Paper Code: MTME-012 **Roll No.**

M.Tech.
FIRST SEMESTER EXAMINATION, 2016-17
ADVANCED HEAT AND MASS TRANSFER

[Time: 3 Hours] [Max. Marks: 70]

Note: Attempt all questions. Assume missing data suitably, if any. Use appropriate equation/ correlation and property data provided. Use of Heisler's Charts is permitted.

1. Attempt any *TWO* parts of the following:- **(7x2=14)**

(a) A truncated solid cone is of circular cross section, and its diameter is related to the axial coordinate by an expression of the form $D = ax^{3/2}$,where $a = 1.0\ m^{-1/2}$.
The sides are well insulated, while the top surface of the cone at x_1 is maintained at T_1 and the bottom surface at x_2 is maintained at T_2.
(i) Obtain an expression for the temperature distribution $T(x)$.
(ii) What is the rate of heat transfer across the cone if it is constructed of pure aluminum with x_1 =0.075 m, T_1 = 100°C, x_2 =0.225 m, and T_2 = 20°C. Take k = 238 W/m.K.

(b) A plane wall of thickness 0.1m and thermal conductivity 25 W/m.K having uniform volumetric heat generation of 0.3 MW/m^3 is insulated on one side, while the other side is exposed to a fluid at 92°C. The convection heat transfer coefficient between the wall and the fluid is 500 W/m^2 K. Determine the maximum and minimum temperature in the wall and prove that the heat transfer rate from the wall is equal to heat generated.

(c) An electric wire having a radius of r_i = 5 mm and a resistance per unit length of $10^{-4}\Omega$/m is coated with a plastic insulation of thermal conductivity k=0.20W/m.K. The insulation is exposed to ambient air at 300K for which h=10W/m^2.K. If the insulation has a maximum allowable temperature of 450 K, what is the maximum possible current that may be passed by the wire?

2. Attempt any *TWO* parts of the following:- **(7x2=14)**

(a) Using Heisler's Charts, estimate the time required to cook a hot dog in boiling water. Assume that the hot dog is initially at 6 ºC, that the convection heat transfer coefficient is 100 W/m^2 K, and that the final temperature (after cooking) is 80 ºC at the centerline. Treat the hot dog as a long cylinder of 20-mm diameter having the properties: ρ=880 kg/m^3, c_p=3350 J/kg.K, andk=0.52 W/m.

(b) Discuss the effect of increasing the length of fin on Fin effectiveness and Fin Efficiency. A brass rod 100 mm long and 5 mm in diameter extends horizontally from a casting at 200 °C. The rod is in an air environment with T_∞ =20 °C and h = 30 W/m^2 K. Find the temperature of the rod 25 mm, 50 mm, and 100mm from casting.

(c) Discuss the effect of various parameters on the time constant. A mild steel ball of diameter 10 mm, initially at 600 ºC is suddenly exposed to air at 25 ºC (h=120 W/m^{2}K). Determine the time required for ball to reach 100ºC. For mild steel take: ρ=7850 kg/m^3, c_p=475 J/kg.K, and k=45 W/m.

3. Attempt any *TWO* parts of the following:- **(7x2=14)**

(a) Explain the physical mechanism of free convection. Also discuss the significance of Grashof number and Rayligh number. What do you understand by thermally fully developed flow?

(b) The heat transfer rate per unit width (normal to the page) from a length segment of a flat plat can be expressed $q_{12}=\bar{h}_{12}$ $(x_2 - x_1)(T_s - T_\infty)$, where $\bar{h}_{12}$ is the average coefficient for the section of length $(x_2 - x_1)$. Consider laminar flow over the flat with a uniform temperature T_∞. The spatial variation of the local convection coefficient is of the form $h_x = C\, x^{-1/2}$, where C is a constant. Beginning with the (local) convection rate equation in the form $dq = h_x\, dx\, (T_s - T_\infty)$, derive an expression for $\bar{h}_{12}$ in terms of C, x_1, and x_2

(c) Explain Reynold's analogy between skin friction and heat transfer.

(d) 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: ν = 43.54 x 10 -6 m2/s ; k = 0.0429 W/m. K ; Pr = 0.683

4. Attempt any *TWO* parts of the following:- **(7x2=14)**

(a) Derive general expression for the view factor F_{1-2} and prove the reciprocity rule.

(b) Consider two large, diffuse gray, parallel surfaces separated by a small distance. If the surface emissivities are 0.9, what emissivity should a thin radiation shield (placed between the surfaces) have to reduce the radiation heat transfer rate between the surfaces to 20 % of the original?

(c) Consider a diffuse circular disk of diameter D and area A2 and a plane diffuse surface of area A1 (A1<<A2). The surfaces are parallel, and A1 is located at a distance H from the center of A2. Obtain an expression for the view factor F1-2.

5. Attempt any *TWO* parts of the following:- **(7x2=14)**

(a) What do you understand by the following?
- (i) Emissive power of a surface.
- (ii) Gray Surface
- (iii)Kirchoff's Law

(b) Discuss various modes of boiling with the help of Pool boiling curve.

or

Explain the phenomenon of drop wise and film wise condensation.

(c) What do you understand by effectiveness of heat exchanger? Derive an expression for effectiveness of counter flow heat exchanger in terms of NTU.

(d) With the help of appropriate example, explain the Hottel's method.

<u>Correlation:</u>

1. For Turbulent flow over a flat plate:
   $Nu_x = 0.0296\, Re_x^{4/5}\, Pr^{1/3}$ $(0.6 < Pr < 60)$
2. For Mixed boundary layer flow over a flat plate:
   $Nu_L = (0.037\, Re_L^{4/5} - 871)\, Pr^{1/3}$ $(0.6 < Pr < 60;\ Re_{x,c} < Re_L < 10^8;\ Re_{x,c} = 5 \times 10^5)$