Bachelor of Mechanical Engineering (Evening) Supplementary Examination, 2017
(2^{nd} Year 1^{st} Semester)

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) Write down the one-dimensional transient heat conduction equation for a plane wall with constant thermal conductivity and heat generation in its simplest form, and indicate what each variable represents.

   (b) Consider a 1.2 m high and 1.5 m wide double pane window consisting of two 2 mm thick layers of glass ($k = 0.780\ W/m.^0C$) separated by a 6 mm wide space filled up with stagnant air ($k = 0.026\ W/m.^0C$). 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 23 ^0C while the temperature of the outdoors is -8 ^0C. Take the heat transfer coefficients on the inner and the outer surfaces of the window to be 12 $W/m^2.^0C$ and 24 $W/m^2.^0C$, respectively. **(5+15)**

2. (a) What is fin effectiveness? The fins attached to a surface are determined to have an effectiveness of 0.9. Do you think rate of heat transfer from the finned surface has increased or decreased, due to attachment of these fins?

   (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. Hence, solve for the temperature distribution in the fin, assuming it to be a fin with insulated tip. **(4+16)**

3. (a) What is lumped system analysis in transient heat conduction? Consider heat transfer between two identical solid bodies and the air surrounding them. The first solid is being cooled by a fan and the second is being allowed to cool naturally. For which solid, is the lumped system analysis more likely to be applicable?

   (b) Consider a hot metal body, 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_∞. Heat loss from the hot forging to the quenching bath takes place with constant heat transfer coefficient h. Treating the body as a lumped system, derive the governing equation, and solve for the variation of temperature of the sphere with respect to time. **(6+14)**

4. (a) Find an expression for the overall heat transfer coefficient for one dimensional heat flow along the radial direction through a tube of length L and thermal conductivity k. The internal and external radii of the tube are r_i and r_o respectively. The heat transfer coefficients on the inside and outside of the tube are h_i and h_o respectively.

   (b) Steam at 250 ^0C flows in a stainless steel pipe (k = 15 $W/m.^0C$) whose inner and outer diameters are 5 cm and 5.5 cm, respectively. The pipe is covered with 3 cm thick glass wool insulation (k = 0.038 $W/m.^0C$). Heat is lost to the surroundings at 5 ^0C by convection with a heat transfer coefficient of 14 $W/m^2.^0C$. Taking the heat transfer coefficient inside the pipe to be 70 $W/m^2.^0C$, determine the rate of heat loss from the pipe per unit length of the pipe. **(12+8)**

5. 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)**

6. (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)**

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

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

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

8. (a) Derive the expression for $LMTD$ of a parallel heat exchanger.

   (b) In a double pipe counter flow heat exchanger hot water flows at a rate of 1 kg/s and gets cooled from 90 ^0C to 60 ^0C. Cooling is achieved by circulating 1.5 kg/s of water, which enters the heat exchanger at 30 ^0C. Assuming specific heat for both the streams c_p = 4.18 kJ/kgK and an overall heat transfer coefficient U = 2400 W/m^2K, calculate the heat transfer areas required for the heat exchanger. **(10+10)**