Code No: 07A40801 **R07** **Set No. 2**

II B.Tech II Semester Examinations,December 2010
PROCESS HEAT TRANSFER
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. Atmospheric air is between two parallel, vertical plates separated by 2.5cm. The plates, which are 1.8m high and 1.2m wide, are at temperature of 50 ^{0}C and 4 ^{0}C, respectively. Estimate the heat transfer across the air space by natural convection. Nu = 0.18 $(Gr)^{1/4}(L/b)^{-1/9}$. thermal conductivity = 0.02624 W/m ^{0}K; Kinematic viscosity = 15.68×10^{-6}m^2/s; [16]

2. (a) Define biot no. and fourier number and explain their physical significance in unsteady heat transfer.

   (b) A stain less steel ball 50mm in diameter and initially at a uniform temperature of 450^{0}C is suddenly placed in a controlled environment in which the temperature is maintained at 100^{0}C. The convection heat transfer coefficient is 9w/m^{2o}C. Specifie heat of ball is 0.46kJ/kg^{0}c and thermal conductivity of the ball is 35w/m^{0}C. Calculate the time required for the ball to attain a tempertature of 120^{0}C. [6+10]

3. (a) What is the significance of heat transfer coefficient. Write the units of heat transfer coefficient.

   (b) Hot oil is used to heat water, flowing at the rate of 0.1 kg/s from 40 ^{0}C to 80^{0}C in a counter flow double pipe heat exchanger. For an overall heat transfer coefficient of 300 w/m^2 ^{0}K, find the heat transfer area if the oil enters at 105 ^{0}C and leaves at 70 ^{0}C. [4+12]

4. (a) A heat exchanger is to cool organic liquid from 105 to 50^{0}C. The hot fluid liquid flow rate is 2.8 kg/sec. cooling medium is water which enters at 25^{0}C and leaves at 40^{0}C. It is proposed to use 1-2 heat exchanger for the above duty.
   Specific heat of water= 4180 J/kg ^{o}k.
   Specific heat of hot liquid = 26850 J/kg ^{o}k.
   LMTD correction factor = 0.85.
   Over all heat transfer coefficient is 600 W/m^{2o}k.
   Calculate the heat transfer area for a heat exchanger.

   (b) A hot process stream available at 300^{0}C is to be cooled to 200^{0}C. The heat is used for heating cold stream from 25^{0}C to 175^{0}C. Calculate the log mean temperature difference if the streams flow in counter current manner and co current manner.

   [10+6]

5. A solution of organic collides is to be concentrated from 15 to 50 % solids in a vertical- tube evaporator. The solution has a negligible elevation in boiling points, and the specific heat of the feed is 0.93. Saturated steam is available at 0.8 atm abs, and the pressure in the condenser is 100mm Hg abs. the feed enters at 15^0C. The overall coefficient is 1700W/m^2 ^{0}C. The evaporator must evaporate 25,0000kg of water per hour. How many square meters of surface are required, and what is the steam consumption in kilogram per hour. [16]

6. A Vertical tubular condenser is to be used to condense 650 kg/hr of ethyl alcohol, which enters at a atmospheric pressure. Cooling water is to flow through the tubes at an average temperature of 30^0C, The tubes are 2.5 cm OD and 2.1 cm ID. The water side coefficient is 2440 Kcal/m^2 hr ^{0}C. If the available tubes are2.5m long. Calculate the number of tubes required for the job.
Data : Condensation Temperature of Alcohol : 78^0C
Heat of Vaporization = 205 Kcal/Kg
Density of Alcohol = 768/kg/m^3. [16]

7. A thermocouple shielded by aluminium foil of emissivity 0.1 is used to measure the temperature of hot gasses flowing in a duct whose walls are maintained at 380^ok. The thermometer shows a temperature reading of 530^ok. Assuming the emissitivity of the thermocouple junction be 0.8 and the convection heat transfer coefficient be 120w/m^{2o}C, determine the actual temperature of the gas. [16]

8. Air flowing at 4.75m/s through a pipe of inner diameter of 0.025m is used for cooling a nuclear reactor. Air enters the pipe at 15 ^{0}C and the surface temperature of the pipe is maintained at 150 ^{0}C. Find the following: the exit temperature of the air and the total heat transfer rate for a pipe length of 5m using Colburn analogy.
Data: Density = 1 kg/m^3; C_p = 1.01 KJ/kg ^{0}K ; Viscosity = 2.03*10^{-5} PaS; Thermal conductivity = 0.03 w/m ^{0}K; The skin friction may be computed from, f = 0.0014 + 0.125 $Re^{(-0.32)}$. [16]

