DEPARTMENT OF CHEMICAL ENGINEERING IIT KHARAGPUR

END SEMESTER EXAMINATION 2010, SPRING SEMESTER

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

No of Students: 82

FULL MARKS: 50 (25 For each part) **Closed Book/ Closed Notes**

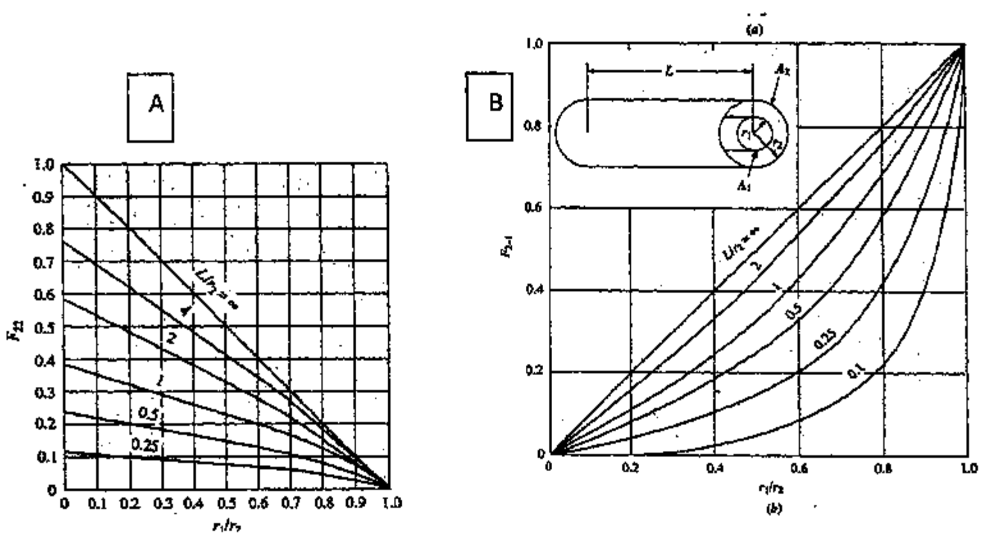
General Instructions:

1. All Questions are compulsory
2. **Use separate Answer Books for Each Part.**
3. Clearly write your name, Roll No., Subject Name, Subject Number and Part No. on both the Answer Book.
4. Fell free to assume any missing data with proper justifications.
5. **All the parts of a Question MUST be answered together.**

Part 1

Answer all questions

1. Define (a) Blackbody and Grey body (b) Radiation shape factor (c) Irradiation and Radiosity (d) Monochromatic emissive power and Total emissive power 4
2. Two concentric cylinders having diameters 10 and 20 cm have a length of 20 cm. Calculate the shape factor between the two flat surface ends. The attached chart for shape factors can be used if necessary. 4
3. Two parallel plates 0.5m by 1.0 m are spaced 0.5m apart. One plate is maintained at 1000^0C and the other at 500^0C. The emissivities of the plates are 0.2 and 0.5 respectively. The plates are located in a very large room, the walls of which are maintained at 27^0C. The plates exchange heat with each other and with the room. Only the plate surfaces facing each other are to be considered in the analysis. Using network analysis, find the net transfer to each plate and to the room. Value of shape factors between the two surfaces is 0.285, which can be obtained from the standard chart. 4



Radiation Shape Factors for two concentric cylinders of finite length (A) Outer cylinder to itself and (B) outer cylinder to inner cylinder.

