III B.Tech. I Semester Supplementary Examinations, May -2005
HEAT TRANSFER
(Chemical Engineering)

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

Answer any FIVE Questions
All Questions carry equal marks

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1. A 15mm dia steel sphere ,k = 42W/m^0C, is exposed to cooling airflow at 20^0C resulting in the convective coefficient h = 120 W/m^2.C. Determine
   (a) Time required to cool the sphere from 550 to 90^0C
   (b) Instantaneous H T rate 2 min. after the start of the cooling
   (c) Total energy transferred from the sphere during the first 2 min. Data: Density = 7850 kg/m^3, C_p = 475 J/kg^0C and α=0.045 m^2/h

2. The outside and inside surface temperatures of a 20cm outer diameter and 18cm inner diameter pipe (k=40w/mk) are 400^oC and 460^oC respectively. Calculate the reduction in heat loss if a 5cm layer of insulation (k=0.06 w/mk) is put on the pipe. Assume that the inner and outer surface temperature of insulation is 390^oC and 140^oC . What is the inside surface temperature of this pipe in this case?

3. (a) What is dimensional analysis? Explain any one method of dimensional analysis?
   (b) Ethylene glycol enters a 5 m length of 0.1m diameter copper tube in a cooling system at a velocity of 5 m/s. Estimate the heat transfer rate if the average bulk temperature is 20^0C and the tube wall is maintained at 100^0C. The properties of ethylene glycol at 20^0C are as follows.
   Thermal conductivity is 0.249 W/m^0K
   Kinematic viscosity is 1.92 $\times$ 10^{-5} m^2/s
   Pr = 204.

4. Benzene is cooled from 61^0C to 21^0C in the inner pipe of a double pipe heat exchanger. Cooling water flows countercurrently to the benzene, entering the jacket at 16^0C and leaving at 27^0C. The linear velocity of benzene is 1.52 m/s and that of the water is 1.25 m/s. Neglecting the wall and scale resistances, compute the film coefficients of the benzene and water and the overall coefficient based on the outside area of the inner pipe. The inner diameter and outer diameter of the inner tube are 0.0189 m and 0.0222 m respectively. The inside diameter of the jacket is 0.0409 m. The physical properties of benzene and water at the average temperatures are given in the table below:

Property	Benzene	Water
Density kg/m^3	851	998
Viscosity kg/m-s	4.795 $\times$ 10^{-4}	9.67$\times$ 10^{-4}
Thermal conductivity W/ (m.K)	0.1549	0.598
Specific heat kJ/(kg.K)	1.8212	4.187
Viscosity correction factor	0.969	1.018

5. Show that the Heat transfer coefficient for film type condensation over a vertical plate is $h = 0.943 \left(\frac{k_f^3 \rho_f^2 g \lambda}{\Delta T_o L \mu_f}\right)^{1/4}$

6. (a) Making use of the Plank's law of distribution, establish the relation for the Wein's displacement law.
   (b) The sun emits maximum radiation at $\lambda = 0.52\ \mu$. Assuming the sun to be a black body, calculate the surface temperature of sun and the emissive ability of the sun's surface at that temperature.
   (c) Determine the maximum monochromatic emissive power of the sun's surface.

7. (a) Discuss the advantages of NTU method over the LMTD method in the design of heat exchanger
   (b) Classify various types of evaporators with industrial applications.

8. (a) With a neat diagram, explain the working of a Floating head Heat Exchanger.
   (b) With a neat diagram, explain the working of a forced circulation evaporator.

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3. (a) How the local and average convection coefficients for flow past a flat plate are related? Derive the relationship.
   (b) Water at 75^0C flows through a 0.005 m diameter tube with a velocity of 1m/s. If the tube wall temperature is 25^0C, make calculations for the heat transfer coefficient. Use the correlation,
   St = 0.023 $Re^{0.2}$ $Pr^{-0.667}$.
   The thermo-physical properties of water are:
   Thermal conductivity is 0.647 W/(m.K) Viscosity is 1.977 kg/h.m
   Density is 1000 kg/m^3 Specific heat 4.187 kJ/(kg.K)

4. (a) Determine the hydraulic radius for the following cross sections:
      i. Circular tube of diameter D
      ii. Square tube of dimensions s × s.
   (b) Estimate the heat transfer from a 40 W incandescent bulb at 125^0C to 25^0C in quiescent air. Approximate the bulb as a 0.05 m diameter sphere. What percentage of the power is lost by free convection? The appropriate correlation for the free convection coefficient is Nu=0.60$(GrPr)^{0.25}$ where the different parameters are evaluated at the mean film temperature and the characteristic length is diameter of the sphere. The properties at mean temperature are
   Thermal conductivity is 0.03 W/(m.K)
   Kinematic viscosity is 20.55 × 10^{-6} m^2/s
   Pr = 0.693.

5. (a) Write a short notes on pool boiling of saturated liquid.

(b) Explain the effect of pressure on maximum boiling heat flux and critical temperature drop.

6. (a) List the salient features of a black body radiation.
   (b) Calculate the radiant flux density from a black body at 400 C.
   (c) If the emitted radiant energy is to be doubled, to what temperature surface of the black body be raised?

7. Cold water at the rate of 4 Kg/sec is heated from30^oC to 50^oC in a single shell and two tube pass heat exchanger. Heating medium is hot water supplied at 95^oC at the rate of 2 Kg / sec. Cold water flows through the tubes. The overall heat transfer coefficient is 1330 W/m^{2o}C. The average water velocity is 0.38 m/sec inside the tubes. The diameter of tube is 2 cms. Calculate
   (a) Number of tubes in each pass
   (b) Length of tube in each pass
   Take specific heat of water to be constant at 4.17 kJ/kg.k.