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PROCESS HEAT TRANSFER
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. The two concentric spheres of diameter D1 = 20 cm and D2 = 30 cm are separated by air at 1 atm pressure. The surface temperature of the two spheres enclosing the air are T1 = 320 ^{0}K and T2 = 280 ^{0}K, respectively. Determine the rate of heat transfer from the inner sphere to the outer sphere by natural convection. Use Nu = 0.228 $(\text{Gr Pr})^{0.226}$; K = 0.0261W/m ^{0}C; Pr = 0.712; Kinematic viscosity = 1.57 $\times 10^{-5}$ m^2/s [16]

2. (a) Two equal, parallel black disks each of diameter 0.5m, are located 0.25m apart, directly opposing each other. If the temperature s of the discs are, respectively, 200^0C and 50^0C, find out the net radiation heat transfer rate between the discs.
   (b) Two very large, parallel gray bodies have surface emissivities of 0.8 and 0.7, respectively, with their temperatures being held at 800^0C and 1500^0C. Determine the rate of net radiative energy exchange between the two. Find the percentage decrease in net heat transition if a radiation shield of polished aluminum of surface emissivity 0.04 is held between them. [6+10]

3. (a) Write the limitations of LMTD.
   (b) In a food processing plant a brine solution is heated from 6^0C to 12^0C in a double pipe heat exchanger by water entering at 50^0C and leaving at 40 ^{0}C at the rate of 0.166 kg/s. If the overall heat transfer coefficient is 850 w/m^2 ^{0}C, What heat exchanger area is required for a parallel flow and counter flow. [4+12]

4. Air is heated by passing it through a tube of 2.5 cm diameter and with a velocity of 6m/sec. Find the heat transfer coefficient and heat flow from tube of one meter length to the air assuming the tube wall temperature is maintained at 150^oC. The mean temperature of air is 50^oC. The properties of air are as follows:
   Density=0.946kg/m^3, specific heat =0.241Kcal/kg ^{o}C,
   Thermal conductivity =0.0276kcal/mhr^{o}C,
   Viscosity = 22×10^{-6} kg/m-s Kinematic viscosity = 23.13x10^{-6}.m^2/sec [16]

5. (a) With diagrams give the different types of feeding in a multiple effect evaporator?
   (b) A solution of organic colloids is to be concentrated from 20 to 50 % solids in a vertical tube evaporator the solution has a negligible elevation in boiling point, and the specific heat of the feed is 0.93. Saturated steam is available at 0.7 atm.abs, and the pressure in the condenser is 100mm hg. Abs. The feed enters at 20 ^{0}C. The over all coefficient is 1700 w/m2 ^{0}C. The evaporator

must evaporate 20,000 kg of water/hr. How many square meters of surface are required, and what is the steam consumption in kg/hr. [6+10]

6. (a) Find out the length of the tube required for the following heat transfer where air is heated by exhaust gases.
   Q (heat transfer/hr) = 8000 Kcal
   Inside (D_i) and outside diameter (D_0) of tube are 5 cm and 6 cm respectively.
   h_i (Inside heat transfer coefficient Air side) = 100 Kcal /m^2 hr^{0}C
   h_0 (out heat transfer coefficient gas side) = 160 Kcal/m^2 hr ^{0}C
   T_{hi} = 400 ^{0}C T_{ho} = 150 ^{0}C T_{ci} = 50 ^{0}C T_{co} = 100 ^{0}C.
   Neglect the tube resistance and assume flow arrangement is parallel If the flow is made counter current then what is the percentage saving in the tube length.

   (b) Write the applications of extended surface heat exchangers. [12+4]

7. (a) Differentiate between, pool boiling and boilling; saturated Briling and subscribed Briling

   (b) Write briefly on.
      i. Critical temperature drop.
      ii. nucleate boiling. [8+8]

8. (a) What is meant by a lumped capacity analysis? What are the physical assumptions necessary for a lumped capacity analysis to apply?

