(Following Paper ID and Roll No. to be filled in your Answer Book)

PAPER ID : 2104 **Roll No.** | | | | | | | | | | |

B.Tech.

(SEM. V) THEORY EXAMINATION 2011-12

HEAT AND MASS TRANSFER

Time : 3 Hours *Total Marks : 100*

Note :— (1) Attempt **all** questions. Marks are indicated against each question/part.

(2) You may use the correlations provided at the end of the question paper.

(3) Assume missing data suitably, if any.

(4) Use of Heisler's Chart is permitted.

1. Answer any **two** parts of the following : **(10×2=20)**

(a) (i) Derive an expression for thermal resistance for spherical wall.

(ii) What do you understand by contact resistance ?

(iii) What do you understand by overall heat transfer coefficient ?

(b) A copper (k = 401 W/m. K) cable of 30 mm diameter has an electrical resistance of 5×10^{-3} Ω/m and is used to carry an electrical current of 250 A. The cable is exposed to an ambient air at 20° C, and the associated convection coefficient is 25 W/m^2. K. What are the surface and centerline temperatures of the cable ?

(c) A 10 mm diameter electric wire with a resistance per unit length of 2×10^{-4} Ω/m is coated with an insulation of thermal conductivity k = 0.20 W/m.K. The insulation is exposed to ambient air at 30° C for which heat transfer coefficient is

10 $W/m^2.K$. Calculate the value of highest current that may be passed through the wire so that the temperature in any part of insulation does not exceed 200° C.

2. Answer any **two** parts of the following : **(10×2=20)**

(a) For a fin of rectangular cross section with insulated tip derive the expressions for temperature profile, heat transfer rate through fin, fin efficiency, and fin effectiveness.

(b) What do you understand by "Corrected Length of Fin" ? Consider two long slender rods (A and B) (assume infinite fins) of the same diameter but different materials. One end of each rod is attached to a base surface at 100° C, and the rods are exposed to the ambient air at 20° C. By traversing the length of each rod with a thermocouple, it was observed that the temperatures of the rods were equal at the positions $x_A = 0.15$ m and $x_B = 0.075$ m, where x is measured from the base surface. If the thermal conductivity of rod A is known to be $k_A = 70$ W/m.K, determine the value of k_B for rod B.

(c) A large aluminum plate of 10 cm thickness is initially at a uniform temperature of 500° C is suddenly immersed in a liquid at 100° C with heat transfer coefficient as 1200 $W/m^2.K$. Find :

(i) The temperature at the centre line and at the outer surface of the plate 1 minute after immersion.

(ii) Time taken by the mid plane to reach a temperature of 300° C.

For Aluminum take : $\alpha = 8.4 \times 10^{-5}$ m^2/s, k = 215 W/m.K, $\rho = 2700$ kg/m^3, and $c_p = 900$ J/kg.K.

3. Answer any **two** parts of the following : **(10×2=20)**

(a) An electrical air heater consists of a horizontal array of thin metal strips that are each 10 mm long in the direction of an air stream that is in parallel flow over the top of the strips. Each strip is 0.2 m wide, and 25 strips are arranged side by side, forming a continuous and smooth surface over which the air flows at 2 m/s. Each strip is maintained at 500° C and the air is at 25° C.

What is the rate of convection heat transfer from the first strip ?

The fifth strip ?

All the strips ?

For air at 535 K, take : $\nu = 43.54\times10^{-6}$ m²/s; k = 0.0429 W/m. K; Pr = 0.683.

(b) Oil (k = 0.133 W/m.K.) at 150° C flows slowly through a long, thin-walled pipe of 30-mm inner diameter. The pipe is exposed to air at temperature of 20° C and the outside convection coefficient is 11 W/m².K. Estimate the heat loss per unit length of tube. Assume fully developed flow and negligible thermal resistance of tube wall.

(c) (i) For laminar/turbulent flow over a flat plate the heat transfer coefficient decreases with the distance from leading edge. Whether the statement is true or false ? Substantiate your reply.

(ii) Discuss the significance of non-dimensional numbers in free convection.

4. Answer any **two** parts of the following : **(10×2=20)**

(a) For two very large parallel plates A and B with diffuse, gray surfaces the temperatures and emissivities are given as : T_A = 1000 K, T_B = 500 K, ε_A = 1, and ε_B = 0.8. Determine the net radiation exchange between the plates per unit area of the plates. Calculate the percentage decrease in net radiation exchange, if a radiation shield with emissivity (on both sides) ε_S = 0.1 is used between the surfaces. Take $\sigma = 5.670\times10^{-8}$ W/m².K⁴.

(b) What do you understand by the following ?

(i) Self Radiation Rule

(ii) Colored Surface

(iii) Wien's Displacement Law.

(c) Consider a diffuse circular disk of diameter D and area A_2 and a plane diffuse surface of area A_1 ($A_1 << A_2$). The surfaces are parallel, and A_1 is located at a distance H from the centre of A_2. Obtain an expression for the view factor F_{1-2}.

5. Answer any **two** parts of the following : **(10×2=20)**

(a) Describe various modes of condensation.

(b) Saturated steam at 373 K condenses in a double pipe heat exchanger with a surface area of 0.5 m^2 and an overall heat transfer coefficient of 2000 $W/m^2.K$. Water enters at 0.5 kg/s and 288 K. Determine the outlet temperature of the water and the rate of steam condensation (Latent heat = 2257 kJ/kg).

(c) Discuss Fick's law for steady state diffusion through stationary medium consisting of two species and derive an expression for species diffusion resistance.

<u>Some Correlations :</u>

1. For Laminar flow over a flat plate :

$$Nu_x = 0.332\ Re_x^{1/2}\ Pr^{1/3}$$
$$(0.6 < Pr)$$

2. For Turbulent flow over a flat plate :

$$Nu_x = 0.0296\ Re_x^{4/5}\ Pr^{1/3}$$
$$(0.6 < Pr < 60)$$

3. For Mixed boundary layer flow over a flat plate :

$$Nu_x = (0.037\ Re_L^{4/5} - 871)\ Pr^{1/3}$$
$$(0.6 < Pr < 60;\ Re_{x,c} < Re_L < 10^8;\ Re_{x,c} = 5 \times 10^5)$$

4. For Double pipe heat exchanger :

$$\varepsilon = 1 - \exp(-NTU)\ ;\quad \text{for } C_{min}/C_{max} = 0$$
$$\varepsilon = NTU/(1 + NTU)\ ;\quad \text{for } C_{min}/C_{max} = 1$$

5. For Fully developed laminar flow through tube :

$Nu_D = 4.36$; for uniform surface heat flux condition

$Nu_D = 3.66$; for uniform surface temperature condition.