Ref. No. : Ex/Che/PC/B/T/314/2023(S)

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER SUPPLEMENTARY EXAMINATION 2023

PROCESS HEAT TRANSFER

Time : Three hours Full Marks : 100

(50 Marks for each Part) Use separate answer script for each Part

PART I (50 Marks)

CO-1	1. A spherical container of negligible thickness holding a hot fluid at 140^0C and having an outer diameter of 0.4 m is insulated with three layers of each 50 mm thick insulation of $k_1 = 0.02$: $k_2 = 0.06$ and $k_3 = 0.16$ W/mK. (Starting from inside). The outside surface temperature is 30^0C. Determine (i) the heat loss, and (ii) Interface temperatures of insulating layers. **Or** 2. A spherical element of 40 mm diameter is initially at temperature of 27^OC. It is placed in boiling water for 4 minutes. After 4 minutes, at what temperature, the spherical element will reach? If the same spherical element is initially at 0^OC , find out by lump theory that how much time will be taken by the element to reach at that temperature? Take properties of the given spherical element as: $K = 10W/m^Oc$; $\rho = 1200$ kg/m^3;$C_p = 2kj/kg^OC$; $h = 100$ W/m^{2O}c	10
CO-2	A steam pipe of 10 cm ID and 11 cm OD is covered with an insulating substance k = 1W/mK. The steam temperature is 200^0C and ambient temperature is 20^0C. If the convective heat transfer coefficient between insulating surface and air is 8 W/m^{2}K, find the critical radius of insulation for this value of r_c. Calculate the heat loss per meter of pipe and the outer surface temperature. Neglect the resistance of the pipe material. **Or** A motor body is 360 mm in diameter (outside) and 240 mm long. Its surface temperature should not exceed 55°C when dissipating 340W. Longitudinal fins of 15 mm thickness and 40 mm height are proposed. The convection coefficient is 40W/m^{2o}C. determine the number of fins required. Atmospheric temperature is 30°C. Thermal conductivity = 40 W/m°C.	10
CO-3	A 70 mm thick metal plate with a circular hole of 35 mm diameter along the thickness is maintained at a uniform temperature 250^OC. Find out the associated view factors and the loss of energy to the surroundings at 27 ^{O}C, assuming the two ends of the hole to be as parallel discs and the metallic surfaces and surroundings have black body characteristics. Given : $F_{2-3} = 0.065$ and $F_{2-2} = 0$	10
CO-5	1. Hot oil enters into a counter flow heat exchanger at 150°C and leaves at 40°C. The mass flow rate of oil is 4500 kg/hr and its specific heat is 2 kJ/kg-K. The oil is cooled by water which enters the heat exchanger at 20°C. The overall heat transfer coefficient is 1400 W/m^{2}K. The exit temperature is not to exceed 80°C. Using effectiveness-NTU method, find a) Mass flow rate of water b) Effectiveness of heat exchanger c) Surface area required. 2. Write short note on Temperature Cross.	15+5

[Turn over

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B.E. CHEMICAL ENGINEERING SUPPLEMENTARY EXAM – 2023

3rd Year, 1st Semester

PROCESS HEAT TRANSFER

Use Separate Answer Scripts for Part I and Part II

PART II (50 Marks)

Time: 3 Hours (Maximum) Full Marks: 100

Answer Q1, Q2 and Q3 OR Q4

Q1. Natural Convection **[8+12=20]**

a) Define: *Rayleigh Number* and *Grashof Number*. What are the physical significances of each of them?

b) Derive the dimensionless equation for the heat transfer coefficient for natural convection in a horizontal pipe. The controlling physical variables, given below, are to be represented in terms of the fundamental dimensions length (L), mass (M), temperature (T), and time (θ). Use Buckingham's pi theorem.

$h = f(\rho, L, v, \mu, C_p, k)$

L: Length of the Pipe; μ: Absolute viscosity; v: Velocity; C_p: Specific heat; k : Thermal conductivity; h: Heat transfer coefficient; ρ: Density.

Q2. Condensation and Boiling **[7+7+3+3=20]**

a) State two differences between dropwise and film-wise condensation. Which one is greatly influenced by the presence of non-condensable gases? Explain briefly.

b) Draw a Pool Boiling Curve. Explain with the help of the pool boiling curve: a) Leiden Frost Point and b) Critical Heat Flux.

c) Write a short note on the effectiveness of nucleate boiling.

d) What are the factors on which the heat transfer coefficient of nucleate boiling depends ?

Q3. Radiation **[10]**

Consider a copper kettle that has a flat bottom with a 0.254 m diameter. Water is boiled at a rate of 22.68 kg/hr at atmospheric pressure. Find the burning out heat flux for nucleate boiling.

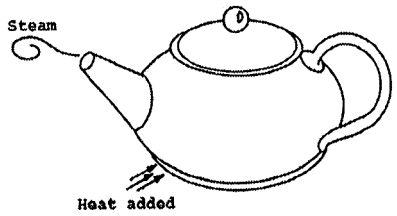

Fig. 1

Assume that the heat transfer from the surface of the kettle to the surrounding liquid takes place purely by convection until the temperature of the kettle surface is a few degrees above the boiling temperature of the liquid (pool boiling). Also, assume that steady-state conditions prevail in the system. From steam tables, at atmospheric pressure: $T_{sat} = 100°C$. $h_{fg} = 2256\ kJ/kg$; $\sigma = 0.00006\ kN/m$; $\rho_l = 961.1\ kg/m^3$; $\rho_v = 0.61\ kg/m^3$.

Q4. Evaporation **[6+4=10]**

a) Sketch the diagram of Forward Feed arrangement of a Triple-Effect evaporator.
b) Why do you think it is less energy efficient in comparison to Backward Feed evaporator. [Qualitative answer expected]