   (b) A steel ball 80mm in diameter is intially at 485^0c. It is suddenly dipped in a both having uniform temperature of 85^0c the connective heat transfer coefficient at the surface of the ball $20w/m^2\ ^o$k. Calculate the time required to gain a temperature of 115^0C..
   Physical properties of steel ball
   specifie heat = $460w/m^ok$, Density = $7800\,kg/m^3$ thermal conductivity = $43w/m^ok$. [6+10]

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1. Liquid mercury at the rate of 1.5 kg/s, flows through a copper tube having inside diameter 25mm. Mercury enters the tube at 20 ^{0}C and leaves at 30 ^{0}C. The tube surface is maintained at a uniform temperature of 50 ^{0}C. Properties of mercury at average temperature are: Density = 13582 kg/m^3; thermal conductivity = 8.69 w/m ^{0}K; specific heat = 140 J/kg ^{0}K; Calculate the tube length required for the operation. Use Nu = 7 + 0.025 (Re Pr)$^{0.3}$. [16]

2. (a) Show that coefficient of thermal expansion of an ideal gas equals the reciprocal of absolute temperature.
   (b) What is Peclet number?
   (c) Define Grashof number and write the units of each parameter. [6+5+5]

3. A solution containing 10% solids is to be concentrated to 50% solids in a single effect evaporator. The steam is supplied at 2 bar (120.5^{o}C). Vacuum is maintained in the vapour space at 0.12 bar (52^{o}C).
   Feed rate to the evaporator is 7 kg/sec.
   Feed is supplied at 52^{o}C. The overall heat transfer coefficient is 2000 W/m^{2o}k.
   Specific heat of feed solution = 3770 J/kg.
   Latent heat of condensation of steam = 2200 kJ/kg.
   Latent heat of vaporization of water = 2378 kJ/kg.
   Calculate:
   (a) Quantity of water evaporated.
   (b) Steam economy.
   (c) Heat transfer area for the evaporator. [16]

4. (a) Classify heat exchangers and write their importance for Industrial use.
   (b) Hot oil flowing through a tubular heat exchanger at the rate of 46kg/s. It enters at 380^{0}C and leaves at 280^{0}C. cooling is affected by circulating cold oil that enters at 30^{0}C and leaves at 200^{0}C. If the overall heat transfer coefficient is 1000w/m^{o}k. Calculate the heat transfer area required for parallel flow and also for counter flow specific heat of hot oil is 5.2kJ/kg^{o}k and for cold oil is 4.8kJ/kg^{o}k. [8+8]

5. Water, at the rate of 4080 kg/h, is heated from 35^{0}C to 65^{0}C, by using an oil having a specific heat of 1900 J/kg ^{0}k. The heat exchanger used for the purpose of above heat transfer is at 1 shell-1 Tube, parallel-flow, multi-tubular heat exchanger, with oil entering the shell at 110^{0}C and leaving the shell at 75^{0}C. Determine the design area of the heat exchanger necessary to handle the load, if the overall heat transfer coefficient is estimated to be 32 w/m^{2}k. What would be the solution if the heat exchanger were to operate in counter-current mode? [16]

6. Saturated steam at 1.8 bar pressure and 118^0C condenses on a 38mm outside diameter vertical tube which is 1m long. The tube wall is maintained at 100^0C. Calculate.

   (a) The average film coefficient of steam.

   (b) Rate of condensation of steam.
   Data: Latent heat of condensation = 2239 KJ/kg Density = 947 kg/m^3 viscosity = 0.25×10^{-3} N-s/m^2 Thermal Conductivity = 0.685 W/m^ok. [16]

7. (a) A pipe carrying steam having an outside diameter of 20cm runs in a large room and is exposed to air at a temperature of 30^0C. the pipe surface temperature is 400^0C. Calculate the loss of heat to surroundings per meter length of pipe due to thermal radiation. The emissivity of the pipe surface is 0.8.
   What would be the loss of heat due to radiation if the pipe is enclosed in a40cm diameter brick conduit of emissivity 0.91.
   $\sigma = 5.669\times 10^{-8}$ w/m^2 $^o K^4$.

