[This question paper contains 4 printed pages.]

Your Roll No. .....

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MEM

Paper—ME.551

HEAT TRANSFER

Time : 3 *Hours* *Maximum Marks* : 100

(Write your Roll No. on the top immediately on receipt of this question paper.)

Attempt any four questions.

Use Heat & Mass Transfer Data Book is permissible.

1. (a) A large volume of exhaust gas available at 573 K is used to heat process water. The gas flows across a tube bank and water flows through the tubes. The outside diameter of the tubes is 60 mm. The tube bank has 15 transverse rows and 14 longitudinal rows. The tubes are spaced 150 mm centre to centre in an equilateral triangular arrangement. The hot gas approaches the tubes bank at a velocity of 16 m/sec. If the tube surface is 343 K, calculate the rate of heat transfer to water per metre length of the tube bank. 10

(b) What are the factors to be considered in the thermal design of heat exchanger. Derive the expression for total heat exchanger cost. 15

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2. A steam pipe line has exact outer diameter of 0.168 m, carries saturated steam at an absolute pressure of 8.2 bar. Calculate the optimum thickness of the bonded rock-wool insulation for the steam pipe line. The following data are given :

Saturation temperature of steam at 8.2 bar is 445 K, Ambient temperature is 293 K, Latent heat of condensation of steam at 445 K is 487 kcal/kg, outer surface heat transfer coefficient is 10.32 kcal/hr m^2 K, Thermal conductivity of the insulation is 0.031 kcal/hr m K,

Service life of insulation is 5 years, Interest rate = 0.18 Rs./year. The Insulation cost including the cost of installation, cladding, labour and supervision is 15750 Rs./m^3. 25

3. (a) A long rectangular bar of sides a and b has uniform initial temperature distribution T_i at the zero time, all the four surfaces of the bar are raised to a temperature T_s and maintained at that value. Calculate unsteady state temperature distribution in the bar. 15

(b) Air at 298 K flows over both sides of a 400 × 300 mm copper plate, 25.4 mm thick. If the air velocity is 1 m/sec. and the plate temperature is assumed to remain uniform. Calculate the temperature of the plate after 3600 second if its initial temperature is 398 K. 10

4. (a) Benzene from the condenser at the top of a distillation column is cooled at a rate of 1000 kg/hr from 348 K to 323 K in a counter-current double pipe heat exchanger. The inner tube of carbon steel using 21 mm inner dia and 25.4 mm outer diameter, 14 BWG. The effective length of heat exchanger is 15 m. The outer pipe is of inner diameter 41 mm and outer diameter 48 mm. Benzene flows through the annulus. Water which flows through the inner tube, entering at 303 K and leaving at 313 K is the coolent.

   (i) Calculate the heat duty of the exchanger and water flow rate.

   (ii) Calculate the individual film coefficients and the overall coefficient based on both inside and outside areas.

   (iii) Fouling Factor. 15

   (b) Derive the expression for optimum mass flow rate and optimum outlet water temperature of optimum cost of heat exchanger. 10

5. (a) Consider a small plane surface area dA_1 directly opposite to a circular rings A_2 of inner radius 50 mm and width 30 mm. Calculate the fraction of the radiation emitted by the surface dA_1 that is intercepted by the ring (area=A'_2) and also the fraction that passes through the hole (area=A''_2) in the ring if the surfaces are placed 200 mm apart. 13

(b) Determine the configuration factor between two infinitely long directly opposed parallel flat plates of breadth B separated by a distance H. 12

6. (a) Derive the generalized equation for fins. 3

(b) Derive the expression for temperature distribution and rate of heat transfer in (i) Straight triangular fins, (ii) parabolic fins. 8 + 7

(c) An air cooled cylindrical wall is to be fitted with triangular fins of 30 mm thickness at base and 120 mm in height. The fins are made from stainless steel with density 800 kg/m^3 and thermal conductivity of 15.5 W/mK. The wall temperature is 873 K and the fin is exposed in an environment with ambient temperature of 303 K with convective heat transfer coefficient of 20 W/m^{2}K. Derive the relation for temperature distribution along the fin and calculate the rate of heat flow per unit mass of fin material used. 4 + 3