BACHELOR OF ENGINEERING (MECH. ENG'G.) SECOND YEAR FIRST SEMESTER SUPPLEMENTARY EXAMINATION 2023

HEAT TRANSFER

Time: Three hours Full marks: 100

Answer any ***five*** questions

1. a) Consider steady one-dimensional heat transfer through a plane wall of thickness th_w = 0.001 m. The wall has a thermal conductivity k = 100 W/mK and it separates two fluids, A and B. Fluid A is at T_A = 100°C and the heat transfer coefficient between the fluid and the wall is h_A = 10 W/m^2 K while fluid B is at T_B = 0°C with h_B = 100 W/m^2 K.

   Draw a thermal resistance network that represents this situation and calculate the value of each resistance, assuming a unit surface area for the wall, A = 1 m^2. Calculate the rate of heat transfer across the wall and the temperatures of the two surfaces of the wall.

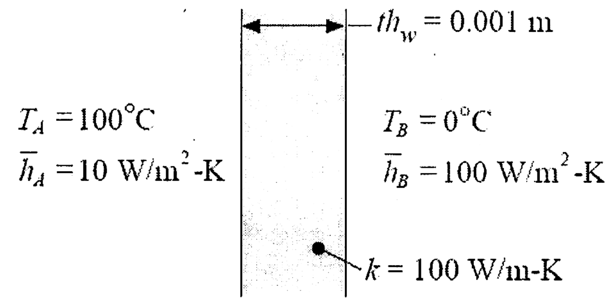

Figure Q.1(a)

   b) Consider steady one-dimensional heat conduction through a plane wall of thickness L, having uniform and constant thermal conductivity k. There is internal volumetric heat generation at a uniform rate of q_{gen}. The two sides of the wall are subjected to constant temperature of T_1 and T_2. Starting from general heat conduction equation, simplify the governing equation with appropriate assumptions. Specify the boundary conditions and solve for the temperature distribution across the wall thickness. **(10+10)**

2. (a) Explain how fins enhance the rate of heat transfer from a surface.

   (b) Derive the expression for the temperature distribution and heat dissipation from a fin with insulated tip. Also, find the rate of heat loss from the fin. **(4+16)**

3. (a) What is critical radius of insulation? Will the critical radius of insulation be greater on a windy day or on a day when there is very little air flow? Derive an expression for the critical radius of insulation in terms of the thermal conductivity of the insulator and the heat transfer coefficient for heat loss from a cylindrical hot pipe.

   (b) Discuss when you can use the concept of thermal resistance in heat transfer analysis. **(15+5)**

4. (a) What is lumped system analysis? When can we use lumped system approach for transient heat conduction analysis?

A hot metal body having a volume V, surface area A, density ρ, specific heat c, initially at a uniform temperature T_i is suddenly quenched by immersing it in a liquid reservoir at temperature T_∞. The body loses heat by convection to the liquid with a heat transfer coefficient h. Treating the body as a lumped system, derive an expression for the variation of temperature with time. Plot the variation of temperature with time.

(b) Heat is generated in a long 0.5 cm-diameter cylindrical electric heater at a rate of 75 W/cm^3. Calculate the heat flux at the surface of the heater in steady operation.

(15+5)

5. Consider steady, laminar boundary type flow of a low Prandtl number (Pr<<1) fluid over a flat plate. The free stream velocity and temperature are U_∞ and T_∞ respectively. The plate is maintained at a uniform temperature of T_w. Show the following by the method of scale analysis:

$$\delta / L \sim Re_L^{-1/2}$$

$$\delta_T / L \sim Re_L^{-1/2}\, \mathrm{Pr}^{-1/2}$$

$$Nu_L \sim Re_L^{1/2}\, \mathrm{Pr}^{1/2}$$

(20)

6. (a) Find an expression for LMTD of a counter flow heat exchanger.

(b) A double-pipe counter flow heat exchanger is to heat water (cp = 4180 J/kg °C) from 35°C to 71°C at a rate of 0.4 kg/s. The heating is to be accomplished by geothermal water (cp = 4310 J/kg °C) available at 140°C at a mass flow rate of 0.6 kg/s. If the overall heat transfer coefficient of the heat exchanger is 800 W/m^2 °C, determine the surface area required to achieve the desired heating. **(10+10)**

7. (a) Define effectiveness and NTU for a heat exchanger.

(b) Derive an expression for effectiveness of a parallel flow heat exchanger in terms of appropriate dimensionless numbers. **(5+15)**