INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Department of Chemical Engineering

End-Spring Semester Examination, 2016-2017

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

***Time*: 3 Hrs No. of Students: 77** ***Full Marks*: 50** **Date: April 28, 2017**

***Instructions*:**

1. **Use a SINGLE answer script for both the parts.**
2. All questions are compulsory.
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 expression for the equation for a turbulent thermal boundary layer is given as follows (after incorporation of Reynold's decomposition).

$$\bar{u}\frac{\partial \bar{T}}{\partial x} + \bar{v}\frac{\partial \bar{T}}{\partial y} = \frac{\partial}{\partial y}\left[(\propto + \epsilon)\frac{\partial \bar{T}}{\partial y}\right]$$

For a constant wall heat flux condition **($-q_s^{//}$)** find out the Temperature profile within the Thermal Boundary layer in Wall coordinate system. Feel free to use the equation for a Turbulent momentum boundary layer (do not have to show the derivation or the scaling). It is further given that $\epsilon = l^2 \frac{\partial \bar{u}}{\partial y}$ where l is the Prandalt Mixing Length. (7)

2. Derive an expression for the thickness of the Condensing layer (δ) at a distance **y** from the leading edge of a cold vertical wall, on which saturated vapor is condensing. Assume a linear temperature profile along the depth of the layer. Consider all assumptions of the Boundary Layer to be valid within the condensing layer. (8)

3. What is the mechanism of Bubble formation in Nucleate Boiling? Why does a rising bubble initially fail to reach the surface of the liquid pool? What is slug formation, and how it alters the heat flux? (2+1+1=4)

4. The Boussinisq Approximated momentum transport equation is given below:

$$u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = \gamma\frac{\partial^2 v}{\partial x^2} + g\beta(\Delta T)$$

Starting from the above equation qualitatively discuss the possible velocity profiles in a Vertical Natural Convective Boundary Layer. Symbols have usual meaning. (6)

Please Turn Over

PART – B

5. Consider a rectangular fin with thickness (b) and length (L) as shown in Fig. 1. The width (W) of the fin is very large compared to its length ($W >> L$). The fin has to dissipate heat to the surroundings with heat transfer coefficient (h) and temperature (T_∞). The temperature at the fin base is (T_b) and the fin has an adiabatic tip. The profile area of the rectangular fin (A_P) is defined as $A_P = bL$ and thus there may be several shapes (various combinations of b and L) of the fin for the same profile area (A_P). For a given profile area, find the optimum thickness and length of the fin which removes maximum amount of heat per unit mass of the fin. **[7]**

Given: The following function $f(x)$ has a maximum at $x = 1.4192$, where $\pi = 3.14$.

$$f(x) = \pi \frac{\tanh(x)}{x^{1/3}}$$

6. Consider a long solid cylinder of circular cross section with radius r_0 as shown in Fig. 2. The surface of the cylinder is held at an arbitrary temperature $f(\phi)$. There is no internal heat generation in the cylinder and thermo-physical properties of the cylinder may be assumed to be constant. Determine the steady-state temperature distribution $(T(r,\phi))$ in the cylinder using **Separation of Variables**. **[8]**

7. Consider a semi-infinite rectangular strip as shown in Fig. 3. The surface at $x = 0$ is perfectly insulated. The initial $(t = 0)$ temperature distribution in the strip is given as $T_i(x,y)$. For times $t \geq 0$, the surface at $x = L$ is kept at a temperature $T_1(y,t)$ and the surface at $y = 0$ is kept at a temperature $T_2(x,t)$. Both $T_i(x,y)$ and $T_1(y,t)$ vanish as $y \to \infty$. There is no internal heat generation in the strip and thermo-physical properties may be assumed to be constant. Determine the unsteady-state temperature distribution $T(x,y,t)$ in the above semi-infinite rectangular strip for $t \geq 0$ using **Fourier Transforms**. **[10]**

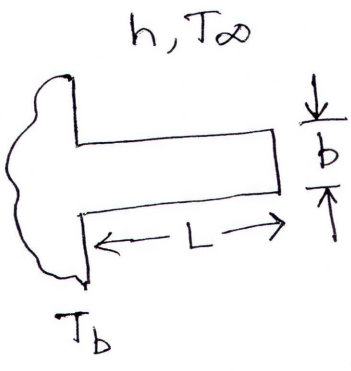

Fig. 1

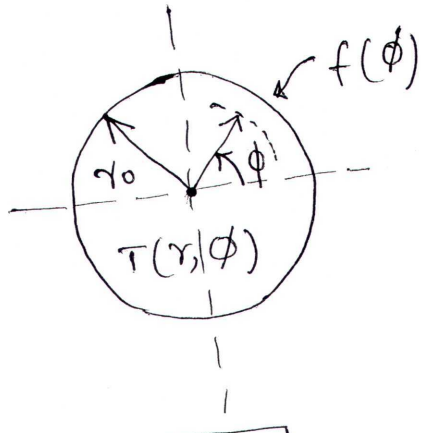

Fig. 2

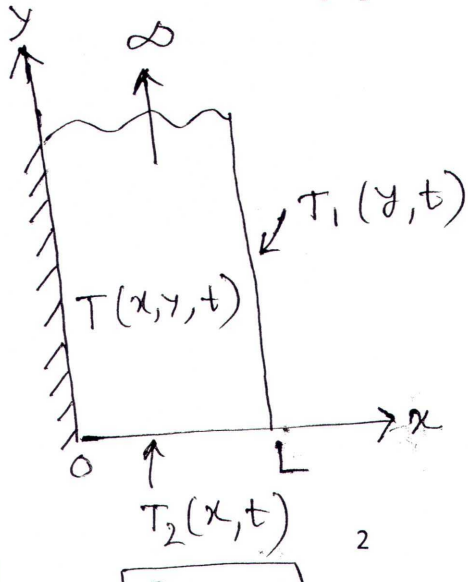

Fig. 3