May - June - 2011

[3963] – 212

T.E. (Mechanical) (Semester – I) Examination, 2011
HEAT TRANSFER
(2008 Pattern) (New)

Time : 3 Hours Max. Marks : 100

Instructions : *1) Answer **3** questions from Section **I** and **3** questions from Section **II**.*
*2) Answers to the **two** Sections should be written in **separate** books.*
*3) Neat diagrams must be drawn **wherever** necessary.*
*4) Black figures to the **right** indicate **full** marks.*
*5) Use of logarithmic tables, slide rule, Mollier charts, electronic pocket calculator and steam tables is **allowed**.*
*6) Assume suitable data, **if** necessary.*

SECTION – I

Unit – I

1. a) Identify the mode(s) of heat transfer in the following :
   i) Heat transfer from a room heater
   ii) Hot plate exposed to atmosphere
   iii) Heat loss from thermos flask
   iv) Coding of Activa scooter engine
   v) Heat loss from automobile radiator
   vi) Heat transfer of sun energy to your classroom. **6**

   b) A steel pipe (K = 50 W/mk) of ID 100 mm and OD 110 mm is to be covered with two layers of insulations, each having a thickness of 50 mm. The thermal conductivity of first insulation is 0.06 W/m°C and that of the second is 0.12 W/mK. Calculate the loss of heat per meter length of pipe and the interface temperature between the two layers of insulations, when the temperature of the inside tube surface is 250°C and that of the outside surface of the insulation is 50°C.

   If the order of insulations is reversed, find the change in heat loss and comment on the result from insulation point of view. **10**

OR

2. a) Derive the expression for Logarithmic Mean Area (LMA) for hollow cylinder as;

   $A_m = \dfrac{A_o - A_i}{ln(A_o / A_i)}$; where A_m is LMA, A_o outer surface area and A_i inner surface area of the cylinder. **8**

b) Calculate the rate of heat loss for a red brick wall of length 5 m, height 4 m and thickness 25 cm. Temperature of the inner surface is 110°C and that of the outer surface is 40°C. Thermal conductivity of the red brick is 0.7 W/mK. Also, calculate the temperature at an interior point of the wall (in the thickness), 20 cm away from the inner surface of the wall. **8**

Unit – II

3. a) Prove that critical radius of insulation for cylinder is k/h and that for sphere is 2k/h; where k is conductivity of insulation and h is heat transfer coefficient between insulation and surroundings. Use standard notations. **8**

b) A hollow sphere of inside radius 30 mm and outside radius 50 mm is electrically heated at its inner surface at a constant rate of 10^5 W/m^2. The outer surface is exposed to a fluid at 30°C with heat transfer coefficient of 170 W/m^{2}K. Thermal conductivity of the sphere material is 20 W/mK. Calculate the inner and outer surface temperatures. **8**

OR

4. a) The inside and outside surfaces of a hollow sphere $a \le r \le b$ at $r = a$ and $r = b$ are maintained at temperatures T_1 and T_2 respectively. The thermal conductivity of the sphere material varies with temperature as :

$k(T) = k_0(1 + \alpha T + \beta T^2)$. Prove that the total heat flow rate Q. through the sphere is given as :

$$Q = \frac{4\pi k_0 ab}{(b-a)}(T_1 - T_2)\left[1 + \frac{\alpha}{2}(T_1 + T_2) + \frac{\beta}{3}(T_1^{\ 2} + T_1T_2 + T_2)^2\right].$$ **8**

b) Nichrome wire, having a resistivity of $100\,\mu\Omega - \text{cm}$, is to be used as a heating element in a 10 kW heater. The wire surface temperature should not exceed 1220°C. Take surrounding air temperature as 20°C. Convective heat transfer coefficient on 1.15 kW/m^{2}K and thermal conductivity of Nichrome as 17 W/mK. Find out what diameter of Nichrome wire is necessary for 1 m long heater. **8**

Unit – III

5. a) Derive the expressions for heat transfer rate Q and temperature distribution for a short fin using standard notations. **9**

b) In an experiment to determine the thermal conductivity of a very long solid rod of 2.5 cm diameter, its one end is placed in a furnace and rod is projecting into a room with ambient air at 22°C. After steady-state conditions are achieved, the temperatures at two points 10 cm apart, are found to be 110°C and 85°C respectively. Convective heat transfer coefficient between the rod surface and the surrounding air is 28.4 W/m^{2}K. Determine the thermal conductivity of the rod material. **9**

OR

6. a) State the assumptions made in Lumped Heat Capacity Method for analysis of transient heat conduction. Derive the expression for temperature variation during quenching of a billet by this method. **9**

b) A stainless steel rod of 1 cm diameter initially at 320°C is suddenly immersed in a liquid at 120°C, for which the convective heat transfer coefficient is 100 W/m^2K. Determine the time required for the rod to attain a temperature of 200°C. Steel properties : density = 7800 kg/m^3, C = 460 J/kgK, K = 40 W/mK.

