FDE 208 HEAT TRANSFER AND THERMAL PROCESSES

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STEADY STATE HEAT CONDUCTION

- What is steady state?
  - It is defined as the condition when the system properties are fixed at any given location.
  - In other word, temperature or heat flux remains constant with time during steady state heat transfer at a specified location within the system.

- What is unsteady state (transient)?
  - If the temperature at any point varies with time as well as with position, the transfer is at transient state.

- In steady state heat transfer;
  Temperature is a function of position only

- In unsteady state heat transfer;
  It is a function of both position and time

STEADY STATE CONDUCTiON THROUGH PLAiN WALLS

- To analyze the heat transfer through a plane wall with a thickness of L;

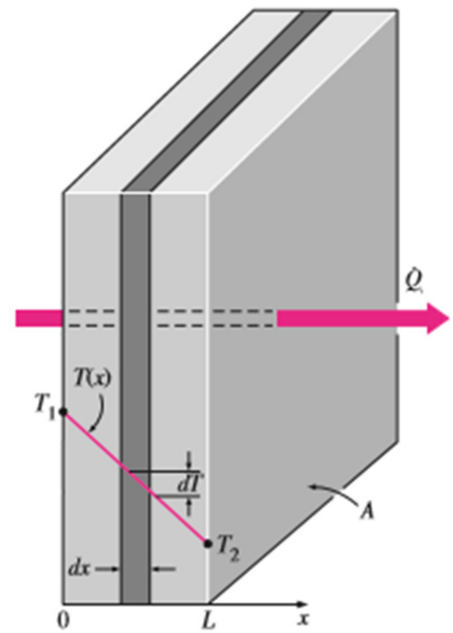
$(\text{Rate of Energy})_{in}$- $(\text{Rate of Energy})_{out}$±$(\text{Rate of Energy})_{generated/consumed}$=$(\text{Rate of Energy})_{accumulated}$

Since the system is steady and there is no generation;

$(\text{Rate of Energy})_{in}$= $(\text{Rate of Energy})_{out}$

or

$$Q_{in}=Q_{out}=Q$$



- Fourier's law of heat conduction;

$$Q = -kA\frac{dT}{dx}$$

- As we have already discussed in the previous course, integrating the equation resulted in;

$$Q = \frac{T_1 - T_2}{L/_{kA}}$$

Example 14.2

Consider steady state heat transfer through the solid, truncated cone shown below. The top (truncated)face of the cone is kept constant at a temperature T1 while the base of the cone is at a lower temperature T2. The sides of the cone are well-insulated.Thermal conductivity of the solid depends on temperature according to the relation;

$k=k_0 - aT$

How the following quantities affected with increasing x?

