

II B.Tech II Semester Regular Examinations, Apr/May 2008**PROCESS HEAT TRANSFER****(Chemical Engineering)****Time: 3 hours****Max Marks: 80****Answer any FIVE Questions****All Questions carry equal marks**

1. A hot chamber has an 8cm thick inner layer of fire brick ($1.04 \text{ w/m}^\circ\text{C}$) and a 13cm outer layer of ordinary brick ($0.69 \text{ w/m}^\circ\text{C}$). The inside and the outside surface temperatures of the composite wall are 400°C and 75°C , respectively. Considering that the outer surface temperature is too high, it is decided to apply a 5cm thick layer of plaster on the outer surface. On doing this, the outer temperature is reduced to 60°C and the rate of heat loss decreases by 250 w/m^2 of the wall area. Calculate the thermal conductivity of the layer of plaster. [16]
2. Kerosene is to be heated from 25°C to 50°C in a heat exchanger. Flow rate of kerosene is 0.38 kg/s . It flows through the tube having inside diameter of 30 mm and outside diameter of 34 mm. Water at 94°C is used for the heating purpose. Flow rate of water is 0.125 kg/s . Outer surface area of the heat exchanger is insulated. Properties of kerosene are: Density: 815 kg/m^3 ; C_p water = $4180 \text{ J/kg}^\circ\text{K}$; C_p Kerosene = $2090 \text{ J/kg}^\circ\text{K}$; Convective heat transfer coefficient on water side = $1350 \text{ w/m}^2^\circ\text{K}$; Convective heat transfer coefficient kerosene side = $730 \text{ w/m}^2^\circ\text{K}$. Thermal conductivity = $380 \text{ w/m}^\circ\text{K}$. Calculate the length of heat exchanger in a parallel flow and counter flow arrangement. [16]
3. For a certain forced convection process, the following correlation applies: $Nu = 0.031 (Re)^{0.75} (Pr)^{0.3}$. Work out the percentage change in the rate of heat flow per degree temperature difference when the original coolant is replaced by another fluid having viscosity equal to two thirds that of the original coolant. Assume that the other fluid variables and configuration remain the same. [16]
4. Estimate the heat transfer from a 40 w incandescent bulb at 127°C to 27°C quiescent air. Approximate the bulb as a 50 mm diameter sphere. What percentage of the power is lost by free convection. $Nu = 0.6 (Gr Pr)^{1/4}$. Density = 994 kg/m^3 ; thermal conductivity = $0.628 \text{ W/m}^\circ\text{K}$; Kinematic viscosity = $0.658 \times 10^{-6} \text{ m}^2/\text{s}$; $Pr = 4.876$ [16]
5. (a) Write a note on radiation in film boiling
(b) Explain drop wise and film condensation [16]
6. (a) Describe with reasons the types of leakages that can occur in shell and tube heat exchanger.
(b) How does the shell side and tube side fluids in a heat exchanger are decided. [8+8]
7. (a) Classify the types of evaporators with industrial application.

- (b) Explain the long vertical tube evaporator with a neat sketch. [16]
8. (a) Define the properties emissivity and absorptivity. When are these two properties equal.
- (b) Define the properties reflectivity and transmissivity and discuss the different forms of reflection.
- (c) What is a gray body? How does it differ from a black body? What is a diffusive gray surface?
- (d) Discuss the advantages of using radiation shields. [16]

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1. The wall of a cold storage consists of three layers - an outer layer of ordinary bricks, 25mm thick, a middle layer of cork, 10cm thick and an inner layer of cement, 6cm thick. The thermal conductivities of the materials are: Brick ($0.7 \text{ W/m}^\circ\text{K}$); Cork ($0.043 \text{ W/m}^\circ\text{K}$); cement ($0.72 \text{ W/m}^\circ\text{K}$); the temperature of the outer surface of the wall is 30°C and that of the inner surface is -15°C . Calculate the
 - (a) Steady state rate of heat gain per unit area of the wall
 - (b) The temperature at the interfaces of the composite wall
 - (c) The % of the total heat transfer resistance offered by the individual layers.

[16]
2. Explain the different types of flows used in heat exchangers and draw the temperature profiles.

