Indian Institute of Technology, Kharagpur

Date of Examination: Time: 2Hrs. Full Marks 80
Mid Semester Exam. 2009 **3th Yr (BTech+Dual Degree)**
Sub No. ME30005 Sub Name: **Heat Transfer**
No. of Students: 120 of the dept. of: **Mech Engg**

Answer all questions. The marks are given on the left margin in the box
Wherever necessary, make suitable assumptions and state them clearly

10 1. An electrically heated sphere with a diameter D = 6 cm is exposed to ambient air at a temperature of 25°C and a heat transfer coefficient of 20 W/m^2.K. The surface of the sphere is to be maintained at 125°C. Calculate the heat transfer rate from the sphere to the air when

(a) the sphere is bare and

(b) the sphere is covered with a layer of insulation (k_{ins} =1.0 W/m.K) having a radius corresponding to that of critical radius for sphere.

10 2. The inner and outer radii of a hollow cylinder are 5 cm and 10 cm, respectively. The inner surface of the cylinder is maintained at a temperature of 300°C, while the outer surface is at a temperature of 100°C. The thermal conductivity of the cylinder material varies over the range of 100°C < T < 300°C as k(T) = 0.5[1.0 + 10^{-3}T], where T is in °C and k(T) is in W/m.°C. Find the heat transfer rate per unit length of the cylinder.

10 3. Two very long and slender rods of same diameter are given. One rod is made of aluminium (k_1 = 200 W/m.°C). The other rod is made of an unknown material whose k-value (k_2) is to be determined. To find the thermal conductivity (k_2) of the unknown material, one end of each rod is thermally attached to a metallic surface that is maintained at a constant temperature T_0. Both the rods loose heat by convection to surrounding air at T_∞. The surface temperature of each rod is measured at various distances from the metallic surface. Measurements show that the temperature of the aluminium rod at a distance of 40 cm from the metallic surface is same as that of the rod of unknown material at a distance of 25 cm from the metallic surface. Determine

(a) the thermal conductivity k_2 of the rod made of unknown material, and

(b) ratio of heat transfer rates from aluminium rod and the rod of unknown material.

15 4. Heat is generated at a constant rate of q_g W/m^3 in a thin cylindrical rod of length L and diameter D by the passage of electrical current. The two ends of the rod (x=0 and x=L) are maintained at constant temperatures of T_0 (°C) and 0°C, respectively, while heat is transferred from the lateral surface of the rod by convection into surrounding air that is at 0°C. The convective heat transfer coefficient is h. Find an expression for temperature distribution T(x) in the rod.

10 5. A 5cm diameter copper sphere [k=372$W/m°C$, α=11.2 × $10^{-5}m^2/s$] is initially at a uniform temperature of 200°C. It is suddenly exposed to an environment at 20°C having heat transfer coefficient h=28$W/m^2°C$.

(a) Using the lumped-capacity method of analysis, calculate the time required for the sphere to reach 90°C.

(b) Is the lumped-capacity method of analysis justified for this case?

Continued...

[15] 6. An infinite plate having thickness $2L$ is initially at a uniform temperature of T_i and the surface of the plate is suddenly lowered to T_w. The material of the plate has thermal diffusivity α and thermal conductivity k.

(a) Find the temperature distribution in the plate after time t using separation of variables technique.

(b) What is the cumulative heat loss from the plate at time t?

Express all the results in dimensionless form.

[10] 7. Calculate the heat transfer from a 20cm X 20 cm square plate over which air flows at 300K at 1 atm pressure. The plate temperature is 340K, and the free stream velocity is 10m/s. The properties of air are $\nu = 18.2 \times 10^{-6}\, m^2/s$, $k = 0.028\, W/m°C$, Pr=0.7.