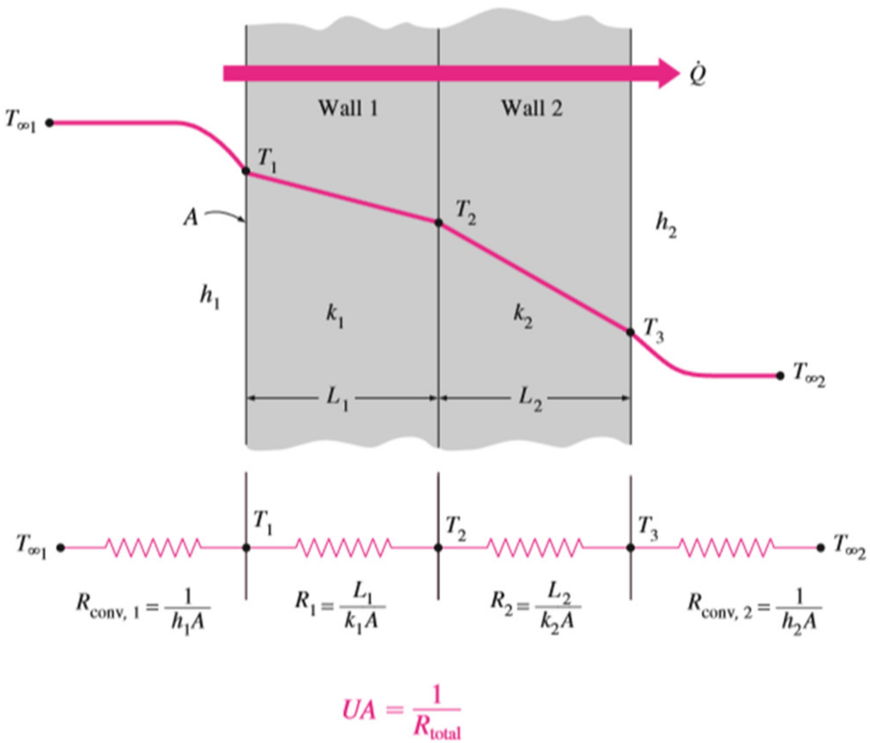
-heat transfer rate

-heat flux

-thermal conductivity

-temperature gradient (dT/dx)

STEADY STATE HEAT TRANSFER THROUGH MULTILAYER PLANE WALLS AND OVERALL HEAT TRANSFER COEFFICIENT



Consider a composite wall made of two different layers having different thermal conductivities. Heat transfer is at steady state and there is no generation in the system. It means heat transfer rate through different layers of wall are the same.

$$Q_{conv,1}=Q_1=Q_2=Q_{conv,2}=Q$$

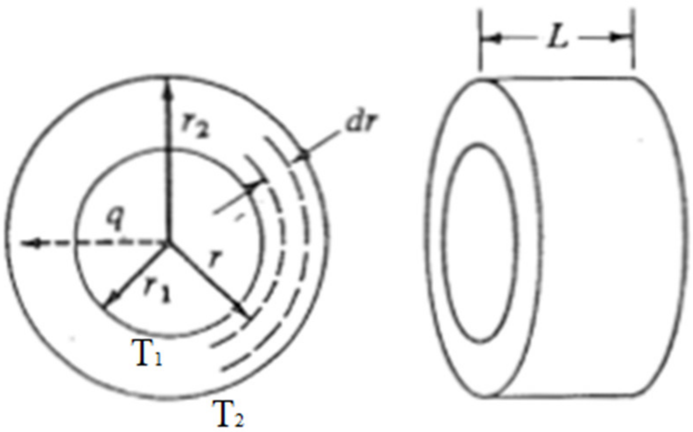
Since the area perpendicular to heat flow for each layer is constant, the relation can be rewrittten for heat fluxes.

$$q_{conv,1}=q_1=q_2=q_{conv,2}=q$$

- Example 14.3

The ceiling of a house consists of 15 cm thick concrete slab of 15 m wide and 20 m long. Thermal conductivity of concrete is 2 W/mK. The ceiling is insulated with a rock wool of thermal conductivity 0.03 W/mK to reduce heat loss. What should be the minimum thickness of insulation so that heat loss through the ceiling is less than 1150W?Assume that the lower and upper surface temperature of ceiling is 29 and 7 °C, respectively.

CONDUCTiON THROUGH A HALLOW CYLiNDER



- Consider the steady state conduction heat transfer through the wall of a pipe.
- Heat is flowing from the inner side to the outer side.

$$\frac{q}{A} = -k\frac{dT}{dr}$$

The cross-sectional area normal to the heat flow is

$$A = 2\pi rL$$

$$\frac{q}{2\pi L}\int_{r_1}^{r_2}\frac{dr}{r} = -k\int_{T_1}^{T_2} dT$$

$$q = k\frac{2\pi L}{\ln(r_2/r_1)}(T_1 - T_2)$$

$$q = kA_{lm}\frac{T_1 - T_2}{r_2 - r_1} = \frac{T_1 - T_2}{(r_2 - r_1)/(kA_{lm})} = \frac{T_1 - T_2}{R}$$

where

$$A_{lm} = \frac{(2\pi Lr_2) - (2\pi Lr_1)}{\ln(2\pi Lr_2/2\pi Lr_1)} = \frac{A_2 - A_1}{\ln(A_2/A_1)}$$

$$R = \frac{r_2 - r_1}{kA_{lm}} = \frac{\ln(r_2/r_1)}{2\pi kL}$$

Example:

A thick-walled cylindrical tubing of hard rubber having an inside radius of 5 mm and an outside radius of 20 mm is being used as a temporary cooling coil in a bath. Ice water is flowing rapidly inside and the inside wall temperature is 274.9 K. The outside surface temperature is 297.1 K. A total of 14.65W must be removed from the bath by the cooling coil. How long tubing should be used for this purpose?