Date________ FN/AN, Time: 2 hrs., Full Marks: 60 , Deptt: Mechanical Engg.

No. of Students: 184, Mid Autumn Semester Examination

Sub. No. ME30005, Sub. Name: Heat Transfer

3rd Yr. B.Tech.(H)

Attempt all questions

1. Electric heater wires are installed in a plane solid wall with constant cross-sectional area having a thickness of L and thermal conductivity k. The right face of the wall is exposed to an environment with heat transfer coefficient h_2 and temperature T_{f2}, while the left face is exposed to an environment with heat transfer coefficient h_1 and temperature T_{f1}. Thermal energy is generated at a constant volumetric rate of q_G.

a. Derive the governing differential equation for temperature distribution in the wall. Write the boundary conditions.

b. Find a relation between the temperature of the left and right faces of the wall (T_1 and T_2) in terms of $q_G, h_1, T_{f1}, h_2, T_{f2}, L$. [Hints: Use the boundary conditions at left and right faces of the wall]

c. Now consider the following case:

$$L = 80\,\text{mm}, k = 2.5\,\text{W/m}\cdot\text{K}, h_2 = 50\,\text{W}/(\text{m}^2\cdot\text{K}), T_{f2} = 30\,^\circ\text{C}, h_1 = 75\,\text{W}/\left(\text{m}^2\cdot\text{K}\right), T_{f1} = 50\,^\circ\text{C}$$

What is the maximum allowable heat generation rate such that the maximum temperature in the solid wall doesn't exceed $450\,^\circ\text{C}$? **4+5+6=15 marks**

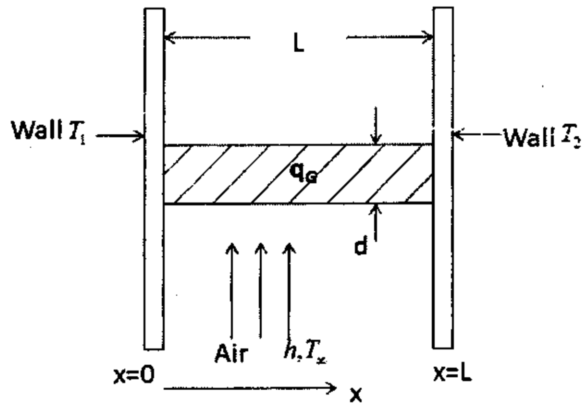
2. One end of a cylindrical rod (of thermal conductivity k) of length L, is connected to a wall at T_1 while the other end is connected to a wall that is maintained at T_2 as shown in the figure below. Air is blown across the rod so that a heat transfer coefficient of h is maintained over the entire surface. The diameter of the rod is d and the temperature of the air is T_∞ such that $T_1 > T_2 > T_\infty$. Thermal energy is generated within the rod at the rate of q_G per unit volume where $q_G = a\left(\frac{x}{L}\right)^2$, where a is a constant.

P.T.O.

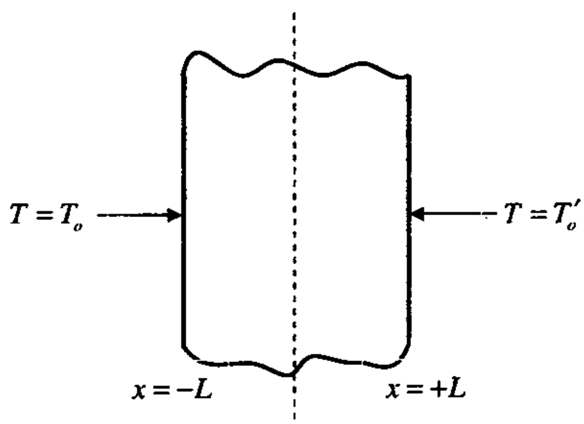
a. Find an expression for temperature distribution along the rod.

b. Find an expression for rate of heat loss due to convection from the lateral surface of the rod.

9+6=15 marks



3. Consider rectangular slab of length 2L, as shown in the figure. The other dimensions are significantly larger as compared to the dimension along x. Initially, the slab is at a uniform temperature T_i. At $t > 0$, the wall at $x = -L$ is subjected to a temperature T_o' and the wall at $x = +L$ is subjected to a temperature T_o $(T_o \neq T_o')$. Obtain the evolution of the temperature of the slab as a function of position and time, starting from the general heat conduction equation, after accounting for the necessary simplification. Assume all properties to be constant.



P.T.O.

[Hints : Reduce the problem to the superposition of a steady problem and an unsteady problem, such that $T(x,t) = \underbrace{T_1(x)}_{\text{steady part}} + \underbrace{T_2(x,t)}_{\text{unsteady part}}$. Use appropriate initial and boundary conditions for T_2 so that method of separation of variables can be applied for the same. Finally link T_2 and T_1 through the initial condition for T_2.]

15 marks

4. Consider a 2 kW iron, made of aluminum alloy $\left(\rho = 2800\,\text{kg/m}^3,\ c_p = 0.87\,\text{kJ/(kg}\cdot\text{K)},\ \alpha = 7\times10^{-5}\,\text{m}^2/\text{s}\right)$, whose base plate has a volume to area ratio of 30 mm. The base plate has a surface area of $0.05\,\text{m}^2$. Initially, the iron is in thermal equilibrium with the ambient air at $25\,^\circ\text{C}$. Taking the heat transfer coefficient at the surface of the base plate to be $10\,\text{W}/\left(\text{m}^2\cdot\text{K}\right)$ and assuming that the entire heat generated in the resistance wires is transferred to the plate, determine how long will it take for the plate temperature to reach $150\,^\circ\text{C}$? Is it realistic to assume the plate temperature to be uniform at all times?

15 marks