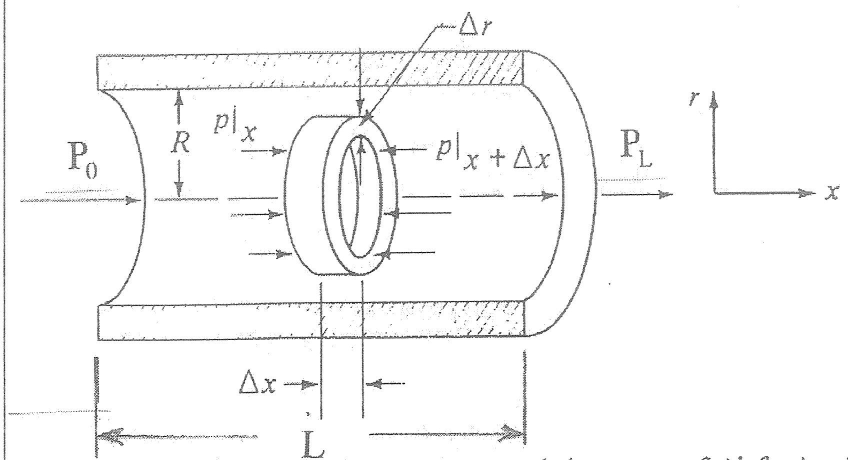
國 立 清 華 大 學 命 題 紙

97 學年度____化學工程學__系（所）______________組碩士班入學考試

科目__輸送現象及單元操作__ 科目代碼__0701__共__4__頁第___1__頁 *請在【答案卷卡】內作答

1. Below is a horizontal section of pipe in which an incompressible *Newtonian* fluid is flowing in one-dimensional, steady-state, fully-developed, laminar flow.
   (a) Please use the shell-momentum balance to derive its shear stress and velocity profiles (6%);
   (b) Derive its average velocity and then the so-called *Hagen-Posieuille* equation (4%);
   (c) Define what the Fanning friction factor (*f*) is (please explain the physical meaning of each term in the Fanning friction factor) (4%);
   (d) Derive the Fanning friction for laminar flow (6%).



Control volume for shell momentum balance on a fluid flowing in a circular tube.

2.

As shown in the figure, a(A) gold metal bar, a(B) beef steak and a(C) rectangular polymer laminate which has many temperature-resistant foamed layers, initially maintained at room temperature To are suddenly placed on a platform with high surface temperature Ts. Assuming Ts is much higher than To, please answer the following questions. Note that the three objects have the same heights H.

(a) What object has the temperature T=(To+Ts)/2 on the top in the shortest time? Please explain.(2%)

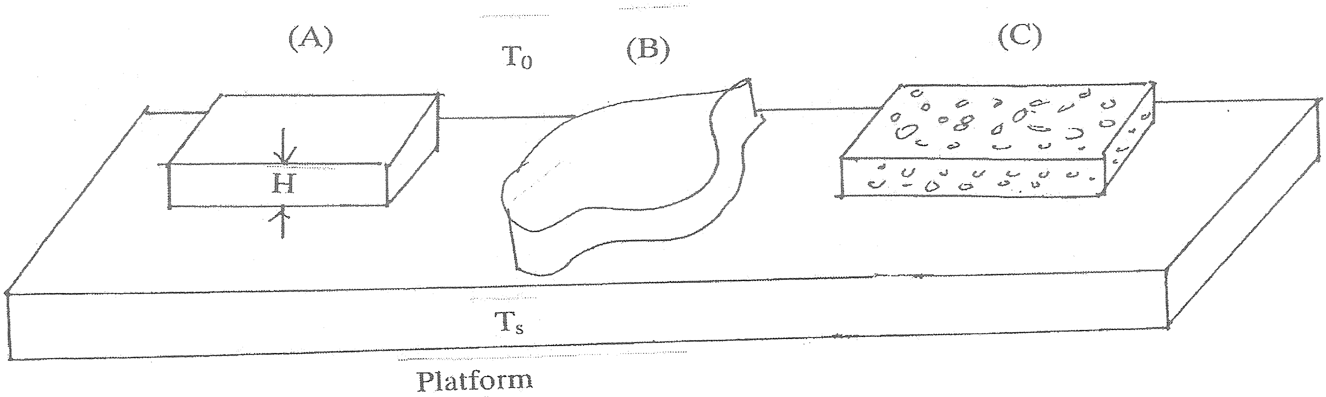
(b) If the time is short after contact, the governing equation for heat transfer in the three objects is assumed to be

$$\rho C_P \frac{\partial T}{\partial t} = \frac{\partial}{\partial X}\left(K \frac{\partial T}{\partial X}\right) \qquad \text{Eq(1)}$$

Here T is temperature, ρ , C_P and K are density, heat capacity and thermal conductivity of the objects, respectively. X is the direction that points onward form the platform surface. Give the necessary initial and boundary conditions of Eq(1).(5%)

(c) If thermal conductivity K is not a constant, but is a function of Temperature, i.e., K=Ko + AT, here Ko and A are constants, introduce K into Eq(1) and expand the equation. Is this a linear partial differential equation? Why?(5%)

(d)If all the physical properties are constant in Eq(1), define a new variable Y=X/(BT), here B is a constant. Substitute Y into Eq(1), define B and reduce Eq(1) to a ordinary differential equation. Write down the proper boundary conditions for a short contact itme. You do not need to solve the equation.(8%).



3. (I) Answer the following questions regarding mass transport:

(a) What are the basic mechanisms of mass transport ? Describe their basic features. (3%)

(b) What are the Fick's first and second laws? Under what circumstances are they applicable? (4%)

(c) Distinguish between homogeneous and heterogeneous reactions. Which ones are described by boundary conditions and which ones manifest themselves in the differential equation of change for mass transport ? (3%)

(II) A solid sphere of substance A is suspended in a liquid B in which it is slightly soluble, and with which A undergoes a first-order chemical reaction with rate constant k_1. At steady state the diffusion is exactly balanced by the chemical reaction.

