DEPARTMENT OF CHEMICAL ENGINEERING IIT KHARAGPUR
MID-SPRING SEMESTER EXAMINATION 2016

Subject: Advanced Heat Transfer **Subject No: CH 61014**
Full Marks: 30 (15 for each part) **Closed Book/ Closed Notes**
General Instructions: **Time: 2 hours**

1. All questions are compulsory. Answer all questions of a part at one place.
2. Fell free to assume any missing data with proper justifications.

Part – A

1. A one dimensional concrete slab (thermal conductivity $=k$) of thickness L is "setting", which is an exothermic process that releases heat at a rate of $\dot{q}$ W/m^3. Consider that both the outside surfaces are maintained at ambient temperature T_∞. What is maximum value of internal dimensionless temperature? **[3]**

2. Consider a one dimensional slab (thermal conductivity $=k$) of thickness L with no internal heat generation. At $x=0$, the temperature is maintained at a value T_0. At $x=L$, there is convective heat transfer to the surroundings with heat transfer coefficient h.

   (i) Obtain the steady-state temperature distribution in the slab. **[2]**

   (ii) Write this solution in terms of Biot number. **[1]**

   (iii) Analyze the result in the limits of small and large Biot number and discuss each limit physically. **[3]**

3. Consider a one dimensional plane symmetrical wall of thickness L. Initially the wall is at a uniform temperature T_1. At time $t=0$, the boundary at $x=0$ is kept insulated and the boundary at $x=L$ is brought to temperature T_2 $(T_2 > T_1)$. The thermal diffusivity of the wall is α.

   (i) Set-up the mathematical formulation of the 1-D unsteady-state heat conduction problem in dimensionless form. **[2]**

   (ii) Present a realistic sketch (you do not have to solve for actual temperature distribution) for the dimensionless temperature against dimensionless x for three different dimensionless times: say at 0.01, 0.1, and 0.9. **[2]**

4. What will be the form of the heat conduction equation (energy equation) if we consider the heat propagation velocity to be finite? **[2]**

Part - B

5. (a) What are the various types of convection possible? Mathematically what is the key difference between the different regimes of convection? (0.5+1)

   (b) A stream of liquid is flowing over a hot wall. The flow-rate slowly drops to zero. What will happen in terms of the nature of heat transfer within the fluid? (2)

   (c) Derive an expression for convective heat transfer coefficient? What are the likely parameters on which is expected to depend? Does it depend on fluid temperature? (Justify your answer) (1.5+1+1)

Total Marks in Q5: 7

6. (a) What are different terms you would consider if you wanted to derive the convective Energy Transport Equation for a 2-D flowing system? Write the individual terms (as well as mark them on appropriate figures). Please mention how you can obtain the basic balance equation from 1st Law of Thermodynamics? (3+1)

   (b) Find out the qualitative dependence of **Nusselt Number** on other Dimensionless groups for a system where the momentum boundary layer is thicker than the thermal boundary layer. (2)

   (c) Obtain the convective Energy Transport Equation for a 2-D flow, approximated over a horizontal thermal boundary layer, in the integral form. (Start from the differential form of the equation, in its boundary layer approximated form). (2)

Total Marks in Q6: 8