九十二學年度　化學工程學　系（所）　組碩士班研究生招生考試

科目　輸送現象及單元操作　科號　1201　共　3　頁第　1　頁　*請在試卷【答案卷】內作答

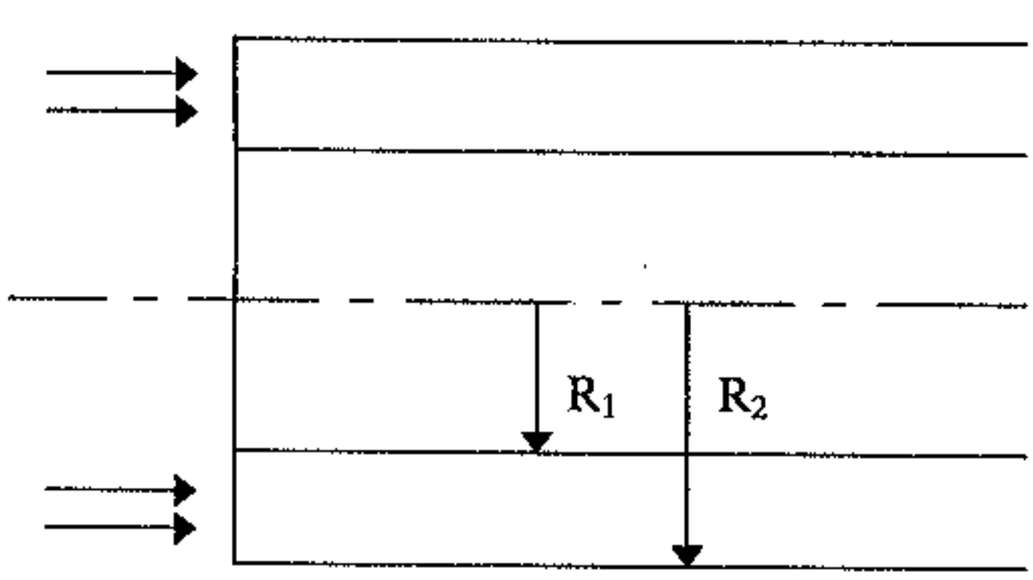
Problem 1 (20%)

Consider a Newtonian liquid with constant density ρ and viscosity μ is flowing through an annulus as shown in the figure. The inner and outer radii of the annulus are R_1 and R_2, respectively. The fluid motion is steady and volumetric flow rate is Q.

(a) Can you define a dimensionless group, say X, such that X can represent the ratio of inertial force to viscous force for the flow system? Note that you may need to define a characteristic length L, and L is defined as the ratio of the cross-sectional area for flow to the wetted perimeter. (6%)

(b) Can you justify why X represents the ratio of inertial force to viscous force? (6%)

(c) Suppose that X=0.001, can you set up a simplified equation with proper boundary conditions that can describe the fluid motion? This equation should be one dimensional, list your assumptions. Do not solve the equation. (8%)



Problem 2 (20%)

A spherical catalyst pellet has a radius R and a thermal conductivity k (which may be assumed constant). Because of the chemical reaction occurring within the porous pellet, heat is generated at a rate of S_c (cal/cm^3 s). Heat is lost at the outer surface of the pellet to a gas stream at constant temperature T_g by convective heat transfer with heat transfer coefficient h.

(a) Find the steady-state temperature profile, T(r), assuming S_c is constant throughout. (10%)

(b) What is the limiting form of T(r) when $h \rightarrow \infty$? (5%)

(c) What is the maximum temperature in the system ? (5%)

Problem 3 (20%)

Short questions: [(a):2,2,2%; (b):4,4,3%; (c):3%]

(a) Give the physical meaning of Schmidt number (Sc). What is the order of magnitude of Sc for ordinary gases, >>1, ~1, or <<1? Explain.

(b) In reference to the following heat transfer coefficient correlation equation for forced convection heat transfer from a heated sphere:

$$Nu_m = 2 + 0.60\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3},$$

give the analogous mass transfer coefficient correlation equation for forced convection mass transfer from a dissolving or an evaporating sphere (explain the symbols you use in your equation). According to the above equation, there are two types of contributions to the relevant transfer coefficient. Explain what the two contributions are. Which of the two contributions is responsible for the faster drying of wet clothes in stronger wind? Explain.

(c) Consider the unsteady state evaporation of liquid A into gas B in a tube of infinite length. It can be shown that the rate of production of vapor from a surface of area S is equal to

$$S\phi\sqrt{\frac{D_{AB}}{t}}.$$

Here, ϕ is a monotonically increasing function of the interfacial gas-phase concentration, D_{AB} is the binary diffusion coefficient, and t is the elapsed time. According to the above equation, the rate of vapor production drops with increasing time. Why?