[16]
3. Air at 35°C and atmospheric pressure flows over a flat plate at a velocity of 2.4 m/s . The plate is maintained at 115°C . The length of the plate is 2.2 m . Calculate the rate of heat transfer per unit width by exact method. Properties of air are : Density = 1.015 kg/m^3 ; Specific heat = $1009 \text{ J/kg}^\circ\text{K}$; thermal conductivity = $0.03 \text{ W/m}^\circ\text{K}$; viscosity = $2.065 \times 10^{-5} \text{ N-s/m}^2$.

[16]
4. Water available at 24°C is heated by a heating element having 30 mm outside diameter and 0.4 m length. The heating element is dipped in water. Surface temperature of heating element is 80°C . Properties of water at average temperature are: Density = 988 kg/m^3 ; Viscosity = $0.55 \times 10^{-3} \text{ N-s/m}^2$; Specific heat = $4180 \text{ J/kg}^\circ\text{C}$; thermal conductivity = $0.64 \text{ W/m}^\circ\text{C}$; Pr = 3.592 ; Volume coefficient of expansion = $3.37 \times 10^{-3} \text{ }^\circ\text{K}^{-1}$. Calculate the average value of heat transfer coefficient over the entire length of the heating element and total heat transferred to water by the heating element.

[16]
5. (a) Write briefly on
 - i. Condensation of super heated vapors
 - ii. Drop wise condensation
 - iii. Film condensation(b) Explain the effect of non condensable gases on rate of condensation

[16]
6. Ethanol is vaporized at 78°C (hfg = 846 kJ/kg) in a double pipe parallel flow heat exchanger at a rate of 0.03 kg/s by hot oil ($C_p = 2200 \text{ J/kg}^\circ\text{C}$) that enters at 120°C . If the heat transfer surface area and the overall heat transfer coefficients

are 7.8 m^2 and $210 \text{ W/m}^2 \text{ } ^\circ\text{C}$, respectively, determine the outlet temperature and the mass flow rate of the oil using

(a) the LMTD method and

(b) the ϵ - NTU method. [16]

7. (a) Explain boiling point elevation and Duhring's rule.

(b) Explain the effect of liquid head and friction on temperature drop with respect to long tube vertical evaporator. [16]

8. A thin aluminium sheet with an emissivity of 0.15 on both sides is placed between two very large parallel plates, which are maintained at uniform temperatures 900°K and 650°K and have emissivities 0.5 and 0.8, respectively. Determine the net rate of the plates and compare the result with and without the shield. [16]

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1. Consider a 3m high, 5m wide and 0.3m thick wall whose thermal conductivity is $0.9 \text{ W/m}^\circ\text{C}$. On a certain day, the temperature of the inner and the outer surfaces of the wall are measured to be 16°C and 2°C respectively. Determine the rate of heat loss through the wall on that day. [16]
2. A concentric tube heat exchanger is used to cool methyl alcohol. Methyl alcohol flows through the tube while water flows through the annulus. The following data is available. ID of inner pipe = 25mm and OD of inner pipe is 30mm. Thermal conductivity of metal pipe is $43 \text{ W/m}^\circ\text{K}$. Film coefficient of heat transfer from methyl alcohol is $1060 \text{ W/m}^2^\circ\text{K}$. film coefficient of heat transfer for water is $1850 \text{ W/m}^2^\circ\text{K}$. Dirt coefficient on inner side of the pipe is $0.000167 \text{ m}^2^\circ\text{K/W}$. Dirt coefficient on outside of pipe is $0.00033 \text{ m}^2^\circ\text{K/W}$. Calculate the overall heat transfer coefficient on the inner surface of the pipe and on the outer surface of pipe when, wall resistance is included and also when the wall resistance is neglected. [16]
3. Water at a rate of 0.015 kg/s is heated from 20°C to 48°C in a steel tube of 25 mm diameter. Steam is used for heating and it condenses on the outer surface of the tube. Wall temperature is maintained at 108°C . The flow is fully developed. Calculate the value of heat transfer coefficient and the length of the tube required. [16]
4. Water available at 24°C is heated by a heating element having 30 mm outside diameter and 0.4m length. The heating element is dipped in water. Surface temperature of heating element is 80°C . Properties of water at average temperature are: Density = 988 kg/m^3 ; Viscosity = $0.55 \times 10^{-3} \text{ N-s/m}^2$; Specific heat = $4180 \text{ J/kg}^\circ\text{C}$; thermal conductivity = $0.64 \text{ W/m}^\circ\text{C}$; Pr = 3.592; Volume coefficient of expansion = $3.37 \times 10^{-3} \text{ }^\circ\text{K}^{-1}$. Calculate the average value of heat transfer coefficient over the entire length of the heating element and total heat transferred to water by the heating element. [16]
5. At a low overall ΔT the boiling heat flux for a tube bundle is about 4 times that for a single tube, but at a high ΔT the flux is much lower than that for a single tube. Give a logical explanation of the difference. [16]
6. (a) How is a heat exchanger cleaned? Give the answer with respect to the tube side shell side of a fixed head / floating head exchanger.
(b) Explain the factors responsible for deterioration of performance of heat exchanger with time. [8+8]

