COLLEGE OF ENGINEERING, PUNE
2012-2013
End Semester Examination
ME303 Heat Transfer

Mech

Programme: T.Y. B. Tech **Branch: Mechanical**
Duration: 3.00 Hr **Max. Marks: 50**

Instructions: **1. Solve any FIVE questions.**

2. Make suitable assumptions and use suitable standard data wherever necessary.
3. Illustrate your answers with neat sketches wherever required.
4. **Use of steam table, non-programmable calculator and Heat Transfer data book is permitted.**
5. Figures to right indicate full-marks.
6. Enough importance will be given to the neatness of writing.

Q1 a Develop a controlling differential equation for conduction heat flow through a homogeneous cylinder along r-direction, only under steady state condition when the body is not generating heat. **5**

Using the above equation, prove that the heat flow through a hollow cylinder is given by

$$Q = \frac{2\pi k L(T_1 - T_2)}{\ln\left(\frac{R_2}{R_1}\right)}$$

Where the notations carry the usual meaning.

b A steam pipe of 20 cm diameter carries saturated steam at considerably high pressure when the surrounding temperature is 30°C and outer surface heat transfer coefficient is 10 W/m^2-°C. To reduce the heat flow, two insulating materials having conductivity 0.5 W/m-°C and 0.72 W/m-°C, each of 4 cm thickness, are provided. The better insulating material is to be provided first and second next. **5**

(i) By mistake of the worker, inferior insulation is provided first and better next. Find the percentage change in the heat flow. Assume insulation work is done in the insulation factory where all type types of insulations are available in abundant quantity.

(ii) The same mistake is done but the required material is purchased from the market and insulation work is done at required site.

Q2 a Write down the controlling differential equation for the heat flow through homogeneous sphere when the sphere is generating heat (q''' W/m^3) uniformly under steady state condition. Consider heat flow is along r-direction only. **5**

Using the above equation, prove that the maximum temperature occurred in the sphere is given by

$$T_{max} = T_a + \frac{q''' R^2}{6}\left[\frac{2k}{Rh} + 1\right]$$

Where the sphere is surrounded by atmospheric air at T_a. Other notations carry the usual meaning.

b A square plate heater 16 cm x 16 cm having rating of 1 kW is inserted between two slabs. Slab A is 2 cm thick(k_1= 60 W/m-°C) and slab B is 1 cm thick (k_2 = 0.25 W/m-°C). The outside heat transfer coefficients on side A and B are 200 W/m^2-°C and 50 W/m^2-°C respectively. If the surrounding air is at 20°C find out the maximum temperature in the system and outer surface temperatures of the slabs. 5

Also calculate the heat transfer through each slab.

Q3 a Define effectiveness of fin and find out required equation for the same. From the equation, form the criterion required to decide whether the fin should be used or not. 5

b A 200 cc engine cylinder is designed for a 2-stroke petrol engine to develop 7.5 kW when running at 5000 rpm. The engine stroke is 1.3 times of its diameter. For the effective cooling of engine cylinder, 8-fins made of aluminum alloy (k= 150 W/m-K) whose height is 4 cm and thickness of 4 mm are provided along the axis of the cylinder. The cylinder surface temperature is 400°C, when the ambient temperature is 20°C. Assuming h = 20 W/m^2-K, find 5

(a) Effectiveness of cylinder after providing the fins.

(b) If the vehicle is moving with 80 km/hr on the high-way, find out the percentage change in the effectiveness of the fin. The heat transfer coefficient is increased from 20 to 50 W/m^2-K.

Q4 a For forced convection, list out the physical parameters and their fundamental dimensions which control the heat transfer coefficient. 4

Using Buckingham π-theorem, prove that the non-dimensional relation between these parameters is given by,

$Nu = C\,(Re)^m (Pr)^n$, where m, n and C are constants.

b A thin copper plate 50 cm x 30 cm in size maintained at 100°C is located in vertical plane keeping 50 cm side vertical to the horizontal plane when surrounding air temperature is 20°C. Find (a) heat lost by the plate in kJ/min, (b) If the air is made to flow at a velocity of 5 m/s parallel to 30 cm side, find out the percentage change in heat lost by the plate. 6

Q5 a Define LMTD and prove that LMTD for parallel flow double pipe heat exchanger is given by 4

$$LMTD = \frac{\theta_i - \theta_o}{\ln\left(\frac{\theta_i}{\theta_o}\right)}$$

Where the notations carry the usual meaning.

Draw the temperature distribution for hot and cold flow for parallel-flow arrangement when LMTD becomes maximum.

b A single pass shell and tube type condenser is designed for a steam power plant of 20 MW capacity whose specific steam consumption is 4.35 kg/kWh. Steam enters the condenser at 0.1 bar and saturated condition. **6**

Find out the number of tubes required in the condenser.

Take the following data:

Length of tube = 15 m and its diameter = 12 cm. The cooling water inlet and outlet temperatures are 25 °C and 35 °C respectively.

h_i (water side heat transfer coefficient) = 1080 W/m^2-K.

Assume h_o (steam side heat transfer coefficient) for single horizontal tube is same irrespective of tube arrangement).

Fouling factor of water side = 0.0005 °C/W

Q6 a Draw the curves between λ and $E_{b\lambda}$ taking T as parameter. From the graph, define Wien's law of displacement and then prove that it is given by **4**

$$\lambda_m T = 2.9 \text{ mm-k}$$

Where λ_m is the value of λ at temperature T where $E_{b\lambda}$ becomes maximum.

b A metal rod of 10 cm diameter and 20 cm in length at 500°C is suspended in natural air at 30°C. The rod surface emissivity = 0.8. Find **6**

(i) the time required to cool down the rod from 500 °C to 200 °C,

(ii) If the heated rod is concentrically located in a hollow square duct whose cross-sectional area is 144 cm^2 and its inner emissivity is 0.65 and inner surface temperature is 30°C, find the percentage change in the time required to cool from 500 °C to 200 °C.

Assume the initial cooling rate remains constant in both the cases till required cooling and consider only radiation heat transfer.

Take C_p (metal rod) = 0.4 kJ/kg-°C and ρ= 2520 kg/m^3.