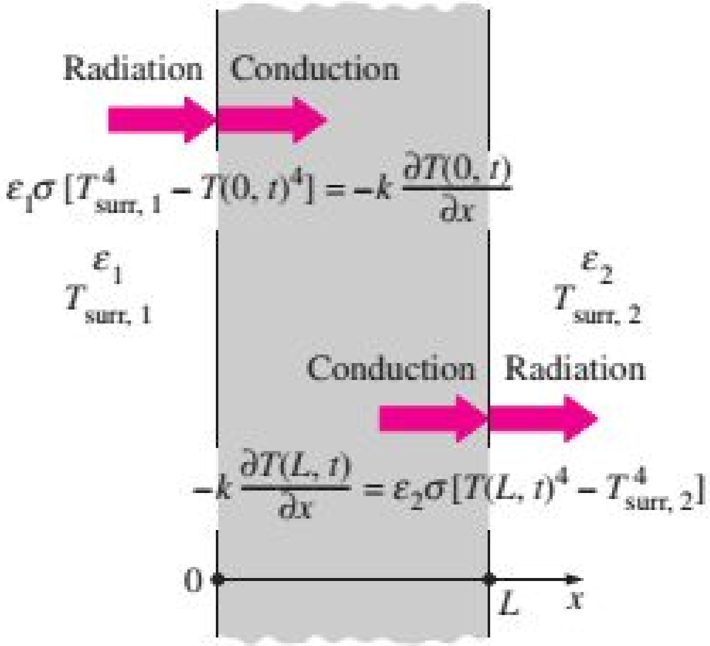
Specified Heat Flux Boundary Condition

- ***Radiation Boundary Condition:***

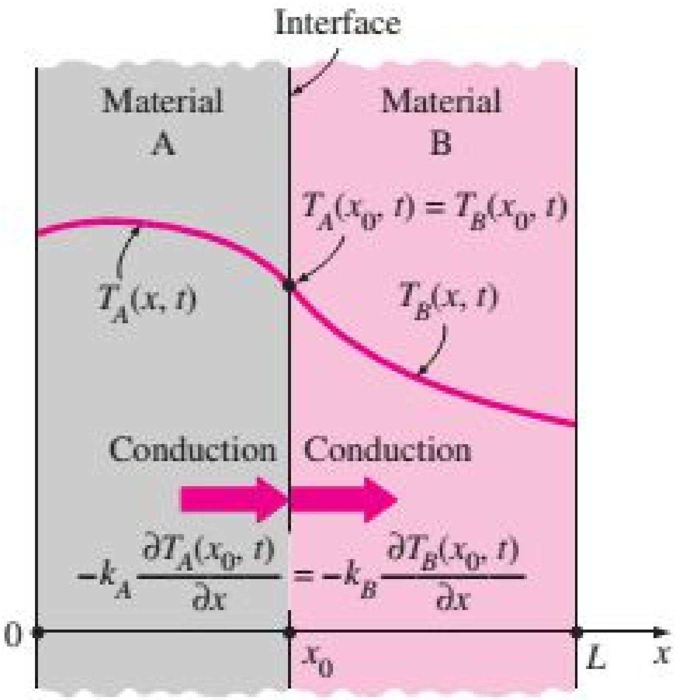


$$-k\frac{\partial T(0,t)}{\partial x} = \varepsilon_1\sigma[T^4_{surr,1} - T(0,t)^4]$$

$$-k\frac{\partial T(L,t)}{\partial x} = \varepsilon_2\sigma[T(L,t)^4 - T^4_{surr,2}]$$

Specified Heat Flux Boundary Condition

- ***Interface Boundary Conditions:***



$$T_A(x_0, t) = T_B(x_0, t)$$

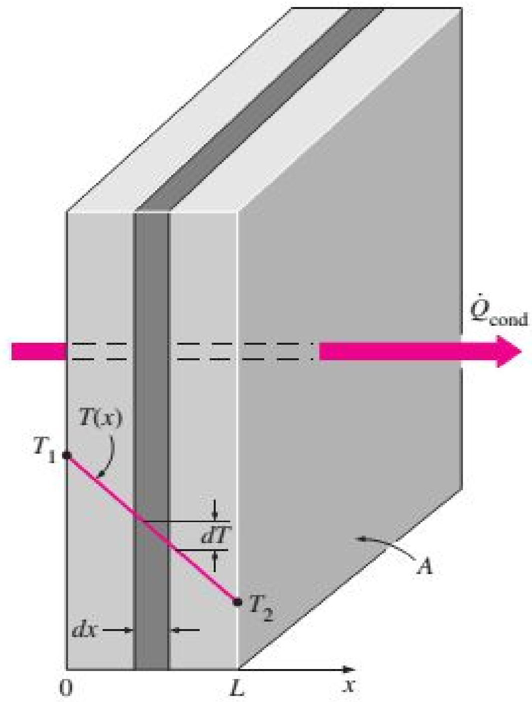
$$-k_A \frac{\partial T_A(x_0, t)}{\partial x} = -k_B \frac{\partial T_B(x_0, t)}{\partial x}$$

