DEPARTMENT OF CHEMICAL ENGINEERING IIT KHARAGPUR
MID-SPRING SEMESTER EXAMINATION 2017-18

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. **Use a single answer sheet.**
2. Feel free to assume any missing data with proper justifications.

Part – A

1. (a) Obtain the similarity solution for a thermal boundary layer above a flat plate where the plate and the fluid are at different temperatures.

Governing Equation is : $u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2}$

Given, $\psi = (\nu U_\infty x)^{0.5} f(\eta)$; $\eta = \frac{y}{\delta}$; $\delta = x(Re_x)^{-0.5}$; $\frac{\partial\psi}{\partial\eta} = (\nu U_\infty x)^{0.5}\frac{\partial f}{\partial\eta}$;

$\frac{\partial\eta}{\partial y} = \sqrt{\left(\frac{U_\infty}{\nu x}\right)}$; $\frac{\partial\eta}{\partial x} = \left(-\frac{\eta}{2x}\right)$; $u = U_\infty\frac{df}{d\eta}$ and $v = 0.5\sqrt{\left(\frac{\nu U_\infty}{x}\right)}\left(\eta\frac{df}{d\eta} - f\right)$.

Also use normalized temperature $\theta = \left(\frac{T_S - T}{T_S - T_\infty}\right)$ (5+2.5=7.5)

(b) How does one obtain the expression for ψ that is given above? (1.5)

Total Marks in Question 1: 09

2. (a) 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)

(b) 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 governing equation in question 1). Is there any condition under which the derived equation valid, and if so, why? (2+2=4)

Total Marks in Question 2: 06

PART – B

3. A steam pipe is wrapped with insulation of inner and outer radii R_i and R_o, respectively. At a particular instant the temperature distribution in insulation is known to be

$$T(r) = A\ln\left(\frac{r}{R_o}\right) + B$$

where A and B are constants. How do the heat flux and heat rate vary with insulation radius (r) ? [2]

4. Consider the problem of steady-state heat conduction in a stationary opaque solid with constant internal volumetric heat generation. The initial and surface temperatures are known. Thermo-physical properties of the solid may be considered as constant. Prove that the solution of this heat conduction problem is unique. [5]

5. A very long metallic rod of radius 2.5 cm diameter is heated at one end. The surrounding air temperature is 25 °C. There are two thermocouples, which are 7.5 cm apart, along the length of the rod. At steady state, the temperatures at these two locations are reported as 125 °C and 90 °C. If the heat transfer coefficient is 20 W/(m^{2}K), estimate the value of thermal conductivity of the rod. [4]

6. Consider the extrusion of plastics where a sheet of uniform cross-sectional area is being drawn with a constant velocity u through two rollers kept at a constant temperature T_0. The heat is transferred along the length of the sheet by conduction and the sheet exchanges heat with its surrounding air by convection and radiation. Derive heat the equation for this system. [4]

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