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15ME63

Sixth Semester B.E. Degree Examination, Aug./Sept.2020
Heat Transfer

Time: 3 hrs. Max. Marks: 80

Note: **1.** ***Answer any FIVE full questions, choosing ONE full question from each module.***
2. ***Use of Heat and Mass Transfer data handbook is permitted.***

Module-1

1 a. Derive the 3-D heat conduction equation in Cartesian coordinate system for an isotropic material. Also write special forms of 3-D heat conduction equation. **(08 Marks)**

b. A furnace wall is made up of three layers of thickness 250 mm, 100 mm, 150 mm with thermal conductivities of 1.65, K, 9.2 W/m-K respectively. The inside is exposed to gases at 1250°C with convection coefficient of 25 W/m^2-K and outside surface is exposed to air at 25°C with convection coefficient of 12 W/m^2-K, inside surface is maintained at 1100°C. Determine:
- (i) The unknown thermal conductivity
- (ii) Overall heat transfer coefficient
- (iii) All surface temperatures. **(08 Marks)**

OR

2 a. Explain the modes of heat transfer with corresponding governing laws. **(06 Marks)**

b. Explain the three kinds of boundary conditions to solve conduction problems. **(04 Marks)**

c. A wall of steam boiler furnace is made of layers of fire clay of thickness 12.5 cm (K_1 = 0.28 + 0.00023T W/m°C) and red brick of 50 cm (K_2 = 0.7 W/m°C) where T is in °C. The inside surface temperature of fire clay is 1100°C and outside brick wall temperature is 50°C. Calculate the amount of heat loss per unit area of the furnace wall and the temperature at the interface. **(06 Marks)**

Module-2

3 a. What do you mean by critical thickness of insulation? Derive an expression for critical thickness of insulation for cylinder. **(05 Marks)**

b. In a thermal conductivity measuring experiment two identical long rods are used. One rod is made of aluminium (K = 200 W/m-K). The other rod is specimen. One end of both the rods is fixed to a wall at 100°C, while the other end is suspended in air at 25°C. The steady temperature at the same distance along the rods were measured and found to be 75°C on aluminium and 60°C on specimen rod. Find thermal conductivity of the specimen. Assume that the fin is insulated at the tip. **(05 Marks)**

c. Show that the temperature distribution under lumped analysis is given by, $\frac{T - T_\infty}{T_i - T_\infty} = e^{-Bi.Fo}$

where T_i is the initial temperature and T_∞ is the surrounding temperature. **(06 Marks)**

OR

4 a. What is the main purpose of fins? Define fin efficiency and fin effectiveness. **(04 Marks)**

b. What are Heisler charts? Explain their significance in solving transient conduction problems. **(04 Marks)**

c. A 12 mm diameter mild steel sphere at 540°C is exposed to cooling air flow at 27°C and heat transfer coefficient of 114 W/m2-K. Find:
  (i) The time required to cool the sphere from 540°C to 95°C
  (ii) Instantaneous heat transfer rate, two minutes after start of cooling
  (iii) Total heat transferred from the sphere during first two minutes.
  Properties of mild steel are: ρ = 7850 kg/m^3, C = 475 J/kg-K and α = 0.045 m^2/hr. **(08 Marks)**

Module-3

5 a. Why numerical methods are preferred over analytical methods? List the numerical methods which are used in solving heat conduction problems. **(04 Marks)**

b. The boundary temperatures of a thin plate are as shown in Fig.Q5(b). Determine the temperature at the centre of the plate.

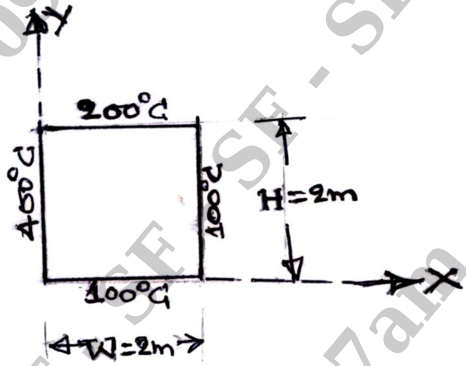

Fig.Q5(b) **(06 Marks)**

c. Explain:
  (i) Kirchhoff's law
  (ii) Plank's law
  (iii) Wien's displacement law **(06 Marks)**

OR

6 a. How is Laplace equation for 2D heat conduction approximated to the finite difference equations? **(08 Marks)**

b. Calculate the net radiant heat exchange per unit area for two large parallel plates at temperature of 427°C and 27°C respectively. Take emissivity of hot plate and cold plates are 0.9 and 0.6 respectively. If a polished aluminium shield is placed between them, find percentage reduction in the heat transfer. Take emissivity of shield as 0.4. **(08 Marks)**

Module-4

7 a. With the help of dimensional analysis obtain the fundamental relation between dimensionless numbers required for
  (i) Forced convection
  (ii) Natural convection. **(10 Marks)**

b. Water at a velocity of 1.5 m/s enters a 2 cm diameter heat exchanger tube at 40°C. The heat exchanger tube wall is maintained at a temperature of 100°C. If the water is heated to a temperature of 80°C in the heat exchanger tube, find the length of the exchanger tube required. **(06 Marks)**

OR

8 a. Define an explain the physical significance of the following dimensionless numbers:
   (i) Grashoff number
   (ii) Reynolds number **(04 Marks)**

b. For fluid flow over a flat plate, sketch (i) Velocity boundary layer (ii) Thermal boundary layer. Clearly mention salient points on the figure. **(04 Marks)**

c. A tube of 0.036 m OD and 40 cm length is maintained at a uniform temperature of 100°C. It is exposed to air at a uniform temperature of 20°C. Determine the rate of heat transfer from the surface of the tube when (i) the tube is vertical (ii) the tube is horizontal. **(08 Marks)**

Module-5

9 a. What is the importance of NTU effectiveness method? Derive an expression for the effectiveness of a parallel flow heat exchanger. **(08 Marks)**

b. Sketch pool boiling curve for water and explain the various regimes in boiling heat transfer. **(08 Marks)**

OR

10 a. List the assumptions made in Nusselt's theory of laminar film condensation on a plane vertical surface. **(04 Marks)**

b. Saturated steam at 80°C condenses as a film on a vertical plate at a temperature of 70°C. Calculate the average heat transfer coefficient and the rate of steam condensation per hour. Assume that the latent heat of vaporization at 80°C as 2309 kJ/kg. **(06 Marks)**

c. An oil cooler for a large diesel engine is to cool engine oil from 60 to 45°C using sea water at an inlet temperature of 20°C with a temperature rise of 15°C. The design load Q = 140 KW and the mean overall heat transfer coefficient based on the outer surface area of the tubes is 70 $W/m^2{}^\circ C$. Calculate the heat transfer surface area for single pass counter flow and parallel flow arrangement. **(06 Marks)**

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