Problem 4 (20%)

Water must be heated from 15 to 50 °C in a simple double-pipe heat exchanger at a rate of 3500 kg/h. The water is flowing inside the inner tube with steam condensing at 110 °C on the outside. The tube wall is so thin that the wall resistance may be neglected. Assume that the steam-film coefficient ho = 11 kW/m^2 °C. What is the length of the shortest heat exchanger that will heat the water to the desired temperature? Average properties of water are as follows:

$\rho = 993$ kg/m^3; $\mu = 0.78$ cP; k = 0.61 W/m-°C; $C_P = 4.19$ J/g-°C

Since you don't have a calculator to work with you, all you have to do now is to write down all the necessary equations and use a flow chart to illustrate the procedure to solve this problem.

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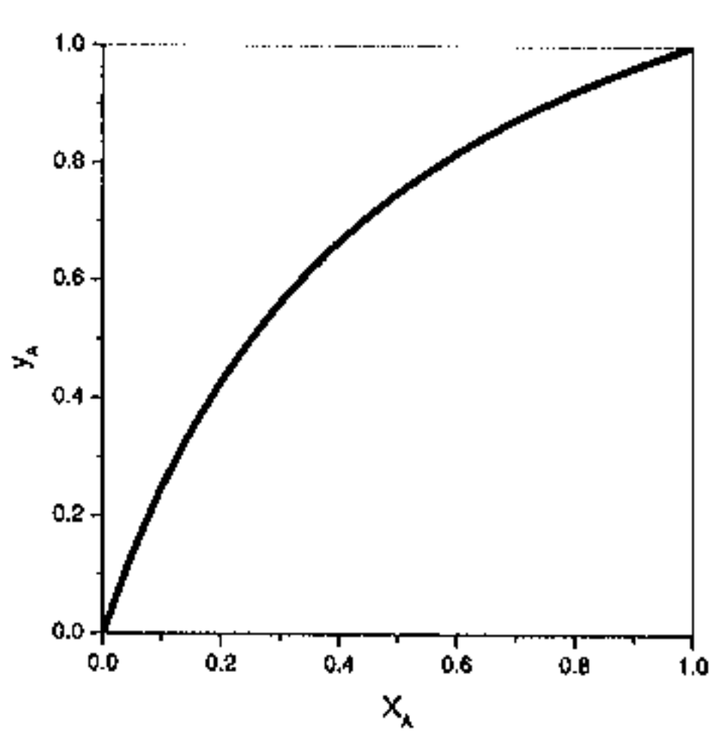
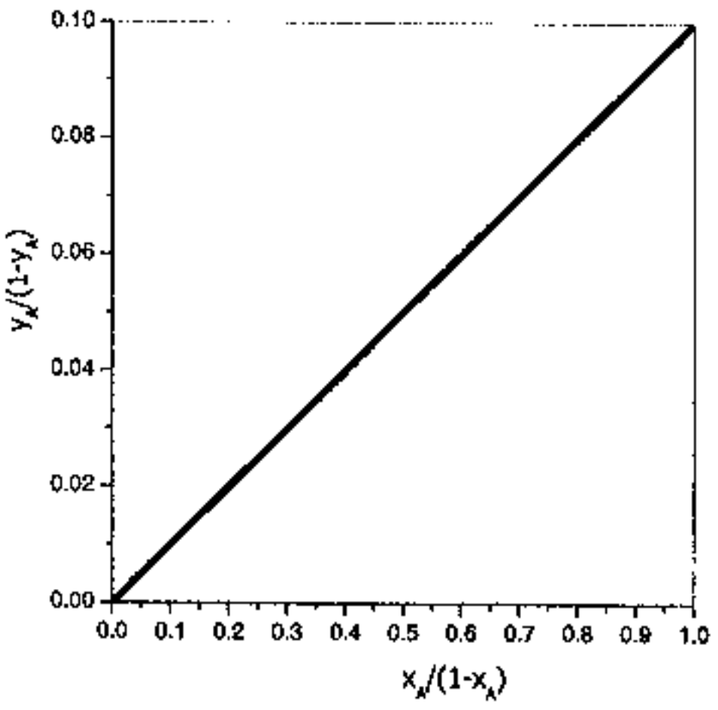
Problem 5 (20%)

(a) (10%)



The above is a y-x diagram of a binary liquid mixture containing A. What is the minimum number of stage when a mixture of 50 mol% A is separated into a stream containing 90 mol% A, and another stream containing 10 mol% A.

(b) (10%)



The above is the equilibrium relation between $y_A/(1-y_A)$, y_A being concentration of a gas A in a gas stream, and $x_A/(1-x_A)$, x_A being concentration of a gas A in a solvent. Assume that the solvent is involatile and the other components in the gas stream are insoluble. Find the minimum solvent rate required to reduce the concentration of A from $y_A/(1-y_A)=0.1$ ($y_A=0.091$) to $y_A/(1-y_A)=0.01$ ($y_A=0.0099$). Assume that the inert gas rate is 1 mol/s, and the clean solvent contains no A.