Ex/ChE/T/314/2018(S)

Bachelor of Chemical Engineering Supplementary Examination, 2018

3rd Year, 1st Semester

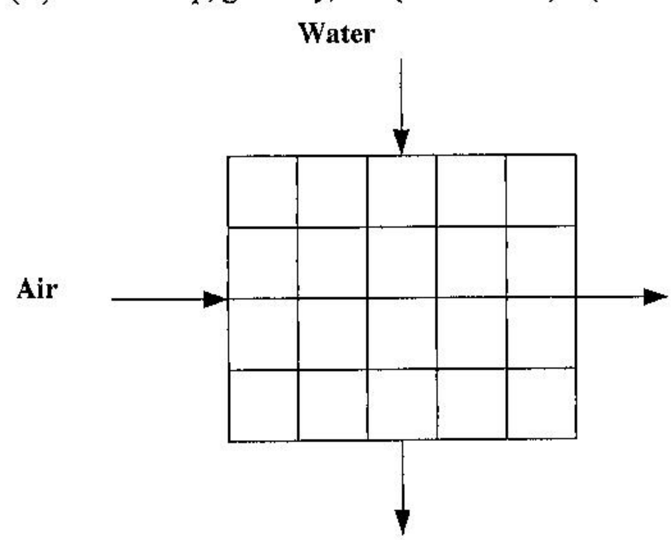
Process Heat Transfer

Time: Three Hours | Full Marks: 50

Answer any Two questions

1. **Natural Convection** **(6+4+15=25)**
   a. What do you mean by Natural Convection? Give two practical examples.
   b. What is the difference between a forced and a natural convection in terms of effects of properties of fluid on their heat transfer coefficients.
   c. In case of natural convection, h could depend on a characteristic length L, a temperature difference ΔT, the conductivity k, the viscosity μ, the specific heat capacity c_p , the density ρ and the volumetric thermal expansion coefficient β of the fluid. *β is usually grouped with g and ΔT as one term ($\beta g \Delta T$) as this group is proportional to the buoyancy force*. Use principles of dimensional analysis to work out a set of non-dimensional groups affecting natural convection.

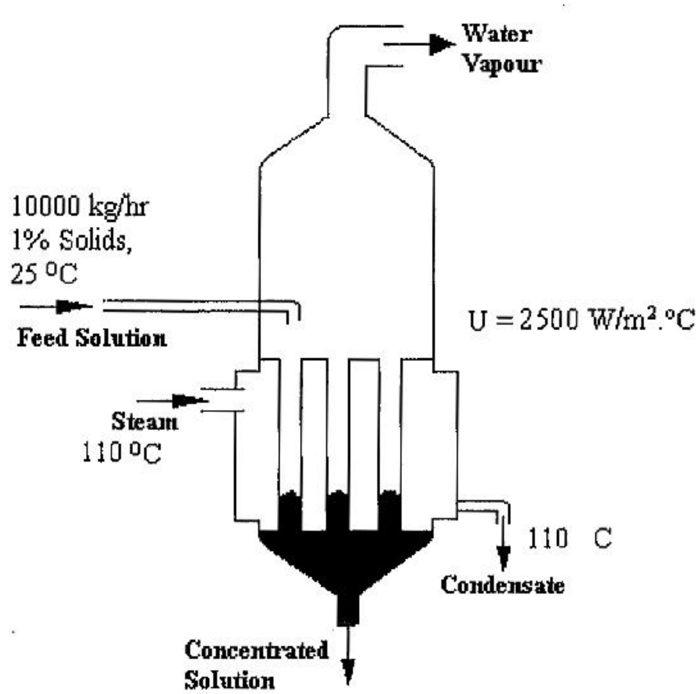
2. **Heat Exchanger** **(5+8+12=25)**
   a. In a condenser of a power plant, the steam condenser is at a temperature of 60°C. The cooling water enters at 30°C and leaves at 45°C. Find out the logarithmic mean temperature difference (LMTD) of the condenser.
   b. In a parallel flow heat exchanger operating under steady state, the heat capacity rates (product of specific heat at constant pressure and mass flow rate) of the hot and cold fluid are equal. The hot fluid, flowing at 1 kg/s with $C_p = 4\ kJ/kg.K$, enters the heat exchanger at 102°C, while the cold fluid has an inlet temperature of 15°C. The overall heat transfer coefficient for the heat exchanger is estimated to be $1\ kW/m^2.K$ and the corresponding heat transfer surface area is $5m^2$. Neglect heat transfer between the heat exchanger and the ambient. The heat exchanger is characterized by the following relation: $2\varepsilon = -exp(-2NTU)$. What is the exit temperature (in°C) for the cold fluid?
   c. Water with a flow rate of 0.05kg/s enters an automobile radiator at 400K and leaves at 330K. The water is cooled by air in cross flow which enters at 0.75kg/s and leaves at 300K. If the overall heat transfer coefficient is $200 W/m^2.K$, what is the required heat transfer surface area? Use the NTU method. Use Effectiveness – NTU (N) relationship, given by, $\varepsilon = \{1 - e^{[-N(1-C)]}\} / \{1 - Ce^{[-N(1-C)]}\}; C = C_{min}/C_{max}$.



