CBCS SCHEME

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18ME63

Sixth Semester B.E. Degree Examination, June/July 2024
Heat Transfer

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Use of Heat Transfer Data handbook permitted.

Module-1

1 a. Explain with suitable sketches, the 1st, 2nd and 3rd kind of boundary conditions. **(06 Marks)**

b. Explain briefly:
(i) Thermal conductivity
(ii) Thermal diffusivity
(iii) Thermal contact resistance **(06 Marks)**

c. A mild steel tank of wall thickness 20 mm is used to store water at 95°C. Thermal conductivity of mild steel is 45 W/m-°C, and the heat transfer coefficient inside and outside the tank are 2850 W/m^2-°C and 10 W/m^2-°C respectively. If the surrounding air temperature is 20°C, calculate the rate of heat transfer per unit area of the tank. **(08 Marks)**

OR

2 a. Derive an equation for critical thickness of insulation in cylinder. **(06 Marks)**

b. A small spherical vessel of outside diameter 60 mm is covered with as asbestos (K = 0.1105 W/m-K) and left in the atmospheric air at 30°C. The film coefficient between air and asbestos is 5 W/m^2-K. If it is desired to maximize the heat transfer rate from the contents of the vessel to the air, determine the thickness of asbestos cover needed and also the rate of heat flow at this thickness if the surface the vessel to be maintained at 120°C. **(06 Marks)**

c. An insulated steam pipe having outside diameter of 30 mm is to be covered with two layers of insulation each having a thickness of 25 mm. The average thermal conductivity of one material is 5 times that of the other. Assuming that the inner and outer surface temperatures of composite insulation are fixed, how much will the heat transfer be reduced when the better conducting material is next to the pipe than it is outer layer? **(08 Marks)**

Module-2

3 a. Derive the expression for temperature distribution and rate of heat transfer from a fin when its end is insulated. **(10 Marks)**

b. A handle of a ladle used for pouring molten lead at 327°C is 30 cm long and is made of 2.5 cm × 1.5 cm mild steel bar stock (K = 43 W/m-K). In order to reduce the grip temperature, it is proposed to make a hallow handle of mild steel plate 1.5 mm thick to the same rectangular shape. If the surface heat transfer coefficient is 14.5 W/m^2-K and the ambient temperature is 27°C, estimate the reduction in the temperature of the grip. Neglect the heat transfer from the inner surface of the hallow shape. **(10 Marks)**

OR

4 a. Derive the expression for temperature distribution and heat flow using lumped parameter analysis in transient heat conduction. **(10 Marks)**

b. A 50 mm thick iron plate [$K = 60$ W/m-K, $\rho = 7350$ kg/m^3, $C_p = 460$ J/kg-K] is initially at 225°C. Suddenly the plate is immersed in a fluid medium maintaining at a uniform temperature of 25°C with a surface heat transfer coefficient of 500 W/m^2-K. Calculate:
(i) The temperature at the centre of the plate 2 minutes after the start of cooling
(ii) Temperature at a depth of 10 mm from plate surface 2 minutes after the start of cooling
(iii) Temperature at the plate surface 2 minutes after the start of cooling
(iv) The energy removed from the plate per m^2 during this time. **(10 Marks)**

Module-3

5 a. Explain implicit and explicit method for discretization of 1-dimensional transient heat conduction problem. **(08 Marks)**

b. An iron rod $L = 5$ cm long of diameter $D = 2$ cm with thermal conductivity $K = 50$ W/(m-°C) protrudes from a wall and is exposed to an ambient at $T_\infty = 20$°C and $h = 100$ W/(m^2-°C). The base of the rod is at $T_0 = 320$°C and its tip is insulated. Assuming 1-D steady state heat flow, calculate the temperature distribution along the rod and the rate of heat flow into the ambient by using finite differences method.
Assume the initial guess for temperature as 200°C and the length of the fin is divided into 5 equal parts. **(12 Marks)**

OR

6 a. Define and explain the following:
(i) Kirchoff's law
(ii) Stefan Boltzman law
(iii) Wein's displacement law **(06 Marks)**

b. A furnace wall emits radiation at 2000 K. Treating it as black body radiation, calculate:
(i) Manochromatic radiant flux density at 1 μm wave length
(ii) Wavelength at which emission is maximum and the corresponding emissive power
(iii) Total emissive power **(06 Marks)**

c. Emissivities of two large parallel plates maintained at 800°C and 300°C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per m^2 for these plates. Find the percentage reduction in heat transfer when a polished aluminium radiation shield of emissivity 0.06 is placed between them. Also find the temperature of the shield. **(08 Marks)**

Module-4

7 a. Explain with neat sketches: (i) Velocity boundary layer (ii) Thermal boundary layer **(06 Marks)**

b. Atmospheric air at 300 K flow with a velocity of 5 m/s, along a flat plate of length 1m long. The plate has a width of 0.5 m. The total drag force acting on the plate is determined to be 18×10^{-3} N. By using the Reynold's-Colburn analogy, estimate the average heat transfer coefficient for flow of air over the plate. **(06 Marks)**

c. Water flows with a mean velocity of 2 m/s inside a circular pipe of inside diameter 5 cm. The pipe is considered to be a smooth pipe and its wall is maintained at a uniform temperature of 100°C by condensing steam on its outer surface. At a location where the fluid is hydrodynamically and thermally developed, the bulk mean temperature of water is 60°C. Calculate the heat transfer coefficient by using:
(i) Dittus-Boelter equation
(ii) Sieder-Tate equation **(08 Marks)**

OR

8 a. Explain the physical significance of the following dimensionless numbers:
(i) Reynold's number (ii) Prandtl number
(iii) Nusselt number (iv) Grashof number **(08 Marks)**

b. Consider a square plate 0.5 m by 0.5 m with one surface insulated and the other surface maintained at a uniform temperature of 110°C which is placed in quiescent air at atmospheric pressure and 40°C. Calculate the average heat transfer coefficient for free convection for the following orientations of the hot surface:
(i) The plate is horizontal with hot surface faces up
(ii) The plate is horizontal with hot surface faces down
(iii) The plate is vertical **(12 Marks)**

Module-5

9 a. Derive an expression for LMTD for parallel flow heat exchanger and the assumptions made. **(10 Marks)**

b. A cross flow heat exchanger with both threads unmixed having a heat transfer area of 8.4 m^2 is to heat air (C_{pc} = 1005 J/kg-°C) with water (C_{ph} = 4180 J/kg-°C). Air enters at 15°C with 2.0 kg/s, while the water enters at 90°C with 0.25 kg/s. The overall heat transfer coefficient is 250 W/m^2-°C. Calculate the exit temperatures of both air water as well as total heat transfer rate. **(10 Marks)**

OR

10 a. Explain different regimes of pool boiling with neat sketches. **(06 Marks)**

b. Saturated water at 100°C is boiled with a copper heating element having a heating surface of 500 sq.cm, which is maintained at a uniform temperature of 115°C. Calculate the surface heat flux and rate of evaporation. **(06 Marks)**

c. Air free saturated steam at T_V = 85°C condenses on the outer surface of 225 horizontal tubes of 1.27 cm OD arranged in a 15-by-15 array. Tube surfaces are maintained at a uniform temperature T_w = 75°C. Calculate the total condensation rate per meter length of the tube bundle. **(08 Marks)**

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