BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)
SECOND YEAR FIRST SEMESTER EXAM 2019

HEAT TRANSFER

Time: Three hours Full marks: 100

Answer any *five* questions.
All questions carry equal marks.
Assume any unfurnished data relevant to the solutions.

1. (a) If the effectiveness of a fin is 0.9, make your comments on the suitability of use of such a fin.

   (b) Consider a straight fin of length L, cross sectional area A and perimeter P with its base maintained at a temperature T_b. The fin loses heat by convection to an ambient at a temperature T_∞ with heat transfer coefficient h. The thermal conductivity of the fin material is k.

   Derive the differential equation that governs the temperature distribution in the fin stating the assumptions. Hence solve for the temperature distribution in the fin, considering it to be infinitely long. Also find the rate of heat flow through the fin and the efficiency of the fin. **(3+17)**

2. (a) What is lumped system analysis and when is it applicable?

   (b) Consider a hot metal forging having a volume V, surface area A, density ρ, specific heat c that is initially at a uniform temperature T_i and is suddenly quenched by immersing it in a liquid reservoir at temperature T_∞.. h is the heat transfer coefficient of convection from the forging to the quenching bath. Treating the body as a lumped system, derive an expression for the temperature transient.

   (c) Consider a 1.2 m high and 2 m wide double pane window consisting of two 3 mm thick layers of glass (k = 0.78 W/m.^{0}C) separated by a 12 mm wide stagnant air space (k = 0.026 W/m.^{0}C). Determine the steady rate of heat transfer through the double pane window and the temperature of its inner surface for a day during which the room temperature is maintained at 24 ^{0}C while the temperature of the outdoors is -5 ^{0}C. Take the heat transfer coefficients on the inner and the outer surfaces of the window to be 10 W/m^2.^{0}C and 25 W/m^2.^{0}C, respectively. **(3+5+12)**

3. Consider Couette flow between two parallel plates, where, the upper plate is moving with a velocity U. The temperatures of the upper and lower plates are T_L and T_0 respectively ($T_L > T_0$). Obtain the velocity and temperature distributions for the flow, considering zero pressure gradient in the axial direction. **(20)**

4. Consider steady, laminar boundary type flow of a low Prandtl number ($Pr \ll 1$) fluid over a flat plate. The free stream velocity and temperature are U_∞ and T_∞

[Turn over

respectively. The plate is maintained at a uniform temperature of T_w. Show the following by the method of scale analysis:

$$\delta / L \sim Re_L^{-1/2}$$

$$\delta_T / L \sim Re_L^{-1/2}\,\mathrm{Pr}^{-1/2}$$

$$Nu_L \sim Re_L^{1/2}\,\mathrm{Pr}^{1/2}$$ **(20)**

5. (a) Define spectral intensity and directional spectral emissive power of a black body. Derive the relation between them.

   (b) Define transmissivity, absorptivity and reflectivity and state how they are related.

   (c) Define shape factor. What is reciprocity relation in this connection? **(8+6+6)**

6. (a) Define effectiveness and NTU for a heat exchanger.

   (b) Show that for a parallel flow heat exchanger, effectiveness is given by

$$\varepsilon = \frac{1-\exp[-NTU(1+C_r)]}{1+C_r}$$ **(6+14)**

7. (a) Derive the expression for LMTD of a counterflow heat exchanger.

   (b) A concentric tube heat exchanger is used to cool lubricating oil for a gas turbine. The flow rate of cooling water through the inner tube is 0.2 kg/s and its specific heat is 4178 J/kgK. The flow rate of the lubricating oil through the outer annulus is 0.1 kg/s and the specific heat of the lubricating is 2131 J/kgK. The hot oil enters the heat exchanger at 100 ^{0}C and leaves at 60 ^{0}C . The inlet temperature of the cooling water is 30 ^{0}C. The overall heat transfer coefficient is 200 W/m^{2}K. Find the area of heat transfer for the heat exchanger, considering a counter flow arrangement. **(12+8)**