Assuming above rod of 1 m length, it is converted into sphere and same process repeated with no change in any condition, will there be any change in time required for this steel sphere to achieve the same temperature of 200°C. Find out. **9**

SECTION – II

Unit – IV

7. a) Compare natural and forced convection heat transfer. **4**

b) Name and write formulae of 4 dimensionless numbers each for natural and forced convection using standard symbols/notations. **4**

c) Liquid metal at the rate of 5 kg/s flows in a tube of 6 cm diameter. It enters at 400°C into the tube and leaves at 430°C. A constant heat flux is maintained along the tube. The tube surface temperature is 22°C higher than the temperature of liquid metal. Calculate the length of tube required for the purpose. Take properties of liquid metal : $\mu = 1.35 \times 10^{-3}$ kg/ms, Cp = 150 J/kgK, Pr = 0.011, k = 16 W/mK. Use the following correlation : $Nu = 4.82 + 0.0185\,(Re.Pr)^{0.83}$. **8**

OR

8. a) A circular disc of 25 cm diameter is exposed to air at 20°C. If the disc is maintained at 120°C, estimate the heat transfer rate from it, when :

i) Disc is kept horizontal

ii) Disc is kept vertical.

For air at 70°C : k = 0.03 W/mK; Pr = 0.697; $\nu = 2.076 \times 10^{-6}$ m^2/s

Use the following correlations :

$Nu = 0.14\,(Gr.Pr)^{0.334}$ for top/upward surface

$Nu = 0.27\,(Gr.Pr)^{0.25}$ for bottom/downward surface

$Nu = 0.59\,(Gr.Pr)^{0.25}$ for vertical surface

Use characteristic length as A/P when the plate is horizontal. **8**

b) Give 4 practical examples of natural and 4 practical examples of forced convection. Do not include lab practicals. **8**

Unit – V

9. a) Explain :

   i) Wien's Displacement Law

   ii) Lambert's Law of Radiation

   iii) Planck's Law of Radiation

   iv) Radiation Shield. **8**

   b) Determine the rate of heat loss by radiation from a steel tube of outside diameter 70 mm and 3 meter long at a temperature of 227°C, if the tube is located within a square brick conduit of 30 cm side which is at 27°C. Take emissivity of steel as 0.79 and that of brick as 0.93. **8**

OR

10. a) Derive the expression for net heat transfer rate by radiation between two parallel gray plates placed closely having a third parallel plate kept between these two plate having emissivities as $\in_1, \in_2$ and $\in_3$ at temperatures T_1, T_2 and T_3 respectively. **8**

    b) Three hollow thin walled cylinders having diameters 10 cm, 20 cm and 30 cm are arranged concentrically. The temperatures of the inner most and outer most cylinders are 100 K and 300 K respectively. Assuming vacuum between the annular spaces, find the steady state temperature attained the 20 cm diameter cylinder. Take emissivities of all cylinders as 0.05. **8**

Unit – VI

11. a) Derive the expression for LMTD of counter flow heat exchanger using standard notations. **9**

    b) In a shell and tube counter flow heat exchanger, water flows through a copper tube 20 mm ID and 23 mm DD, while oil flows through the shell. Water enters at 20°C and comes out at 30°C, while oil enters at 75°C and comes out of heat exchanger at 60°C. Water and oil side film coefficients are 4500 and 1250 W/m^2K respectively. Thermal conductivity of copper is 355°C and fouling factors on water and oil sides may be taken as 0.0004 and 0.001 m^2K/W. If the length of the tube is 2.4 m, calculate the heat transfer rate in the heat exchanger. **9**

OR

12. a) With the help of neat curve, explain six regimes of pool boiling. **9**

    b) Explain dropwise and filmwise condensation. **4**

    c) Tubes may be arranged horizontally or vertically in a condenser. Workout the relation of tube diameter and its length, when condensation rate will not change, whether tubes are arranged vertically or horizontally. **5**