[Turn over

3. **Evaporator** **(5+20=25)**

a. What are the *advantages* of a *Backward Feed* arrangement in evaporators.
b. 10,000 kg/hr of an aqueous feed containing 1% dissolved solids is to be concentrated to 20% solids, in a single effect evaporator. The feed enters at 25°C. The steam chest is fed with saturated steam at 110°C. The absolute pressure maintained in the evaporator is such that the water will boil at 55°C. The boiling point elevations are as follows:
Feed: 0.2°C
20% solution: 15°C
The overall heat transfer coefficient, under normal operating conditions would be 2500 W/m2.°C
Estimate the steam requirement assuming no sub cooling of condensate, heat load on the condenser, and the heat transfer area.
Assumption: Condensate water leaves as saturated liquid corresponding to the vapor space pressure.
Data:
Enthalpy of feed at 25°C (H_F) = 104.8 kJ/kg (the data for water at 25°C - *from Steam Tables*)
Enthalpy of product at 70°C (H_P) = 293.0 kJ/kg (the data for water at 70°C - *from Steam Tables*)
Pressure in the evaporator vapor space = 15.74 kPa (abs) (saturation pressure of water vapor at 55°C - *from Steam Tables*)
Enthalpy of water vapor leaving at 70°C and 15.74 kPa (abs) (H_V)= 2640 kJ/kg (*from Mollier Diagram*)
Enthalpy of saturated water at 15.74 kPa (abs) = 230.2 kJ/kg
Latent heat of steam at 110°C (λ_S) = 2230 kJ/kg (from Steam Tables)



Ex/ChE/T/314/2018(S)

B.E. Chemical Engineering - Third Year - First Semester

PROCESS HEAT TRANSFER Time: Three Hours Full Marks: 100

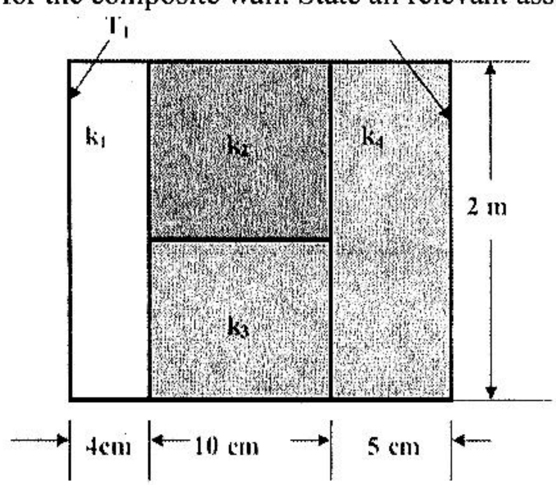
Part- II
(50 marks for each part)
Use separate answer scripts for each part

Answer __any two__ questions.
__Assume any missing data.__
Write all assumptions clearly.

CONDUCTION

1. (a) Consider a solid cylinder of radius R and height H. Heat is generated in the solid cylinder at a uniform rate of q W/m^3. One of the circular faces of the cylinder is insulated and the other circular face dissipates heat by convection into a medium at a temperature of T_∞ with a surface heat transfer coefficient h. The outer curved surface of the cylinder is maintained at a uniform temperature of T_0. Write the mathematical formulation to determine the two dimensional steady state temperature distribution T (r,z) in the cylinder (You don't have to solve, just write the mathematical expression and corresponding boundary conditions).

(b) A composite wall consisting of four different materials is shown in Fig. Using thermal resistance concept, determine the heat transfer rate per m^2 of the exposed surface for a temperature difference of 500°C between the two outer surfaces. Also draw thermal circuit for the composite wall. State all relevant assumptions clearly.



$k_1 = 100$ W/(m-K) ; $L_1 = 0.04$ m;
$k_2 = 0.04$ W/(m-K) ; $L_2 = 0.1$ m;
$k_3 = 20$ W/(m-K) ; $L_3 = 0.1$ m;
$k_4 = 70$ W/(m-K) ; $L_4 = 0.05$ m;

(c) Derive an expression for critical thickness of insulation? How do you decide the thickness of insulation for electrical wires and steam pipes? **[5+10+10]**

CONVECTION

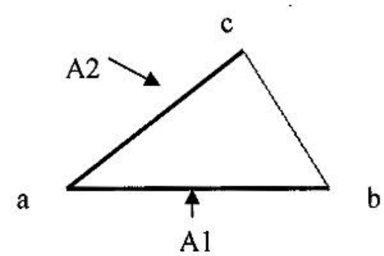
2. (a) The velocity profile for hydrodynamically developed laminar flow inside a circular tube of radius R is given by $u(r) = 2u_m[1 - (r/R)^2]$, where u_m is the average velocity of the fluid in the tube. Develop an expression for friction factor f and express it in terms of the Reynolds number Re_d where Re_d is defined as $Re_d = (u_m D)/\nu$.

   (b) Water at 30°C with a mass flow rate of 2kg/s enters a 2.5 cm ID tube whose wall is maintained at a uniform temperature of 100°C using condensing steam. Calculate the length of the tube required to heat the water to 70°C. Mention all the assumptions clearly.
   Properties of water: ρ = 990 kg/m^3, c_p= 4181 J/kg. K, k = 0.644 W/ m.K, μ = 0.547x 10^{-3} kg/m.s **[10+15]**

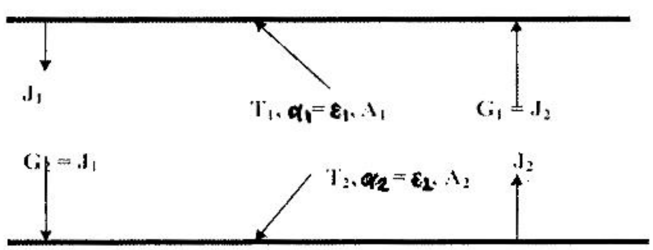
RADIATION

3. (a) A1 and A2 are two rectangular flat surfaces having a common edge and inclined at an arbitrary angle α to each other. They are very long along the common edge and have lengths of ab and ac respectively in the other direction. Show that

$$F_{1-2} = \frac{(ab + ac) - bc}{2ab}$$



   (b) Derive an expression for heat exchange between two parallel infinite gray surfaces.



[15+10]