8. A fruit juice solution of 15% concentration is evaporated to a final concentration of 75% at a rate of 250 litre/hr of feed in a vacuum pan evaporator with heating coils. Vacuum is adjusted continuously such that the solution boils at only $60o^C$ always. Steam at 120^oC is used in the coils for heating, average overall heat transfer coefficient is 2513 kJ/hrm^{2o}C. Estimate the heating surface area required. State your assumptions clearly. Given: Mean specific gravity of feed solution is 1.4 and specific heat is 3.56 kJ/kg^oC.
   λ of steem = 2197 kJ/kg
   λ in vapour space = 2375 kJ/kg.

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Code No: RR310803 **Set No.3**

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1. Heat is flowing through an annular pipe of inside radius r_0 and outside radius r_1. The thermal conductivity varies linearly with temperature from k_0 at T_0 to $k_1$at T_1. Develop an expression for heat flow through the pipe. Simply the expression assuming that r_1-r_0 is very small.
   Interpret the result physically.

2. (a) Develop an equation for rate of heat transfer from a composite wall.
   (b) Determine the loss of heat transferring through wall (L=5m, h=10m, t=250mm) laid from red brick (k=0.7 w/m 0C) if the temperature on the wall surfaces are maintained constant. T1=150^oc T2=80^oC.

3. (a) Define Reynolds number. Why is it important?
   (b) What is Dittus-Boelter equation? When does it apply?
   (c) A vertical plate at 100^0C is 1 m wide and 20 cm high. It rests in still air at 1 atm and 20^0C. Determine the local heat transfer coefficient at 10 cm from the leading edge of the plate. The properties of the air at film temperature may be taken as: Thermal conductivity is 0.03 W/(m.K)
   Viscosity is 2.03$\times$ 10^{-5} PaS
   Density is 1.00 kg/m^3.
   Specific heat 1.01 kJ/(kg.K)

4. Air flowing at 4.75 m/s through a pipe of inner diameter of 0.025 m is used for cooling a nuclear reactor. Air enters the pipe at 15^0C and the surface temperature of the pipe is maintained at 150^0C. Find the following:
   (a) the exit temperature of air, and
   (b) the total heat transfer rate for a pipe length of 5 m using Colburn analogy.

   The average fluid properties may be taken as:
   Thermal conductivity is 0.03 W/(m.K)
   Viscosity is 2.03 $\times$ 10^{-5} PaS
   Density is 1.00 kg/m^3.
   Specific heat 1.01 kJ/(kg.K)
   The skin friction may be computed from f = 0.0014 + 0.125 $Re^{-0.32}$

5. 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^oC, The tubes are 2.5 cm OD and 2.1 cm ID.

The waterside coefficient is 2440 Kcal/m^2 hr_oC. Neglect fouling factors and the resistance of the metal wall. If the available tubes are 2.5m long. Calculate the number of tubes required for the job.
Given condensation temperature of alcohol = 78^oC.
Heat of vaporization = 205 Kcal/Kg
Density of alcohol = 768 Kg/m^3
Water properties at 30^oC.
Specific heat : 4.174 kJ/kg^ok.
Viscosity : 6.5 x 10^{-4} N sec/m^2
k = 0.634 w/m.k

6. (a) Explain in detail how the combined heat losses by conduction, convection and radiation can be estimated.
   (b) Give three practical examples for the above situation.
   (c) Write a note on radiation in film boiling.

7. (a) Derive the relationship between effectiveness and number of transfer units for a parallel flow heat exchanger.
   (b) Determine the heat transfer area required for a heat exchanger constructed from a 2 cm OD tube to cool 26,000 kg/hr of an alcohol solution (C_p =3.81 kJ/kgK) from 90 to 50^oC, using H_2O which enters at 20^oC and leaves at 40^oC and for the following arrangements:
      i. co current shell and tube
      ii. counter current shell and tube heat exchanger, alcohol in shell and H_2O through the tubes. (Assume correction factor for LMTD = 0.95). Assume that the overall heat transfer coefficient based on the outer tube area is 830 kJ/hrm^2K.

8. (a) Discuss the salient features of multiple effect evaporators.
   (b) Explain the various feeding methods employed in evaporators.

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   Thermal conductivity is 0.03 W/(m.K)
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5. Steam saturated at 68.9kPa (10 psia) is condensing on a vertical tube 1.22m, high, having an OD of 0.0254m and a surface temperature of 86.11^oC. Calculate the average heat-transfer coefficient using English and SI units.

Properties of water
$\rho = 968$ kg/m^3
k = 0.58 w/m^oC
$C_p = 4180$ j/kg^oC
$\mu = 1.14$ x 10^{-6} N.sec/m^2

6. (a) Calculate the net radiant interchange per square meter for two very large planes at temperatures of 600 C and 400 C respectively. Assume that the emissivity of the hot and cold planes are 0.9 and 0.7 respectively.
   (b) A 5 cm oxidized iron pipe at 150 C passes through a room in which the surroundings are at a temperature of 30 C. If the emissivity of the pipe metal is 0.8, what is the net interchange of radiant energy per meter length of the pipe?
   (c) Compute the heat loss from a 10 mm dia circular opening in a large enclosed furnace. The temperature within the furnace is 1000 C and the surrounding temperature is 25 C. Assume black-body radiation.

7. Cold water at the rate of 4 Kg/sec is heated from30^oC to 50^oC in a single shell and two tube pass heat exchanger. Heating medium is hot water supplied at 95^oC at the rate of 2 Kg / sec. Cold water flows through the tubes. The overall heat transfer coefficient is 1330 W/m^{2o}C. The average water velocity is 0.38 m/sec inside the tubes. The diameter of tube is 2 cms. Calculate
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