Total No. of Questions : 5] [Total No. of Printed Pages : 6

Roll No. ....

ME–605

B. E. (Sixth Semester) EXAMINATION, June, 2012

(Mechanical Engg. Branch)

HEAT AND MASS TRANSFER

(ME–605)

Time : Three Hours

Maximum Marks : 100

Minimum Pass Marks : 35

Note : Attempt all questions as per internal choice given. Use of HMT data book and Steam table is permitted. Assume suitable missing data if any.

1. Attempt any *two* of the following : 10 each

(a) Define Fourier's law of heat conduction. Derive expressions for temperature distribution and heat transfer, under one-dimensional steady state heat conduction for the following system :

(i) Plane wall

(ii) Cylinder

(b) A layer of 5 cm thick insulating brick having conductivity of 1·5 W/m/K is placed between two 0·5 cm thick steel plates. The conductivity of mild steel is 50 W/m/K. The faces of brick adjacent to the plates are rough having solid to solid contact of 30% of total area. The average height of the asperities is

P. T. O.

0·1 cm. If the outer plate surface temperatures are 100°C and 500°C respectively, calculate the rate of heat transfer per unit area. The conductivity of air is 0·2 W/m/K.

(c) An electric wire of 1 mm diameter is covered with a 2 mm thick layer of plastic insulation (k = 0·5 W/m/K). Air surrounding the wire is at 25°C and h = 10 W/m^2/K. The wire temperature is 100°C, and it is not affected by the presence of insulation. Estimate the rate of heat dissipation from the wire per unit length with and without the insulation. Find the radius of insulation when the rate of heat dissipation is maximum. What is the maximum value of this heat dissipation ?

2. Attempt any *two* of the following : 10 each

(a) Derive expression for temperature distribution and heat dissipation in a straight fin of rectangular cross section for fin with insulated tip. What would be the value of fin efficiency in the above case ?

(b) An electronic semiconductor device generates heat equal to 480×10^{-3} W. In order to keep the surface temperature at the upper safe limit of 70°C, the generated heat has to be dissipated to the surroundings which is at 30°C. To accomplish this task, aluminium fins of 0·7 mm square cross-section and 12 mm long are attached to the surface. The thermal conductivity of aluminium fins is 170 W/m/K. If the heat transfer coefficient is 12 W/m^2/K, calculate the number of fins required. Assume no heat loss from the tip of fins.

(c) The temperature distribution in a long cylindrical tube at a certain instant is given by :

$$T = 800 + 1000\,r - 5000\,r^2$$

where 'r' is the radial distance in metres and T is in °C. Find :

(i) the rate of heat flow at inside and outside surfaces per m length.

(ii) the rate of heat storage per m length.

(iii) the rate of change of temperature with time at the inner and outer surfaces.

Take the following data :

Inner Diameter = 60 cm

Outer Diameter = 1 m

$k = 58$ W/m/K

$\alpha = 0 \cdot 004$ m^2/h

3. Attempt any *two* of the following : 10 each

(a) Define Nusselt, Reynolds', Prandtl and Stanton numbers. Explain their significance in forced convection.

(b) Air at 10°C and at atmospheric pressure flows at a velocity of 4·5 m/s past a flat plate with a sharp leading edge. The entire plate surface is maintained at a temperature of 60°C. Assuming that the transition occurs at a critical Reynolds' numbers of 5×10^5, find the distance from the leading edge at which the boundary layer changes from laminar to turbulent. At the location, calculate the following :

(i) Thickness of thermal boundary.

(ii) Local and average convective heat transfer coefficient.

(iii) Heat transfer rate from both sides per unit width of plate.

Assume cubic velocity profile and approximate method. Thermophysical properties of air at mean film temperature of 40°C are $\rho = 1 \cdot 128$ kg/m^3, $\nu = 16 \cdot 96 \times 10^{-6}$ m^2/s, $k = 0 \cdot 02755$ W/m/K and $Pr = 0 \cdot 7$.

(c) A vertical cylinder 1·5 m high and 180 mm in diameter is maintained at 100°C in an atmosphere environment of 20°C. Calculate heat loss by free convection from the surface of the cylinder. Assume properties of air at mean temperature as $\rho = 1 \cdot 06$ kg/m^3, $\nu = 18 \cdot 97 \times 10^{-6}$ m^2/s, $C_p = 1 \cdot 004$ kJ/kg/°C and $k = 0 \cdot 1042$ kJ/m/hr/°C.

4. Define the terms NTU and effectiveness. Derive an expression for effectiveness of a counterflow heat exchanger in terms of NTU and capacity ratio. 20

In a parallel flow double pipe heat exchanger water flows through the inner pipe and is heated from 20°C to 70°C. Oil flowing through the annulus is cooled from 200°C to 100°C. It is desired to cool the oil to a lower exit temperature by increasing the length of the heat exchanger. Determine the minimum temperature to which the oil may be cooled. 20

Or

In counterflow double pipe heat exchanger water flows through a copper tube (19 mm OD and 16 mm ID) at a flow rate of 1·48 m/s. The oil flows through the annulus formed by inner copper tube and outer steel tube (30 mm

OD and 26 mm ID). The steel tube is insulated from outside. The oil enters at 0·4 kg/s and is cooled from 65°C to 50°C whereas water enters at 32°C. Neglecting the resistance of the copper tube, calculate the length of the tube required. Data given :

$$Nu = 0{\cdot}023\,(Re)^{0{\cdot}8}\,(Pr)^{0{\cdot}3}$$

Fouling Factor, Water side = $0{\cdot}0005\ m^2\,k/W$

Fouling Factor, Oil side = $0{\cdot}0008\ m^2\,k/W$

Water and oil properties :

Property	Oil	Water
ρ (kg/m³)	850	995
C_p (kJ/kg/K)	1·89	4·187
k (W/m/K)	0·138	0·615
ν (m²/s)	$7{\cdot}44 \times 10^{-6}$	$4{\cdot}18 \times 10^{-7}$

5. (a) Define the following : 6
   (i) Kirchhoff's law
   (ii) Dropwise condensation
   (iii) Stefan-Boltzmann law

(b) The radiation shape factor of the circular surface of a thin hollow cylinder of 10 cm diameter and 10 cm length is 0·1716. What is the shape factor of the curved surface of the cylinder with respect to itself ? 4

(c) A brick wall having an emissivity of 0·85 is 6 m wide and 4 m high. It is at a distance of 4 m from a 500 mm × 400 mm opening in a furnace wall. The centre line of the opening lies 1 m lower and 1 m left of the centre of the wall. The furnace temperature is 1500°C and that of the wall is 37°C. Calculate the rate of radiation heat transfer between the opening and the wall. 10

Or

(c) A small sphere (outside radius = 60 mm) with a surface temperature of 300°C is located at the geometric centre of a large sphere (inside diameter = 360 mm) with an inner surface temperature of 15°C. Calculate how much of heat emitted from the large sphere inner surface is incident upon the outer surface of the small sphere, assuming that both surfaces approach black body behaviour. What is the net exchange of heat between the two spheres ? 10