CBCS SCHEME

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21AU51

Fifth Semester B.E. Degree Examination, Dec.2023/Jan.2024
Heat and Mass Transfer

Time: 3 hrs. Max. Marks: 100

Note: 1. ***Answer any FIVE full questions, choosing ONE full question from each module.***
2. Use of Thermodynamics, Heat transfer Data hand book is permitted.

Module-1

1 a. Discuss the three basic modes of heat transfer. Write the governing equations for the same and the governing laws. **(12 Marks)**

b. The heat flow rate across an insulating material of thickness 30 mm with thermal conductivity 0.1 W/m°C is 250 W/m^2. If the hot surface is 175°C, find the temperature of the cold surface. **(08 Marks)**

OR

2 a. Derive one dimensional heat conduction equation for rectangular or Cartesian co-ordinates, in differential form. **(10 Marks)**

b. An aircraft heat exchanger has a maximum wall temperature of 810 K. The hot and cold side heat transfer coefficients are respectively 200 W/m^{2}K and 400 W/m^{2}K. Find the maximum possible unit thermal resistance per m^2 area of the metallic wall separating the hot gas from the cold gas, if the hot gas temperature is 1200 K and the coolant temperature is 300 K. **(10 Marks)**

Module-2

3 a. Define :
   (i) Fin efficiency
   (ii) Fin effectiveness using the basic definition, arrive at the efficiency for,
   - a long fin of rectangular cross section
   - rectangular fin with insulated tip. **(10 Marks)**

b. Calculate the heat loss rate from a rectangular fin surface on a plane wall. The fin is 20 mm long, the breadth and thickness being 200 mm and 2 mm respectively. Assume negligible heat loss from the fin tip. Take $\theta_0 = 200°$ C, h = 15 W/m^{2}K and K = 45 W/mK. **(10 Marks)**

OR

4 a. Show that the temperature history of a cooling body with negligible internal resistance is given by, $\dfrac{\theta}{\theta_D} = e^{\left(\frac{-hA}{\rho C_P V}\right)t}$. **(10 Marks)**

b. A ball of 60 mm diameter at 600°C is suddenly immersed in controlled medium at 100°C. Calculate the time required for the ball to obtain a temperature of 150°C. Assume K = 40 W/mK, ρ = 800 kg/m^3, C_P = 500 J/kgK, h = 20 W/m^{2}K for the ball. **(10 Marks)**

Module-3

5 a. Using dimensional analysis, show that Nu = f(Gr, Pr) for natural convection. **(12 Marks)**

b. Find the heat loss from both sides of a hot square plate 50 cm × 50 cm at 100°C, exposed to atmosphere at 20°C, if the plate is kept vertical. Use the following relation.

$Nu = 0.13(Gr.Pr)^{\frac{1}{3}} \rightarrow$ vertical position at 60°C, take ρ = 1.06 kg/m^3, K = 0.028 W/mK
$\gamma = 18.97\times10^{-6}$ m^2/s, C_P = 1.008 kJ/kg-K . **(08 Marks)**

OR

6 a. Define the following dimensionless numbers and mention their significance, writing relevant equations:
(i) Pradtl number
(ii) Reynolds number
(iii) Nusselt number
(iv) Stanton number **(10 Marks)**

b. Air at 27°C is moving at 0.3 m/s across a 100 W electric bulb at 127°C. If the bulb is approximated by a 10 cm diameter and 1 m high cylinder, estimate the heat transfer rate and percentage of power lost due to convection. At 77°C, take Pr = 0.697, k = 0.03 W/mK, $\gamma = 2.08\times10^{-5}$ m^2/s. **(10 Marks)**

Module-4

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

b. A heat exchanger is required to cool 55000 kg/h of alcohol from 66°C to 40°C using 40000 kg/h of water entering at 5°C. Assuming parallel flow, calculate
(i) the exit temperature of water (ii) heat transfer (iii) surface area required.
Take u = 580 W/m^2K, C_P(alcohol) = 3760 J/kgK, C_p(water) = 4180 J/kgK. **(10 Marks)**

OR

8 a. Sketch and explain different regimes of boiling mechanism. **(10 Marks)**

b. Air free saturated steam at 85°C and pressure of 57.8 kPa condenses on the outer surface of 225 horizontal tubes of 1.27 cm OD arranged in a 15×15 array. Tube surface is maintained at 75°C. Find the total condensation rate per m length of the tube bundle.

Take : $h_m = 0.725\left[\dfrac{g\rho_1^2 h_{fg} K_c^3}{\mu_1(T_V - T_w)DN}\right]$

where N = Number of tubes ; D = Tube diameter,
Physical properties of water at film temperature of 80°C , K_1 = 0.668 W/m°C, $\mu_1 = 0.355\times10^{-3}$ kg/m-s, h_{fg} = 2309 kJ/kg, $\rho_1 = 974\ kg/m^3$. **(10 Marks)**

Module-5

9 a. Define the following laws of radiation, write appropriate relations. Discuss both of them :
(i) Stefan-Boltzman law
(ii) Kirchoff's law. **(12 Marks)**

b. Assuming the sun to be a black body, calculate the surface temperature of the sun and emissive power of the sun's surface. Determine the maximum monochromatic emissive power, taking maximum radiation intensity from sun at $\lambda = 0.52\ \mu$. **(08 Marks)**

OR

10 a. Define :
(i) Intensity of radiation
(ii) Solid angle
(iii) Lambert's law. **(12 Marks)**

b. Two large parallel plates are at 1000 K and 800 K. Determine the heat exchange per unit area when (i) The surfaces are black (ii) The hot surface has an emissivity of 0.9 and cold, 0.6. **(08 Marks)**

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