STEADY HEAT CONDUCTION IN PLANE WALLS

- Heat flow through a wall is one dimensional when the temperature of the wall varies in one direction only.
  - The small thickness of the wall causes the temperature gradient in that direction to be large. Further, if the air temperatures in and outside the house remain constant, and then heat transfer through the wall of a house can be modeled as steady and one-dimensional.
  - The temperature of the wall in this case will depend on one direction only (say the x-direction) and can be expressed as T(x).

$$\begin{pmatrix} \text{Rate of} \\ \text{heat transfer} \\ \text{into the wall} \end{pmatrix} - \begin{pmatrix} \text{Rate of} \\ \text{heat transfer} \\ \text{out of the wall} \end{pmatrix} = \begin{pmatrix} \text{Rate of} \\ \text{change of the energy} \\ \text{of the wall} \end{pmatrix}$$

$$\dot{Q}_{in} - \dot{Q}_{out} = \frac{dE_{wall}}{dt}$$



STEADY HEAT CONDUCTION IN PLANE WALLS

- But $\frac{dE_{wall}}{dt} = 0$ for steady operation, since there is no change in the temperature of the wall with time at any point. Therefore, the rate of heat transfer into the wall must be equal to the rate of heat transfer out of it. In other words, the rate of heat transfer through the wall must be constant.
- Fourier's Law of heat conduction

$$\dot{Q}_{cond,wall} = -kA\frac{dT}{dx}$$

- Consider a plane wall of thickness ***L*** and average thermal conductivity ***k***. The two surfaces of the wall are maintained at constant temperatures of T_1 and T_2

$$\dot{Q}_{cond,wall} = kA\frac{T_1 - T_2}{L}$$

THE THERMAL RESISTANCE CONCEPT

- **Conduction**

- Consider a plane wall of thickness ***L*** and average thermal conductivity ***k***. The two surfaces of the wall are maintained at constant temperatures of ***T₁*** and ***T₂***

$$\dot{Q}_{cond,wall} = \frac{T_1 - T_2}{R_{wall}}$$

$$where\ R_{wall} = \frac{L}{kA}$$

$R_{wall} = \frac{L}{kA}$ ***Thermal resistance of the wall against heat conduction*** or simply the ***conduction resistance of the wall***.

Thermal resistance of a medium depends on the ***geometry*** and the ***thermal properties*** of the medium.

Questions

Q1 Water is boiling in a 25-cm-diameter aluminium pan (k = 237 W/m · °C) at 95°C. Heat is transferred steadily to the boiling water in the pan through its 0.5-cm-thick flat bottom at a rate of 800 W. If the inner surface temperature of the bottom of the pan is 108°C, determine (a) the boiling heat transfer coefficient on the inner surface of the pan, and (b) the outer surface temperature of the bottom of the pan.

Q2 Consider a person standing in a room at 20°C with an exposed surface area of 1.7 m2. The deep body temperature of the human body is 37°C, and the thermal conductivity of the human tissue near the skin is about 0.3 W/m · °C. The body is losing heat at a rate of 150 W by natural convection and radiation to the surroundings. Taking the body temperature 0.5 cm beneath the skin to be 37°C, determine the skin temperature of the person.

Questions

Q3 A cylindrical resistor element on a circuit board dissipates 0.15 W of power in an environment at 40°C. The resistor is 1.2 cm long, and has a diameter of 0.3 cm. Assuming heat to be transferred uniformly from all surfaces, determine (a) the amount of heat this resistor dissipates during a 24-h period, (b) the heat flux on the surface of the resistor, in W/m2, and (c) the surface temperature of the resistor for a combined convection and radiation heat transfer coefficient of 9 W/m2 · °C.

Q4 Consider a 1.2-m-high and 2-m-wide glass window whose thickness is 6 mm and thermal conductivity is k = 0.78 W/m · °C. Determine the steady rate of heat transfer through this glass window and the temperature of its inner surface for a day during which the room is maintained at 24°C while the temperature of the outdoors is -5°C. Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be h1 = 10 W/m2 · °C and h2 = 25 W/m2 · °C, and dis-regard any heat transfer by radiation..

Questions

Q5 The bottom of a pan is made of a 4-mm-thick aluminum layer. In order to increase the rate of heat transfer through the bottom of the pan, someone proposes a design for the bottom that consists of a 3-mm-thick copper layer sandwiched between two 2-mm-thick aluminum layers. Will the new design conduct heat better? Explain. Assume perfect con-tact between the layers