Total number of printed pages – 10

B. Tech

CPME 6307

Sixth Semester Examination – 2010

HEAT TRANSFER

Full Marks – 70

Time : 3 Hours

Answer Question No. ***1*** *which is compulsory and any* ***five*** *from the rest.*

The figures in the right-hand margin indicate marks.

Use of steam table allowed.

1. Answer the following questions : 2×10

   (a) Write down the general three-dimensional heat conduction equation in Cartesian coordinates. What are the conditions involved ? Reduce this equation to Laplace and Poisson's equations. State the conditions for the above equations.

8. (a) Show the temperature profiles along the length of heat exchangers in cases of an evaporator and a condenser. 2

   (b) Water at 20°C flows through a parallel flow heat exchanger to cool oil from 60°C to 30°C. The outlet temperature of the water is 26°C. The rate of flow of oil is 10kg/s. The specific heat of oil is 2200J/kgK. The overall heat transfer coefficient U = 300 W/m^2K. Compare the area required for a counter flow heat exchanger. Draw the temperature distribution in both cases with data. 8

(b) The heat flux, q is 6000 W/m^2 at the surface of an electrical heater. The heater temperature is 120°C when it is cooled by air at 70°C. What is the average convective heat transfer coefficient, h ? What will the heater temperature be if the power is reduced so that q is 2000 W/m^2?

(c) (i) What are the parameters that influence the convection heat transfer?

(ii) What is the physical significance of Nusselt Number ? How is it related with convection and conduction heat transfer ? Hence work out its relationship with the appropriate parameters.

(d) The inner and outer surfaces of a 0.5 cm thick, 2m × 2m window glass in winter are 10°C and 3°C respectively. If the thermal conductivity of the glass is 0.78 W/mK,

determine the amount of heat loss through the glass over a period of 5 hours. What would your answer be if the glass were 1 cm thick ?

(e) What are the physical mechanisms associated with heat transfer by conduction, convection and radiation ? What are the transport properties associated with the above modes of heat transfer? State their units.

(f) (i) What is the difference between mixed and unmixed fluids in cross-flow heat exchanger ? Show it by neat sketches.

(ii) Draw a 2-shell-passes and 8-tube-passes shell and tube heat exchanger.

(g) (i) How does transient heat transfer differs from steady heat transfer? Give one example for each.

(ii) What is the difference between the fin efficiency and fin effectiveness ?

(h) (i) What is the difference between pool boiling and flow boiling ?

(ii) What is the difference between external and internal flow boiling ?

(i) What is the critical radius of insulation ? Work out a relation for the same for a cylindrical layer in terms of h and k.

(j) A room is maintained at 22°C at all times. The inner surfaces of the walls, floor and the ceiling of the room are observed to be at an average temperature of 10°C in winter and 25°C in summer. A person is standing inside the room. Determine the rate of radiation heat transfer between the person and the surrounding surfaces if the exposed surface area and the

average outer surface temperature of the person are 1.4 m^2 and 30°C respectively. The emissivity of a person is 0.95.

2. A plane wall is constructed of several layers. The first layer consists of masonry brick (k= 0.66 W/mK) 25 cm thick, the second layer of 2.5 cm thick mortar(k = 0.7 W/mK), the 3rd layer of 10 cm thick lime stone (k=0.66 W/mK) and the outer layer consists of 1.25 cm thick plaster (k = 0.7 W/mK). The heat transfer coefficients on the interior and exterior of the wall fluid layer are 5.8 W/m^2K and 11.6 W/m^2K respectively. 10

(a) Draw the temperature distribution of the composite wall with the fluid layers as well as its electric analog.

(b) Find

(i) The U-factor from the air on the interior to the air at the exterior on the wall

(ii) The overall thermal resistance per sq. meter.

(iii) The rate of heat transfer per sq. meter if the interior of the room is 26°C while the outside air is at a temperature of -7°C.

(iv) The temperature of the junction between the mortar and the lime-stone.

3. Steam flows through a pipe of length 20 m, inner diameter 12 cm and outer dia. 16 cm. The thermal conductivity (k) of the pipe material is 20 W/m°C. The inner and outer surfaces of the pipe are maintained at average temperatures of T_1= 150°C and T_2 = 60°C respectively. Obtain a general relation for the temperature distribution inside the pipe under steady conditions and determine the rate of heat loss from the steam through the pipe. 10

4. (a) What is the reason for the wide spread use of fins on surfaces ? Justify your answer 3

(b) A steel fin (k = 54 W/mK) with a cross-section of an equilateral triangle (side 5mm) is 80 mm long. It is attached to a plane wall maintained at 400°C. The ambient air temperature is 50°C and unit surface conductance is 90 W/m^{2}K. Calculate the heat dissipation rate by rod. Assume steady state conditions. Draw the schematic of the triangular fin. 7

5. A 2m × 3m flat plate is suspended in a room, and is subjected to air flow parallel to its surfaces along its 3 m long side. The free stream temperature and velocity of air are 20°C and 7 m/sec. The total drag force acting on the plate is measured to be 0.86 N. Determine the

average convection heat transfer coefficient for the plate. Draw the schematic of the given system with data. Use the following properties of air

ρ = 1.204 kg/m^3, Cp = 1.007 kJ/kgK,

Pr. = 0.7309

Use modified Reynold's analogy to solve the problem. 10

6. (a) Define emissivity. What is its unit ? What is the value of emissivity for a black surface ? What is a radiation shield ? 3

(b) Two parallel plates have emissivity of 0.8 and 0.5. A radiation shield having some emissivity on both sides is placed between them. Calculate the emissivity of the shield in order to reduce the radiation losses from the system to 1/10th of that without shield. 7

7. (a) Define condensation, filmwise condensation and dropwise condensation. 2

(b) The condenser of a steam power plant operates at a pressure of 7.38 kPa. Steam at this pressure condenses on the outer surfaces of horizontal tubes through which cooling water circulates. The outer diameter of the pipes is 3 cm and the outer surfaces of the tubes are maintained at 30°C. Determine the following :

(i) The rate of heat transfer to the cooling water circulating in the tubes.

(ii) The rate of condensation of steam per unit length of a horizontal tube.

The heat transfer coefficient for condensation on a single horizontal tube is given by

$$h_{horizontal} = 0.729 \left[\frac{g\rho_l(\rho_l - \rho_v)h_{fg}k_l^3}{\mu_l(T_{sat} - T_s)D} \right]^{0.25}$$

The symbols have usual meaning. 8