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

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

FOURTH SEMESTER B.TECH DEGREE EXAMINATION (S), SEPT 2022

CHEMICAL ENGINEERING

(2020 SCHEME)

Course Code : **20CHT204**

Course Name: **Heat Transfer Operations**

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

PART A

(Answer all questions. Each question carries 3 marks)

1. Define Fourier's law of heat conduction. Write the mathematical expression for heat flux through a composite slab.
2. What is Biot number? Write its significance.
3. Differentiate natural and forced convection with an example of each.
4. Explain the thermal boundary layer with the help of a figure.
5. What is the difference between a black body, grey body and white body?
6. How the drop wise condensation differ from film wise condensation?
7. What is LMTD? What are the significances of LMTD?
8. Draw and label the shell side and tube side fluid for a 2-2 pass shell and tube heat exchanger for heating hydrocarbon by using hot water.
9. Make a classification for multiple effect evaporator on the basis of direction of flow.
10. Define capacity and economy. How it is related for multiple effect evaporator with single effect evaporator?

PART B

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

MODULE I

11. a) Explain critical radius of insulation with the help of a graph. (5)

b) A brick wall of 20 cm thickness has thermal conductivity of 0.7 $Wm^{-1}K^{-1}$. An insulation of thermal conductivity 0.2 $Wm^{-1}K^{-1}$ is to be applied on one side of the wall, so that the heat transfer through the wall is reduced by 75%. What is the required thickness of insulation for maintaining the same temperature difference across the wall before and after applying insulation? (9)

OR

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

b) Two plates of equal thickness (t) and cross-sectional area are joined together to form a composite wall. If the thermal conductivity of the plates are k and 2k, what will be the effective thermal conductivity of the composite wall? (4)

MODULE II

13. Water at 303 K enters a 25 mm ID tube at a rate of 1200 l/h. Steam condenses on the outside surface of tube of 28 mm OD at a temperature of 393 K and its film heat transfer coefficient may be taken as 600 W/m^2 K. Estimate the length of the tube required heat water to 343 K. Data: K for tube wall = 348.9 W/mK, properties of water mean temperature of 323 K are: k= 0.628 W/m K, density = 980 kg/m^3, viscosity = $6 \times 10^{-4}\,\frac{kg}{m \cdot s}$, C_P= 4.187 kJ/kg · K. (14)

OR

14. a) A hot fluid is flowing at a velocity of 2 m/s through a metallic pipe having an inner diameter of 3.5 cm and length 20 cm. The temperature at the inlet of the pipe is 90 °C. Following data is given for liquid at 90 °C. Density = 950 kg/m^3, specific heat = 4.23 kJ/kg °C, viscosity = 2.55x10^{-4} kg/m· s, thermal conductivity = 0.685 W/m °C. Find the heat transfer co-efficient inside the tube. (8)

b) Air is flowing through the outer surface of a fluid flowing pipe at a velocity of 3m/s perpendicular to the direction of fluid flow. The outer diameter of the pipe is 6 cm and the temperature at the outside surface of the pipe is maintained at 100 ^{0}C. The temperature of the air far from the tube is 30^{0}C. Kinematic viscosity of air = 18x10^{-6} m^2/s, thermal conductivity = 0.03 W/m· K. Find the rate of heat loss per unit length from the pipe to air by using Nusselt correlation: Nu = 0.024 Re$^{0.8}$. (6)

MODULE III

15. a) Explain the different regimes of boiling in detail with figure. (10)

b) The space between two hollow concentric spheres of radii 0.1 m and 0.2 m is under vacuum. Exchange of radiation (uniform in all directions) occurs only between the outer surface (S_1) of the smaller sphere and the inner suface (S_2) of the larger sphere. Find the fraction of radiation energy leaving from S_2 and which reaches S_1. (4)

OR

16. Sate your assumptions and derive an expression for convective heat transfer co-efficient in a laminar film condensation on a vertical plate with a suitable figure. (14)

MODULE IV

17. a) A countercurrent double pipe heat exchanger is used to heat water flowing at 1kg/s from 40 ^{0}C to 80 ^{0}C. Oil is used for heating and its temperature changes from 100 ^{0}C to 70 ^{0}C. The overall heat transfer co-efficient is 300 W/m^2 ^{0}C. If it is replaced by a 1-2 pass shell and tube heat exchanger with counter flow configuration with water flowing in shell side and oil in tube side, what is the excess area required with respect to the double pipe heat exchanger? (8)

Data's given: LMTD correction factor, Ft = 0.5, $C_{P,water}$=4180 J/kg ^{0}C, $C_{P,oil=}$

2000J/kg ^{0}C.
(Heat transfer co-efficient remains unchanged, and the same inlet and outlet conditions are maintained)

b) What is fouling in heat exchanger? Explain with its types, fouling factors and its effect on heat transfer rate. (6)

OR

18. a) Derive an expression for overall heat transfer co-efficient in a shell and tube heat exchanger when it is working on both co-current and countercurrent mode. (6)

b) In a double pipe counter current heat exchanger, the hot fluid is entering at 100 ^{0}C and leaves at 60 ^{0}C. The cold fluid is entering at 40 ^{0}C and leaves at 80 ^{0}C. During operation, due to fouling inside the pipe, heat transfer rate reduces to half of the original value. Find out the LMTD in the new situation by assuming that there is no change in flow rates and physical properties of the fluids. (8)

MODULE V

19. a) Explain the principle and working of long tube vertical type evaporator with a neat figure. (8)

b) An aqueous sodium chloride solution (10 wt %) is fed into a single effect evaporator at a rate of 10000 kg/hr. It is concentrated to a 20 wt % sodium chloride solution. The rate of consumption of steam in the evaporation is 8000 kg/hr. Find the evaporator capacity and economy? (6)

OR

20. a) Explain the working of Calandria type evaporator with a neat figure. (7)

b) It is desired to concentrate a 20% salt solution (20 kg of salt in 100 kg of solution) to a 30% salt solution in an evaporator. Consider a feed of 300 kg/min at 30 ^{0}C. The boiling point of the solution is 110 ^{0}C, latent heat of vaporization is 2100 kJ/kg, and the specific heat of the solution is 4 kJ/kg· K. Determine the rate at which heat has to be supplied to the evaporator to get the required concentrated product. (7)

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