7. A 5% aqueous solution of a high molecular weight solute has to be concentrated to 40% in a forward feed double effect evaporator at the rate of 8000 kg/hr. The feed temperature is 40 °C. Saturated steam at 3.5 kg/cm² is available. A vacuum of 600 mm Hg is maintained in the second effect. Calculate the area requirements, if calandrias of equal areas are used. The overall heat transfer coefficients are 550 kcal /h m² °C and 370 kcal /h m² °C in the first and the second effect respectively. The specific heat of concentrated liquor is 0.87 kcal/kg °C. [16]
8. Two very large parallel plates are maintained at uniform temperatures of T₁ = 800 °K and T₂ = 500°K and have emissivities of 0.2 and 0.7 respectively. Determine the net rate of radiation heat transfer between the two surfaces per unit surface area of the plates. [16]

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1. (a) The inner surface of a thick invar cylinder ($k = 10.7 \text{ W/m}^0\text{K}$) of ID 2 cm and OD 12 cm is held at 150°C , while the outer furnace is at 50°C . Calculate the temperatures at $r = 2, 3, 4$ and 5 cm .
(b) A steel pipe of 5 cm OD is covered with 0.5 cm asbestos ($k = 0.1105 \text{ W/m}^0\text{k}$) followed by 0.5 cm thick glass wool ($k = 0.038 \text{ W/m}^0\text{C}$) insulation. It was found that the insulation temperature reached a steady state value of 40°C , while the pipe surface is at 150°C and the atmospheric air to which the insulated pipe is exposed to 25°C . Determine the temperature at the interface of the asbestos and glass wool and the film coefficient between the glass wool and atmospheric air. [16]
2. (a) In a parallel flow double pipe heat exchanger, the hot fluid enters the heat exchanger at 90°C and leaves at 50°C , while the cold fluid enters the heat exchanger at 20°C and leaves at 40°C . Calculate the LMTD.
(b) In a counter current double pipe heat exchanger, the hot fluid enters at 200°C and leaves at 100°C , while the cold fluid enters the heat exchanger at 20°C and leaves at 80°C . Calculate the LMTD. [8+8]
3. Calculate the heat transfer coefficient for a fluid through a tube having 6.0m length and 16 mm inside diameter. Fluid flow rate is 0.33 kg/s. Also calculate the heat transfer coefficient if the flow rate is reduced to 0.01 kg/s. Data: Density = 985 kg/m^3 ; $C_p = 4190 \text{ J/kg}^0\text{K}$; Viscosity = $0.5 \times 10^{-3} \text{ N-s/m}^2$; Thermal conductivity = $0.66 \text{ W/m}^0\text{K}$. [16]
4. (a) Write the heat transfer correlations for free convection.
(b) Differentiate between free convection and forced convection with examples. [8+8]
5. (a) Explain pool boiling
(b) Write briefly on
 - i. Critical temperature drop
 - ii. nucleate boiling[16]
6. (a) How is a heat exchanger cleaned? Give the answer with respect to the tube side shell side of a fixed head / floating head exchanger.
(b) Explain the factors responsible for deterioration of performance of heat exchanger with time. [8+8]

7. (a) What are the advantages and limitations of different types of evaporators.
(b) Make a list of ten examples of industrial evaporation operation. [16]
8. A black body of total area 0.045 m^2 is completely enclosed in a sphere bounded by 5 cm thick walls. The walls have a surface area 0.5 m^2 and the thermal conductivity is $1.1 \text{ W/m}^\circ\text{C}$. If the inner surface of the enveloping wall is to be maintained at 215°C and the outer wall surface is at 30°C , calculate the temperature of the black body. Black body radiation constant is $5.67 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$. [16]