   (b) Emissivities of two large parallel plates maintained at 800^0C and 300^0C are 0.3 and 0.5respectively. Find the net radiant heat exchange per square metre for these plates. $\sigma = 5.669\times 10^{-8}$ w/m^2 K^4. [10+6]

8. (a) Derive an expression for the heat transfer rate through hallow sphere of having inside radius r_1 and outside radius r_2 and where internal and external surfaces are maintained at temperatures T_1 and T_2 respectively. The thermal conductivity of the sphere material has a quadrate variation with temperature $K = K_0(1 + \alpha T + \beta T^2)$

   (b) 10mm thick stainless steel plate is maintained at 110^0C at one side and the otherside is at 90^0C. Under steady state conditions, calculate the rate of heat transfer per unit area through the plate. The thermal conductivity of the plate is 17W/m^0c [10+6]

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Code No: 07A40801 **R07** **Set No. 3**

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PROCESS HEAT TRANSFER
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. A tube 15cm OD and 1m long is used in a condenser to condense the steam at 0.5 atm. Estimate the heat transfer/ unit area.
   (a) In vertical position
   (b) horizontal position.
   Also find out the amount of condensate formed/hr in both cases
   Saturation temp of the steam = 75.4 ^{0}C. Average wall temperature = 50^{0}C
   K = 0.586 kcal/m hr ^{0}C Vicosity = 1.59 kgf-sec/m^2
   Density = 972.5 kg/m^3 λ = 591.4 Kcal / m hr ^{0}C. [16]

2. A cross flow heat exchanger with both fluids unmixed is used to heat water (C_p = 4.181 KJ/kg ^{0}K) from 40 ^{0}C to 80 ^{0}C, flowing at the rate of 1.0 kg/s. What is the overall heat transfer coefficient if hot engine oil (C_p = 1.9 KJ/kg ^{0}K), flowing at the rate of 2.6 kg/s enters at 100 ^{0}C. The heat transfer area is 20 m^2. The correction factor is 0.81. [16]

3. The vertical 0.8m high, 2m wide double pane window consists of two sheets of glass separated by a 2 cm air gap at atmospheric pressure. If the glass surface temperature across the air gap are measured to be 12 ^{0}C and 2 ^{0}C, determine the rate of heat transfer through the window by natural convection. Use Nu = 0.197 (Gr Pr)$^{1/4}$ (H/δ)$^{-1/9}$; K = 0.0246 W/m ^{0}C; Pr = 0.717; Kinematic viscosity = 1.40 × 10^{-5} m^2/s [16]

4. (a) Determine the net heat transfer by radiation between the two surfaces A and B per hour per unit area if the temperatures of A and B are 800^{0}C and 350oC respectively. Emissivities of A and B are 0.9 and 0.25 respectively. Both surfaces are gray and are infinite parallel lines, 3.5 m apart.
   (b) Explain the significance of Stefan-Boltzmann's law. [10+6]

5. (a) What are the various mehtods available for the estimation of unsteady state heat transfer. Explain in brief any one of the method.
   (b) A large piece of beef 20cm in thickness is intially at 40^{0}c it is to be cooled so that the temperature at the centre of the piece is 8^{0}C. Chilled air at 1.0^{0}c is circulated for chilling purpose. convective heat transfer coefficient at the surface of the beef is $35w/m^2k$ and density 1080 kg/m^3 and specifie heat is 34900 j/kg and thermal conductivity of beef is 0.5w/mk calculate the time needed for chilling the beef. [8+8]

6. 8000kg/hr of alcohol is to be cooled from 60^0C to 40^0C in a shell and tube heat exchanger using 6000kg/hr of water entering at 10^0C. The over all heat transfer coefficient is 500 kcal/hr m^{2o}C. If the outer diameter of the tubes of the exchanger is 2.5cm, calculate the number of tubes of each 2 metre length required for he exchanger, when the flow of fluids is counter-current.
   Specific heat for alcohol = 0.9 kcal/kg ^{0}C.
   Specific heat of water = 1.0 kcal/kg^{0}C. [16]

7. A single effect evaporator is to concentrate 9070 kg/hr of a 20% solution of NaOH to 60% solids. The gauge pressure of the steam is 1.5 kgs/cm^2. The absolute pressure in the vapour space is 100mm Hg. The feed temperature is 38^0C and the overall heat transfer coefficient is 1220 Kcal/m^2 hr ^{0}C (1420W/m^{0}2 K). Calculate the steam consumption, economy and the heating surface required.
   DATA: Boiling point of water at 100mm Hg = 51^0C
   Boiling point elevation = 56^0C
   Enthalpy of feed at 38^0C = 30.6 Kcal/Kg
   Enthalpy of Thick Liquor = 156 Kcal/Kg. [16]

8. For forced convection heat transfer in laminar flow over a flat plate show that average Nusselt number = 0.664 $Npr^{0.33}$ $Nre^{0.5}$. [16]

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