21/4/11
AN

DEPARTMENT OF CHEMICAL ENGINEERING IIT KHARAGPUR
END SEMESTER EXAMINATION 2011, SPRING SEMESTER
Subject: Advanced Heat Transfer **Subject No: CH 61014**

No of Students: 95

FULL MARKS: 50 (Part-1: 20 Marks, Part-2: 30 Marks) **Closed Book/ Closed Notes**

General Instructions:

1. All Questions are compulsory. Answer all questions of a part at one place.
2. Clearly write your name, Roll No., Subject Name, Subject Number and Part No. on the Answer Book.
3. Fell free to assume any missing data with proper justifications.

Part – 1

1. During the flight of a nuclear-powered spacecraft, plutonium oxide ($Pu^{238}O_2{}^{16}$) was used to generate electrical power for its various instruments. Heat was uniformly generated at a rate of $\dot{q}$ W/m^3 due to alpha particles emission from the fuel (Pu^{238}). Consider a spherical pellet of this fuel (diameter = 1 inch, thermal conductivity = 4.2 W/m·K) covered with thermo-electric elements for converting heat into electrical energy. Various considerations dictate that the fuel may achieve a maximum temperature of 1800°C and the outside temperature of the pellet must be at 250°C. With these constraints in place, calculate the steady-state temperature distribution in the fuel pellet and the maximum allowable volumetric heating rate $\dot{q}$. **[6]**

2. Consider the case of two-dimensional transient heat conduction in a solid of dimension L (in x direction) by H (in y direction), with constant thermal properties and no internal heat generation. The initial temperature distribution of the solid is given as $T_0(x,y)$. The following boundary conditions are maintained for time $t \geq 0$. At $x=0$, the surface is perfectly insulated; at $x = L$ there is convection with a fluid characterized by temperature T_∞ and heat transfer coefficient h; at $y=0$ the surface is maintained at constant temperature T_1; and the surface at $y=H$ is subjected to a constant flux of magnitude q'' (into the solid). Ignore radiation.

   (a) Provide a neat sketch of the problem clearly identifying the boundary conditions. **[2]**

   (b) Transform the governing equation and all boundary & initial conditions into two related problems using $T(x,y,t) = T_s(x,y) + T_t(x,y,t)$, where T_s is the steady state solution and T_t is the transient solution. Do **NOT** attempt to solve the resulting equations. **[4]**

3. Consider a plane wall which is sufficiently large in y and z directions compared to its thickness L in the x direction. Let the initial temperature distribution be $T_0(x)$ at $t=0$. Internal energy is generated in this wall at a rate of $\dot{q}(x,t)$ per unit volume for times $t \geq 0$ and heat is dissipated by convection from the surfaces at $x = 0$ and $x = L$ into a surrounding medium whose temperature T_∞ varies with time. Assume that the thermal conductivity k and the thermal diffusivity α are constants, and that the heat transfer coefficients h_1 and h_2 are very large. Determine the unsteady-state temperature distribution $T(x,t)$ in this wall by **Finite Fourier Transforms.** **[8]**

Part - 2

Specific Instructions

- Be precise with your answers. Unnecessarily long, redundant answers may potentially fetch zero!
- **All the parts of a Question MUST be answered together.**

4. (a) What is Benard Convection Cell? Under which boiling regime do they appear and why? (1+1)

   (b) Please draw the boling curve qualitatively, with properly marking the distinct zones/ regimes and axes. Identify the burnout point and discuss why there is a drop in heat flux with increase in temperature. (2+1)

   (c) What is the fundamental difference in Film boiling and Nucleate boiling regimes? (1)

   (d) Why in nucleate boling would one expect to see series of bubbles rising from the same point on the heated surface? (1)

   (e) What is Liedenfrost Temperature? (1) **[8]**

5. (a) For a condensing laminar film on a vertical surface, draw and explain the qualitative velocity profile in the vapor phase adjacent to the condensing layer. (2)

   (b) How will the velocity profile look if the surrounding temperature is identical to the saturation temperature and why? (1)

   (c) Derive the expression for the velocity profile for a laminar condensing film on a vertical surface (start from the y component momentum balance equation). (2)

   (d) What is the expression and physical significance of Jacob Number? (2) **[7]**

6. (a) How is the Thermal and Electrical Conductivity of a material Related? (2)

   (b) Does Convection depend on Conduction? Please justify your answer in a few sentences (2)

   (c) What is the significance of turbulent Prandalt Number? (1)

   (d) How would you identify if mixed convection is dominated by Natural Convection or Forced Convection? (2) **[7]**

7. (a) Calculate the solid angle at the centre of a hemisphere. (3)

   (b) What is Irradiation and Radiosity? Give an expression for Total Radiosity with its unit (1+1)

   (c) What is the general trend of shift in wavelength of radiative emission with increase in temperature? (1)

   (d) At a given temperature, why is the emission from a black body maximum? (2) **[8]**

All the Best! ☺