INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Department of Chemical Engineering

End-Spring Semester Examination, 2017-2018

***Subject*: Advanced Heat Transfer** **Subject No.: CH 61014**

***Time*: 3 Hrs No. of Students: 92 *Full Marks*: 50**

***Instructions*:**

1. **Use a SINGLE answer script for both the parts.**
2. All Questions are compulsory.**All parts of a question MUST be written at the same place.**
3. Clearly write your name, Roll No., Subject Name, Subject Number on the Answer Book.
4. Feel free to assume any missing data with proper justifications.
5. Please try to answer all the questions of each part together. **Also, all sub parts of each question MUST be answered together.**

PART - A

1. The simplified equation for a Thermal Boundary Layer for a Wall Coordinate System is given as: $\frac{dT^+}{dy^+} = \frac{1}{\frac{1}{Pr}+\frac{1}{Pr_T}\frac{\epsilon}{\gamma}}$

   Find out the Temperature profile within the Thermal Boundary layer in Wall coordinate system. It is further given that $\epsilon = l^2 \frac{\partial \bar{u}}{\partial y}$where $l$is the Prandalt Mixing Length. Also given,$\frac{\partial \bar{u}}{\partial y} = u^* \frac{du^+}{dy}$, $y^+ = \frac{yu^*}{\gamma}$ and $\frac{\epsilon}{\gamma}\frac{du^+}{dy^+} = 1$. Clearly highlight the assumptions in your derivation. What is the limitation of the Temperature profile obtained? (4+1=5)

2. (a) What is the mechanism of bubble nucleation and detachment in Nucleate boiling?

   (b) How does roughness of the heating surface affect the boiling process? Would you like to have a smooth or a rough surface to achieve faster boiling?

   (c) What is **Benard** Convection? (2+1.5+1.5=5)

3. (a) Derive the **Boussinesq** approximated momentum transport equation close to a solid surface in a Natural convection flow of cold liquid along the surface of hot vertical wall. Assume steady state, Newtonian fluid and 2 – D flow.

   (b) Based on a scaling analysis of the equation you have derived in (a), qualitatively discuss the velocity profiles with in the boundary layer, as a function of Pr. (3+4=7)

4. (a) Define Spectral Intensity of Emitted Radiation (with expression). Based on it, find out the expression for Net Heat transfer between two flat surfaces, both of which are black bodies. (Feel free to use the final Expression of Stefan Boltzman Equation.

(b) Find out the Solid Angle subtended by a Hemisphere at its Centre [(2+4)+2=**8**]

PART - B

5. Consider the heat conduction in a rectangular bar as shown in cross-section in Fig. 1. Internal energy is generated in this bar at a constant rate $\dot{q}$ per unit volume (W/m^3). The boundary conditions are shown on the figure itself. There is no temperature gradient in z-direction and the thermo-physical properties of the material of the bar may be considered as constant. Determine the steady-state temperature distribution $T(x,y)$ in the bar by

(a) Method of **separation of variables** [6]

(b) Method of **finite Fourier transforms** [6]

6. Consider a solid sphere of radius r_0. The surface of the sphere is maintained at some arbitrary temperature distribution $f(\theta)$. There are no internal energy sources or sinks in the sphere and the thermo-physical properties of the material of the sphere may be considered as constant. Find the steady-state two dimensional temperature distribution $T(r,\theta)$ in the sphere using **Fourier-Legendre series.** [7]

7. Consider a long solid cylinder of semi-circular cross-section as shown in Fig. 2. The cylindrical surface at $r = r_0$ is maintained at some arbitrary temperature distribution $f(\phi)$. The planar surfaces at $\phi = 0$ and $\phi = \pi$ are both maintained at constant temperature T_0. There are no internal energy sources or sinks in the cylinder and the thermo-physical properties of the material of the cylinder may be considered as constant. Find the steady-state two dimensional temperature distribution $T(r,\phi)$ in the cylinder using **Hankel transforms.** [6]

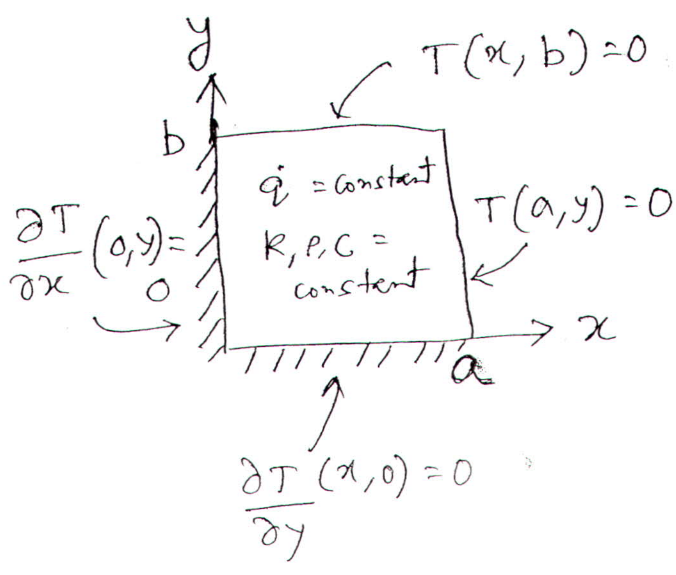

Fig. 1

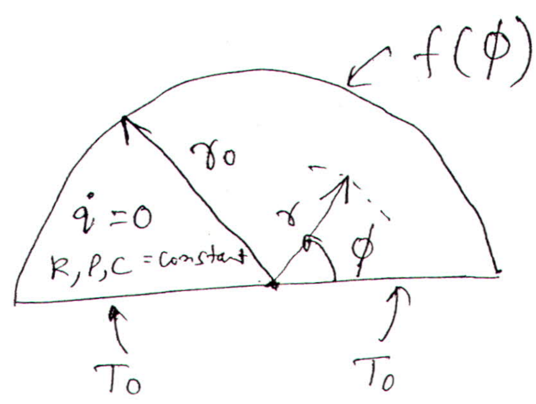

Fig. 2