Register No.: .... Name: ....

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

FOURTH SEMESTER B.TECH DEGREE EXAMINATION (R), MAY 2023
CHEMICAL ENGINEERING
(2020 SCHEME)

Course Code : **20CHT204**

Course Name: **Heat Transfer Operations**

Max. Marks : **100** **Duration: 3 Hours**

Use of Photostat copies of the following equations duly attested by the concerned faculty shall be permitted in the exam hall.

1. Heisler chart and table.
2. Thermophysical property tables and charts.
Approved temperature profile Reynolds and Nusselt number relationships table.

PART A

(Answer all questions. Each question carries 3 marks)

1. Define thermal conductivity and thermal resistance. How they are related?
2. What is critical radius of insulation? Write its significance.
3. Explain natural convection and forced convection with a suitable example of each.
4. Differentiate between thermal boundary layer and hydrodynamic boundary layer.
5. State Stefan-Boltzmann law with its mathematical expression.
6. Define emissivity, absorptivity & transmissivity.
7. Draw and label a shell and tube heat exchanger having a 1-2 pass flow for cooling a hydrocarbon by using cooling water.
8. What is fouling? Write its significance.
9. What are the factors affecting the performance of an evaporator?
10. Draw and label a single effect evaporator.

PART B

(Answer one full question from each module, each question carries 14 marks)

MODULE I

11. a) A stagnant liquid film of 0.4 mm thickness is held between two parallel plates. The top plate is maintained at 40^0C and the bottom plate is maintained at 30^0C. If the thermal conductivity of the liquid is 0.14 W/(m K), calculate the steady state heat flux, assuming one-dimensional heat transfer. (4)

b) Derive the general heat conduction equation in Cartesian coordinates. (10)

OR

12. a) Derive an expression for thermal resistance of a composite slab which consist of 3 different materials having thermal conductivity k_1, k_2 and k_3 respectively. (7)

b) A metal ball of radius 0.1 m at a uniform temperature of 90^0C is left in air at 30^0C. The density and the specific heat of the metal are 3000 kg/m^3 and 0.4 kJ/(kg K), respectively. The heat transfer coefficient is 50 W/(m^2 K). By neglecting the temperature gradients inside the ball, find the time taken for the ball to cool to 60^0C. (7)

MODULE II

13. a) Heat is generated at a steady rate of 100 W due to resistance heating in a long wire (Length – 5 m, dia – 2 mm). This wire is wrapped with an insulation of thickness 1 mm that has a thermal conductivity of 0.1 W/mK. The insulated wire is exposed to air at 30^0C. Considering the heat transfer co-efficient as 10 W/m^2K, calculate the temperature at the interface between the wire and the insulation. (7)

b) Consider the flow of a gas with density 1 kg/m^3,viscosity 1.5 x 10^{-5} kg/(ms), specific heat 846 J/kg K and thermal conductivity 0.01665 W/m K in a pipe of diameter 0.01 m and length 1 m, and assume the viscosity does not change with temperature. The Nusselt number for a pipe with (L/D) ratio greater than 10 and Reynolds number greater than 20000 is given by Nu = 0.026 $Re^{0.8}Pr^{0.33}$. (7)

While the Nusselt number for a laminar flow for Reynolds number less than 2100 and (Re Pr D/L) < 10 is Nu = 1.86 $[Re\ Pr\ (D/L)]^{0.33}$. Find the heat transfer co-efficient, if the gas flows through the pipe with an average velocity of 0.1 m/s.

OR

14. a) With a neat sketch explain the thermal boundary layer for flow over a flat plate. (4)

b) A liquid of mass 7 kg and specific heat 4 kJ/(kg^{0}C) is contained in a cylindrical heater of diameter 0.15 m and height 0.4 m. The cylindrical surface of the heater is exposed to air at 25^0C while the end caps are insulated. The liquid is initially maintained at a temperature of 75^0C. At time t = 0, the heater is switched off and the temperature of the liquid in the heater decreases due to heat loss across the cylindrical surface. What is the time required for the temperature of the liquid to reduce to 50^0C after the heater is switched off? Assuming lumped system analysis is valid. (10)

Data: Thickness of the wall of the heater = 2 mm, The wall thermal conductivity = 10 W/(mK), The heat transfer co-efficient in the liquid = 100 W/(m^2K), The heat transfer co-efficient in air = 10 W/(m^2 K)

MODULE III

15. Derive an expression for the convective heat transfer co-efficient for the laminar film condensation on a vertical plate with all assumptions. (14)

OR

16. a) Explain the various regimes of boiling in detail with a neat sketch. (10)

b) Consider two black bodies with surface S_1 (area = 1 m^2) and S_2 (area = 4 m^2). They exchange heat only by radiation. 40% of the energy emitted by S_1 is received by S_2. Find the fraction of energy emitted by S_2 that is received by S_1? (4)

MODULE IV

17. a) A double pipe heat exchanger is to be designed to heat 4 kg/s of a cold feed from 20^0C to 40^0C using a hot stream available at 160^0C and a flow rate of 1kg/s. The two streams have equal capacities and the overall heat transfer co-efficient of the heat exchanger is 640 W/m^2K. Find the ratio of the heat transfer area required for the co-current to counter current modes of operation. (7)

b) Derive an expression for estimating the overall heat transfer coefficient for a shell and tube heat exchanger when it is working in a counter current mode with fouling factor. (7)

OR

18. a) A 1-2 pass shell and tube counter current heat exchanger is used to heat toluene from 20^0C to 50^0C by hot water which enters the thin walled 2 cm diameter tubes at 80^0C and leaves at 40^0C. The total length of the tubes in the exchanger is 60 m. The convection heat transfer co-efficient is 25 W/m^2 ^{0}C on the tube side (water). Find the rate of heat transfer before any fouling occurs and after fouling with a fouling factor of 0.0006 m^2 ^{0}C/W occurs on the outer surface of the tubes. (8)

b) Explain the method for calculating the number of tubes in multi pass exchanger by NTU method. (6)

MODULE V

19. a) A single effect evaporator is used to concentrate 7 kg/s of a solution from 10 to 50% solids. Steam is available at 394 K with an enthalpy of 2530 kJ/kg and evaporation takes place at 324 K with an enthalpy of 2594 kJ/kg. If the overall heat transfer co-efficient is 3 kW/m^2K, estimate the amount of steam used if the feed to the evaporator is at 294 K and the condensate leave the evaporator at 352 K. (The specific heat of 10% and 50% solution are 3.76 and 3.14 kJ/kgK) (7)

b) Explain the principle, construction and working of Calandria type evaporator. (7)

OR

20. a) With a neat sketch explain the three different feeding arrangements in multiple effect evaporator. (9)

b) Explain the importance of the terms Capacity and Economy associated with evaporators. (5)

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