(a) Obtain the concentration profile $c_A(r)$ in terms of the radius of the sphere (R) and the molar solubility of A in B (c_{A0}). (6%)

(b) Obtain the total loss of A from the sphere in moles per unit time, W_A. (4%)

4.

(a) For a countercurrent single pass heat exchanger, please derive the working equation (with necessary assumptions) : $q_T = U A_T \Delta T_{lm}$, where ΔT_{lm} = logarithmic mean temperature difference, q_T = rate of heat exchange in entire exchanger; U = overall heat transfer coefficient; A_T = total heat transfer surface area; (6%)

(b) Please draw the schematic temperature profile versus heat flow for the above case. What would the temperature profile be like for the cooling and condensing of superheated vapor? (4%)

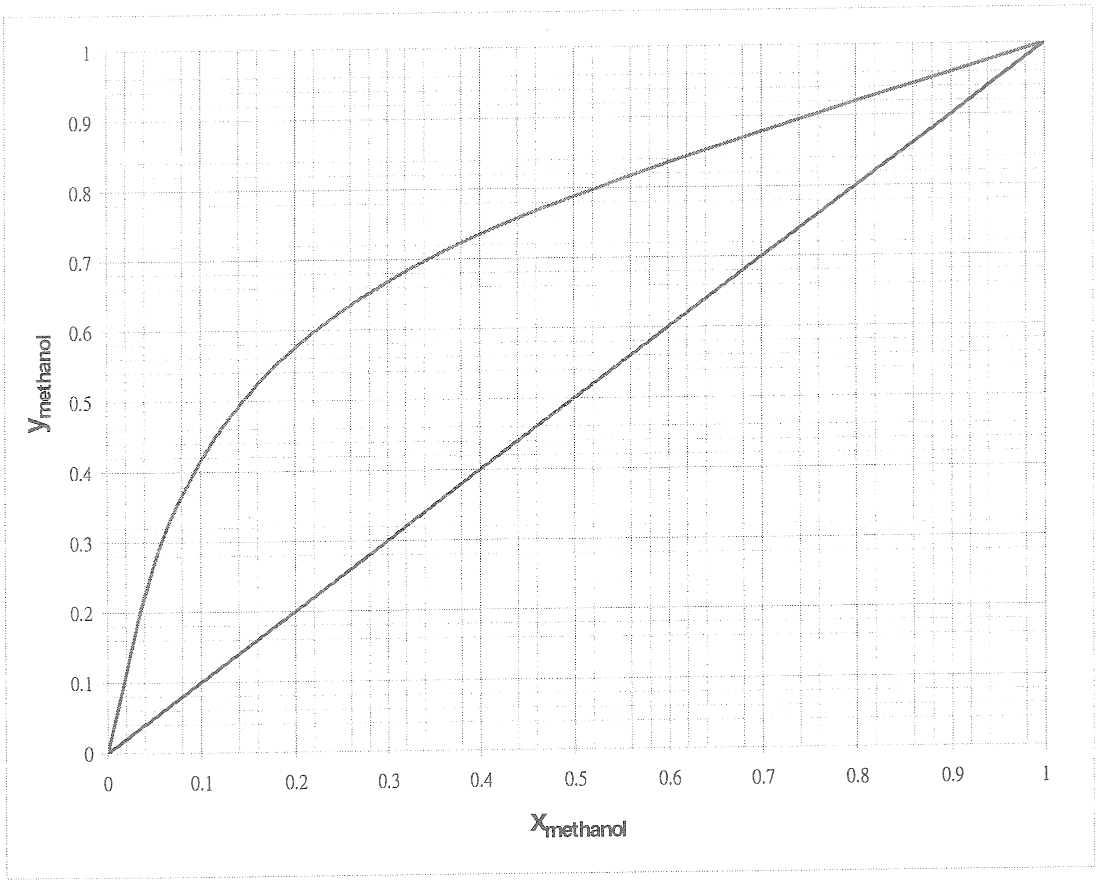
(c) Write down the expression for U in terms of individual thermal resistances (5%)

(d) Please draw a schematic diagram of a 1-2 parallel-counter-flow exchanger (with explanation) and its temperature-length profiles. (5%)

5.

(a) A gas contains 30 mol% acetone, 97% of which is to be removed by a solvent oil. The Henry's constant of acetone in oil is 1.9. Determine the minimum solvent rate required. (5%)

(b)A distillation column is designed to separate methanol and water continuously. The feed contains saturated liquid contains 30 mol% of methanol and 70 mol% of water. A distillate containing 90 mol% of methanol and a bottom containing 10 mol% of methanol is desired. Find the minimum number stages required for the separation (5%)



(c)A tube of agar 0.04 m long connects two large volumes of agitated solutions of urea in water. The cross-section of the tube is 0.01 m^2. The concentration of urea in the first solution is 0.2 gmol/L and the concentration of urea in the first solution is 0.02 gmol/L. The diffusivity of urea in agar is 0.727×10^{-9} m^2/s. Calculate the steady state flux. Calculate the steady state rate of mass transfer from the first solution to the second solution. (5%)

(d)Pure water is flowing parallel to a plate of solid benzoic acid with cross-section area of 0.01 m^2. The solubility of benozoic acid in water is 0.03 $kmol/m^3$. The mass transfer coefficient is estimated to be 6×10^{-6} m/s. Estimate the rate of solution of benzoic acid. Molecular weight of benzoic acid is 122.12. (5%)