Part 2

Answer all questions

4. The Boussinesq approximated momentum equation is given as (for natural convection of a fluid along the side of a vertical wall at temp Ts (bulk fluid temp is T_∞)

$$U\ (\partial V/\partial X) + V\ (\partial V/\partial Y) = \gamma\,(\partial^2 V/\partial X^2) + g\beta\,(T - T_\infty)$$

(i) Perform an order of magnitude analysis to show that the orders of the Inertial and Friction terms are:

$(H/\partial_T)^4 .\ Ra_H^{-1} .\ Pr^{-1}$ and $(H/\partial_T)^4 .\ Ra_H^{-1}$ respectively. (7)

You can use the expression of $Ra_H = H^3\, g\beta\,(T - T_\infty)/\,\gamma\alpha$

(Hint: Start from order of magnitude analysis of the continuity eqn.)

ii) Get the functionality of V for High Pr fluids based on the above derivation. (2)

iii) What is the physical sinficance of Ra_H? **Please discuss with expression** (2)

iv) What are the significances of Pr and Pr_T? **Please discuss with expression** (2)

5. The inner surface of a plane wall is insulated while the outer surface is exposed to the surrounding airstream at T_∞ (Fig. 1). Initially, the wall is at a uniform temperature corresponding to that of the surrounding airstream. Suddenly, a heat source is switched on applying a uniform heat flux q''_0 to the outer surface. Sketch, on T-x coordinates, the following temperature distributions: initial, steady-state, and at two intermediate times corresponding to early unsteady state and late unsteady state. [4]

Note: DO NOT SOLVE!

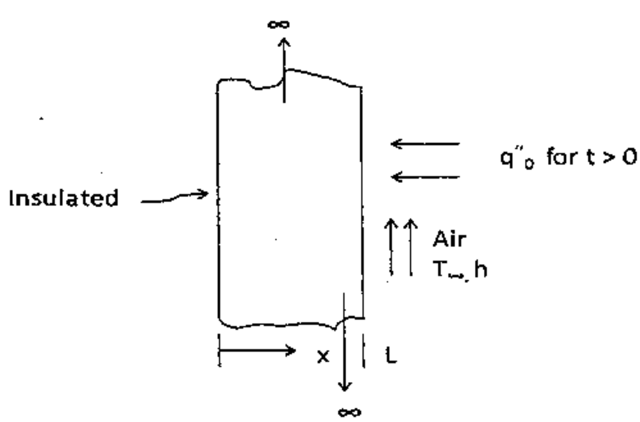


Fig. 1

6. A very long rod of constant thermophysical properties and having 25 mm diameter is heated at one end to a constant temperature T_b (Fig. 2). The temperatures at two different locations along the rod, which are 75 mm apart, are measured to be 135°C and 100°C under steady state conditions. If the surrounding air temperature (T_∞) is 35°C and the heat transfer coefficient (h) is 20 W/(m^2 · K), estimate the value of thermal conductivity of the rod. [10]

   Note: Write down the mathematical formulation for this problem, including the boundary conditions and derive all the necessary equations.

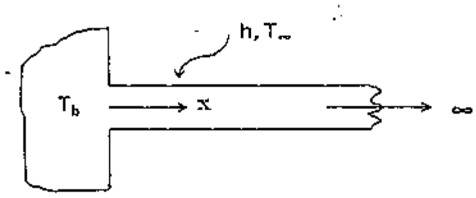


Fig. 2

7. Consider one-dimensional unsteady state heat conduction in a flat plate of thickness 2L with no internal heat generation (Fig. 3). The initial temperature of the plate is T_∞. The constant heat flux of q''_0 is applied to both the surfaces. The thermophysical properties of the plate may be assumed constant.

   (a) Write down the complete mathematical formulation for the problem, including initial and boundary conditions.

   (b) Solve the resulting heat conduction equation to determine the unsteady temperature distribution in the plate. [3+8]

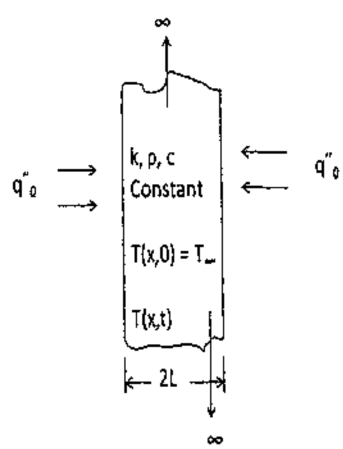


Fig. 3

All the Best ☺